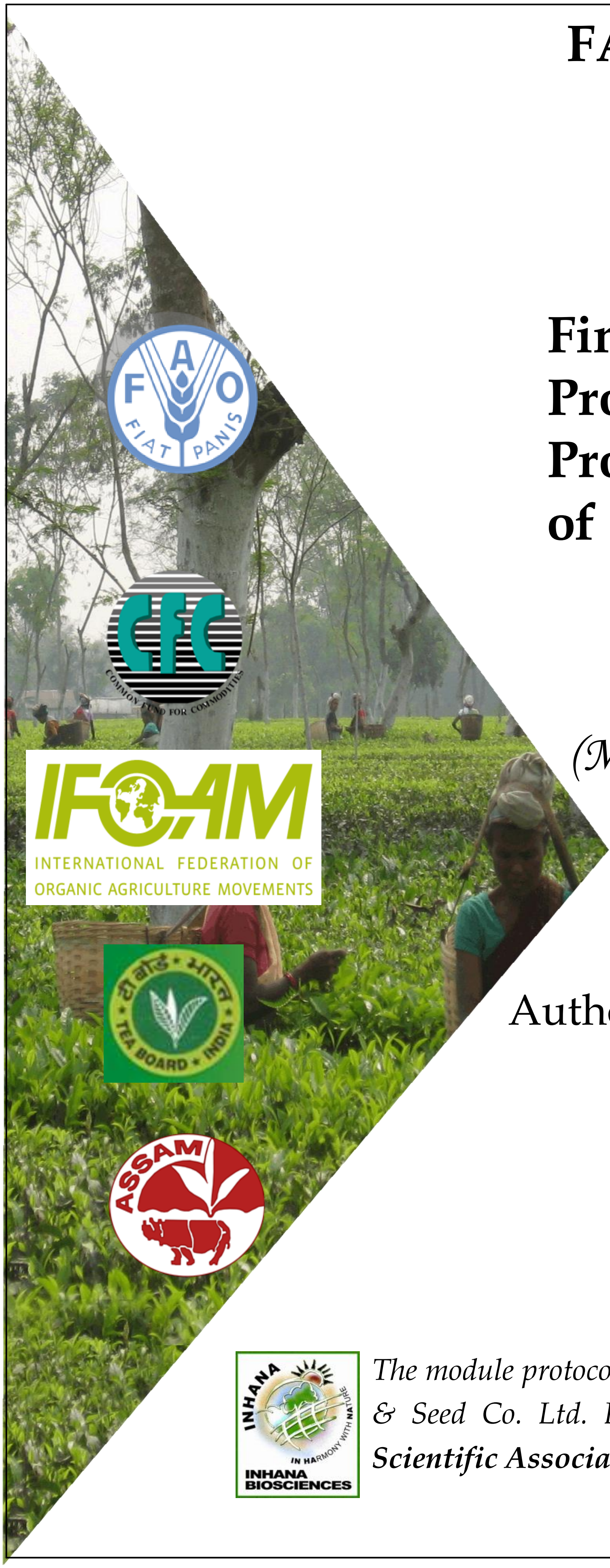
FAO-CFC-TBI Project



Final Report of the Project 'Development Production and Trade of Organic Tea'

Assam Chapter
(Model Organic Farm), India

Author : Inhana Biosciences
Project Team

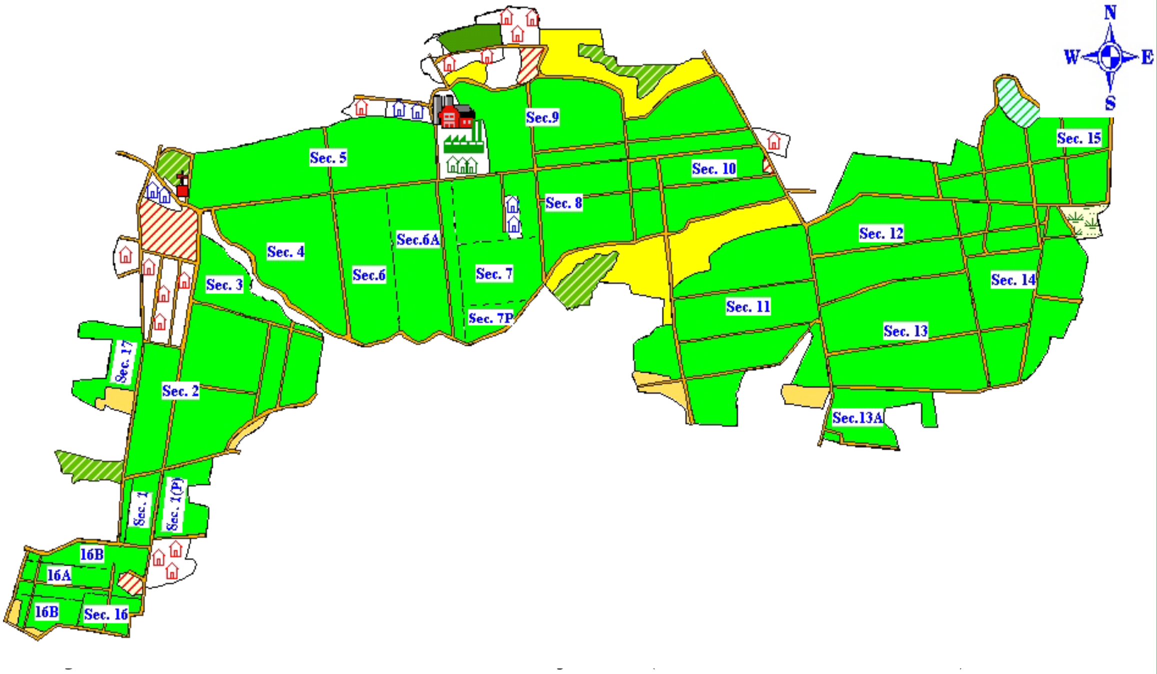
Period : 2009 - 2012

The module protocol & research is designed for Maud Tea & Seed Co. Ltd. By ***Inhana Biosciences, Kolkata - Scientific Associate & Technical Advisor.***

CFC - TBI - FAO PROJECT

Development Production & Trade of Organic Tea

FINAL REPORT (2013)



Operator : **Maud Tea and Seed Company Ltd.**

Project Site : P.O – Chabua, Assam

Project Area : 100 hec.

Project Funded By : **CFC - TBI**

Project Executing Agency : **IFOAM**

Project Supervisory Body : **FAO Intergovernmental Group on Tea**

The module protocol & research is designed for Maud Tea & Seed Co.Ltd. By
Inhana Biosciences, Kolkata - Scientific Associate & Technical Advisor.

Development Production & Trade of Organic Tea

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CHAMONG GROUP – Organic Tradition

Maud Tea and Seed Company Ltd. belong to Chamong Group of Companies, which has been involved in Tea production and marketing since 1916, when the Tea Industry was still Organic. After inception of chemical farming in the mid sixties, the group slowly moved to 'Organic by Choice' witnessing the upcoming 'Global Organic Trend' and presently it is the Largest Producer & Exporter of India Organic Tea of about 2.5 million kg annually (Darjeeling - about 1.5 million kg & Assam - about 1.0 million kg). The group boasts of an Organic Journey of more than 15 years, and one of the first to move to Organic in Darjeeling (13 gardens) and the Pioneer in Assam (3 gardens).

INHANA BIOSCIENCES – In Harmony with Nature

Inhana Biosciences - a Research Organization based in Kolkata (India) is the Scientific Associate & Technical Advisor of Maud Tea & Seed Company Ltd. The organization started its journey about 10 years ago, with formulations for organic agriculture and of Organic Practices' (Inhana Rational Farming Method) realizing that for effective and sustainable organic management, the input substitution theory has to be transformed to a comprehensive approach. About 1.8 million kg Organic Tea is being produced for the last 7 years under Inhana Rational Farming from 1300 hec.

'INHANA- ADVISORY BOARD' for Project Supervision & Guidance

'Inhana Advisory Board' comprises Professors from different Agricultural Universities, acclaimed stalwatrs in their respective fields and at the same time having right analytical bent of mind to accept and study the Science behind Organic Practices. They are associated with Inhana Biosciences right from the formulation, guidance and evaluation of the research findings and their intricate relationships.

संस्थापक
रवीन्द्रनाथ ठाकुर
Founded by
RABINDRANATH TAGORE

ACHARYA
DR. MANMOHAN SINGH

UPACHARYA
PROF. SUSHANTA DATTAGUPTA

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पल्ली शिक्षा भवन
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Date 21.12.2012

From :
Prof. G.C. De
Principal (Dean)

MESSAGE

*It gives me immense pleasure that the ''**Final Report**" of **FAO-CFC-TBI Project (Period: 2009 to 2011)** entitled '**Development, Production and Trade of Organic Tea**', which was conducted at Maud tea estate, Assam, India, is going to be published by Inhana Biosciences, a research organization, based in Kolkata.*

As member of the 'Advisory Board' which was formed by Inhana Biosciences for the project, I appreciate that the report will perhaps be the first detailed documentation on organic tea production made so far, which can provide effective guidelines to enable ecologically and economically sustainable cultivation of the crop in eastern India (in particular) and the country and the globe as a whole.

21.12.12

(G.C. De)
Principal (Dean)

From the Desk of Advisory Board

The FAO-CFC-TBI Project (Period: 2009-2011) for finding out 'An Effective Road Map for Organic Tea Cultivation' at Maud Tea Estate gave us the opportunity to observe, examine and interpret the application of Organic Science towards practical utility at large scale in the experiments designed and conducted by Inhana Biosciences, the R&D Institute engaged in organic research for more than one decade.

The outcome of this project is perhaps the first of it's kind that has delivered the concept of 'Packages of Practice', hence shifting from the input- based approach or component research. This project has conclusively showed the pathway that can be conveniently adopted for large scale organic tea cultivation in an Economically Sustainable manner through attending to all related components.

As professors of Agricultural Science we are glad to bring forth the various outcomes of the project in the form of 'Annual Report', which can provide effective guidelines for the tea growers in order to enable natural conversion of tea plantations to organic or for gradual shedding of chemical inputs in an effective manner. Most importantly the findings shall also help to formulate effective Road Map for ecologically and economically sustainable organic production of various other agricultural crops.

Prof. A. K. Chatterjee
(*on behalf of Advisory Board*)

CONTENT

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BRIEF SUMMARY

The present study under FAO-CFC-TBI Project entitled 'Development, Production and Trade of Organic Tea' was **aimed to bring forth the comprehensive organic pathway/ package of practice, which can ensure crop and soil sustainability in the most cost- effective manner.**

To achieve the project objectivity different organic methods (i.e. the ones which are commonly practiced in present day agriculture) were taken up for evaluation. However, organic methods are relatively few in number at the same time a large variety of organic products are available and in wide use. However, it has been commonly experienced that combined application of these products for soil and plant management does not provide the desired additive effect. Hence, for development of comprehensive management system individual input evaluation was transformed to evaluation of 'Package of Practice' (POP), which may be composed of various individual inputs, but they must operate in an integrated manner, in order to be effectively functional.

The organic methods/ Packages of Practice (POP) were evaluated in terms of crop performance, soil development as well as economics under all growth stages of tea plantation (*viz.* nursery, new plantation: age- 0 to 2 years, young tea: age- 3 to 6 years and mature tea: age- 20 to 23 years) for the period of 2009 to 2011. In a separate experiment different types of soil inputs were evaluated for their quality as well as post soil application effectivity in terms of crop response and soil development. There were total eleven treatments for POP experiment in Mature tea (Sec. 4) and soil input experiment (Sec. 6A), while eight treatments were selected for POP experiments in young tea (Sec. 13A) and new plantation (Sec. 7P). In Mature tea the experimental plots were laid out in the form of BIBD or balanced incomplete block design with 3 replications (individual plot size: 0.20 ha on an average) while RBD (randomized block design) with 3 replications was used in case of young tea and new plantation (individual plot size : 0.02 ha and 0.01 ha respectively). To study the adaptability potential of different organic packages of practice on large scale basis or in other words their lab to land potential, repetitive study was taken up in mature tea plantation (Sec. 5) from 2nd year i.e. 2010 onwards using five packages as treatments, selected on the basis of their 1st year performance under POP experiment in mature tea (i.e., Sec.4) as well as considering their individual relevance in organic tea cultivation. No specific experimental design

was followed and bigger plot size varying from 1.31 to 2.12 ha was taken up to evaluate the performance of different treatments.

The treatments for POP experiment in Mature Tea are as follows: **T_1- ** Control, **T_2- ** Vermicompost @ 9.4 ton/ ha + Herbal concoctions for pest and disease management, **T_3- ** Vermicompost @ 9.4 ton/ ha + Bio-growth promoter + Bio-pesticides, **T_4- ** Vermicompost @ 9.4 ton/ ha + Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK) + Bio-growth promoter + Bio-pesticides, **T_5- ** Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK) + Bio-growth promoter + Bio-pesticides, **T_6- ** Novcom compost @ 2.6 ton/ha + 40 kg Elemental-S + 80 kg Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management, **T_7- ** Novcom compost @ 8.0 ton/ha + rest same as T_6, **T_8- ** Novcom compost @ 4.0 ton/ha + rest same as T_6, **T_9- ** Novcom compost @ 5.1 ton/ha + rest same as T_6, **T_{10}- ** Biodynamic compost @ 10 ton/ ha + Cow Pat Pit @ 12.5 kg/ ha + Cow horn manure @ 15 ltr. soln/ ha + Biodynamic package for plant management, **T_{11}- ** Indigenous compost/ Farm Yard Manure (FYM) @ 13.5 ton/ ha + Herbal concoctions for pest and disease management. In other POP experiments selective treatments were taken *viz.* T_1, T_2, T_5, T_9, T_{10} and T_{11} for **nursery** and T_1, T_2, T_4, T_5, T_6, T_9, T_{10} and T_{11} for **new plantation** as well as **young tea** (each). Dose of organic soil inputs that are soil management components of different organic POP, was calculated to supply 60 kg N to plants per hectare (target yield considered as 1500 kg made tea, with 4 percent N requirement for one kg of made tea) based on their individual nitrogen and moisture content with 80 percent utilization efficiency. **Plant management in the respective plots was done as per protocol suggested by experts**.

The treatments for Soil Input experiment in Mature Tea are as follows: **T_1- ** Control, **T_2- ** Vermicompost @ 9.4 ton/ ha, **T_3- ** Vermicompost @ 9.4 ton/ ha + Bio-growth promoter, **T_4- ** Novcom compost @ 8.0 ton/ha+ 40 kg Elemental-S + 80 kg Rock Phosphate, , **T_5- ** Novcom compost @ 2.6 ton/ha + rest same as T_4, **T_6- ** Novcom compost @ 5.1 ton/ha + rest same as T_4, **T_7- ** Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK), **T_8- ** Biodynamic compost @ 10 ton/ ha + Cow Pat Pit @ 12.5 kg/ ha + Cow horn manure @ 15 ltr. soln/ ha, **T_9- ** Indigenous compost/ Farm Yard Manure (FYM - 1) @ 13.5 ton/ ha, **T_{10}- ** Indigenous compost/ Farm Yard Manure (FYM - 2) @ 13.5 ton/ ha, **T_{11}- ** Oil Cake @ 1.7 ton/ha. Dose of organic soil inputs used are same as taken for organic POP experiments, **to find out effect of organic plant management**.

Evaluation of the Quality of different Organic Soil Inputs and their Post Soil Application Effectivity in terms of Crop Response, Soil Development and Economics.

The soil input experiment comprised of three segments i) evaluation of different on- farm composting processes in terms of composting speed, convenience etc., ii) organic soil input quality, iii) post soil application effectivity in terms of crop yield, soil development and economics. Different process *viz.* vermi composting (VC), Biodynamic (BD), Indigenous (IC) or FYM and Novcom (NOV) composting methods were evaluated in terms of process convenience, economics of compost production, end product quality and post soil application effectivity in terms of yield and soil quality development.

Except vermi compost, all others showed no raw material specificity, with shortest biodegradation period (21 to 30 days) recorded in case of Novcom composting method. Though the different types of compost were prepared from similar type of garden weeds and cow dung, however; **highest enrichment of N content in the end product, was recorded in case of Novcom compost (207.8%)** followed by Biodynamic compost (172.1%) and Vermi compost (142.9%). N-enrichment in Novcom compost not only indicated minimal volatilization losses under intensive biodegradation process but also better fixation of atmospheric- N by the huge inherent and self- generated microbial population.

The different organic soil inputs were evaluated for their physicochemical properties, nutrient content, microbial potential as well as stability, maturity and phytotoxicity rating. All the types of compost met the suggested standards for different compost quality parameters, however; special mention will be required for **Novcom compost, which recorded highest nutrient content (total N+P+K 4.05%) as well as significantly high microbial potential (total bactera + fungi + actinomycetes expressed as $\log_{10}$ value) of 18.0 as compared to value (13.78 to 14.07) noted for other evaluated compost types.**

Evaluation of crop response under application of different organic soil inputs revealed **highest yield (1500 kg/ha i.e., 30.75 percent higher than control) in Novcom compost applied plots** (NOV-1). The next best crop was obtained under Indigenous compost (FYM-2) applied plots (1479 kg/ ha) and VCBF applied plots (1427 kg/ ha), albeit under high quantitative application in case of the former (i.e., Indigenous compost @ 13.5 ton/ ha) and combined application of vermicompost (@ 9.4 ton/ ha) in combination with city compost organic fertilizer induced with N fixing bacteria and PSB (@ 1.12 ton/ha) and Bio-NPK (i.e., combination of *Bacillus, Pseudomonas, Azotobacter and Azospirillum* @ 37.5 kg/ha) per ha in case of the latter; both as per the protocol suggested by experts.

To express overall soil rejuvenation post application of different organic soil inputs the extent of development of different soil quality indices was quantified for the formulation of Soil Development Index (SDI). The analytical values before initiation of experiment in 2009 and after three consecutive years of compost application (i.e. in 2011) were used as per the following formula to calculate SDI under different treatments:

$$\text{Soil Development Index (SDI)} = \frac{a}{n^2}\left\{\sum_{n=1}^{n} \frac{100(X_1 - C_1)}{C_1} + \frac{100(X_2 - C_2)}{C_2} + \cdots + \frac{100(X_n - C_n)}{C_n}\right\}$$

Where X = Soil Quality parameters after Experimentation; C = Value of individual Soil Quality Parameter before Experimentation ; a = no. of Soil Quality Parameters showing increased over initial value.

Soil Development Index (SDI) was highest in case of Novcom compost (NOV-1) applied plots (SDI: 45.39) followed by NOV-3 (SDI: 32.65), VCBF (SDI: 30.28) and VC (SDI: 30.06) treatments. Highest SDI value in Novcom compost treated plots might indicate maximum soil quality development post compost application. **The effectivity of Novcom compost might be due its high self- generated microbial potential, which brought about positive development in soil quality as also corroborated by the highest crop yield under this treatment**.

Soil management cost covers a major share of the total cost of inputs under organic agriculture, hence; plays a determinant role towards selection of any type of organic soil input. Cost incurred per hectare under different organic soil input was determined using **Value Cost Ratio (VCR) which indicated extra crop grain per rupee invested for organic soil inputs. VCR showed highest value under Novcom compost** followed by FYM-2 (however, 41 percent lower value was obtained under this treatment as compared to highest crop performer NOV-1). Inclusion of vermicompost increased soil management cost by at least 2 to 3 times when compared with the next highest cost. VCR for rest all other treatments like vermicompost, bio-fertilizer, oil cake, Biodynamic compost were very low (i.e. < 3.0).

Performance of Different Organic 'Package of Practice' in Tea Nursery.

Under this project, a nursery (using seed variety TS-463) was initiated in 2009 under five different organic packages of practice with one control. About 300 tubes were segregated, made into batches of 50 numbers and each batch was managed as per specific packages of practice (i.e. CO, VCO, MI, BD and IRF) for one year, in order to assess package potential towards development of healthy planting material. **Plant growth under different packages was assessed (90, 180 and 270 days after germination) in terms of different morphological characteristics** *viz.* shoot height, stem diameter, root mass, and shoot/ root ratio as well as seedling growth indices *viz.* Specific leaf area (SLA), Leaf N Content (LNC), Plant Strength and Dickson quality index.

Specific Leaf Area (SLA) i.e. a measure of density or relative thinness of leaf was highest in case of VCO and IRF (0.173 cm^2/mg in both cases) closely followed by CO and MI (0.171 cm^2/mg in both cases). Leaf N content or seedling nutrient status can affect seedling physiological factors which are related to out-planting survival and was found to be highest in case of IRF (4.52 mmol N/g) followed by BD (4.13 mmol N/g) and CO (3.97 mmol N/g) treated seedlings. Plant strength described as dry matter per unit height, was distinctly higher under IRF management (232.5 mg/cm) followed by seedlings under CO (219.2 mg/cm), MI (219.0 mg/cm) and BD (217.1 mg/cm) packages. Dickson quality index (DQI) was devised by evaluating how well a number of possible combinations of morphological parameters predicted seedling quality and thereby selecting the best combination. Dickson quality index was highest (1.41) in case of IRF treated seedlings followed by MI (1.27) and CO (1.21) treatments. **Evaluation of the morphological properties of the saplings along with quality indices indicated comparatively higher quality of tea seedlings with better survival chances and speedier growth (post transplantation) under IRF package as compared to rest others.**

Performance of Different Organic 'Package of Practice' in New Tea Plantation.

Potential of the different organic 'Packages of Practice' (i.e. CO, VCO, MI, VMI, BD, IRF-1 and IRF-2) towards new tea plantation management was evaluated in terms of successful establishment of young tea seedlings and early growth potential or attaining the commercial plucking stage. To quantify overall plant growth under application of different organic package of practice, Plant Development Index (PDI) was formulated considering different agronomic parameters *viz.* plant height, number of leaves, number of branches and plant girth that were measured under different growth phase of plantation i.e. just after de-centering, before initiation of tipping operation and six months after first frame formation (FFP).

Plant Development Index (PDI)

$$= \frac{1}{n}\left\{\sum_{n=1}^{n} \frac{100(X_1 - C_1)}{C_1} + \frac{100(X_2 - C_2)}{C_2} + \cdots + \frac{100(X_n - C_n)}{C_n}\right\}$$

Where X = Agronomic Parameter; C = Control

Under all the growth stages consistently high PDI was obtained under IRF packages, followed by VCO package of practice. Also strong correlation (r= 0.872**) between PDI and yield obtained under different packages indicated that PDI can be used as an effective tool for predicting crop response under different types of organic practices.

Evaluation of crop response indicated that the newly planted tea saplings attained pluckable stage within a short period of 18 months under all the organic packages. **Crop records taken during the 1st and 2nd production year indicated similar trend showing highest performance under IRF-2 followed by VCO ≈ IRF-1 and CO packages,** accounting 751, 718 and 661 gm green leaf per bush respectively. Value cost ratio, which indicated crop gain per unit rupee invested; also indicated highest economic sustainability under IRF packages (VCR: 8.8 and 11.6 in case of IRF-2 and IRF-1), followed by CO, BD and VCO packages (VCR: 5.4, 3.5 and 2.2 respectively).

Assessment of the overall variation in soil quality under application of different packages was done using soil development index (SDI) and found to be highest in case of plots receiving IRF-2 (SDI: 40.37) followed VMI (SDI: 31.48), CO (SDI : 27.45), IRF-1 (SDI: 17.58) and VCO (SDI: 15.28) packages. **The high SDI value under Inhana Rational Farming was also corroborated by the highest crop yield under this package in new tea plantation.**

Performance of Different Organic 'Package of Practice' in Young Tea Plantation.

Upbringing young tea to the desired productive level under organic management is difficult due to their fertilizer sensitivity as well as dearth of effective pest/ disease control measures, which are necessary for optimum physiological development. Seven different packages of practice (same as new plantation experiment) were taken as treatments to evaluate their comparative effectivity towards achieving healthy and productive young tea.

IRF-2 showed the most promising results in terms of crop yield (made tea: 807 kgha^{-1}), which was 55.2 percent higher than control and about 25.6 percent higher than the next best performing package of practice i.e. VMI (made tea: 653 kgha^{-1}). Agronomic efficiency of plants which quantifies total economic output relative to the utilization of system resources was also assessed for different packages of practice (AE_{POP}). **During all the three years highest AE_{POP} was observed under IRF-2** closely followed by IRF-1. Except IRF packages none of the other treatments showed any consistent performance, rather performed poorly considering the very low AE_{POP} as obtained under rest all other organic packages.

Value cost ratio (VCR) once again indicated highest economic sustainability under IRF-2 (4.37) followed by IRF-1 (2.33). Value cost ratio in case of other organic packages varied between 0.25 and 1.02 and were significantly lower than IRF packages. Assessment of soil development index, revealed highest value in case of plots receiving IRF-2 (SDI: 227.84) followed IRF-1 (SDI: 112.34), VMI (SDI : 87.35), BD (SDI: 61.92) and VCO (SDI: 20.46) packages.

Performance of Different Organic 'Package of Practice' in Mature Tea Plantation.

Evaluation of the potential of different organic packages of practice in mature tea plantation indicated **highest crop performance (in terms of made tea) in case of IRF-2 (1374 kg/ ha) followed by IRF-4 (1369 kg/ ha), VMI (1299 kg/ ha), VMIP (1235 kg/ ha) and VCO (1158 kg/ ha) respectively**. Among all the treatments only the first three *viz*. IRF-2, IRF-4 and VMI accomplished the target yield (crop efficiency: 113.3 %, 110.0 % and 103.5 % respectively) while VMIP performed just close to the target (98.9 %). Lowest yield performance was obtained under MI (excluding control), which indicated very nominal potential of microbial formulations towards effective plant nutrition and as well as pest management. **Addition of vermicompost with MI package (i.e. VMI) certainly boosted up the crop efficiency by influencing 22% increase in made tea/ ha, but also caused an additional hike of 131 percent with respect to package cost under MI or 408 % higher cost than IRF-2 package**.

Agronomic efficiency (NUE-AE) expressed by relative increase in yield per unit of N applied, depends on the ability of the plant to remove N from the soil as well as its utilization efficiency (i.e., ability to use N to produce grain yield). Hence, agronomic efficiency shall not only be the function of soil texture, climate conditions, interactions between soil and bacterial processes and the nature of N sources, but also depend on the management taken towards development of plant physiology. Therefore **NUE-AE can serve as an excellent marker of the effectiveness of plant management protocol under any organic package of practice.** The high values of NUE-AE under IRF packages as compared to the other organic packages could be well corroborated by the highest crop yield obtained under the same.

Comparative study of the cost of inputs under different organic packages of practice indicated that IRF-4 incurred lowest expense per hectare (Rs. 11,302/-) followed by CO (Rs. 12,954/-), IRF-2 (Rs. 13,796/-), BD (Rs. 14,914/-), MI (Rs. 28,657/-), VCO (Rs. 40,184/-), VMIP (Rs. 46,832/-) and VMI (Rs. 66,257/-) packages. Value Cost Ratio (VCR) was calculated for assessment of the impact of packages towards both crop performance and associated cost and the distinctly higher value obtained in case of IRF-2 and IRF-4 (6.20 and 7.49 respectively) indicated that these packages could provide an economically sustainable road map for organic tea production.

N- dynamics of soil under different organic packages of practice was also evaluated considering the critical importance of nitrogen in a vegetative propagated crop like tea; especially under organic management i.e. with the usage of soil inputs with inherently low and slow releasing N content. Different forms of N *viz.* readily available and total mineralizable- N, exchangeable + non-exchangeable and fixed NH_4^+ as well as exchangeable NO_2+NO_3 were analyzed. **The nitrogen dynamics was found to improve post application of different organic packages significantly** so in case of IRF-2 package, particularly increase in the readily available form which comprises both exchangeable- NH_4^+ and NO_2 + NO_3, was critical from the view of plant uptake. The higher N content was once again corroborated by the highest SDI value of IRF-2 treated plots (SDI: 97.9), followed by IRF-4 (SDI: 90.3), CO (SDI: 80.5), VMI (SDI: 79.7), and VCO (SDI: 72.9).

Large Scale Effectivity Assessment of the Different Organic Packages of Practice.

The experiment was initiated to assess how a particular organic Package of Practice delivers in a larger area as compared to its performance in the small experimental plots in the presence of micro-climatic influences as well as wider heterogeneity. Repetitive study was initiated in mature tea plantation from 2010 till 2011 using five organic packages as treatments (i.e. BD, VMI, VCO, IRF-1 and IRF-2), selected on the basis of their 1st year performance under Packages of Practice experiment in mature tea (i.e., Sec.4) as well as considering their individual relevance in organic tea cultivation.

Average yield of two years indicated almost at par and high performance of BD and IRF-2 packages which recorded 97 and 93 percent higher crop over control. The other three packages i.e. VMI, VCO and IRF-1 influenced less than 40 percent variations with respect to control. The high performance of IRF-2 package (93 percent higher crop over control) was in confirmity to the results witnessed under all the other package of practice experiments i.e., in new plantation, young tea and mature tea (Sec. 4). The high crop response was equally supported by the highest development of soil quality under this package as reflected by the highest SDI in comparison to the value obtained for rest other organic packages.

However, the high performance of Biodynamic package was in stark contrast to its less than average performance as witnessed under all other POP experiments covering different growth stages of the tea plant. Further evaluation using benchmark crop data collected from the same plots (when all the plots received similar soil and plant/ pest management programme) and correlated with yield records of 2010 and 2011 revealed an inherently depleting crop gradient on shifting from the plot receiving BD package towards the control plot. The finding confirmed higher inherent crop potential of the former plot that overshadowed the treatment effect, and thereby leading to the highest crop yield.

Performance of Inhana Rational Farming under Large Scale Adoption at Maud T.E.

Inhana Rational Farming (IRF) package was adopted and practiced in the entire area (excluding the micro experimental area) of Maud T.E. i.e. in 130 ha

area, during 2009 to 2011. While same IRF plant management was taken up during all the three years, different types of organic soil inputs [*2009* - Novcom compost (2.0% N, 60% moisture) @ 3 ton/ha + 80 kg RP + 40 kg ES, *2010* - outsourced press mud compost (2.5% N, 45% moisture) @ 9 ton/ha; *2011* - 1 ton castor de-oil cake (8.0 % N content, 4.0% moisture) + 1 ton Novcom compost)] were used for soil management during each year to study their relative effectivity in terms of crop response *vis-a –vis* application dose and economics.

Assessment of crop performance (mature tea) during these three years indicated crop productivity (excluding young tea up to 5 years and HRP sections) of 1440, 1363 and 2001 kg/ha in 2009, 2010 and 2011 respectively, which was 17.0, 3.5 and 41.0 percent higher as compared to 2008. Crop performance *vis-a-vis* total cost of inputs indicated that application of off-farm soil input (press mud compost and Castor DOC) or quantitative increase in their dosage (in terms of press mud) only burdened the cost but could not provide similar incremental benefit towards crop productivity.

Crop performance at Maud T.E was also compared with yield obtained in same tea growing zone i.e. Panitola circle, where all the gardens (except Maud T.E.) are under conventional chemical practice. Year wise percent change (over 2008) in made tea productivity indicated better crop response in Maud T.E. as compared to Panitola Circle. Especially in 2010 under huge helopeltis infestation and unfavourable weather conditions better crop performance (3.5% increase in made tea at Maud T.E. as against 2.3% loss in Panitola Circle) was recorded) at Maud T.E. over 2008, indicated better pest control and crop response, even under stressed conditions.

Another study was taken up to evaluate the impact of IRF Plant Management programme towards activation of plant physiology and simultaneously its reflection on crop yield. Maud T.E. and another sister organic garden in the same agro-climatic zone of Assam received identical organic soil inputs (as described above) and almost similar pest management in 2009, 2010 and 2011. But while Maud T.E. followed IRF Plant Management Package during all the three years the same was discontinued in the sister organic garden after 2009. In 2009, both the gardens showed significantly higher crop performance as compared to 2008 i.e. under conventional organic practice. However, in 2010 and 2011, Maud T.E. (which received IRF plant management package) showed net crop gain of 9424 kg, while the sister organic garden which received identical soil input but discontinued IRF plant management; recorded a net crop loss of 22,352 kg (over 2009). In terms of economics while Maud T.E.

gained revenue to Rs. 18.85 lakh (approx.), the sister organic garden lost revenue of 44.70 lakh (approx.), during these two years.

Assessment of Soil Development Index (SDI) indicated development in soil quality with progress in the period under Inhana Rational Farming. Effort was also made to evaluate quality (in terms of pH, EC, TSS, TDS, total polyphenol and total flavanoid content in tea liquor) of organic tea grown under IRF at Maud T.E. *vis-à-vis* conventionally (under chemical farming) grown tea samples of some good Assam gardens. **Assessment of the different parameters especially in terms of total polyphenol and flavanoid content indicated higher values in case of the organic tea samples of Maud T.E**. (79.7 to 131.4 mg/g) as compared to its chemical counterparts (72.6 to 127.0 mg/g).

Development of Soil Resource Inventory of Maud Tea Estate.

Soil samples collected from general garden area of Maud T.E. before initiation of project and then each year (for three years) before application of organic soil input were analyzed for physicochemical properties, fertility status and microbial potential. **The analytical data was used for preparation of different soil based thematic maps in order to identify the inherent problems and potentials of the garden as well as to evaluate the impact of soil management programme taken up during the project period.**

The carbon stock of Maud T.E. showed an uplifted status from 4500–6500 $kgha^{-1}$ to 6500–7500 $kgha^{-1}$ in significant portion of the plantation post adoption of organic soil management under Inhana Rational Farming. However, the most remarkable finding was increase in area representing very high status of available phosphate, which confirmed the positive impact of Novcom compost containing huge self- generated microbial pool; towards phosphate mineralization in soil of Maud T.E. On the other hand the garden reflected inherently low sulphate content in soil covering major portion of the garden (55.51 % of TGA), and very little elevation in status was recorded during the project period. Considering the immense importance of S towards quality expression of made tea, specific management programme should be taken up towards improvement of available- SO_4 status of the garden. **Analysis of the samples also revealed upliftment in the soil microbial status of Maud T.E. varying from 2000 to 4000 $kgha^{-1}$ (i.e. in terms of microbial load) before initiation of Project to >4000 $kgha^{-1}$ in significant portion of the garden, post three years of management as per Inhana Rational Farming.**

INTRODUCTION

Organic cultivation has been accepted as the only true pathway for sustaining soil and crop productivity. But the continuous failure of input substitution theory i.e. replacing the chemical inputs by organic ones have perhaps led to the belief that though organic farming is better and perhaps necessary, but it is a weaker option and becomes sustainable after long time lag. However, it is not difficult to understand that when even a designed poison (pesticide) fails to control the specific target pest, how a weaker organic option can be more successful. Hence, the success in organic lies not in substituting the inputs or shifting the focus from plant to soil, but through adoption of a comprehensive approach, that takes into account the intertwined and integrated relationships of the soil-plant-ecosystem as a whole.

Sustainability in organic has always remained elusive especially for tea cultivation. Age old bushes, continuous stress on plants due to multiple vegetative propagation, limited scope for soil rejuvenation, soil acidity and the related improper nutrient dynamics along with the unresolved pest and disease infestation; lead to complex problems – which are much different and difficult to address as compared to other crops. Moreover, the fertilizer sensitive tea clones, comprising major portion of tea plantation; fail to give the desired response under ordinary compost or simple organic matter even after their huge quantitative application. At the same time there has been no comprehensive and scientific guideline regarding the parameters for identification of right quality compost or any principle for application depending on their qualitative variations. Furthermore only improvement in the soil status very often is not becoming functional due to depressed soil-plant relationship.

The FAO project at Maud T.E. was initiated to bring forth such conclusive pathway for successful organic tea cultivation, tested for viability under all the different growth phases of tea plant *viz.* nursery, new plantation, young tea and mature tea. On-farm composting production using different composting processes was also taken up and documentation of the degradation period was done along with analysis to assess the quality of final compost.

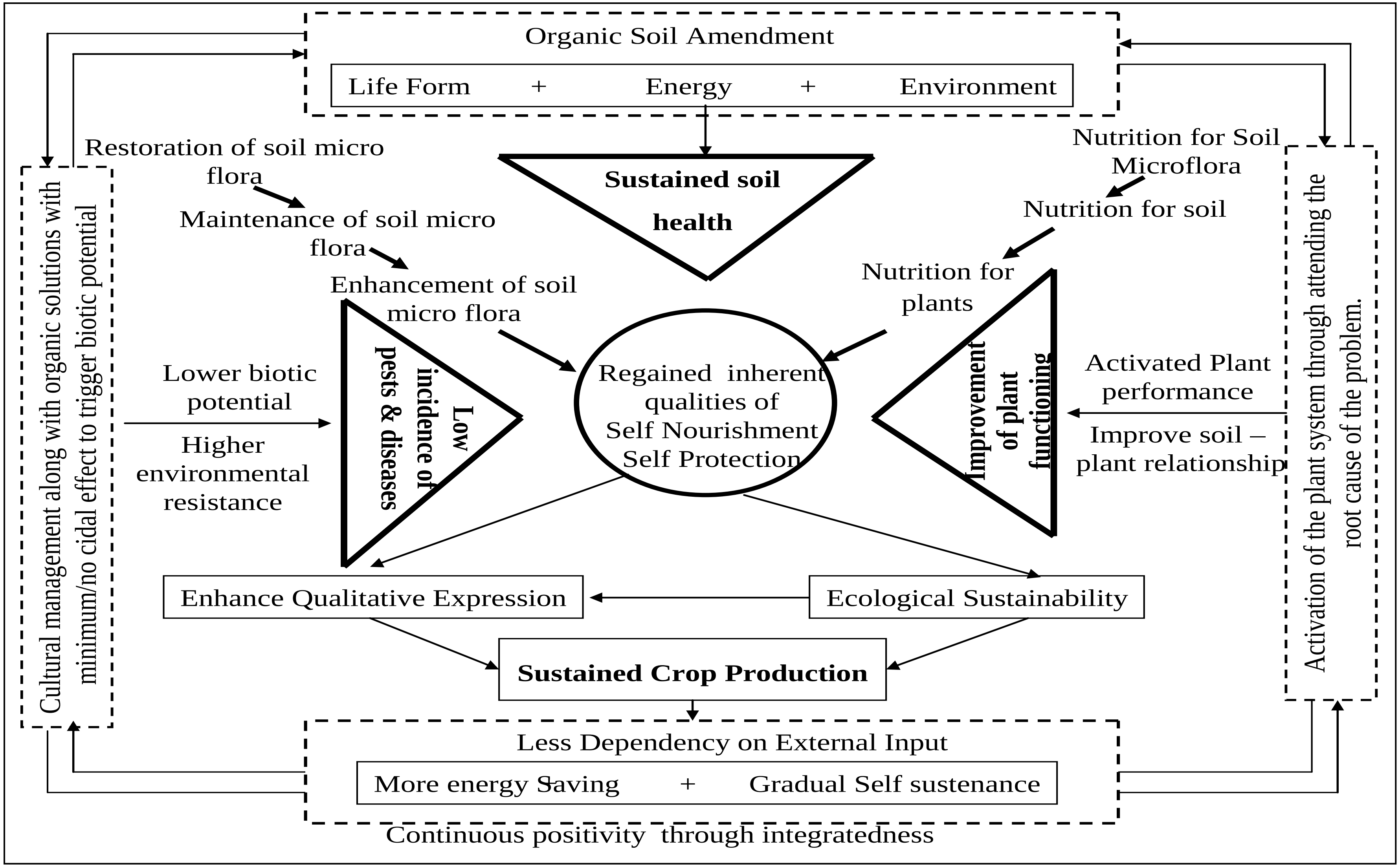


Fig 1 : Comprehensive Interrelationship in Organic Farming (Bera et al, 2011).

GOAL

To Find Out an Effective Pathway for Sustainable Organic Tea Production

Study area

Location

The study area comprised Maud Tea Estate, district Dibrugarh, Assam; India (Fig. 2). It is located in between 27°26′7.0″ to 27°26′39.0″ N latitude and 95°12′54.4″ to 95°14′59.9″ E longitude covering a total area of 154.58 ha.

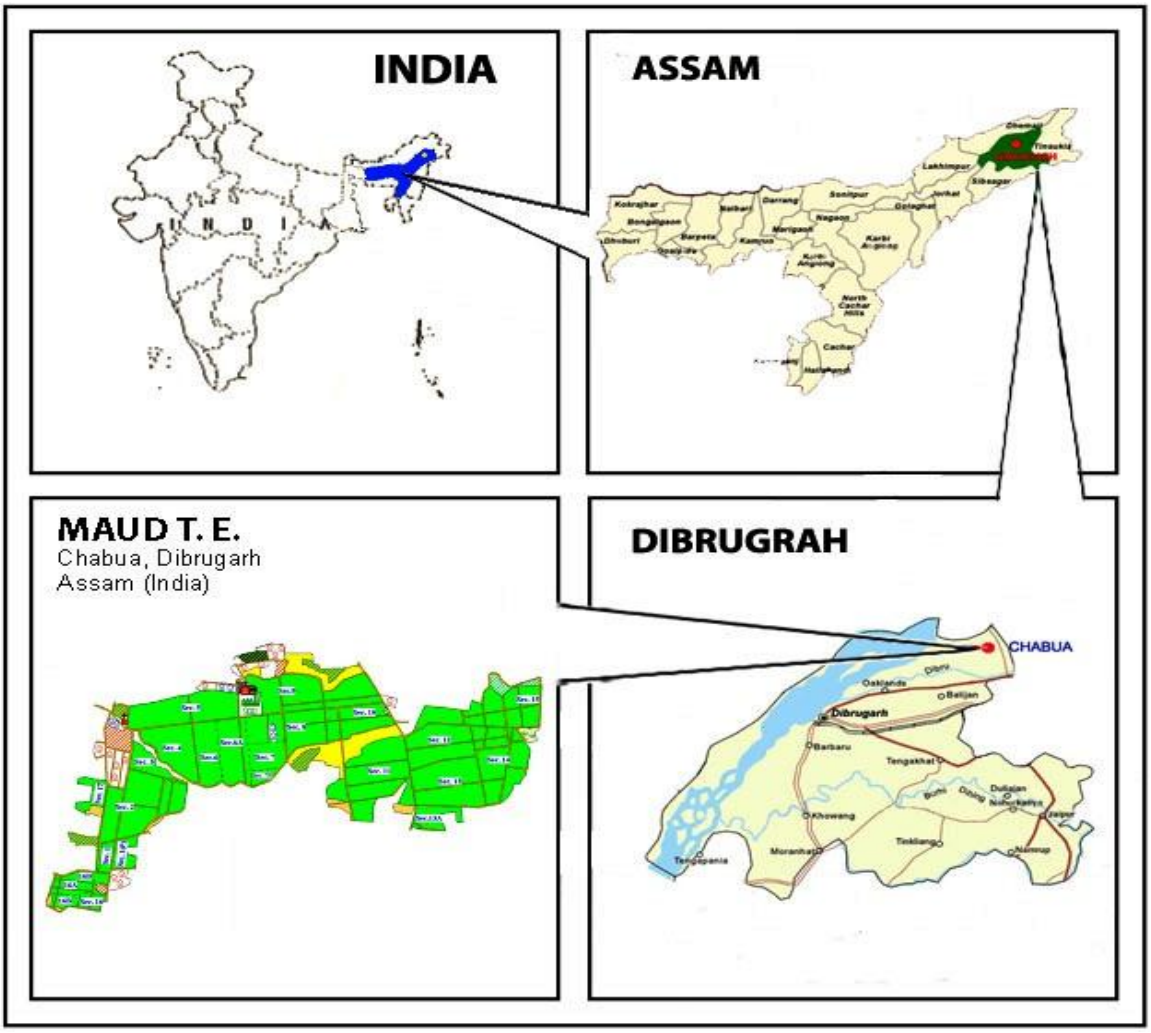
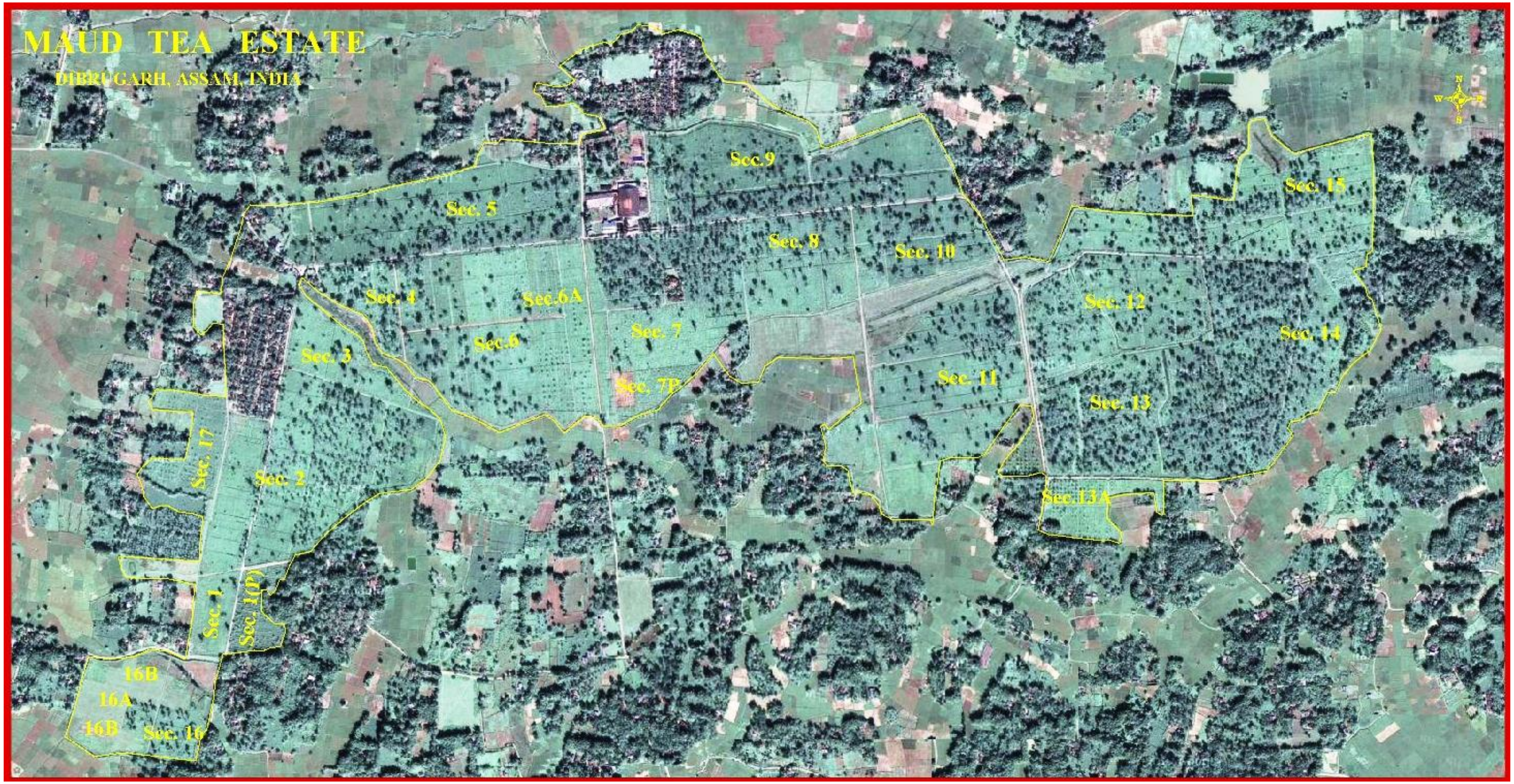


Fig. 2 : Location map of the study area



Pic. 1 : Satellite Imagery of Maud T.E., Assam.

Climate

The study area belongs to Upper Bramhaputra Plain, warm to hot per humid ecological sub region (agro-ecological sub region 15.4) with moderately deep to deep loamy, alluvium-derived soils, medium available water holding capacity (AWC) and length of growing period(LGP) more than 300 days (Velayutham, 1999).

Table 1: Climatic data of Dikom – the nearest meteorological station of TRA from Maud T.E., Assam.

Months	Av. Max. Temp. (^{0}C)	Av. Min. Temp. (^{0}C)	Av. Total Rainfall (mm)	No. of rainy days	Relative humidity (%)			Pan evaporation rate (mm/day)
					Mor ning.	After noon	Mean	
January	23.1	9.5	31.2	5	96	53	74.5	1.2
February	24.4	12.3	65.8	10	95	55	75.0	1.6
March	26.4	15.8	124.2	13	92	57	74.5	2.1
April	27.7	18.7	236.8	17	92	66	79.0	2.2
May	30.0	21.8	323.9	18	91	70	80.5	2.7
June	32.0	24.1	448.8	22	93	77	85.0	2.6
July	31.5	24.8	508.3	25	95	78	86.5	2.5
August	32.0	24.9	415.0	21	95	76	85.5	2.6
September	31.3	23.9	344.8	17	95	75	85.0	2.5
October	30.0	20.7	130.1	10	95	67	81.0	2.1
November	27.6	15.1	24.7	3	96	57	76.5	1.7
December	24.9	10.2	10.6	2	96	52	74.0	1.3

Source: (*Meterological Data Recorded at TRA-Dikom, 2011- average from 1988-2010*)

The area received about 2664.2 mm annual rainfall and the maximum amount (2277.6 mm) occurred during the months of April to September. The highest mean monthly temperature (32.0^{0}C) is observed in the month of June and August, and the lowest (9.5^{0}C) in the month of January (table 1). The difference between Mean Summer Soil Temperature (MSST) and Mean Winter Soil Temperature (MWST) is more than 5^{0}C. Thus the soil temperature regime qualifies for "hyperthermic". The mean monthly relative humidity ranged between 74.0 and 86.5 per cent (Anonymous, 2011).

Out of the total rainfall about 64.44 per cent is received (Fig. 3) during the South West Monsoon (SWM) period (June to September), 25.71 per cent during Hot Weather Period (HWP) (March to May), 6.21 per cent during North East

Monsoon (NEM) period (October to December), while the rest 3.64 per cent is received during the Cold Weather Period (CWP) (January and February). July is the wettest month of the year followed by June, August, September and May. Rainfall in the region occured mainly during the pre-monsoon and monsoon seasons i.e. April to September. During this period the monthly rainfall varied from 236.8 to 508.3 mm. Rainfall started receding in October and there was very little rainfall from November to February.

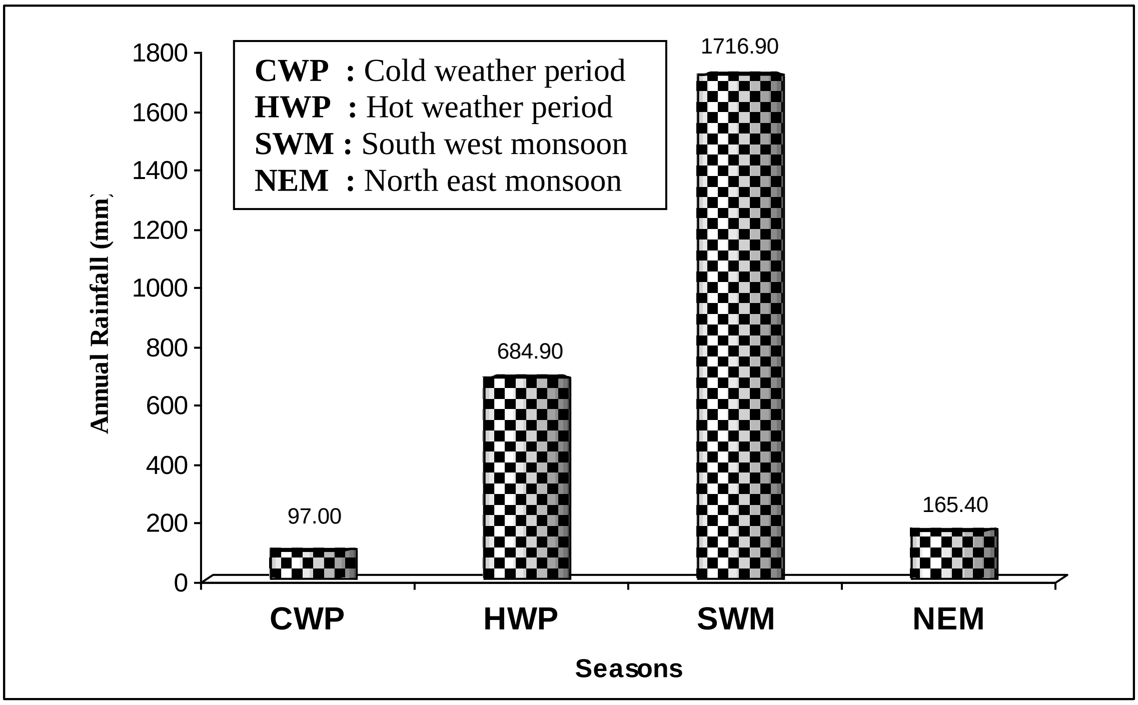


Fig. 3 : Seasonal distribution of rainfall in Maud T.E, Assam

Water balance diagram (Fig. 4) of Maud T.E represents the yearly soil moisture budget. It indicated that in the 1st week of February, precipitation (P) exceeded 0.5 potential evapo-transpiration (PET) indicating sufficient availability of moisture for seed germination. The period from 2nd week of February (P > 0.5PET) to 4th week of March (P = PET) is considered as the moist

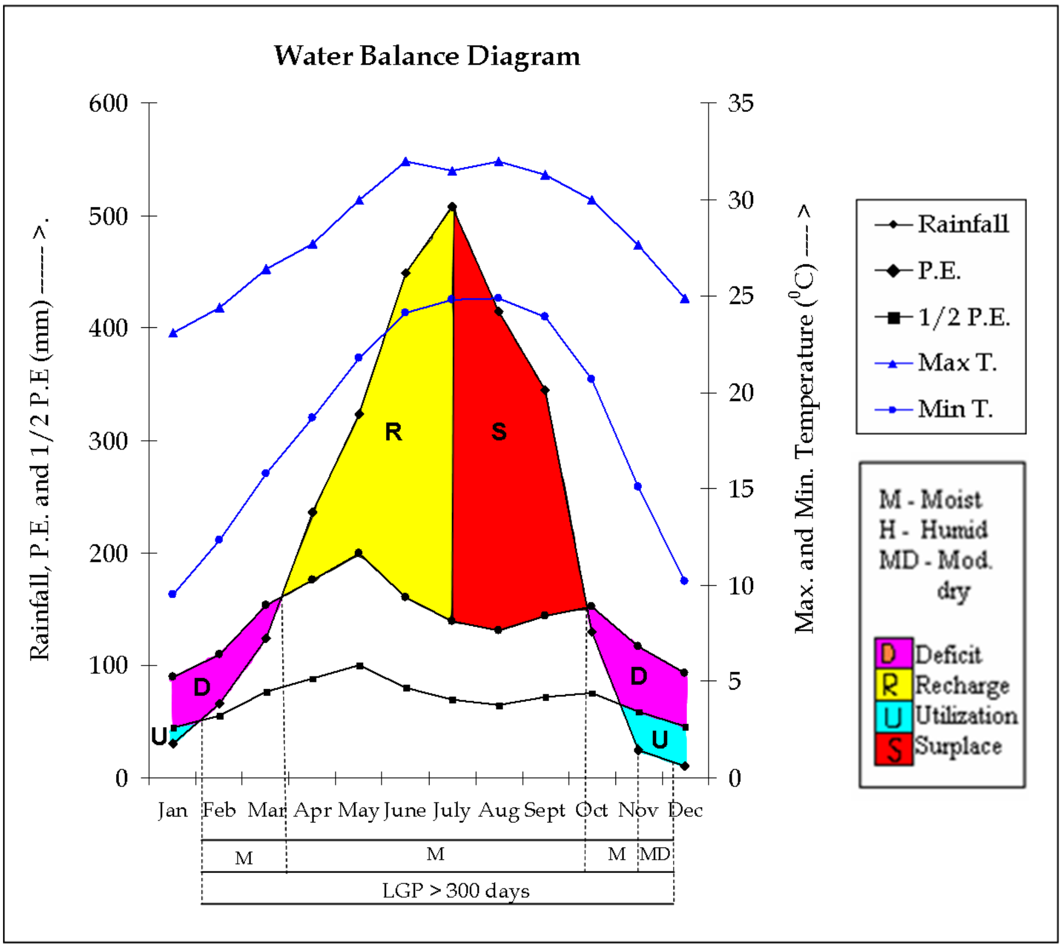


Fig. 4 : Water balance diagram of tea growing zone surrounds Maud T.E.

***Source : Mandal *et al.*(1999).**

period. The period when P is greater than PET is considered as the humid or wet period and meets full evapo-transpiration demand of crop and replenishes the moisture deficit in the soils. In the study area, this period commenced in the 1^{st} week of April and is extended up to almost 2^{nd} week of October when P is again equal to PET.

During the post humid period i.e. after 2^{nd} week of October, P is again less than PET. The stage when P is less than 0.5 P (in post humid period) means the end of rainy season (i.e., 4^{th} week of October). But the growing period still continued up to the first week of December. Hence, the length of growing period (moisture availability period) for soils in the area is more than 300 days.

ANALYTICAL STUDY

Qualitative analysis of soil and organic soil inputs was taken up during the three year project period. **Total 2,548 Soil Samples were analyzed (Table 2), during the three year period of the project in a Periodical Manner i.e. Total 10 Times.**

Table 2 : Soil Analytical parameters

Soil Physical Parameters	Soil Chemical & Fertility Parameters	Soil Biological Parameters (no. per g moist soil)	Nitrogen Dynamics ($kgha^{-1}$)
1. Sand (%)	1. pH (H_2O)	1. Bacterial population	1. Readily Available - N
2. Silt (%)	2. EC (dSm^{-1})	2. Fungal population	2. Total Mineralizable - N
3. Clay (%)	3. Organic carbon (%)	3. Actinomycetes population	3. Total NH_4^+ (Exch.+ Fixed)
4. Bulk density (gcc^{-1})	4. CEC [$cmol(p^+)kg^{-1}$]	4. Total Ammonifiers	4. Exchangeable NH_4^+
5. Pore space (%)	5. Available N ($kgha^{-1}$)	5. Total Nitrosomonas	5. Fixed NH_4^+
6. WHC (%)	6. Available P ($kgha^{-1}$)	6. Total Nitrobacter	6. Exchangeable $NO_2^- + NO_3^-$
7. Particle density (gcc^{-1})	7. Available K ($kgha^{-1}$)	7. Total PSB	
8. Volume Expn. (%)	8. Available S ($kgha^{-1}$)	8. Soil respiration ($mgCO_2 – C/g$ OM/day)	

Total 2520 soil samples were analyzed in detail as per 30 Quality parameters, while the rest were tested for physicochemical properties, nutritional content and microbial potential.

Analysis of different on-farm produced compost like vermicompost, Biodynamic compost, Indigenous compost and Novcom compost was taken up on periodical basis to assess their respective quality. Quality analysis of compost (Table 3) was taken up as part of the experiment for comparative evaluation of different on-farm produced compost, and also for calculating their respective application dose in 'Packages of Practice' and Soil Input experiment (for which oil cake was also considered) based on nitrogen and moisture content of individual compost.

Table 3 : Compost Analysis Parameters

Physical Properties		**Fertility Parameters**	
1.	Moisture percent (%)	11.	Total nitrogen (%)
2.	Bulk density (g/cc)	12.	Total phosphorus (%)
3.	Porosity (%)	13.	Total potassium (%)
4.	Water holding capacity (%)	14.	C/N ratio
Physicochemical Properties		**Microbial Potential**	
5.	pH_{water} (1 : 5)	15.	Total bacterial count (per gram moist compost)
6.	EC (1:5) dS/m	16.	Total fungal count (-do-)
7.	Ash Content (%)	17.	Total actinomycetes count (-do-)
8.	Total volatile solids (%)	18.	Microbial biomass carbon (%)
9.	Organic carbon (%)		
10.	Compost Mineralization Index		
Stability, Maturity & Phytotoxicity		**Readily Available Nutrient Potential**	
19.	CO_2 evolution rate ($mgCO_2$ – C/g OM/day)	26.	Water soluble carbon (%)
20.	NH_4^+ - Nitrogen (%)	27.	Water soluble inorganic N (%)
21.	NO_3^- - Nitrogen ($mgkg^{-1}$)	28.	Water soluble organic N (%)
22.	Nitrification Index	29	Organic C/N ratio
23.	Seedling Emergence (% of control)	30.	CEC {cmol(p+)kg^{-1}}
24.	Root Elongation (% of control)	31.	Sorption Index
25.	Germination Index (phytotoxicity bioassay)	32.	Humification Ratio

Total 308 Compost/ Soil Input samples were analyzed during the 3 Year Project period. Among these, 175 samples were analyzed in detail as per 32 Quality parameters, while the rest were tested for physicochemical properties, nutritional content and microbial potential.

Logic behind Formulation of Treatments (Organic packages of Practice) for Different Experiments in Mature Tea, Young Tea, New Tea Plantation & Nursery

As the objectivity of the project was to bring forth a sustainable organic pathway, it was understood that the objectivity cannot be met through evaluation of individual organic inputs. Hence, the concept of Comprehensive Organic Method/ 'Package of Practice' was introduced for the first time, because Organic means organized or systematic as an 'Organic Whole', where sustainability cannot be obtained by a fragmental approach.

To bring forth the 'Effective Organic Pathway' Organic Methods viz. Biodynamic farming and Inhana Rational Farming Technology, which are presently adopted and practiced in sizeable organic tea plantations, were taken up for scientific evaluation.

Although there are no other popular methods, a large number of organic Inputs *viz.* vermicompost, bio-fertilizer/ pesticides, herbal formulations etc. are also in wide use.

However, individually these inputs do not provide composite benefits and neither their individual evaluation can bring forth the desired pathway, hence they were combined to form different 'Packages of Practice' (based on scientific rationale) before taking up for effectivity assessment.

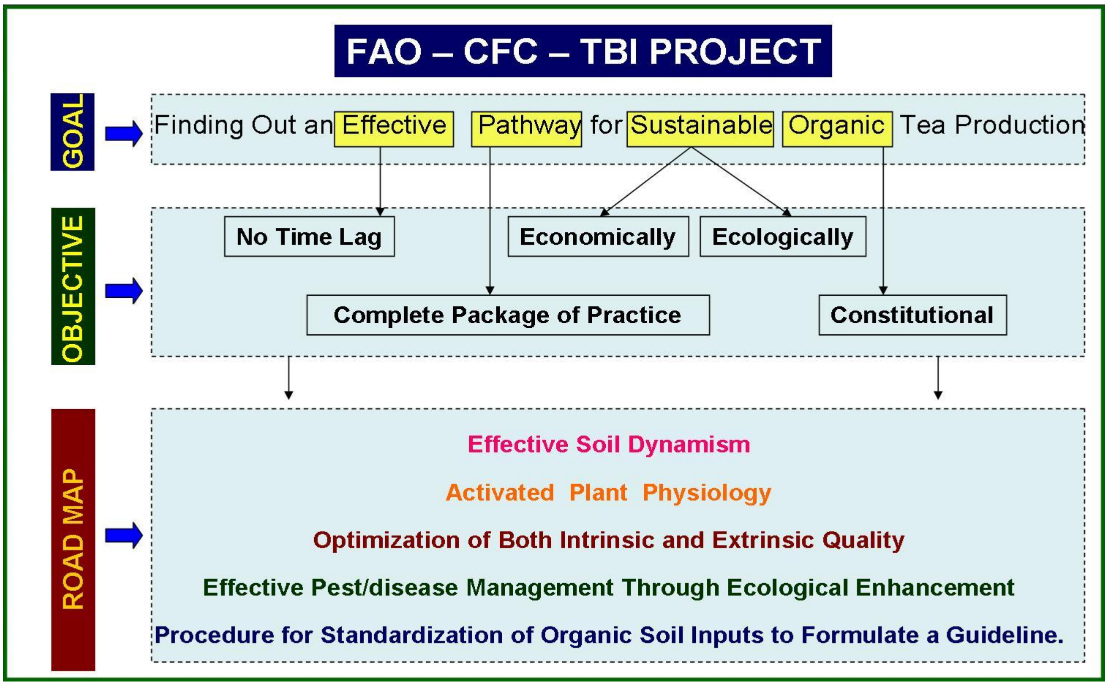


Fig 5 : Road map for attending the desire objectivity

Table 4 : Components of Different Packages of Practice

Organic Farming Methods	Organic Inputs	
	Soil Inputs	*Growth promoters/ pesticides*
1. Biodynamic Farming 2.Inhana Rational Farming Technology (IRF)	1. Vermicompost 2.Indigenous compost (FYM) 3. Bio-fertilizers 4. Oil cake	1. Herbal formulations for pest/ disease control 2. Bio-pesticides

Table 5A: Brief Details of Treatments under different Experiments in Micro Research Area (total area approx. 20 ha) & General Garden Practice at Maud T. E. under FAO-CFC-TBI Project.

Treatments in Mature Tea (NRA –Sec. 4)	Treatments of Soil Inputs (ERA 1- Part of Sec. 6A)
T_1 : Vermi+ Conventional Plant Mgt. (VCO)	T_1 : Control (C1)
T_2 : Vermi + Microbial formulations for Plant Management (VMIP)	T_2 : Vermi Compost (VC) – as per N req.
T_3 : Vermi + Biofertilizer + Microbial formulations for Plant Mgt. (VMI)	T_3 : Vermi Compost – as per N req.+ Biofertilizer (VCBF) – as per recomm.
T_4 : Microbial formulations [Biofertilizers & Biopesticides] (MI)	T_4 : Novcom Compost (NOV-1 as per N req.)
T_5 : Inhana Rational Farming 1 (IRF-1)	T_5 : Novcom Compost (NOV-2 @ 3 ton/hec.)
T_6 : Inhana Rational Farming 2 (IRF-2)	T_6 : Novcom Compost (NOV-3 @ 6 ton/hec.)
T_7 : Inhana Rational Farming 3 (IRF-3)	T_7 : Biofertilizer (BF) - as per recomm.
T_8 : Inhana Rational Farming 4 (IRF-4)	T_8 : Biodynamic Soil Input (BDS)- as per recomm.
T_9 : Biodynamic Farming (BD)	T_9 : Farm Yard Manure (FYM-1 as per N req.)
T_{10}: Conventional Organic Practice (CO)	T_{10}: Farm Yard Manure (FYM-2 as per Recomm.)
T_{11}: Control (C)	T_{11}: Oil Cake (OC as per N req.)

Table 5B : Brief Details of Treatments under different Experiments in Micro Research Area (total area approx. 20 ha) & General Garden Practice at Maud T. E. under FAO-CFC-TBI Project

Treatments of Young Tea Plantation (ERA 2- Part of Sec. 13A)	**Treatments of Uprooting/ Re-plantation (ERA 3- Part of Sec. 7P)**
T_1 : Control (C1)	T_1 : Control (C1)
T_2 : Vermi+ Conventional Plant Mgt. (VCO)	T_2 : Vermi+ Conventional Plant Mgt. (VCO)
T_3 : Vermi + Bio-fertilizer + Microbial formulations for Plant Mgt. (VMI)	T_3 : Vermi + Biofertilizer + Microbial formulations for Plant Mgt (VMI)
T_4 : Inhana Rational Farming 1 (IRF-1)	T_4 : Inhana Rational Farming 1 (IRF-1)
T_5 : Inhana Rational Farming 2 (IRF-2)	T_5 : Inhana Rational Farming 2 (IRF-2)
T_6 : Microbial formulations [Bio-fertilizers & Bio-pesticides] (MI)	T_6 : Microbial formulations [Biofertilizers & Biopesticides] (MI)
T_7 : Biodynamic Farming (BD)	T_7 : Biodynamic Farming (BD)
T_8 : Conventional Organic Practice (CO)	T_8 : Conventional Org. Practice (CO)

Treatments of Applied Research Area (Mature Tea), ARA	**Nursery**
T1 Control (C1) T2 Vermicompost+ Biofertilizer+ Microbial formulations for Plant Management (VMI) T3 Inhana Rational Farming - 1 (IRF - 1) T4 Vermicompost+ Conventional Plant Management (VCO) T5 Inhana Rational Farming 2 (IRF - 2) T6 Biodynamic Farming (BD)	Experiment is being also conducted in seed nursery using five 'Packages of Practice' (each) *viz.* CO, BD, IRF, VCO & MI; to evaluate their effectivity towards development of organic tea nursery.

<u>Practice Followed in Rest Garden Area of Maud T.E (Total Area – 147.03 ha)</u>
<u>Total Project Area</u> (proposed) at Maud Tea Estate is **100 ha** including **<u>Total Micro Research Area</u>** of **about 20 ha**. Hence in **rest 80 ha Project Area + 47.03 ha Rest Garden Area** cultivation is being done under **Inhana Rational Farming Technology (IRF)**, which comprises **three basic steps** i.e. soil management, plant management and pest/ disease management.

Criteria for Selection of Different Experimental Areas

1. ON-FARM COMPOSTING - *Production of different types of compost using available green matter and cow dung*

Organic soil management has become emergent in order to rejuvenate the progressively depleting soil character under chemical farming practices. However, despite their quantitative and long term application soil restoration has remained impending primarily due to poor quality organic soil inputs. To ensure the objectivity focus has to be shifted from quantitative to qualitative approach. Moreover, since quality of compost actually determines its application quantity hence, good quality compost shall be requisite also to ensure soil rejuvenation at an affordable cost.

Composting programme was taken up under the project for production of different types of compost *viz.* vermicompost, Biodynamic compost, Indigenous (FYM) compost and Novcom compost using available on-farm resources. The different composting methods were evaluated for some practical criteria like biodegradation period, raw material specificity etc. followed by quality evaluation of the end product in terms of 32 different parameters as per national protocol, U.S. Composting Council and Australian standards.

2. EXPERIMENTAL RESEARCH AREA 1 (ERA-1)- *Soil Input Experiment in Mature Tea*

In the present day agriculture deterioration of soil support system has been easily felt and presently the emphasis has been more towards organic soil management but at the same time ambiguities regarding the right quality soil input have been hand in hand. At the same time replacement of chemical fertilizers by organic inputs entails huge quantity, which is practically not possible and the response is low as compared to chemical. Moreover, where adoption of a complete method is not possible in the initial phase or only individual organic input is available for use, soil rejuvenation can serve as the stepping stone in the way of sustainability.

Hence, evaluation of different Organic Soil Inputs was taken up in the form of **11 different treatments with three replications making a total of 33 plots** under **Soil Input Experiment in Sec.6A**. The experiment was laid out in the adjacent area of NRA again to minimize heterogeneity in terms of variation in plant variety, yield potential, vacancy percentage etc. **The experiment was conducted for a period of 3 years** and with two major objectivities:

- Formulation of an effective guideline regarding the right quality compost/ soil input for effective soil rejuvenation.
- Assessment of the influence of individual soil inputs towards the results obtained under different treatments in the Package of Practices Exp. (NRA).

Pic. 2 : Lay Out of **Organic Soil input Experiment** at **Experimental Research Area - 1 (ERA – 1)**, at Maud T. E. under FAO-CFC-TBI Project.

3. TEA NURSERY - *Development of Organic Tea Nursery under Different Organic Packages of Practice*

Good nursery management is essential for development of healthy plants for future higher crop potential. Especially in case of tea plantation, where the bushes may remain in the productive phase for even up to 100 years, healthy nursery plants will serve to ensure higher survival rate, speedy establishment as well as early, high and long productive phase of the plants. However, successful development of Nursery under organic management is still considered as a challenging job. Under this project, a package of practice experiment was initiated in nursery (using seeds) in 2009 to bring forth an effective pathway for successful organic nursery management. Five different packages with one control were evaluated under the project.

3. EXPERIMENTAL RESEARCH AREA 3 (ERA-3) - *Package of Practice Experiment in New Plantation*

Successful replanting programme under organic management remains a hard attained objective. In order to ensure survival of the new plants and simultaneously their healthy and faster growth, a healthy soil environment as well as steady and balanced supply of nutrients becomes the prime requisition. However, in the presently depleted soils physiological stress in the young plants becomes widely apparent under organic management in the absence of effective soil rejuvenation and insufficient availability of nutrients under application of the available organic inputs. Hence, bringing forth an Effective Organic Road Map for replanting programme becomes utmost important with an objectivity to reinstate the natural potential of future plantations through provision of sustained organic environment from juvenile stage.

Hence, all available organic methods and different organic soil/ plant inputs (combined to form different packages of practice based on scientific rationale) were evaluated in the form of 8 **different Treatments with 3 Replications making a total of 24 Plots** under **<u>Uprooting/ Replanting Experiment in Sec. 7P</u>. The experiment was conducted for a period of two years.**

Pic. 3 : Members of the 'Inhana Advisory Board' visiting the **Experimental Research Area – 3 (ERA - 3)** at Maud T. E. under FAO-CFC-TBI Project.

4. EXPERIMENTAL RESEARCH AREA 2 (ERA-2) - *Package of Practice Experiment in Young Tea*

Effective management of Young Tea - the future bearers of plantation potential, forms a major challenge in organic tea cultivation due to dependency of clonal variety on chemical inputs. Hence, upbringing of new plants in a comparable manner is a challenge and the deterrent factor for moving into organic. As the different available organic methods/ packages of practice were evaluated under the Project (in NRA) to chalk out the most effective organic pathway, it became all the more relevant to test their potential towards effective management of young plantation.

Hence, all available organic methods and different organic soil/ plant inputs (combined to form different packages of practice based on scientific rationale) were evaluated in the form of **8 different Treatments with 3 Replications making a total of 24 Plots**, under **Young Plantation Experiment in Sec. 13A**. **The experiment was conducted for a period of three years** with an objectivity to conclude proper bush/ frame formation, speedy growth and early crop potential.

Pic. 4 : Members of the 'Inhana Advisory Board' visiting the **Experimental Research Area – 2 (ERA - 2)**, at Maud T. E. under FAO-CFC-TBI Project.

5. NUCLEUS RESEARCH AREA (NRA) - *Package of Practice Experiment in Mature Tea*

In order to chalk out an effective Organic Pathway, the compartmental system of only individual input evaluation has to be transformed to a more comprehensive assessment. This is important not only for identification of the most effective Organic Method (if any) but also for formulation of a comprehensive guideline or a Package of Practice, which may be composed of various individual inputs, but can be effectively functional by operating in an integrated manner.

Hence keeping in view the objectivity, all available organic methods and different organic soil and plant inputs (combined to form different packages of practice based on scientific rationale) were selected (in the form of **11 different Treatments with 3 Replications making a Total of 33 Plots**) for evaluation in NRA, under **Package of practices Experiment in Sec. 4**. **The experiment was conducted for a period of three years.**

Pic. 5: Banner showing Lay Out of 'Package of Practice' Experiment in **Nucleus Research Area (NRA)**, at Maud T.E. under FAO-CFC-TBI Project.

6. APPLIED RESEARCH AREA (ARA) – *Selected Package of Practice Experiment in Mature Tea on Large Scale*

The concept of Applied Research Area was developed to examine the actual potential of selective (4 to 5) Methods/ Package of Practice (screened from NRA on the basis of 1st year performance) in a larger area under wider heterogeneity. The methods/ packages were selected on the basis of their potentials reflected during 1st year of experimentation in NRA as well as their demand/ usage under present organic cultivation practices. Here, each plot size was of 2 ha area, without any replication, except erection of guard line on four sides of each experimental block.

Pic. 6: Applied Research Area, where selective **4 to 5 Packages of Practice (screened from NRA)** were evaluated on a larger scale, at Maud T. E.

8. LARGE SCALE ADOPTION OF ORGANIC FARMING– *Documentation of performance of Inhana Rational Farming (IRF) in Large Scale*

Maud T.E. has a total area of about 155 ha. Hence, excluding about 20 ha area which comprised of different experiments under the project, in rest 135 ha area Inhana Rational Farming (IRF) was adopted and practiced from 2009 to 2011. Evaluation of the potential of IRF was judged through assessment of crop performance at Maud T.E. for the three year project period *vis-a vis* in the same crop growing circle i.e. Panitola Circle; where all other gardens are under chemical practice.

THE EXPERIMENTS WERE LAID OUT IN A MANNER SO THAT THEY COVERED ALL GROWTH STAGES OF TEA PLANT

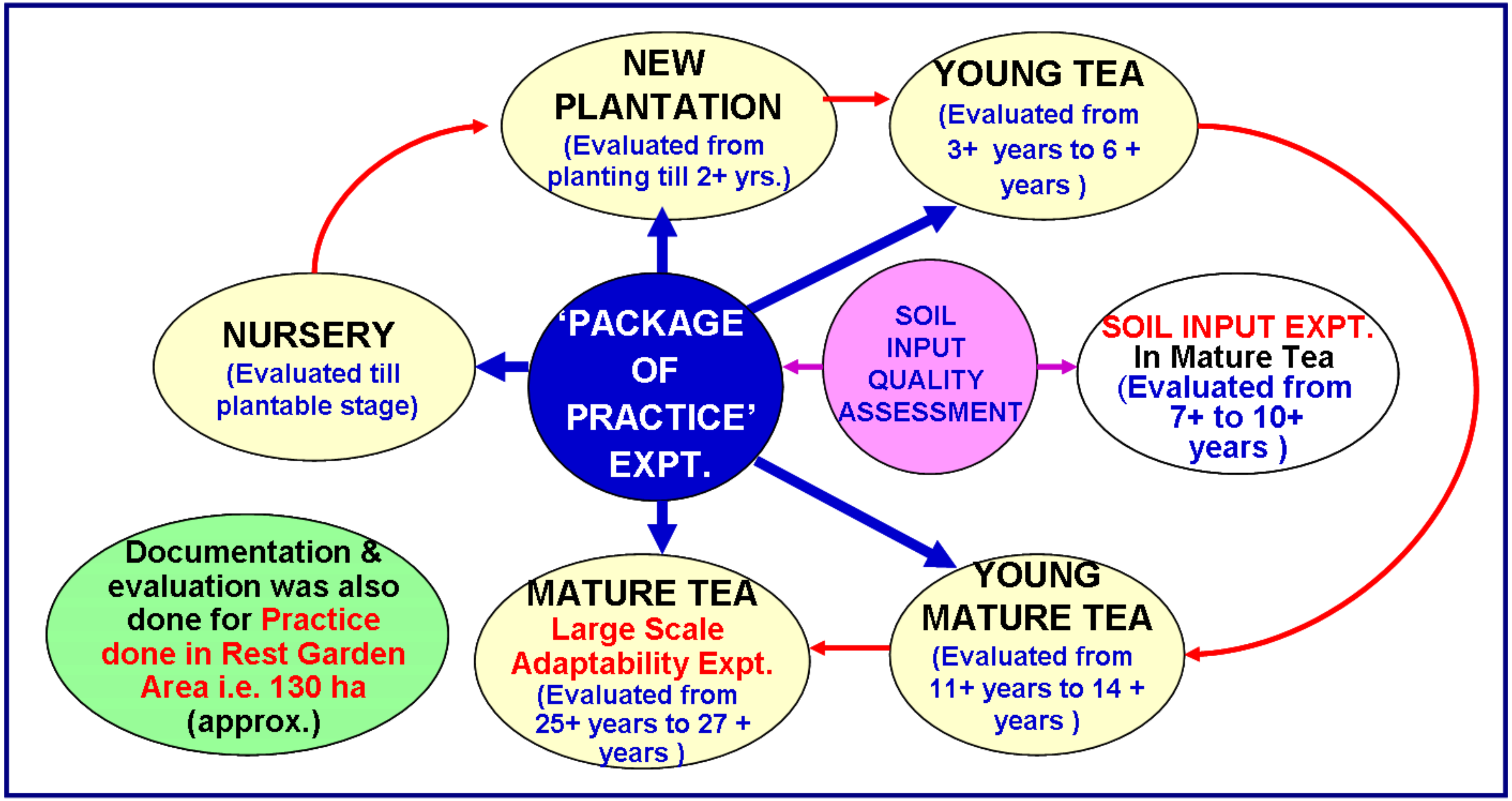
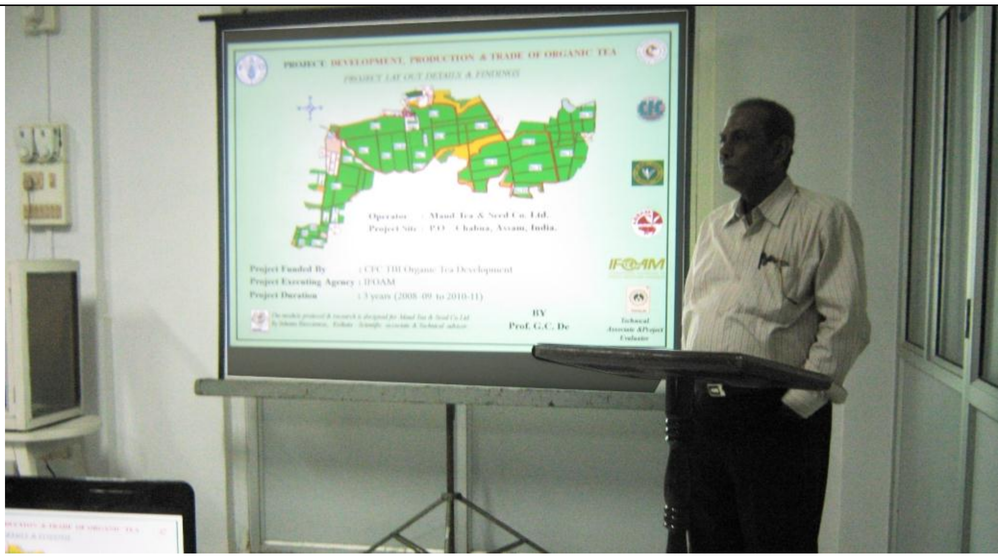


Fig. 6 : Composite Approach of the experimental protocol

Pic. 7: Mr. Ashok Lohia, Chairman of Chamong Group addressed the meeting during visit of CFC team for evaluation of on-going activities under FAO-CFC-TBI Project at Maud T.E. (Assam).

Pic.8: Deliberation of Prof. A. Chatterjee, member of Advisory Board regarding the 'Need for Organic', at Maud T.E.

Pic 9 : Professors from diff. university discussed about the project at Maud T. E.



Pic. 10 : Prof. G.C. De, member of Advisory Board presented the progress of the Project under FAO-CFC-TBI Project at Maud T.E.

Evaluation of Different Organic Soil Inputs Quality under FAO-CFC-TBI Project at Maud T.E., Assam

Brief Summary

Different composting processes viz. vermi composting, Biodynamic, Indigenous or FYM and Novcom composting methods were evaluated on- farm in terms of process convenience viz. biodegradation period, N appreciation in final compost, economics of production and end product quality.

Biodegradation period varied from 21-30 days in case of Novcom compost, 60-75 days for vermi compost and 80-90 days in case of Biodynamic and Indigenous compost. Assessment of nitrogen content in final compost vis-à-vis in raw material (similar raw material was used for all the types of compost) indicated up to 92 percent appreciated value under Novcom compost as against 47, 53 and 56 percent in case of vermin compost, Biodynamic compost and Indigenous compost respectively.

The end product (compost) quality was judged as per 32 different parameters (physicochemical properties, nutrient content, microbial potential, stability, maturity & phytotoxicity status) following national and international standards. Highest nutrient (N+P+K) content was recorded under Novcom compost (4.05%) while lowest (2.69%) for Indigenous compost. The most important finding was the significantly high microbial population (total bacteria, total fungi and total actinomycetes) in Novcom compost (at least 10^4 to 10^6 c.f.u times) as compared to the same noted for other compost samples.

To grade different types of compost in order to enable easy understanding at the planters' level 'Compost Quality Index (CQI)' was developed on the basis of four major representative parameters i.e., total nutrient (N+P+K), microbial potential, germination index and C/N ratio. Highest CQI was obtained for Novcom compost (CQI: 7.28) followed by Biodynamic compost (CQI: 3.59), vermicompost (CQI: 2.82) and Indigenous compost (CQI: 2.24).

Evaluation of Different Organic Soil Inputs Quality under FAO-CFC-TBI Project at Maud T.E., Assam

Introduction

In today's agriculture there has been a growing conviction that organic soil amendment is the best option available to restore and enhance soil potential in order to restrict the continuous decline of productivity (Bhattacharyya and Chakraborty, 2005; Hornick and Parr, 1987). Application of organic soil amendment/ compost in soil is basically aimed at increasing the proliferation and activity of the indigenous population of soil microbes, which being the prime drivers behind all soil ecological processes serve for restoration of soil quality. However, the major bottleneck towards adoption of organic cultivation practices is the poor quality of organic soil inputs in terms of low nutrient (N, P and K) content, microbial status and stability which, entails their voluminous requirement to suffice for crop nutrient requirement (Rupela, 2009). The problem becomes magnified in case of large organic farms *viz.* tea/ coffee plantations etc. where the huge requirement of soil inputs often cannot be met by on- farm production hence, outsourcing remains the only option.

Off- farm compost usually comes at a higher cost and at the same time are mostly of non- uniform quality. In this scenario to ensure speedy restoration of soil potential and sustained crop production without triggering the cost components or entailing soil nutrient mining; application of good quality, stable and mature compost remains the only option. Different on-farm composting programme was taken up at Maud tea estate (Assam, India) under FAO-CFC-TBI Project (2008-2011), to evaluate the processes in terms of their biodegradation pathway, period of composting, end product/ compost quality and cost of production

Objective

To evaluate the different on-farm composting methods in terms of their process convenience, end product/ compost quality and cost of production.

Methodology

On-farm available green matter comprising common garden weeds *viz. Mikania micrantha*, *Ageratum houstonianum*, *Axonopus compressus, Digitaria setigera Roth*, *Clerodendrum viscosum Vent*., *Scoparia dulcis Linn*., *Paspalum longifolium Roxb* etc. were used for making four different types of compost *viz.* Vermi compost, Indigenous (FYM) compost, Biodynamic compost and Novcom compost at Maud tea estate.

Raw materials and compost samples were drawn from 33 composting heaps of individual type during 2008-2009 and 2009–2010. The samples were analyzed as per 32 different quality parameters *viz.* physicochemical properties, nutrient content, microbial status, stability, maturity and phytotoxicity parameters; as per national and international standards.

Qualitative evaluation of different on-farm produced compost at Maud Tea Estate

To evaluate the end product quality under different processes *viz.* Vermi (VC), Biodynamic (BD), Indigenous (IC) and Novcom (NOV) composting method, final compost samples were evaluated for 32 different quality parameters *viz.* physicochemical properties, nutrient content, microbial population, stability, maturity and phytotoxicity status (Table 6 & 7).

Physical parameters of the compost samples

All the compost samples appeared dark brown in colour with an earthy smell, deemed necessary for mature compost (Epstein, 1997). Average moisture in compost samples varied from 46.46 to 56.73 percent, which may be placed in the higher value range (40 to 50) as suggested by Evanylo, (2006). Bulk density of the compost samples (0.47 to 0.70 g/cc,) was well within the standard range (0.4 to 0.7 g/cc) suggested by U.S Composting Council (2002). Porosity of the compost samples, which ranged from 52.43 to 67.01 percent (Table 6) and water holding capacity values (157.51 to 206.36 %) were all in the higher value category (standard range of 100 to 200 with preferred value of >100) as per the range suggested by Evanylo (2006). Water holding capacity may be attributed to the abundance of humus particles in compost (Trautmann and Krasny, 1997) and higher values might indicate higher presence of humus type materials in the samples. Application of compost with higher water holding capacity helped in retaining soil moisture during the dry months (Bhattacharya, 2001).

Physicochemical parameters of the compost samples

The predominant use of compost is to mix it with soil to form a good growing medium for plants, for which pH forms an important criteria of consideration (Watson, 2003). pH values obtained for the different compost samples (except in case of vermicompost) indicated them to be well within the stipulated range (7.2 to 8.5) for good quality and mature compost (Jime`nez and Garcia, 1989). The soluble salt concentration (reflected by the electrical conductivity values) is an important parameter, which indicates the nutrient status of compost. Very high concentration of soluble salts in the plant growth medium is detrimental for germinating seeds and plant growth, while very low electrical conductivity values indicated low nutrient status or poor quality compost. Electrical conductivity value of the compost samples ranged between 1.54 and 2.12 dSm^{-1}, indicating their high nutrient status at the same time being safely below (< 4.0 dSm^{-1}) the stipulated range for saline toxicity as per USCC (Evanylo, 2006). However, comparatively higher EC value in case of Novcom compost might indicate comparatively higher nutritional status within the compost.

Organic matter content in compost is a necessary parameter for determining compost application rate, in order to obtain sustainable agricultural production. Organic carbon content in the compost samples ranged between 23.70 and 27.94 percent, qualifying not only the criteria for field application (16 to 38) as per the range suggested by USCC (2002) but also the standard suggested value of >19.4 percent (Australian Standard 4454, 1999) for nursery application. Ash content of the compost samples varied from 49.71 to 57.34 percent while volatile solids ranged from 42.66 to 50.29 percent. CEC is one of the most important properties of compost and is usually closely related to fertility. The CEC values obtained for different soil inputs indicated the relative presence of organic colloids, having high exchange capacity in the range of 100 to 300 meq/100g of compost. Cation exchange capacity of different compost samples ranged between 140.03 and 267.07 $cmol(p+)kg^{-1}$, where the higher value was obtained in case of Novcom compost followed by Biodynamic and Indigenous (FYM) compost respectively. Compost mineralization index (CMI) expressed as ash content/ oxidizable carbon indicated the ready nutrient supplying potential of compost for plant uptake. The CMI values of the compost samples varied from 1.69 to 2.72 and complied with the standard suggested range (1.78 to 2.42) by Rekha *et al.* (2005). Sorption capacity index, reflected the degree of maturity of specific humic compounds (Inbar *et al.*, 1990) and in compost samples varied within 5.50 and 9.56 once again qualifying the criteria(>1.7) for well humified compost as described by Iglesias & Perez (1992).

Table 6 : Evaluation of physicochemical properties and nutrient status of different Organic Soil Inputs produced on-farm at Maud T.E., as per National and International standards.

Sl. No.	Parameter	Analytical Value			
		Vermi compost	Biodynamic compost	Indige-nous compost	Novcom compost
Physical Parameters					
1.	Moisture percent (%)	54.34^{a}	48.54^{b}	46.46^{b}	56.73^{a}
2.	Bulk density (g/cc)	0.70^{a}	0.63^{b}	0.67^{b}	0.47^{c}
3.	Porosity (%)	55.80^{b}	52.43^{c}	54.23^{bc}	67.01^{a}
4.	WHC[1] (%)	157.51^{b}	165.45^{b}	173.64^{b}	206.36^{a}
Physicochemical Parameters					
5.	pH_{water} (1 : 5)	6.56^{d}	7.23^{b}	7.03^{c}	7.61^{a}
6.	EC (1 :5) dS/m	1.56^{b}	1.68^{b}	1.54^{b}	2.21^{a}
7.	Total Ash Content (%)	54.14^{b}	52.64^{b}	57.34^{a}	49.71^{c}
8.	Total Volatile Solids (%)	45.86^{bc}	47.37^{b}	42.66^{c}	50.29^{a}
9.	Organic carbon (%)	25.48^{b}	26.31^{b}	23.70^{b}	27.94^{a}
10.	CEC (cmol(p+)kg^{-1})	140.03^{c}	215.89^{b}	174.03^{b}	267.07^{a}
11.	CMI[2]	2.12^{b}	2.00^{c}	2.42^{a}	1.78^{c}
12.	Sorption capacity index	5.50^{c}	8.21^{a}	7.34^{b}	9.56^{a}
Nutrient Content					
13.	Total nitrogen (%)	1.74^{b}	1.78^{b}	1.68^{b}	2.19^{a}
14.	Total phosphorus (%)	0.65^{b}	0.77^{a}	0.45^{b}	0.72^{ab}
15.	Total potassium (%)	0.87^{b}	1.18^{a}	0.56^{b}	1.14^{a}
16.	C/N ratio	$14.6 : 1^{a}$	$14.8 : 1^{a}$	$14.1 : 1^{a}$	$12.8 : 1^{b}$

[1]WHC : Water holding capacity; [2]CMI : Compost mineralization index

Note: letters shown in superscript beside mean values are results of Duncan Test

Composting programme under FAO-CFC-TBI Project at Maud T.E., Assam during 2009 to 2011.

Pic. 11: Objectivity taken up for large scale composting programme under FAO – CFC-TBI Project at Maud Tea Estate (Assam).

Pic. 12: Professors of Calcutta University visit Novcom composting at Maud T.E. under FAO-CFC-TBI Project.

Pic. 13 : Regular monitoring of temperature in Novcom composting heap to ensure compost quality.

Nutrient content in the Compost samples:

Although 36 different nutrients are required for plant growth, but the macronutrient (N, P, and K) contribution of compost is usually of major interest (Tisdale *et al.*, 1985). Among the different macronutrients, availability of nitrogen to the plants is most complex. Nitrogen may be present in two significant inorganic forms i.e. NO_3^- -N and NH_4^+-N. Immature compost will contain more ammonium-nitrogen than mature compost. The inorganic nitrogen forms are immediately available source for absorption by plants while the availability of the organic form depends on how rapidly the microorganisms break down the compost (Hadas and Portnoy, 1994).

The total nitrogen content in the compost samples ranged between 1.68 and 2.19 percent, which was well above the reference range (1.0 to 2.0 percent) suggested by Alexander (1994) and Watson (2003). The highest content of nitrogen (2.19 percent) obtained in case of Novcom compost, might indicate higher fixation of atmospheric-N within compost heap during Novcom composting process (fig. 7).

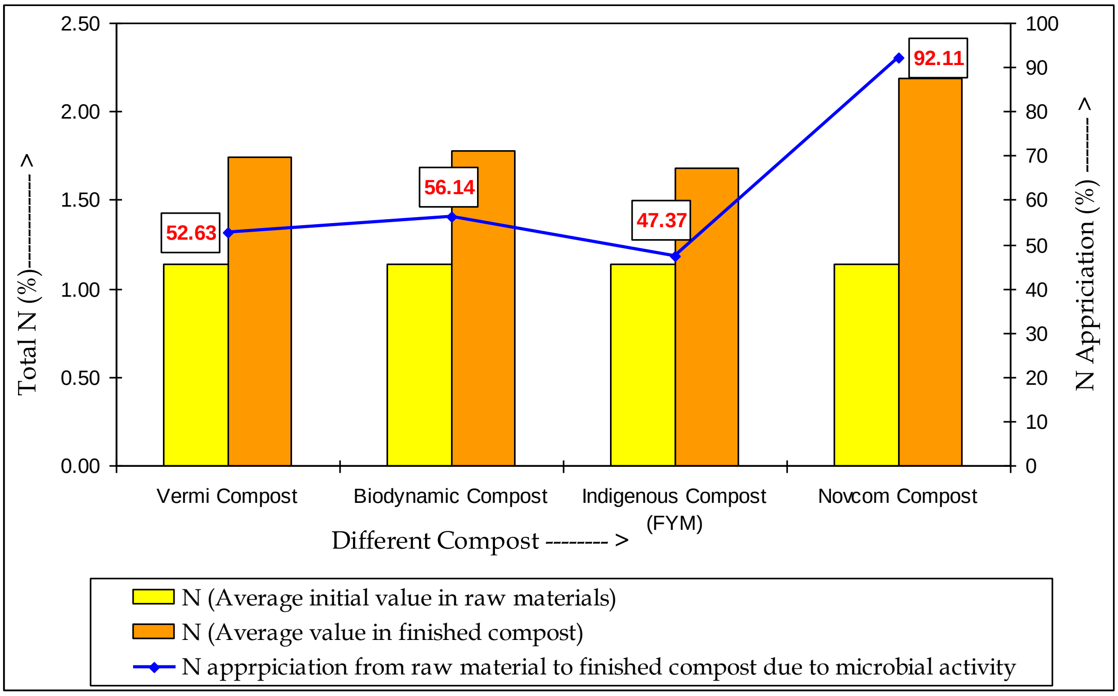


Fig. 7: Comparative study of total nitrogen content in different types of compost and N appreciation under respective composting processes at Maud Tea Estate (Assam) under FAO –CFC-TBI Project.

Total Phosphate (0.45 to 0.77 percent) and total potash content (0.56 to 1.18 percent) were also higher than the minimum suggested standard (0.6 to 0.9 percent and 0.2 to 0.5 percent respectively) by Alexander (1994) and Watson (2003). Total phosphate and total potash content was found to be highest in Biodynamic compost (0.77 and 1.18 percent respectively) closely followed by Novcom compost (0.72 and 1.14 percent respectively).

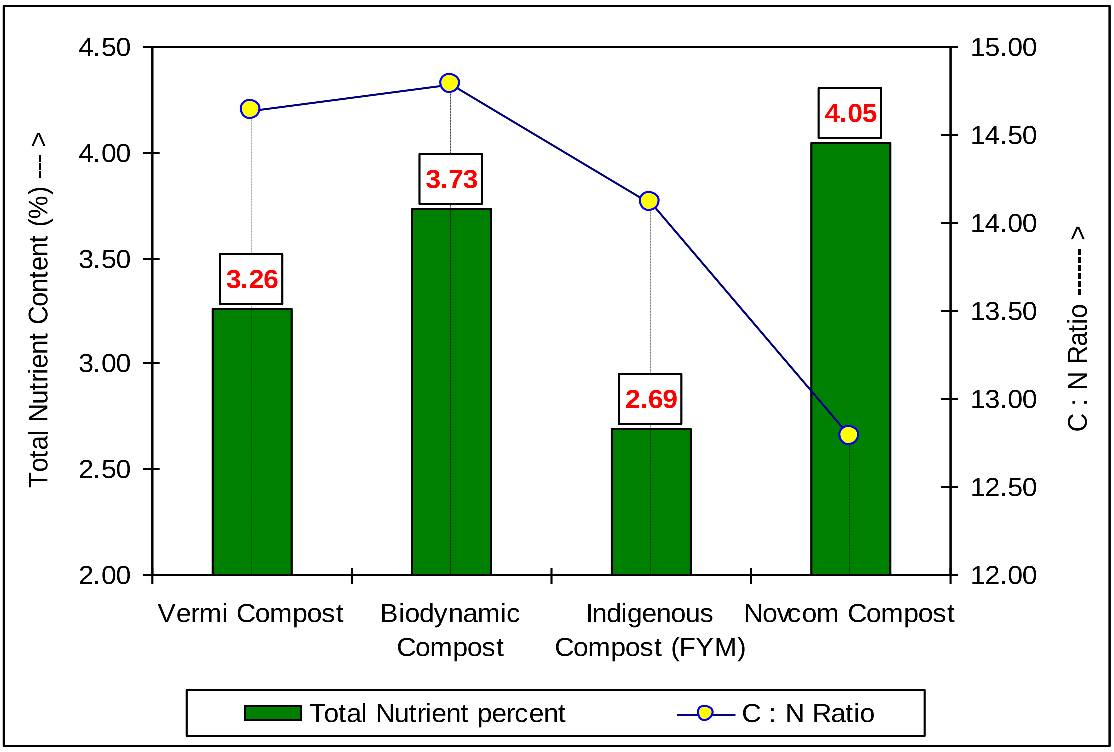


Fig. 8: Total Nutrient Content in different types of compost produced at Maud Tea Estate (Assam) under FAO-CFC-TBI Project.

The ideal C/N ratio of any mature compost should be about 10, as in humus; but it can be hardly achieved in composting (Mathur *et al.*, 1991). However, of greater importance is its critical value (C/N ratio 20), below which further decomposition of compost in soil does not require soil nitrogen, but released mineral nitrogen into the soil (Mathur *et al.*, 1993). C/N ratio varied from 12.8:1 in case of Novcom compost (fig. 8) and 14.8 : 1 in case of Biodynamic compost, which indicated that all the compost samples were mature and suitable for soil application.

Pic. 14 : Large scale Novcom composting programme at Maud T.E.

Pic. 15 : Novcom compost for application in different sections of Maud T.E.

Pic. 16 : Mode of compost application at Maud T.E.

Table 7: Quality evaluation of the different Organic Soil Inputs in terms of their nutrient supplying potential, microbial content, stability, maturity and phytotoxicity status; as per National & International standards.

Sl. No.	Parameter	Value			
		Vermi compost	Biodynamic compost	Indigenous compost	Novcom compost
Ready Nutrient Supplying Potential					
17.	Water soluble carbon (%)	0.250^{b}	0.328^{b}	0.312^{b}	0.390^{a}
18.	Water soluble inorganic N(%)	0. 087^{b}	0.106^{b}	0.086^{b}	0.125^{a}
19.	Water soluble organic N (%)	0.050^{b}	0.062^{b}	0.054^{b}	0.074^{a}
20.	Organic C/N ratio	5.00^{c}	5.29^{b}	5.78^{a}	5.29^{b}
21.	Humification ratio	0.98^{b}	1.25^{b}	1.32^{b}	1.40^{a}
Microbial Parameters (per gm moist soil)					
22.	Total bacterial count[3]	13.78^{b}	13.97^{b}	13.82^{b}	17.81^{a}
23.	Total fungal count[3]	11.53^{d}	13.24^{b}	13.06^{c}	17.32^{a}
24.	Total actinomycetes[3] count	11.15^{d}	12.85^{b}	12.54^{c}	17.15^{a}
25.	MBC[4] (%)	0.45^{d}	1.02^{b}	0.87^{c}	1.24^{a}
Stability Parameters					
26.	CO_2 evolution rate (mgCO_2–C/g OM/day)	1.43^{c}	1.89^{b}	1.81^{b}	2.16^{a}
Maturity & Phytotoxicity Parameters					
27.	NH_4^+ - Nitrogen (%)	0.025^{b}	0.028^{a}	0.024^{b}	0.023^{b}
28.	NO_3^- - Nitrogen (%)	0.062^{b}	0.078^{b}	0.062^{b}	0.102^{a}
29.	Nitrification Index	0.40^{a}	0.36^{a}	0.39^{a}	0.22^{b}
30.	Seedling emergence (% of control)	94.66^{c}	102.56^{b}	89.69^{d}	111.72^{a}
31.	Root elongation (% of control)	97.14^{c}	98.47^{ab}	94.23^{d}	114.16^{a}
32.	Germination index (phytotoxicity bioassay)	0.92^{c}	1.01^{b}	0.85^{d}	1.28^{a}

[3]Count in MPN method, [4]MBC : Microbial biomass carbon

Note: letters shown in superscript beside mean values are results of Duncan Test

Ready nutrient supplying potential of the compost samples

The water soluble forms of carbon and nitrogen representing the plant available forms, increased during compost maturation phase (Drozd *et al.*, 1997; Hsu & Lo, 1999). In the different compost samples water soluble carbon, varied from 0.25 to 0.39 percent, water soluble inorganic nitrogen ranged from 0.086 to 0.125 percent while water soluble organic nitrogen varied between 0.050 and 0.074 percent. Organic C/N ratio in compost water extract is considered to be one of the important indices for compost maturity (Jimenez and Garica, 1989; Chanyasak *et al.*, 1982 and Bhattacharyya, 2001). The values (5.0 : 1 to 5.78 : 1) obtained for compost samples were well within the stipulated range of 5 : 1 to 6 : 1 as proposed by Hirai *et al.* (1985) and Chanyasak *et al.* (1982).

Microbial parameters of compost samples

Microbial status of compost is one of the most important parameter for judging compost quality because microbes are the driving factors behind soil rejuvenation and maintenance of soil–plant-nutrient dynamics. Most organic substrates draw an indigenous population of microbes from the environment. In case of open-air composting processes, further colonization occurs naturally within composting material after heap construction as well as churning of heap (Wallace *et al.*, 2004).

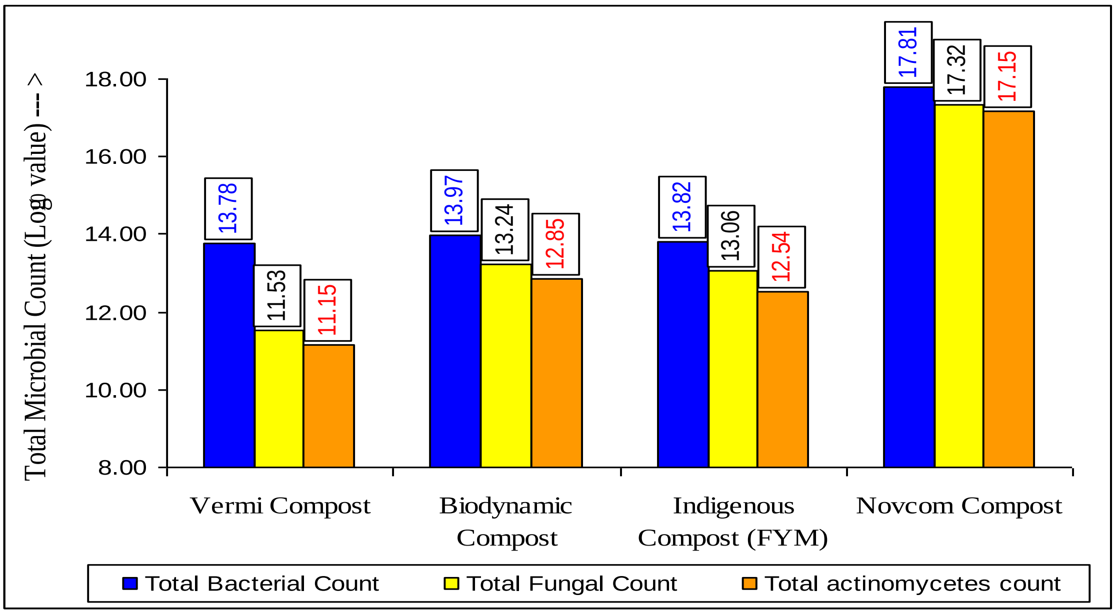


Fig. 9 : Comparative study of Microbial Count in different types of compost produced at Maud Tea Estate (Assam) under FAO-CFC-TBI Project.

The microbial population (total bacteria, total fungi and total actinomycetes) in Novcom compost samples was significantly higher (at least 10^4 to 10^6 c.f.u times) than the population obtained in case of other compost samples (Table 7, fig. 9). The high microbial status of Novcom compost was also of special significance considering that they were not exogenous inoculation but were generated naturally during composting. Measurement of the microbial biomass is considered to be an indicator of bio-maturity (Mathur *et al.*, 1993). The values obtained for different compost samples (0.45 to 1.24) were well within the critical limit of < 1.7 percent for compost maturity/ stability, as proposed by Mondini *et al.* (1997).

Stability, maturity and phytotoxicity parameters of compost samples

Stability of compost sample indicated the status of organic matter decomposition, which is a function of biological activity. Hence, microbial respiration formed an important parameter for determination of compost stability (Gómez *et al.*, 2006). Mean respiration or CO_2 evolution rate obtained for different composts (1.43 to 2.16 mg CO_2-C/gOM/day) indicated their stability considering the stipulated range of 2.0 - 5.0 as proposed for stable compost by Trautmann and Krasny (1997) and Bartha and Pramer (1965). The value obtained was also in close conformity to the respirometry stability class rating of U.S Composting Council (2002) for compost stability (Thompson *et al.*, 2002).

Compost maturity and phytotoxicity rating are the most important criteria for ensuring soil and plant safety post compost application. Immature compost may contain high level of free ammonia, organic acids or other water soluble compounds, which can limit seed germination and root development (USCC, 2002 and Evanylo, 2006). Many studies have shown that application of immature compost in soil caused severe damage to plant growth (Jimenez and Garcia, 1989). However, maturity is not described by a single property and is therefore best assessed by measuring various parameters *viz.* content of NH_4^+, NO_3^-, NH_4^+/NO_3^-, seedling emergence, root elongation and phytotoxicity bioassay index (Mathur *et al.*, 1993; Briton, 2000). Free ammonia released from decaying organic matter inhibited seed germination (Okuda and Takahasi, 1961; Megie *et al.*, 1967; Wong and Chu, 1985), delayed shoot growth (Wong and Lau, 1983) and root elongation processes.

Analytical interpretation of all the compost samples revealed that they satisfied the critical limit (< 0.04 %) for NH_4^+- N and (> 0.03 %) NO_3^-- N (Zucconi and Bartoldi, 1987; Forster *et al.*, 1993). The nitrification index (ratio of NH_4^+- N/ NO_3^-—N) ranged between 0.22 and 0.39, which was in optimum conformity with the standard reference range (0.03 to 18.9) for compost maturity (Hirai *et al.*, 1983 and USCC, 2002). Most importantly the ratio was even much below the stipulated safety limits (< 7.14) for application in Nursery beds (AS 4454, 1999).
A direct assessment of phytotoxicity can be made by growing plants in compost media and calculating seed germination and root elongation percent over control (Brinton, 2000). The phytotoxicity bioassay test, as represented by germination index provided a means of measuring the combined toxicity of whatever contaminants may be present (Zucconi *et al.*, 1981). The test value indicated total absence of any phytotoxic effect in Vermi compost, Biodynamic compost, Indigenous compost and Novcom compost as per the standard suggested range of 0.8 to 1.0 (Fig. 10) by Trautmann and Krasny (1997). At the same time germination index value of >1.0 as obtained in case of Novcom compost indicated not only the absence of phytotoxicity (Tiquia *et al.*, 1996) but moreover, it confirmed that the compost enhanced rather than impaired germination and radical growth (Trautmann and Krasny, 1997).

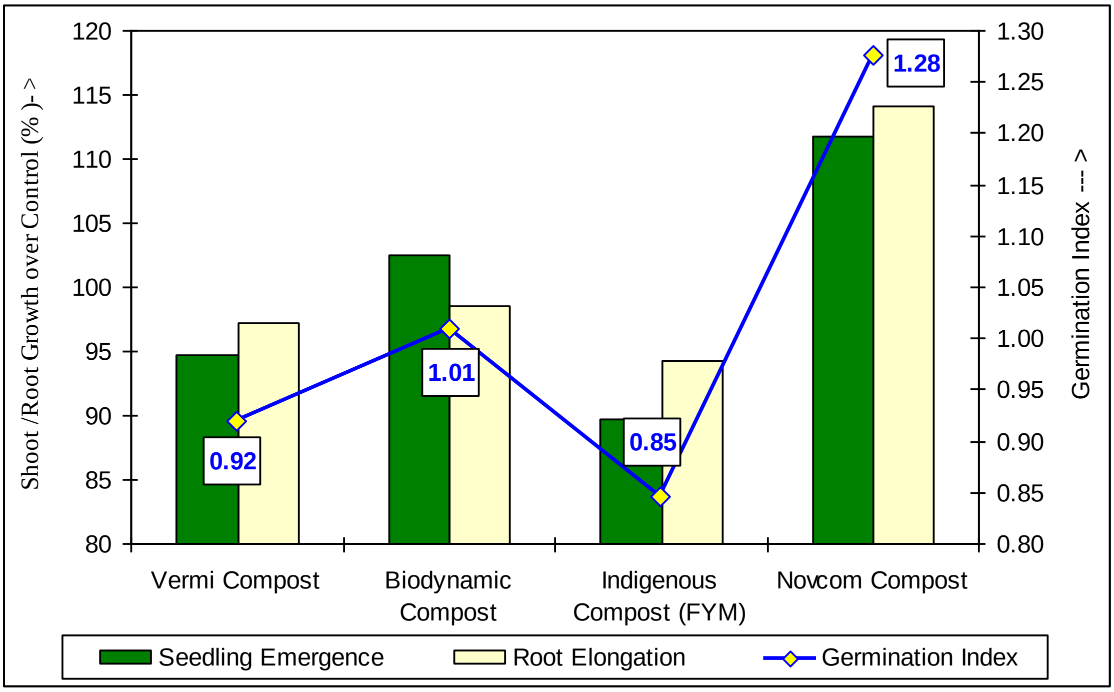


Fig. 10: Comparative study of Seedling Emergence, Root Elongation and Germination Index of different types of compost produced at Maud Tea Estate (Assam) under FAO-CFC-TBI Project.

Evaluation of end product quality indicated that though all the compost samples attained the desired stability and maturity, Novcom compost exhibited relatively higher potential as compared to all others especially in terms of the very high population of self- generated microbes.

Comparative evaluation of different types of compost on the basis of data generated from FAO-CFC-TBI Project.

On-farm compost production using available resources is the best choice because off-farm soil inputs are not only high priced; they are often poor in quality. But, on-farm compost production is still not adopted on large scale due to several associated limitations *viz.* time period required for biodegradation, raw material specificity etc. Hence, adoption potential of the different composting methods were evaluated(table 8) in terms of different factors *viz.* raw material specificity, biodegradation period, compost recovery percent etc.

Table 8: Comparative evaluation of the different types of compost on the basis of data generated from FAO-CFC-TBI Project.

Parameter	Vermi compost	Biodynamic compost	Indigenous (FYM) compost	Novcom compost
Raw material Specificity	Yes	No	No	No
Biodegradation Period	60 - 75	80 - 90	80 - 90	21 - 30
Recovery Percent	67.0	61.0	57.0	69.4
Total nutrient (N+P+K) content (%)	3.26	3.73	2.69	4.05
N enrichment (% increase over initial value in raw material)	142.88	172.1	107.41	207.75
Cost of Production (Rs./ ton final compost)	4000/-	920/-	770/-	860/-
Total soil management cost on the basis of 60 kg N applied/ ha (Rs.)	37,600/-	10,838/-	10,395/-	7,894/-
Crop efficiency (%) (w.r.t. target yield of 1500 kg made tea/ ha)	89	85	88	100
Cost/ kg made tea (Rs.)	26.90	7.19	7.18	5.16

Different composting process *viz.* Vermi composting, Biodynamic, Indigenous (FYM) and Novcom composting methods were evaluated in terms of process convenience, economics of compost production and end product quality. Biodynamic, Indigenous or Novcom methods did not require any specific type of raw material, but vermicompost required evenly chopped, pre-decomposed organic matter for the earthworms to work on them effectively. Recovery percent was found to be highest in case of Novcom and lowest for Indigenous (FYM) composting process. Wide variation in biodegradation period was observed, where Novcom compost was produced within the shortest time period of 21-30 days while Biodynamic and FYM compost required 80 to 90 days. Several workers (Illmer and Schinner, 1997; Sánchez *et al.*, 1999) in their study have indicated that shorter biodegradation period curtails the criteria of nutrient losses thereby leading to higher compost quality.

This was reflected in the total nutrient content of the individual compost samples. Though the different types of compost were produced using similar type of garden weeds and cow dung as raw material, however; highest nutrient content in terms of total NPK was found in Novcom compost (4.05 percent). The nitrogen content in Novcom compost was about 8.5 percent higher than that of 2nd best performing Biodynamic compost. However, the most significant finding was the enrichment of nitrogen in compost heaps during biodegradation period, which was highest for Novcom compost (92.10 %) as compared to all others. Enrichment in nitrogen status in final compost not only indicated the quality as well as intensity of biodegradation but also the presence of huge self- generated microbial population.

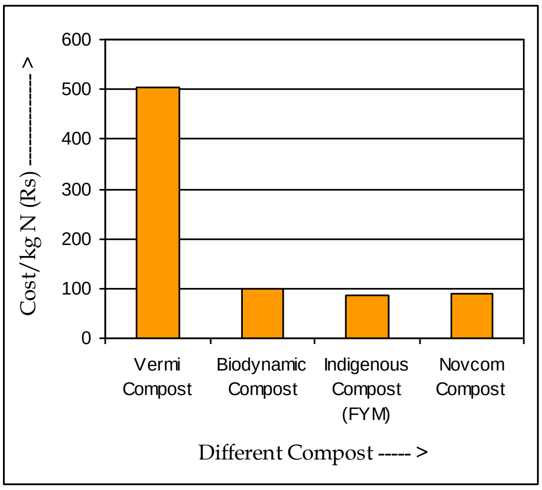


Fig. 11A: Unit cost per kg N for different types of compost

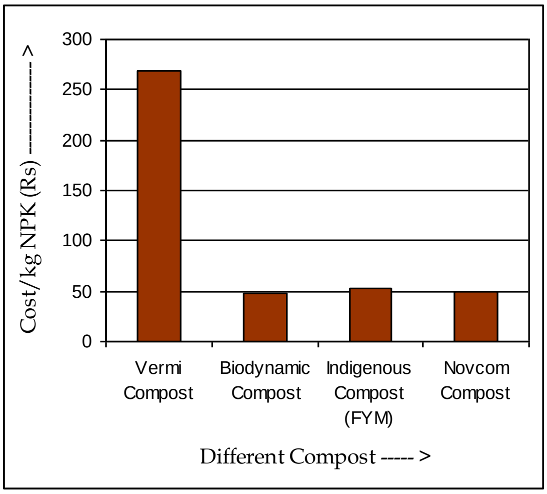


Fig.11B:Unit cost of nutrients (N+P+K) for different types compost.

On-farm compost production under different composting methods under FAO-CFC-TBI Project at Maud T.E., Assam (2009 to 2011)

Pic. 17 : Vermi composting at Maud T.E. under FAO-CFC-TBI Project.

Pic. 18 : Indigenous composting (FYM) at Maud T.E. under FAO-CFC-TBI Project.

Pic. 19 : Biodynamic composting at Maud T.E. under FAO-CFC-TBI Project.

Along with compost quality, cost of compost is the most important criteria for its adoption by the tea planters, considering that cost of soil input comprises 60 to 80 percent of the total expense made on inputs. Hence, for comprehensive assessment of the cost incurred for crop production under individual soil input, cost per kg made tea formed the most suitable index, ; which took into account both cost of compost production and crop efficiency post soil application. Cost per kg made tea was lowest in case of Novcom compost (Rs. 5.16/ kg made tea) followed by FYM (Rs. 7.18/kg made tea), Biodynamic compost (Rs. 7.19/kg made tea) and vermi compost (Rs. 26.90/ kg made tea). The comparatively higher cost of vermi compost is perhaps the most limiting factor towards its large scale application.

From practical considerations, an organic soil input shall be adopted on large scale only when it has least raw material specificity, can be produced within a short time period, has high nutrient content with low production cost.

Development of Compost Quality Index (CQI)

The importance of organic soil management towards soil quality development is no longer a debatable subject for the tea industry and has been well documented by different workers (BGK, 205, Parkinson *et al*., 1999 and Mäder, 2003). However, the extent of benefit that can be derived from any compost is dependant on its quality. Immature compost when applied to the soil continues to decompose and produce odorous gases and products such as ammonia in its immediate surroundings that are often toxic to plants (phytotoxic) (Saviozzi *et al*., 1988). Immature composts with a high carbon/ nitrogen ratio (C:N) cause nitrogen immobilization, starve roots of oxygen due to high microbial activity, support growth of pathogens as well as create high levels of organic acids (Inbar *et al.*, 1990). Numerous organic amendments have also exhibited direct or indirect inhibitory effect on seed germination (Pal and Bhattacharyya, 2003).

In this context an index for classification of compost as per quality will enable the producer to get a fair idea about any compost choice and taking decision for soil management accordingly. All the types of on- farm produced compost at Maud T.E., came out as well matured, good quality compost both in terms of Indian and International Standards. However; when evaluated in terms of post soil application effectivity, the difference in their potentials were widely apparent. Hence, in order to classify the compost types, four specific quality parameters (which were combination of one or more properties) were taken up to formulate Compost Quality Index (CQI).

Nutrients ($N+P_20_5+K_20$): Nutrient status is important to assess the capacity of compost towards maintaining a steady supply of nutrition to plants albeit in a controlled manner (Tisdale *et al.*, 1985). Most of the compost have an average nutrient level ($N+P_2O_5+K_2O$) of < 5%.

C/N ratio : The most commonly used index of compost maturity, is the C/N ratio. When composts with C/N ratios >20:1 are added to soils, mineral-N and any subsequently mineralized organic-N in compost can become immobilized in microbial biomass and made unavailable for plant uptake, leaving plants N deficient (Chukwujindu *et al.*, 2006; Jimenez and Garcia, 1992).

Microbial potential (Bacteria+Fungi+Actinomycetes): The microbial population within ready compost is probably the most important indicative parameter for its effectivity post soil application. In open-air composting processes, colonization of microbes in compost material occurs naturally during heap construction as well as heap turning. The mineralization and immobilization of soil-N and the turnover of organic materials in soil and compost is affected by the heterotrophic soil organism, including bacteria and fungi. High and comparative population of all the three categories of microbes in compost indicates an ideal composting process, ensures better compost utilization in soil and most importantly creates a favourable environment for natural proliferation and activity of the native microbes (Seal *et al.*, 2012; Bera *et al.*, 2011).

Phytotoxicity Bioassay (Germination Index): Phytotoxic effect of any compost is generally manifested in the form of hindered seed germination, plant growth and root proliferation. Mature and good quality compost should not possess any type of phytotoxicity. Cucumber (*Cucumis sativus*) seeds were used for the bioassay because they are sensitive to high salt concentration, ammonia and organic acid toxicity. Values above 80 percent for both percent emergence and vigor are indicative of well-cured compost (Zucconi *et al.*, 1981; Tiquia *et al.*, 1996).

Compost Quality Index was formulated as per the following equation :

$$\text{Compost Quality Index (CQI)} : \frac{Log_{10}\{NV_{NPK} \times MP \times GI\}}{C/N \text{ ratio}}$$

Where NV_{NPK} = Total nutrient value in terms of total ($N+P_20_5+K_20$) percent.

MP = log_{10} value of total microbial population in terms of total bacteria, total fungi and total actinomycetes.

GI = Germination Index

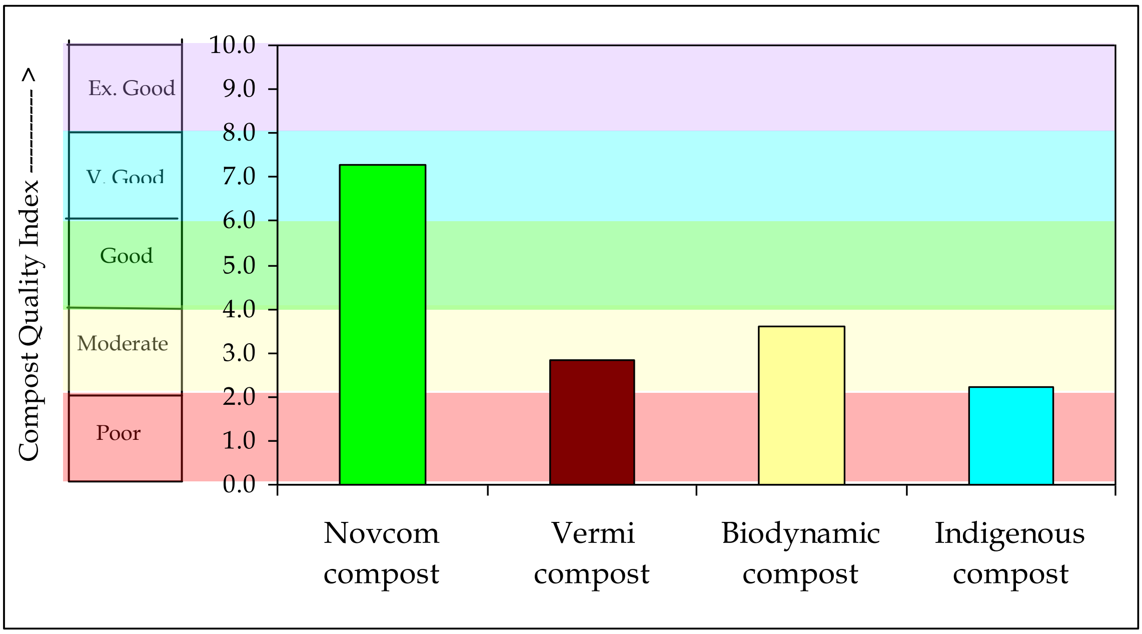


Fig. 12: Quality assessment of different on-farm produced compost using 'Compost Quality Index (CQI)' at Maud T.E (Assam).

Thirty three compost samples were drawn for each type of compost heap at Maud T.E. under FAO-CFC-TBI Project (2009-2011). Compost quality index (CQI) was calculated for each compost sample (fig. 12). Average CQI values obtained for different types of compost revealed highest rating of Novcom compost (average CQI: 7.28) followed by Biodynamic compost (average CQI: 3.59), vermicompost (average CQI: 2.82) and Indigenous compost (average CQI: 2.24). Also in case of Novcom compost 66.7 percent samples were of extremely good status while 27.3 percent and 6.0 percent samples were of very good and good quality respectively (fig. 13). Biodynamic compost was next in line, 55.6 and 30.3 percent of its samples being of very good and good status respectively. Overall assessment of CQI for total 132 compost samples (33 samplesX4 types of compost) indicated that most of samples were of good quality (37.9 percent), while 21.9 percent, 20.5 percent and 16.7 percent samples represented moderate, very good and extremely good status.

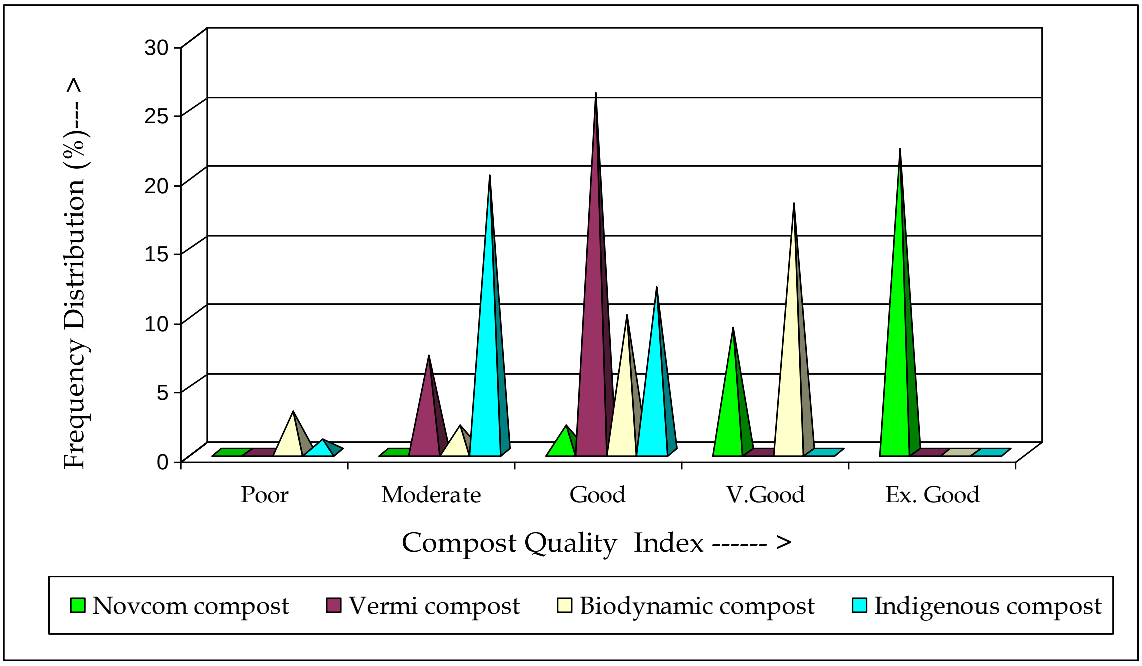
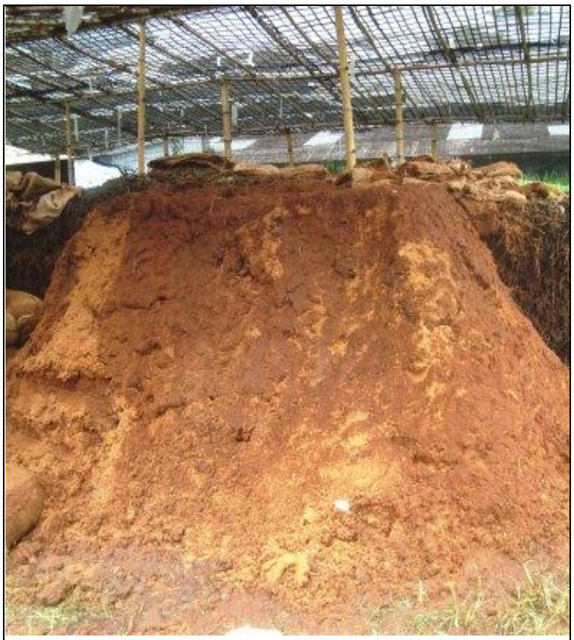


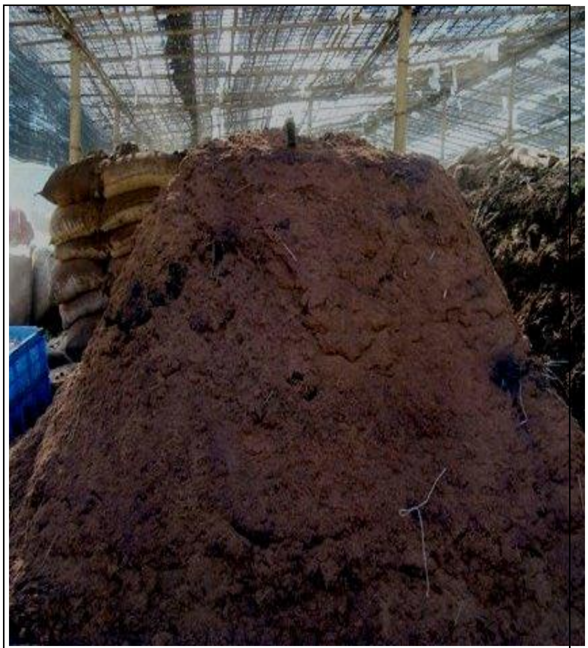
Fig. 13: Frequency distribution (%) of different types of compost on basis of their quality assessed using CQI, at Maud T.E. Assam under FAO – CFC-TBI Project.

Hence, evaluation of different on-farm composting methods in terms of process convenience, end product quality and cost of production indicated better performance of Novcom composting method in terms good quality compost production within a short period and at lowest economics.

On-farm Novcom composting programme at Maud Tea Estate.



Pic. 20: Novcom compost production using Tea Waste - Day 1



Pic. 21 : Mature Novcom tea waste compost on 21st day.

Pic. 22 : Dr. T. C. Chaudury, Project Co-coordinator, FAO-CFC-TBI Project inspecting Novcom composting programme at Maud T.E.

Evaluation of Oil Cake (Castor DOC) as a Potential Organic Soil Amendment at Maud T.E.

Organic soil amendments like oilcake are generally used for improving crops, increasing agricultural productivity and suppressing soil borne diseases (Stone *et al.*, 2003). Oil seed cakes are by-products obtained after oil extraction from the seeds. Non- edible oil cakes such as castor are used as organic nitrogenous fertilizers, due to their high NPK content (Anis *et al.*, 2010). Increase of crop productivity using castor oil cake was documented by several research workers (Gupta *et al.*, 2004). It is observed that several antimicrobial by-products (e.g. organic acids, hydrogen sulfide, phenols, tannins and nitrogenous compounds) are released during the decomposition of organic amendments, or synthesized by microorganisms involved in such degradation (Rodriguez-Kabana *et al.*, 1995). However single application of oilcake is also not recommended for continuous use considering its inherent toxicity as well as practically nil microbial population, as supported by the study results of different workers (Mian and Rodriguez-Kaban, 1982; Krishnaiah and Kalode, 1984; Radwan *et al.*, 2008).

Table 9: Quality parameters of Castor DOC used for Organic Soil Management at Maud T.E.

Sl. No	Quality Parameters	Range value	Mean
1.	Moisture (%) – (Oven dry)	5.42 – 2.65	3.09
2.	pH (water)	6.35 – 6.49	6.42
3.	EC (dSm^{-1})	2.01 – 2.29	2.25
4.	Ash Content (%)	3.15 – 4.87	3.96
5.	Total volatile solids (%)	96.85 – 95.13	96.04
6.	Organic carbon (%)	53.81 – 52.85	53.36
7.	Total N (%)	4.21 – 4.68	4.54
8.	Total P_2O_5 (%)	0.87 – 1.08	0.93
9.	Total K_2O (%)	0.62 – 0.74	0.68
10.	C:N	11.5 : 1 – 12.8 : 1	12:1
11.	Mineralization Index	0.058 – 0.092	0.074
12.	Total Bacterial Count (c.f.u.)	(11 – 32) x 10^3	26 x 10^3
13.	Total Fungal Count (c.f.u.)	(9 – 27) x 10^2	18 x 10^2
14.	Total Actinomycetes Count (c.f.u)	(3 – 9) x 10^2	5 x 10^2

Application of oil cakes was frequently practiced in Maud T.E. before initiation of FAO-CFC-TBI project, however; despite the high nutrient content of the same, desirable crop response had been withstanding. Hence, oil cake (Castor DOC) was taken up as a treatment under 'Soil input experiment' in mature tea (Sec. 6A) in 2009, in order to assess its potential/ negativities towards crop response and soil development in the small experimental area *vis-à-vis* on larger scale i.e. through soil application in the rest garden area of Maud T.E., in 2011. Accordingly 15 samples of castor DOC were collected and analyzed for quality in terms of physicochemical properties, nutrient status and microbial population (table 9).

Castor DOC was found to contain 2.65 to 5.42 percent moisture, 6.35 to 6.49 pH value, with high organic carbon (mean value 53.36 percent). Oilcakes are in high demand primarily due their high nutrient content as supported in this case by the average NPK content of 4.54, 0.93 and 0.68 percent respectively. Due to its high N content, C/N ratio was low and varied within 11.5:1 to 12.8:1. Microbial population is the primary limitation and count as low as 10^2 to 10^3 were observed.

Pic. 23: Bagging of mature Novcom compost before weight taking and simultaneously transportation to the different experimental plots under FAO-CFC-TBI Project, at Maud T.E.

Documentation of Biodegradation Process of Novcom Composting Method under FAO-CFC-TBI Project

Biodegradation pathway of Vermicomposting, Biodynamic and Indigenous (FYM) composting processes are perhaps well documented as they are popular methods for compost production in organic agriculture. In this respect Novcom composting method has come up as an effective process, being used for large scale production of Novcom compost in organic tea plantation covering 1200 ha (approx.) area in Assam and 500 ha (approx.) area in Darjeeling. When this method was taken up for on-farm compost production at Maud T.E. an effort was also made to record the biodegradation pathway followed under this method, as there had not been any significant prior documentation.

Novcom Composting Method is ideally an aerobic process as supported by the shortest and odourless composting period.

The six steps of Bio-degradation under Novcom composting process

1. High temperature of 60-65^0 C pasteurizes and kills pathogens.
2. Thermophilic Bacteria & Actinomycetes were produced.
3. Proliferation of mineralizing bacteria and loss of valuable substances were prevented and thus suitable field/atmosphere was prepared for fungi.
4. There was fall in temperature. Different worms and crustaceans used and decomposed the organic matter.
5. There was breakdown of organic matter and multiplication of fungi.
6. Cellulose and lignin fibre were broken down into simpler form.

Variation in temperature of heap during Novcom composting process.

The temperature variation curve (Fig. 14) shows that there was a steady increase in temperature within the composting heap from day 2. The temperature reached a peak (75.0^{0}C) on day 6 and remained stable until day 7 (i.e. until demolition of the heap). Steep increase in temperature indicated the initiation of microbial activity (de Bertoldi *et al*. 1983), which might be under the influence of energized Novcom solution. After restructuring of the heap on day 7, the temperature again rose steadily, but the average temperature increase between the first (day 7) and second (day 14) turning was lower than the initially recorded data. After the second turning, i.e. on day 14, a steady

Stepwise Operation of Novcom composting method at Maud Tea Estate under FAO-CFC-TBI Project (2009 to 2011) / 1

Fig. 24: Chopping of green matter (garden weeds) for large scale Novcom composting Programme at Maud T.E., under FAO-CFC-TBI Project.

Fig. 25: Formation of base layer using green matter (garden weeds) under Novcom composting Method.

increase in temperature was again noted, but the average temperature variation during this quarter (day 15 to day 21) was lower than previously recorded (i.e. after the first turning) data. The temperature lowered to <45⁰ C from day 19, and from day 21 the curve was almost parallel to x-axis, confirming completion of composting process or simultaneously compost maturity (Tchobanoglous, 1977). Maintenance of a stable temperature of >62.8⁰ C within composting heap, for more than three consecutive days has been found to be effective for the destruction of most human pathogens, insect larvae and weed seeds (Rynk *et al.*, 1992). Hence, the temperature curve of Novcom composting heap suggested that the process could ensure a safe end product for soil application.

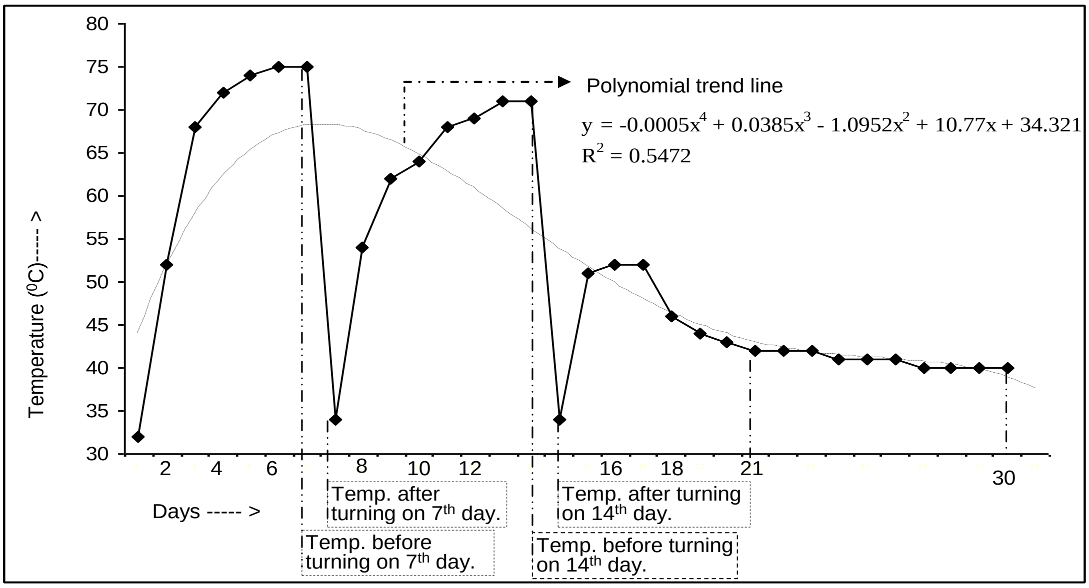


Fig. 14: Variation in temperature of Novcom composting heap during biodegradation period.

Variation in composting heap volume during Novcom composting process.

There was a rapid reduction in volume (41.02%) of Novcom heap during the initial 6 days (Fig. 15), which might be due to structural degradation of organic matter by microbes during the initial phase of composting, causing sharp decrease in heap volume. However, after first turning (day 7), rate of reduction slowed and before heap restructuring i.e. on day 14 net reduction (from day 0 to day 14) was about 59.5 percent. After completion of second turning (on day 14), volume reduction rate slowed further, and the net volume (i.e. from day 0 to day 21) reduced by only about 64.4 percent. The small (4.88 percent) reduction in volume recorded between day 14 to day 21 might be due to the loss of moisture from compost heap rather than degradation of organic

Stepwise Operation of Novcom composting method at Maud Tea Estate under FAO-CFC-TBI Project (2009 to 2011) / 2

Pic. 26: Watering on green matter layer during erection of Novcom heap for ensuring adequate moisture during composting.

Pic. 27: Formation of cowdung layer over green matter layer during Novcom composting programme at Maud T.E. under FA0-CFC-TBI Project.

matter (Zheng, 2004). After 21 days there was practically no reduction in volume and the curve became almost parallel to the x-axis. Measurement on day 30 revealed that there was only 1.81 percent reduction in volume after completion of the composting process on day 21.

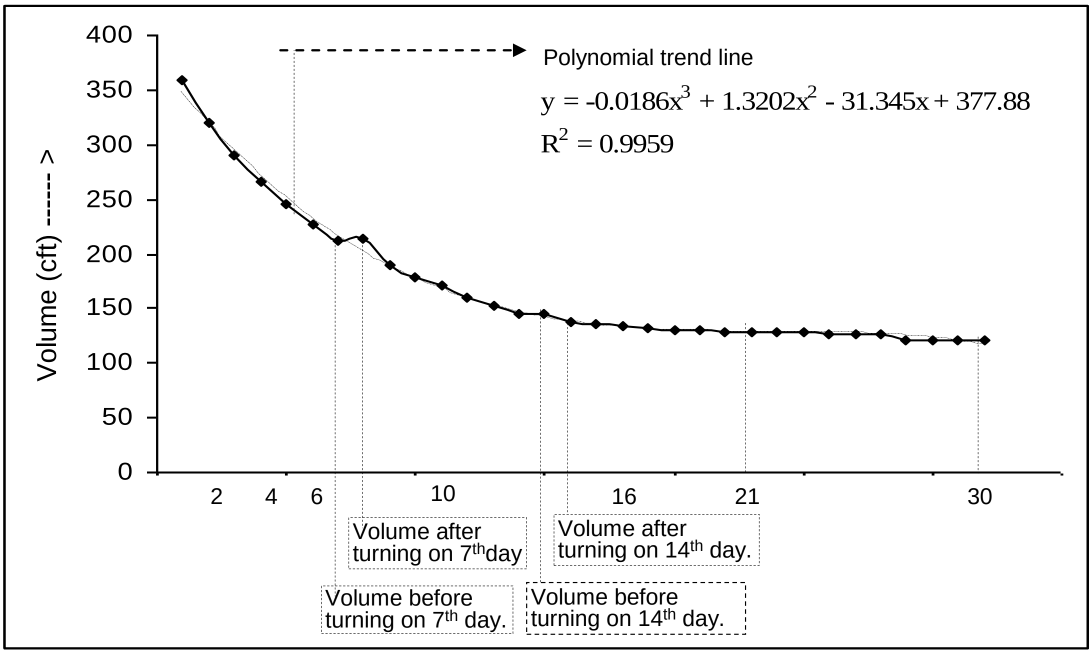


Fig. 15: Variation in heap volume under Novcom composting method.

Variation in Organic carbon and C/N ratio

The organic matter content of compost is useful in estimating its stability and physical characteristics (Benito *et al.*, 2003). Micro organisms break down the chemical bonds of organic materials in the presence of oxygen and moisture, giving off heat. The decrease in carbon content of wastes during composting indicates higher mineralization of organic matter (Bishop and Godfrey, 1983). Hence, the rate of the decomposition of organic matter over time indicates the speed of biodegradation during composting (Dell'Abate *et al.*, 2000; Mondini *et al.*, 2006). The organic carbon content of mature compost, which generally depend on the type of raw material used, varied from 16 to 38 percent (Evanylo, 2006). Hence, change in organic carbon content from 41.91 percent in raw material to 29.06 percent in final Novcom compost (i.e. on day 21 of composting) indicated faster biodegradation and simultaneously pointed to compost maturity within a short time frame (Fig. 16). At the same time, the very low and statistically insignificant variation in organic carbon content from day 21 to day 30 indicated that the biodegradation process practically ceased after 21 days.

Stepwise Operation of Novcom composting method at Maud Tea Estate under FAO-CFC-TBI Project (2009 to 2011) / 3

Pic. 28 : Final Novcom composting Heap on the first day of composting at Maud T.E., Assam under FAO- CFC-TBI Project.

Pi.c 29 : Novcom composting heap after 7 days of composting at Maud T.E., Assam under FAO-CFC-TBI Project.

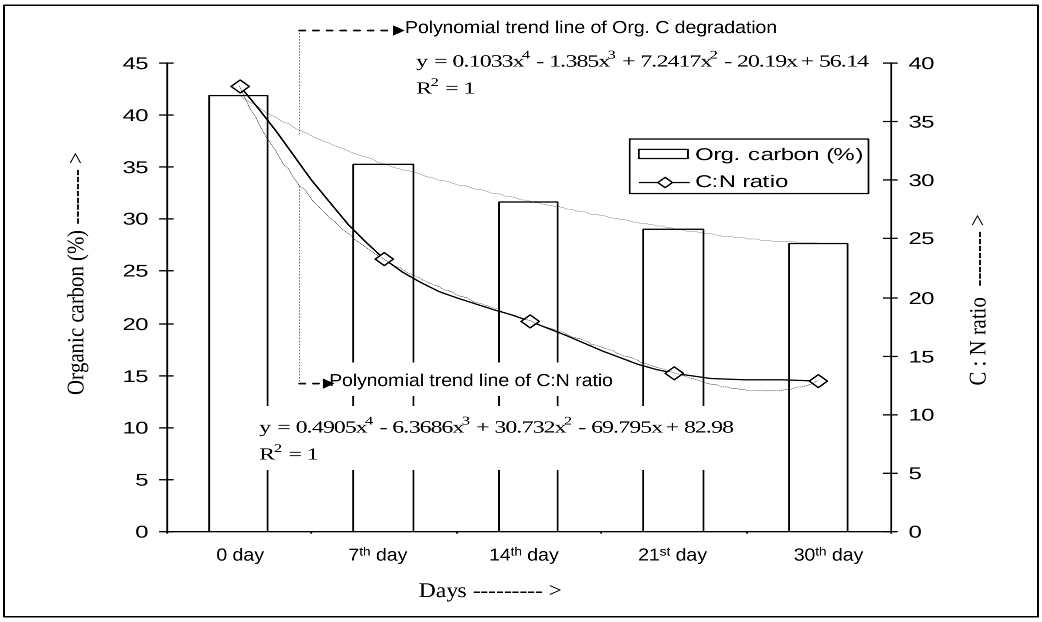


Fig. 16: Variation in the organic carbon content and C:N ratio of Novcom compost during different phases of biodegradation.

The change in C/N ratio of the composting material was also considered for stability assessment, because as the readily available C in organic matter is oxidized and released as carbon dioxide, there is a general reduction in carbon content over time (Bishop and Godfrey, 1983).

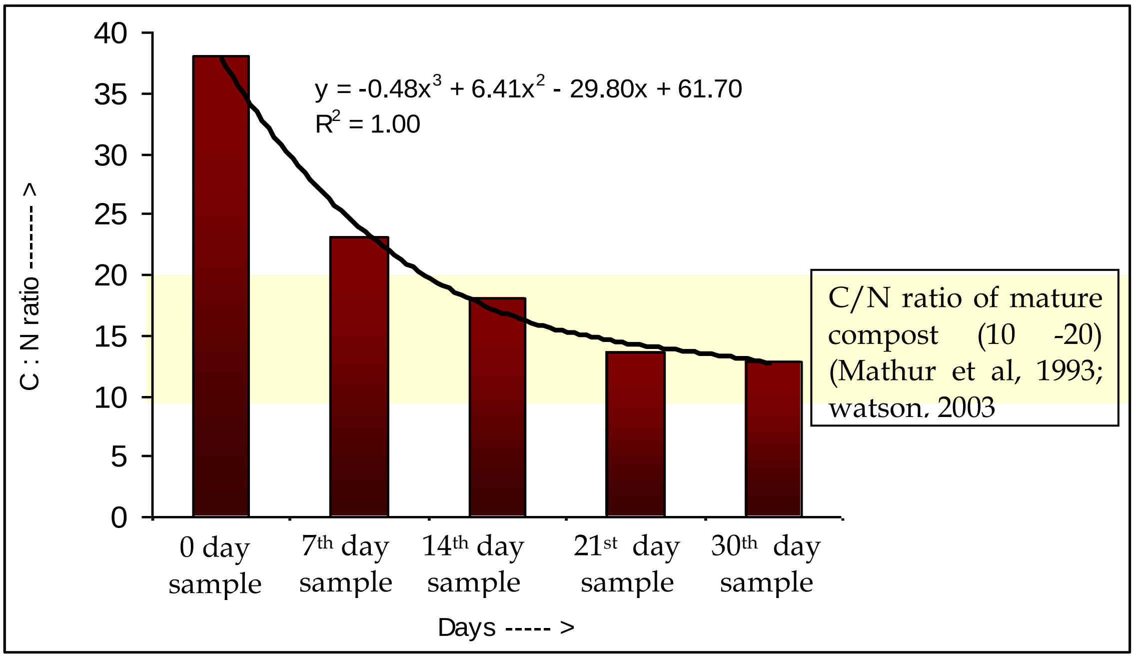


Fig. 17: Variation in C/N ratio of Novcom compost during various stages of biodegradation.

Stepwise Operation of Novcom composting method at Maud Tea Estate under FAO-CFC-TBI Project (2009 to 2011) / 4

Pic. 30 : Heat generation during demolition of Novcom composting heap on 7th day of composting at Maud T.E. under FAO-CFC-TBI Project.

Pic. 31 : Reconstruction of Novcom composting heap on 7th day at Maud T.E., Assam under FAO-CFC-TBI Project.

Novcom compost also met the additional criteria for compost stability, i.e. C/N ratio of <20.0 and C:N final/C:N initial ratio <0.75 (Jime´nez and Garcia, 1989), confirming that it attained maturity within 21 days. This was further substantiated by the nominal decrease in C/N ratio of 30 day compost sample, as compared to the day 21 sample (Fig. 17). C/N ratio of day 21 compost sample was 13.5:1, which is within the standard reference range of 10:1 to 15:1 (Rao *et al.*, 1995) and also ≤ 20:1 (Fertiliser Association of India, 2007) as suggested for well-matured compost.

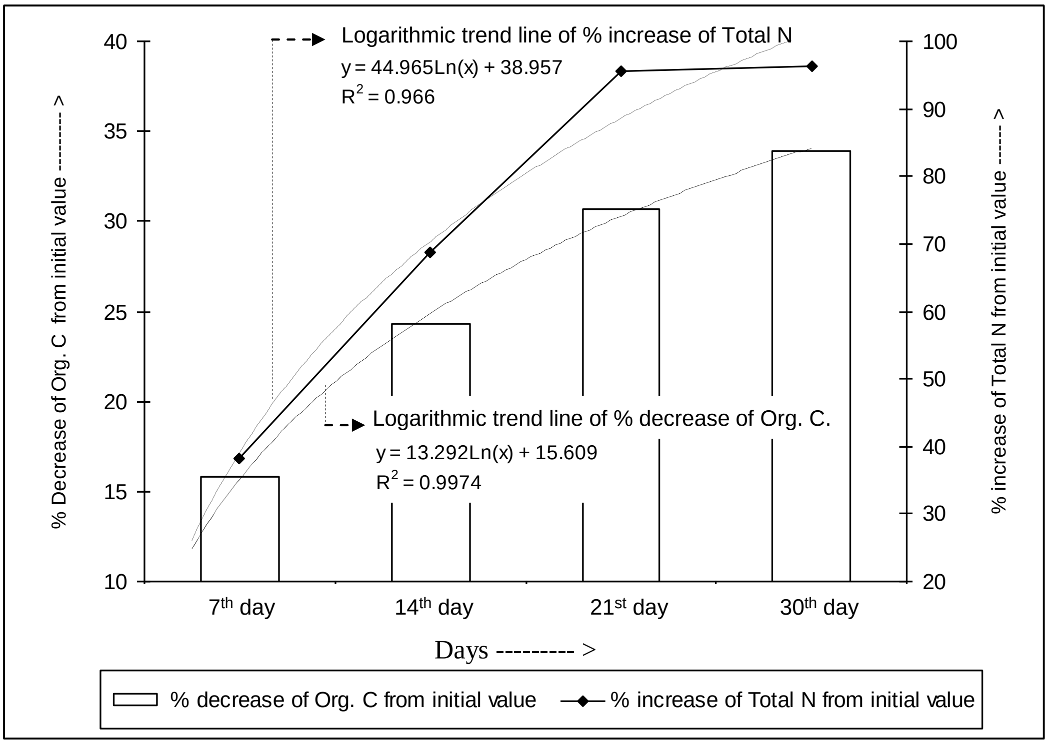


Fig. 18: Percent decrease of organic carbon and increase of Total N of Novcom compost during different stages of biodegradation.

The total nitrogen content in compost samples increased from 1.10 to 1.52 percent during the first phase of composting (days 0 to 7). This might be due to concentration effect following a decrease in substrate carbon (Kapetanios *et al.*, 1993) during the degradation of non-nitrogenous organic matter (Rekha *et al.*, 2005). At the same time, evaluation of the decrease in organic carbon *vis-à-vis* increase in total N value revealed that the trend lines (Fig. 18) gradually separated from each other over time. This indicated that there was a relatively greater increase in total N as compared to the decrease in organic carbon content. The finding might provide an indirect indication regarding the fixation of atmospheric- N within Novcom composting heap by the autotrophic micro organisms generated naturally during biodegradation period.

Stepwise Operation of Novcom composting method at Maud Tea Estate under FAO-CFC-TBI Project (2009 to 2011) / 5

Pic. 32 : Full view of Novcom composting heap after re-construction on 7th day at Maud T.E., Assam under FAO-CFC-TBI Project.

Pic. 33 : Re-construction of Novcom composting heap after demolition and proper churning on 14th day (in similar manner as done on day 7).

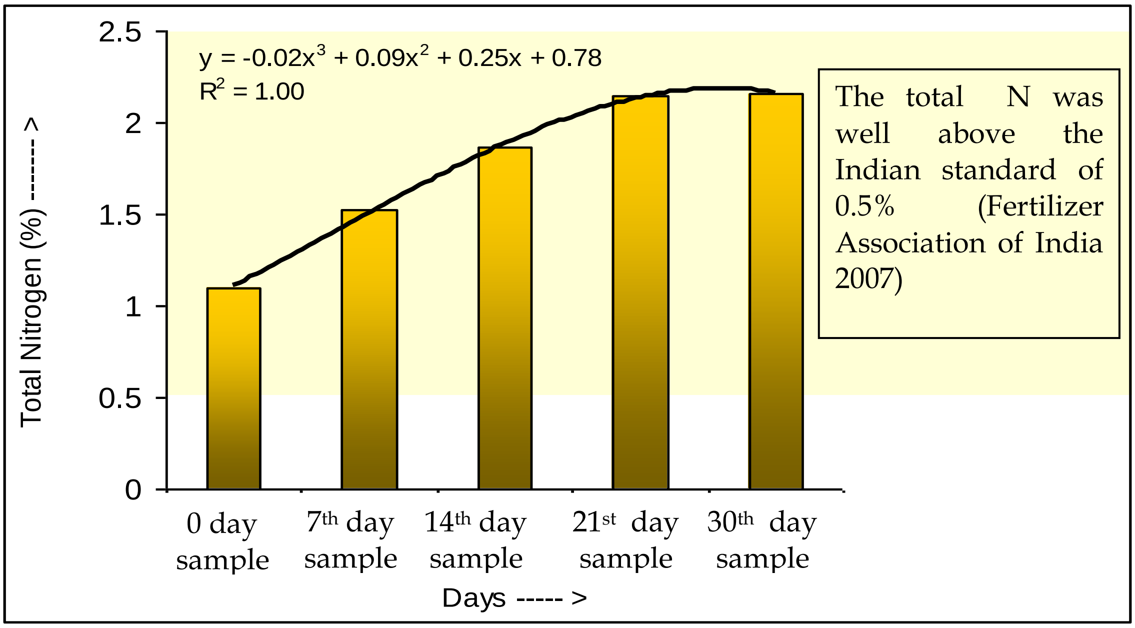


Fig. 19: Increase in total N content in Novcom compost due to autotrophic N- fixation during different phases of biodegradation.

According to de Bertoldi *et al.* (1982, 1983), an increase in the population of N-fixing bacteria in the later phase of composting, can be attributed to the increase in the value of total N in compost, despite volatilization (primarily) losses from composting heap during biodegradation (Fig. 19).

Physicochemical properties, nutrient status and microbial content

The moisture in compost sample decreased gradually from 81 percent at the initiation of composting to 59.91 percent at completion (Table 10). A significant change in the moisture percent during first 7 days of composting might be due to the structural breakdown of organic material. Moisture per cent recorded on 7, 14 and 21 days of composting suggested its conduciveness for proper biodegradation. pH of the compost samples increased with progression of biodegradation, which may be due to volatilization loss of organic acids due to increase in temperature with progress in composting (Fang and Wong 1999).

Stepwise Operation of Novcom composting method at Maud Tea Estate under FAO-CFC-TBI Project (2009 to 2011) / 6

Pic. 34 : Measurement of the dimension of Novcom composting heap at Maud T.E., Assam under FAO-CFC-TBI Project.

Pic. 35 : Large scale Novcom composting programme at Maud T.E., Assam under FAO-CFC-TBI Project 'Development Production & Trade of Organic Tea'.

Pic. 36 : Inhana Technical personnel with Ms. Joelle Kato, Programme Manager, IFOAM, Germany, inspecting Novcom Coompost Heap prepared at Maud T.E., Assam under FAO-CFC-TBI Project 'Development Production and Trade of Organic Tea' in November 2009.

Table 10 : Changes in the status of different quality parameters of compost during different stages of biodegradation (mean data of 30 samples) under FAO-CFC-TBI Project at Maud T.E., Assam.

Sl. No	Parameter	Compost sample in different stage of biodegradation				
1.	Age of compost	0 days	7 days	14 days	21 days	30 days
2.	Moisture	81.18	64.27	60.46	59.91	56.84
3.	pH	6.64	6.77	7.03	7.39	7.37
4.	EC (dSm^{-1})	0.16	0.94	1.57	2.08	2.08
5.	Ash Content (%)	24.56	36.46	42.97	47.70	50.16
6.	Total volatile solids (%)	75.44	63.54	57.10	52.31	49.84
7.	Organic carbon (%)	41.91	35.30	31.72	29.06	27.69
8.	CMI	0.59	1.03	1.40	1.71	1.81
9.	Total N (%)	1.10	1.52	1.86	2.15	2.16
10.	Total P_2O_5 (%)	0.41	0.45	0.52	0.67	0.66
11.	Total K_2O (%)	0.84	0.78	0.87	1.11	1.12
12.	C:N ratio	38.0 : 1	23.2 : 1	18.0 : 1	13.5 : 1	12.8 : 1
13.	Bacteria (total count)	21×10^{5}	46×10^{14}	15×10^{16}	65×10^{16}	43×10^{16}
14.	Fungi (total count)	18×10^{3}	27×10^{14}	8×10^{16}	22×10^{16}	20×10^{16}
15.	Actinomycetes (total count)	8×10^{2}	18×10^{14}	5×10^{16}	15×10^{15}	21×10^{15}
16.	Microbial biomass	-	2.74	2.11	1.26	1.22
17.	CO_2 evolution rate	-	9.47	5.87	1.99	1.84

CMI: compost mineralization index, c.f.u. g^{-1}: total count per g of moist soil, DM: dry matter, OM: organic matter.

Electrical conductivity values increased with progress in biodegradation, which might be due to an increase in salt concentration following degradation of organic matter (Campbell *et al*., 1997). During the initial stage of composting (days 0 to 7) the intense mineralization process was manifested by a considerable decrease in organic carbon (Fig. 20) and increase in ash content. Ash content increased from 24.56 to 47.7 percent, oxidizable carbon decreased from 41.91 to 29.06 percent and the compost mineralization index expressed as ash content/oxidizable carbon (Rekha *et al*., 2005) increased from 0.59 to 1.71.

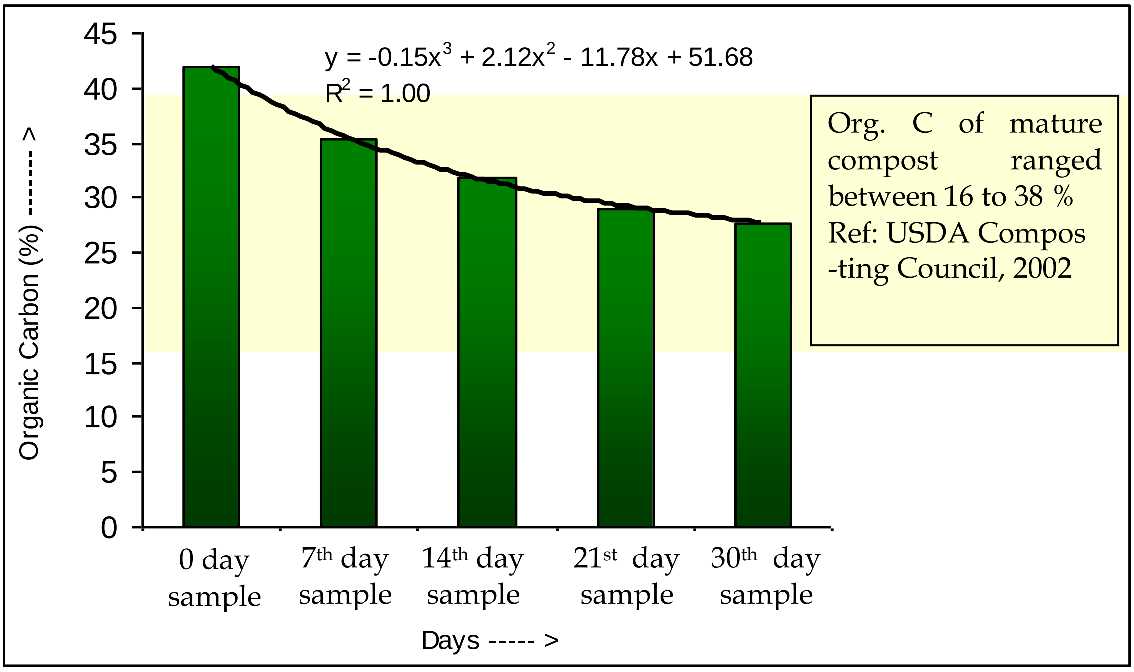


Fig. 20: Variation in organic carbon (%) of Novcom compost during different stages of biodegradation.

The microbial population, their biomass and activity, are key parameters that can be used to elucidate a composting process (Tiquia *et al.*, 2002). Lynch and Wood (1985) observed that the microbial flora built up rapidly with the initiation of composting and, in the case of Novcom composting process, the population of total bacteria, fungi and actinomycetes built up in an exponential manner. It has been established that the diversity of microorganisms contributing to organic matter decomposition changes with progress in biodegradation (Nakasaki *et al.*, 2005). The total count for bacteria, fungi and actinomycetes (in c.f.u. g^{-1} moist compost sample) increased from $21x10^5$, $18x10^3$ and $8x10^2$ on day 0 to $46x10^{14}$, $27x10^{14}$ and $18x10^{14}$ respectively, on day 7. Such high microbial generation could be possible only because of an ideal micro-atmosphere within composting heap influenced by application of Novcom solution. In the 21st day compost sample average population of bacteria, fungi and actinomycetes were $65x10^{16}$, $22x10^{16}$ and $15x10^{16}$ c.f.u. g^{-1} moist compost sample, respectively. Microbial biomass, which decreased as composting progressed towards completion, has also been considered as an indicator of compost biomaturity/stability (Mathur *et al.*, 1993). Microbial biomass carbon in compost sample ranged between 0.35 and 0.46 percent on day 21, which was well below the critical limit of 1.7 percent as proposed by Mondini *et al.* (1997).

Stability of compost sample indicated the status of organic matter decomposition and is a function of biological activity. Hence, microbial respiration formed an important parameter for determination of compost stability (Gómez *et al.*, 2006). Among the methods used to evaluate compost stability, respirometric techniques based on CO_2 production are more widely accepted (Wu and Ma, 2001; Francou *et al.*, 2005).

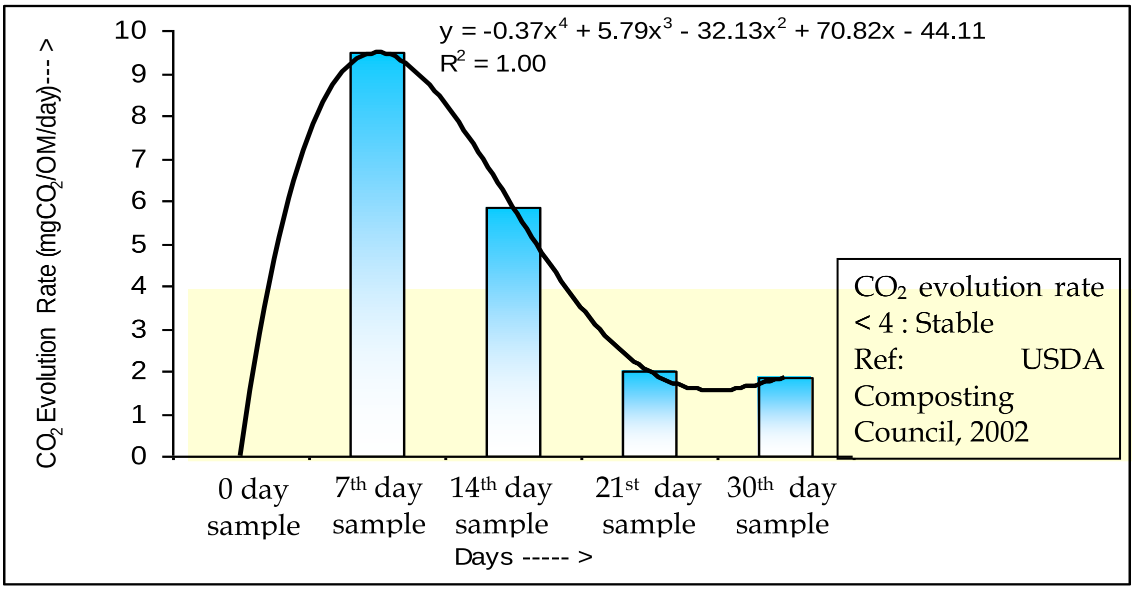


Fig. 21: Variation in CO_2 evolution rate of Novcom compost during different stages of biodegradation.

The highest rates of CO_2 production occur during thermophilic phase, when decomposition rates are at their peak. As the quantities of readily degradable organic matter diminish, the rate of CO_2 production also drops. Accordingly the CO_2 evolution rate of 7th, 14th and 21st day sample decreased rapidly with time (Fig. 21). Mean respiration rate (CO_2 evolution) in 21st day compost sample was 1.99 mg CO_2-C g^{-1} OM day^{-1}, being well within the stipulated range (2–5 CO_2-C g^{-1} $OMday^{-1}$) proposed for stable compost by Trautmann and Krasny (1997) and Bartha and Pramer (1965). The value obtained was also in close conformity to the respirometric stability class rating for compost maturity/ stability (Thompson *et al.*, 2002).

Evaluation of the Post Soil Application Effectivity of Different Organic Soil Inputs in Mature Tea under FAO-CFC-TBI Project

Brief Summary

Study was taken up to evaluate the impact of soil input quality towards crop efficiency, soil rejuvenation and cost of production.

The experiment was done with 10 different treatments (with control) i.e. Vermi compost @ 9.4 ton/ha (VC), Indigenous compost @ 8.3 ton/ha (FYM-1), Indigenous compost @ 13.5ton/ha (FYM-2), Biodynamic compost @ 10 ton/ha (BDS), Novcom compost @ 8 ton/ha (Nov-1), Novcom compost @ 2.6 ton/ha (Nov-2), Novcom compost @ 5.1 ton/ha (Nov-3), Bio-fertilizer @ 1.125 ton City compost + 37.5 kg Bio-NPK (BF), Oilcake @ 1.7 ton/ha (OC) and Vermi Compost+ Bio-fertilizer (VCBF).

The dose of different soil inputs (except in case of BD, BF. FYM-2, Nov-2 & Nov-3; which were applied as per Expert recommendations) were calculated to supply 60 kg N/ha (considering 1500 kg made tea as target yield with 4% N required for one kg of made tea). The rate of application for each soil input was calculated on the basis of their total- N and moisture percent with 80 percent utilization efficiency.

Highest crop response (made tea) was obtained under Novcom compost i.e., NOV-1 (1500 kg/ha) followed by plots receiving Indigenous compost i.e.FYM-2 (1479 kg/ ha) and vermi compost in combination with bio-fertilizers (1427 kg/ ha).

'SOIL DEVELOPMENT INDEX' (SDI) formulated by quantifying the development of different soil quality indices into overall soil rejuvenation, for easy understanding of the end-users; was highest under Nov-1 (SDI : 45.39) followed by VCBF (SDI : 30.28) and VC (SDI : 30.06) treatments.

Economics of crop production under the different types of soil inputs was assessed in terms of Value cost ratio (VCR). VCR, which indicated extra crop grain per rupee invested for input; showed highest value in case of Novcom compost (NOV-1). FYM-2 claimed the 2nd rank, but scored 41 percent lower VCR than the former.

Evaluation of the Post Soil Application Effectivity of Different Organic Soil Inputs in Mature Tea under FAO-CFC-TBI Project

Introduction

The primary role of organic amendments is to rejuvenate the soil by creating a favourable soil–plant–microbial environment, in addition to improving its physical properties. In other words, to make the soil system live for healthy plant growth. However, in a deactivated environment any ordinary organic manure, compost or rotten organic material does not meet this objective. The addition of organic amendment in soil without first judging its qualitative components might increase the risk of possible health hazards towards humans and plants because of the presence of harmful pathogens. At the same time seed germination and plant growth might be hindered following exposure to phytotoxic compounds (Saviozzi *et al.*, 1988).

Effective management of soil in plantation crops like tea, coffee etc. have always been a Herculean task because most of the composting processes are complicated or require long periods for biodegradation along with relatively poor end product quality. Hence, even for partial/ full supplementation of crop nutritional requirements, the amount of compost needed becomes huge. Such quantitative requirement cannot be met by on-farm production so that outsourcing remains the only option. Off-farm compost is usually expensive and mostly of non- uniform quality. As a result production cost, often becomes many fold higher as compared with the cost of fertilizer application under chemical farming practice. In this scenario to ensure speedy restoration of soil potential and sustained crop production without triggering the cost components or entailing soil nutrient mining; application of on-farm produced, good quality, stable and mature compost (confirmed through evaluation) is the only solution.

The following study at Maud tea estate (Assam), India under FAO-CFC-TBI Project (2008-2011); was a lab to land evaluation of the quality of organic soil inputs in terms of their relative impact on crop yield and soil rejuvenation.

Objective

To evaluate the impact of soil input quality towards their application dose, crop efficiency, relative cost and soil rejuvenation.

Methodology

To assess the effectivity of different organic soil inputs in terms of crop yield and soil rejuvenation, experiment was laid out in the form of Randomized Block Design with ten treatments (and control) replicated three times (Fig. 22). Crop- N requirement was calculated as 60 kg per hectare on the basis of 1500 kg made tea as target yield with four percent N required for one kg of made tea. The application dose for each soil input was calculated on the basis of their total- N and moisture percent with 80 percent utilization efficiency. No foliar spray was given except Neem & Karanj oil concoction (in 3:1 ratio i.e., 3 ltr. neem oil and 1 ltr. karanj oil mixed with 1% soap solution per ha) for pest management in the different treatment plots. Soil samples were collected from each treatment plot before the initiation of experiment and 60, 90 and 150 days post application of soil inputs, for analyzing the physicochemical properties, fertility status, nitrogen dynamics and microbial potential.

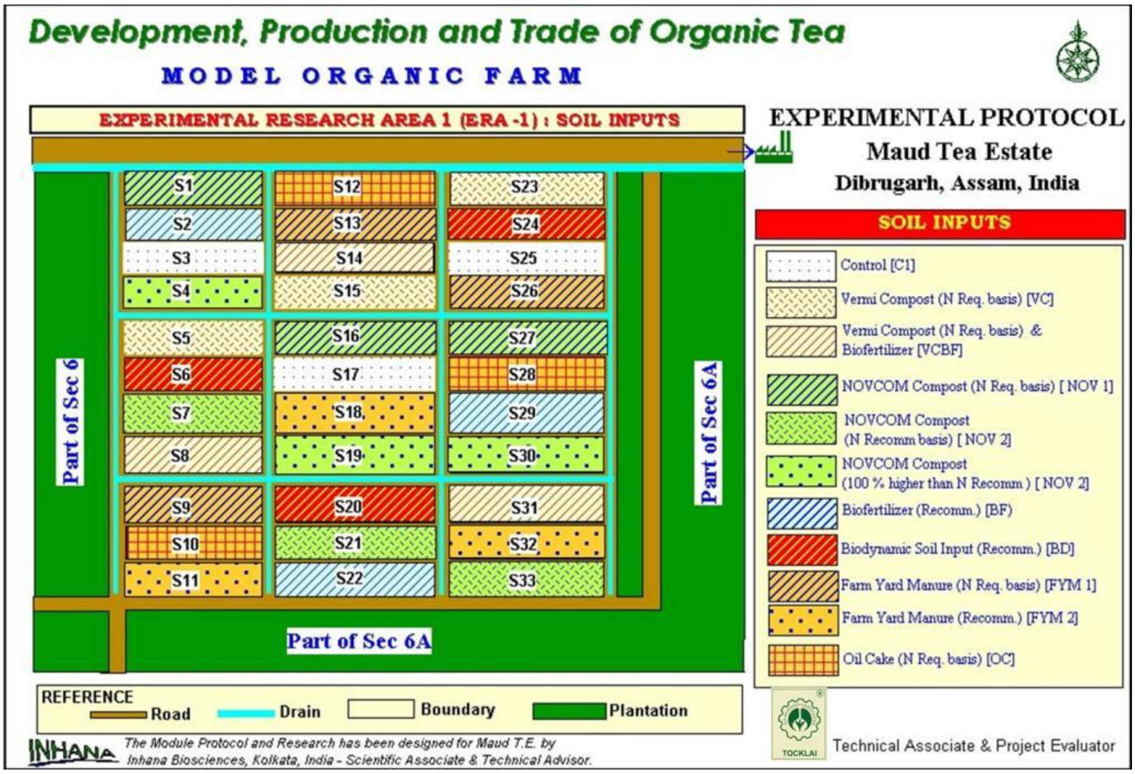


Fig. 22 : Layout of Experimental Research Area– 1 (ERA-1) for evaluation of different organic inputs in mature tea plantation.

Treatment Details

T_1	:	Control (C1)
T_2	:	Vermi Compost (VC) – @ 9.40 ton/ ha (on N requirement basis)
T_3	:	Vermi compost + Biofertilizer (VCBF) – vermicompost @ 9.40 ton/ ha + City compost organic fertilizer induced with N fixing bacteria & PSB @ 1.12 ton and 37.5 kg of Bio-NPK (combination of *Bacillus, Pseudomonas, Azotobacter and Azospirillum*); as per expert recommendation.
T_4	:	Novcom Compost (NOV-1) – @ 8.0 ton/ha (on N requirement basis)
T_5	:	Novcom Compost (NOV-2) - @ 2.6 ton/ha (as per recommendation of Inhana Biosciences)
T_6	:	Novcom Compost (NOV-3) – @ 5.1 ton/hec. (100% higher dose than Inhana recommendation)
T_7	:	Biofertilizer (BF) - City compost organic fertilizer induced with N fixing bacteria & PSB @ 1.12 ton and 37.5 kg of Bio-NPK (combination of *Bacillus, Pseudomonas, Azotobacter and Azospirillum*); as per expert recommendation.
T_8	:	Biodynamic Soil Input (BDS) - @ 10.0 ton/ ha (as per expert recommendation)
T_9	:	Farm Yard Manure (FYM-1) – @ 8.30 ton/ha (on N requirement basis)
T_{10}	:	Farm Yard Manure (FYM-2) – @ 13.50 ton/ha (as per expert recommendation)
T_{11}	:	Oil Cake (OC) – @ 2.60 ton/ ha (on N requirement basis)

Crop response under different types of compost application and interrelation between crop yield and soil quality parameters.

Crop response in terms of made tea yield under different treatments was found to be highest in Novcom compost applied plots (1500 kg/ha) followed by plots receiving Indigenous compost (1479 kg/ha) and Vermi compost in combination with bio-fertilizers (1427 kg/ ha). Crop yield in Novcom compost treated plots were 30.8 percent higher than control, while 27.9 percent higher crop (over control) under Indigenous compost was obtained only after huge quantitative addition i.e. at the rate of 13.5 ton/ha (table 11).

Pic. 37 : Personnel from CFC-TBI Observed Large Scale Novcom Composting Activity at Maud T.E. under FAO-CFC-TBI Project.

Pic. 38 : Field visit of IFOAM and TRA personnel at Maud T.E.

Pic. 39 : Discussion with Dr. R. Bhagat and other TRA personnel regarding activity of the project at Maud T.E. under FAO-CFC-TBI project.

Table 11: Ranking of different organic soil inputs in terms of crop and cost per hectare in mature tea.

Rank	Organic Soil Input (dose of organic soil inputs)	Yield (kg/ha)	Percent over control	RAE[1]	Cost/ha (Rs.)	VCR[2]
1.	Novcom compost-1 (NOV-1) (@ 8 ton/ha)	1500	30.75	100	7,894	8.49
2.	Indigenous compost-2 (FYM-2) (@13.5ton/ha)	1479	27.89	93.73	10,395	6.04
3.	Vermi compost + Biofertilizer (VCBF)	1427	22.85	78.21	57,025	0.92
4.	Novcom compost-3 (NOV-3) (@ 5.1 ton/ha)	1372	18.57	61.79	5,400	7.67
5.	Oilcake (OC) (@ 2.6 ton/ha)	1347	17.29	54.33	13,150	2.77
6.	Vermi compost (VC) (@ 9.4 ton/ha)	1338	16.23	51.64	37,600	0.92
7.	Indigenous compost -1(FYM-1) (@ 8.3 ton/ha)	1321	14.40	46.57	6,422	4.86
8.	Novcom compost -2 (NOV-2) (@ 2.6 ton/ha)	1320	13.76	46.27	3,250	9.54
9.	Biodynamic compost (BDS) (@ 10 ton/ha)	1279	11.33	34.03	10,838	2.10
10.	Bio-fertilizer (BF) (1.125 ton City compost + 37.5 kg Bio-NPK)	1268	9.44	30.75	19,425	1.06

[1]RAE : Relative agronomic effectiveness, [2]VCR : value cost ratio

Note : *Quantity of various soil inputs were calculated on Crop–N requirement basis i.e. for giving 60kg N. Except those ones which had fixed recommended dosage like BF, BD, FYM-2. Actual dosage was calculated based on N and moisture % in the soil input. Novcom compost was applied in combination with 40 kg Elemental-S & 80 kg Rock phosphate per hectare. In case of soil mgt. using Biodynamic compost, CPP @ 12.5 kg/ ha and Cow horn manure (15 ltr. soln/ ha) was also used. Pruning : UP-UP-LP ; Bush Population : 9930/ha ; Age : 7-10 years; VCR was calculated considering Made tea @ Rs. 200/ kg.*

Another phenomenon that is worth mentioning is that except Novcom compost, better crop response in case of other treatments was obtained only under high quantitative application i.e. either single compost applied in high dose (Indigenous compost @ 13.5 ton/ ha) or combined application as in case of VCBF where vermi compost was applied at the rate of 9.4 ton ha in combination with city compost organic fertilizer induced with N fixing bacteria and PSB @ 1.12 ton and 37.5 kg of Bio-NPK (combination of *Bacillus, Pseudomonas, Azotobacter and Azospirillum*) as per recommendation. Biodynamic compost, vermi compost and bio-fertilizer performed poorly even when the former were applied at the rate of 9.4 and 10.0 ton/ ha respectively, while bio-fertilizer was used as per expert recommendation.

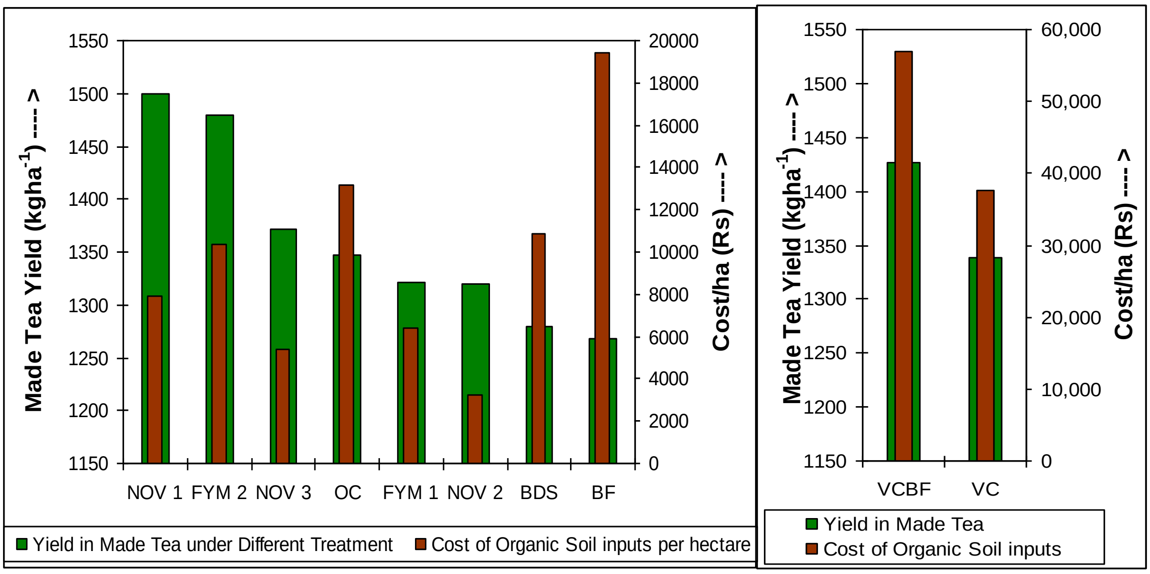


Fig. 23: Crop performance and associated cost of organic soil inputs under different treatments.

Relative Agronomic Effectiveness (RAE) i.e. comparative effectivity of different treatments with respect to the best performer (Novcom compost in this case), indicated that only two other treatments i.e. FYM-2 and VCBF scored highly (RAE: 93.73 % and 78.21 % respectively) while rest all others obtained values lower than 55 percent. Besides crop response, cost incurred per hectare is also a determinant factor towards selection of organic soil inputs. Value cost ratio (VCR) which indicated extra crop grain per rupee invested for organic soil inputs; was high in case of Novcom compost followed by FYM-2 (however, its VCR was 41 percent lower than highest crop performer NOV-1). Figure 23 clearly indicates that inclusion of vermi compost increased the soil management cost by at least 2 to 3 times when compared with the next highest cost. VCR for rest all other treatments like vermi compost, bio-fertilizer, oil cake, Biodynamic compost etc. were very low (i.e. < 3.0).

The results concluded that in terms of both crop response and economics, Novcom compost was undoubtedly the best option followed by FYM and Oil cake. However, single application of oil cake is also not recommended for continuous use, considering its inherent toxicity as well as practically nil microbial population, as supported by the studies of different workers (Krishnaiah and Kalode, 1984; Radwan *et al.*, 2008).

Development of soil quality post application of different organic soil inputs in mature tea plantation

Organic soil management basically aims at achieving sustained crop yield through rejuvenation of soil health. Periodical top and sub soil samples were collected and analyzed for twenty different soil quality parameters *viz.* pH, electrical conductivity, cation exchange capacity, organic carbon, available- N, P, K, S, different forms of N and N-converters as well as total bacteria, fungi, actinomycetes and phosphate solubilizing bacteria.

Physical properties of the soil samples from different treatment plots

Measurement of soil texture, bulk density, water holding capacity etc. provides useful indications regarding the state of soil compactness, translocation of water and air and root transmission. The soil of the experimental plots was found to be medium textured i.e. clay loam in nature with bulk density ranging from 1.26 to 1.60 gcm^{-3} (table 12). Water holding capacity of the soil, which provides information on the ability of soils for storing water and its subsequent availability to the crops varied between 39.6 to 52.0 percent.

Electrochemical properties of the soil samples from different treatment plots

Assessment of soil pH (table 13) especially in acid soils is important because there is universal inhibition of all microbial variables below pH 4.5, which might be due release of free aluminium. Low microbial activity leading to poor soil nutrient dynamics has negative impact especially in tea cultivation, where vegetative propagation throughout the year demands regular and uninterrupted supply of soil nutrients. pH of the soil, which varied form 4.62 to 4.76 was found to increase in general (with few exceptions) post three years of experimentation; going slightly above 5.0 in case of NOV-3 , BF and FYM-1 treatment plots. All these soils received substantial amount of compost during this experiment. Through their high CEC value, organic acids and base functional groups the different types of organic soil inputs

Table 12 : Physical characteristics of soil in the different treatment plots before initiation of experiment.

Treatment	Depth (cm)	Particle size distribution (%) Sand	Silt	Clay	Texture	Bulk density	Particle density	% pore space	Max. WHC (%)	Water in air dry soil (%)	Volume expansion (%)
						< --- gcm^{-3}------ >					
T_1 : C	0- 25	39.23	28.25	32.52	cl*	1.26	2.28	43.97	41.96	5.03	10.08
	25- 50	40.93	28.48	30.59	cl	1.29	2.31	43.04	40.48	4.72	9.40
T_2 : VC	0- 25	37.36	32.02	30.62	cl	1.27	2.29	43.64	41.70	4.93	9.81
	25- 50	42.07	28.84	29.09	cl	1.29	2.32	42.41	40.25	4.55	8.86
T_3 : VCBF	0- 25	34.06	34.70	31.24	cl	1.30	2.28	43.34	52.04	4.81	9.49
	25- 50	36.65	32.92	30.43	cl	1.29	2.32	42.52	40.46	4.64	9.07
T_4 : NOV-1	0- 25	38.95	27.87	33.18	cl	1.27	2.26	43.76	42.23	5.07	10.12
	25- 50	43.56	25.99	30.45	cl	1.29	2.29	42.61	40.68	4.69	9.42
T_5 : NOV-2	0- 25	40.87	22.77	36.36	cl	1.28	2.29	43.60	41.98	5.07	10.16
	25- 50	40.89	25.51	33.60	cl	1.30	2.32	42.08	40.21	4.92	9.79
T_6 : NOV-3	0- 25	40.82	27.00	32.17	cl	1.27	2.29	43.73	41.96	5.05	10.08
	25- 50	41.65	27.38	30.96	cl	1.28	2.31	42.86	39.81	4.76	9.64
T_7 : BF	0- 25	36.88	29.89	33.22	cl	1.28	2.27	43.50	41.67	5.00	9.54
	25- 50	39.29	29.65	31.06	cl	1.29	2.30	42.62	40.80	4.76	8.96
T_8 : BDS	0- 25	37.14	27.72	35.14	cl	1.27	2.31	43.66	41.89	5.04	9.93
	25- 50	40.08	27.54	32.38	cl	1.31	2.33	42.58	40.24	4.87	9.20
T_9 : FYM-1	0- 25	34.36	33.01	32.63	cl	1.60	2.26	43.66	42.05	4.93	9.50
	25- 50	37.44	32.17	30.39	cl	1.30	2.29	41.86	39.58	4.79	8.97
T_{10} : FYM-2	0- 25	38.14	29.84	32.02	cl	1.28	2.29	43.67	41.71	5.01	10.01
	25- 50	41.05	28.60	30.35	cl	1.30	2.30	42.13	39.62	4.82	9.43
T_{11} : OC	0- 25	35.50	30.83	33.67	cl	1.28	2.27	43.78	42.03	5.01	10.04
	25- 50	39.17	28.72	32.11	cl	1.30	2.29	42.77	40.39	4.82	9.60
CD** $_{(P = 0.5)}$ **[top soil]		***NS***	***NS***	***NS***	***-***	***0.12***	***NS***	***NS***	***2.40***	***0.23***	***0.76***
CD** $_{(P = 0.5)}$ **[sub soil]		***NS***	***NS***	***NS***	***-***	***NS***	***NS***	***NS***	***2.14***	***0.21***	***NS***

Table 13 : Variation in electrochemical properties of soil (0 to 50 cm) post application of different types of organic soil inputs.

Treatments	Before Initiation of Experiment			After Completion of Experiment (3 years)		
	pH (H_2O)	EC (dSm^{-1})	CEC cmol $(p^+)kg^{-1}$	pH (H_2O)	EC (dSm^{-1})	CEC cmol $(p+)kg^{-1}$
T_1 : C	4.73	0.021	12.48	4.52	0.023	13.20
T_2 : VC	4.65	0.023	12.47	4.66	0.028	13.68
T_3 : VCBF	4.63	0.024	12.26	4.64	0.030	13.60
T_4 : NOV-1	4.76	0.025	12.01	4.76	0.035	15.36
T_5 : NOV-2	4.65	0.029	12.74	4.78	0.032	14.11
T_6 : NOV-3	4.75	0.024	11.58	5.11	0.031	13.45
T_7 : BF	4.70	0.025	12.80	5.15	0.024	13.29
T_8 : BDS	4.71	0.026	12.80	4.86	0.031	13.59
T_9 : FYM-1	4.67	0.023	13.26	5.04	0.027	13.81
T_{10} : FYM-2	4.62	0.024	12.76	4.91	0.031	15.49
T_{11} : OC	4.69	0.023	13.98	4.75	0.031	14.31
CD (P = 0.5)	***NS***	***NS***	***NS***	***0.12***	***NS***	***2.16***

provided much of the pH buffering capacities in soil, i.e., the soils did not vary widely in their pH values.

Cation exchange capacity (C.E.C.) of the soil were of low to medium range varying from 11.58 to 13.98 cmol (p+)kg^{-1}. Increase in CEC value was noticed post application of different types of organic soil inputs but significant change (as compared to control plots) was noticed only under NOV-1 and FYM-2 treatments.

Fertility status of the soil samples from different treatment plots

Soil organic carbon (SOC) levels are influenced by management practices and in this respect organic farming is known to influence positive impact on soil carbon especially through supply of nutrients through manure application. The organic carbon content in the experimental plots ranged from 0.60 to 0.80 percent and an overall increase in its value (albeit low) was noticed (fig. 24) post three years application of different types of organic soil inputs (except in case of control). However, treatment wise variation in organic carbon values, was found to be non-significant (table 14). Effective nitrogen management is a difficult task in organic crop production especially in case of high demanding crops like tea. The soils were found to be medium in available-N, which varied from 314 to 389 kgha^{-1}. Post three years of experimentation available-N content in soil was found to increase (fig. 25) irrespective of the type of organic soil input applied. Higher increase was noted in case of VCBF plots (436 kgha^{-1}) as compared to BF plots (377 kgha^{-1}) as well as FYM-2 plots (455 kgha^{-1}) *vis-à-vis* FYM-1 plots (402 kgha^{-1}). Additive effect of vermi compost when applied in combination with bio-fertilizer as in case of VCBF plots, while high i.e. 13.5 tonha^{-1} in case of FYM-2 plots might have contributed towards the comparatively higher increase of available-N in the former treatment plots.

The availability of phosphorous is severely limited in acid soils where it gets fixed with Fe^{3+} and Al^{3+} ion in acid soil atmosphere. Therefore, increasing the availability of phosphate in acid tea soil is the most challenging task. Available-P_2O_5 in the treatment plots were of medium status ranging between 26 and 37 kgha^{-1}. However, post three years of experimentation phosphate status was found to increase under application of all types of organic soil inputs (fig. 26) more so significantly in case of NOV-1 (@ 8.0 tonha^{-1}), NOV-3 (@ 6.0 tonha^{-1}) and FYM-2 (@ 13.5 tonha^{-1}) treatments, as compared to control.

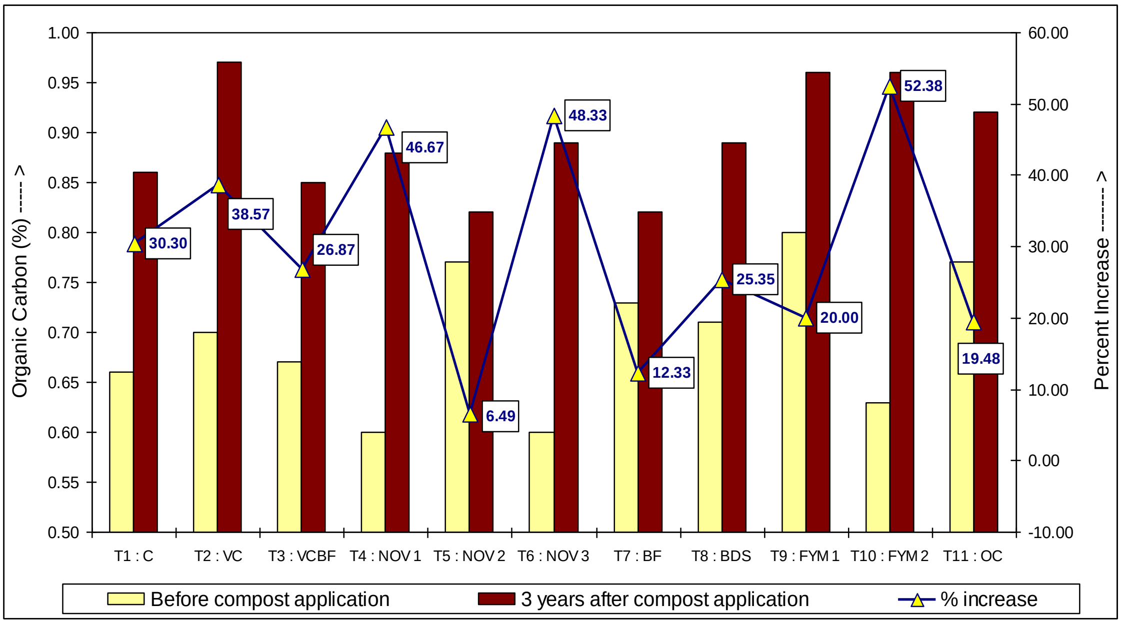


Fig. 24: Variation in soil organic carbon values under different organic soil inputs before and after 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

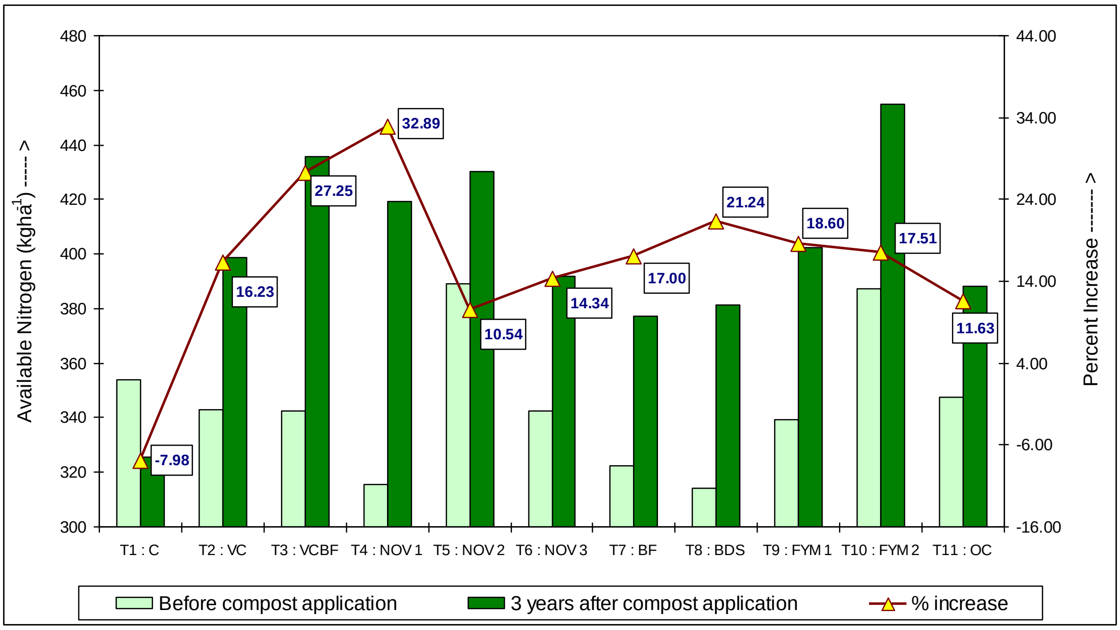


Fig. 25: Variation in soil available-N under application of different organic soil inputs before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

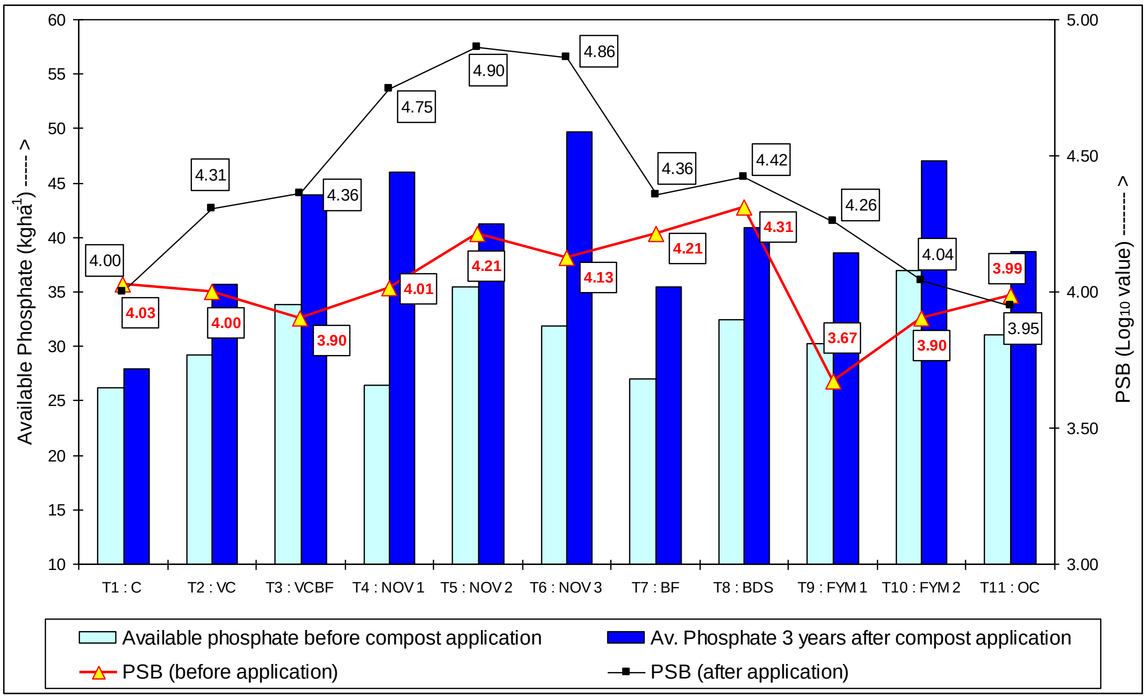


Fig. 26: Variation in soil available- P_2O_5 and phosphate solubilizing bacteria (PSB) under different organic soil inputs before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

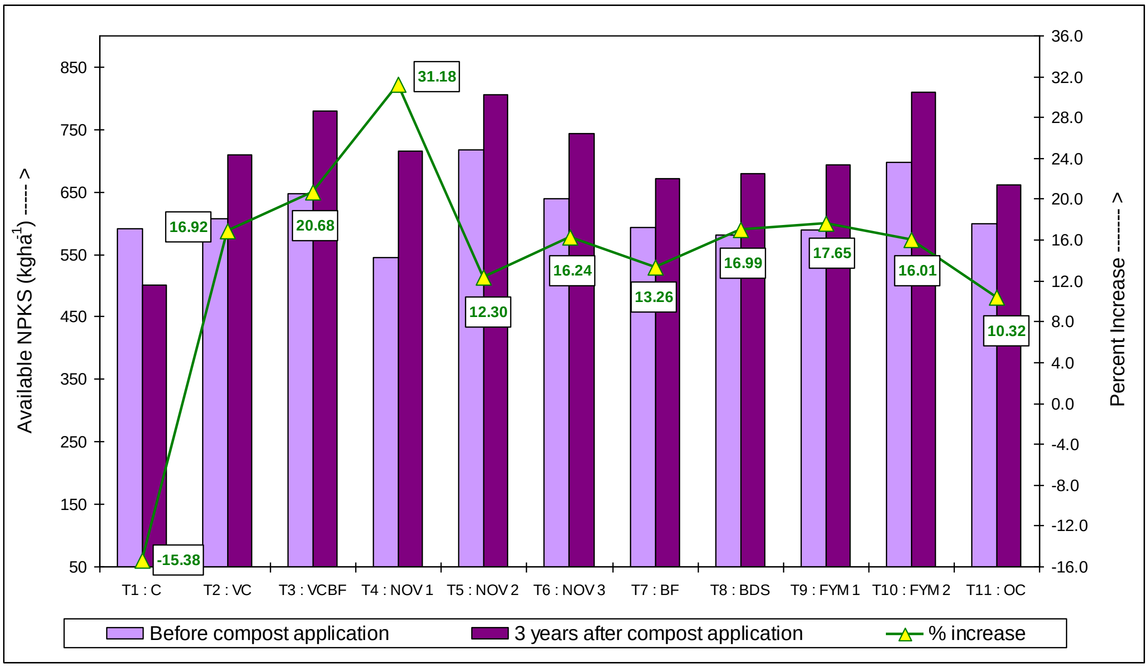


Fig. 27: Variation in soil available- N,P,K,S under application of different organic soil inputs before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

Table 14 : Variation in soil fertility (0 to 50 cm) under application of different types of organic soil inputs.

Treatments	Before Initiation of Experiment					After Completion of Experiment (3 years)				
	Org. C (%)	Av. N	Av. P_2O_5	Av. K_2O	Av. SO_4^{2-}	Org. C (%)	Av. N	Av. P_2O_5	Av. K_2O	Av. SO_4^{2-}
		< ----------------- kgha^{-1}	----------------- >				< ----------------- kgha^{-1}	--------------- >		
T_1 : C	0.66	354.07	26.22	182.38	28.753	0.86	325.80	27.98	121.98	24.713
T_2 : VC	0.70	343.10	29.17	204.27	29.960	0.97	398.79	35.70	229.85	44.780
T_3 : VCBF	0.67	342.37	33.86	238.75	31.580	0.85	435.68	43.86	257.74	43.007
T_4 : NOV-1	0.60	315.55	26.49	173.91	29.067	0.88	419.35	45.98	207.13	42.503
T_5 : NOV-2	0.77	389.07	35.47	254.61	38.097	0.82	430.07	41.29	280.48	53.617
T_6 : NOV-3	0.60	342.63	31.86	230.29	34.883	0.89	391.78	49.69	252.63	49.470
T_7 : BF	0.73	322.22	27.06	207.61	36.260	0.82	377.01	35.47	211.30	48.030
T_8 : BDS	0.71	314.38	32.41	202.44	32.133	0.89	381.15	40.86	216.17	41.950
T_9 : FYM-1	0.80	339.12	30.27	188.96	31.457	0.96	402.21	38.62	208.35	44.723
T_{10} : FYM-2	0.63	387.04	36.98	237.44	35.890	0.96	454.80	46.98	260.21	46.987
T_{11} : OC	0.77	347.54	31.11	184.61	35.667	0.92	387.95	38.73	195.71	38.367
CD (P = 0.5)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***50.52***	***16.76***	***37.15***	***18.73***

The large humic molecules from compost can mask the fixation sites preventing them from interacting with phosphorous. The organic anions may compete with phosphorous for fixation sites or can entrap reactive Fe and Al into stable organic complexes called chelates, thereby increasing the phosphorous availability for plants.

Available-K_2O varied within 174 and 239 kgha^{-1} in the different treatment plots. Post three years of experimentation the values increased under different treatments, especially in case of FYM-2, where significantly high content of potash was recorded over control. The behaviour of potassium in soil is influenced by soil cation exchange capacities rather than microbial processes. This was observed in case of FYM-2 with highest value of CEC.

Available-SO_4^{2-} varied from 29 to 38 kgha^{-1} and the values increased in all the plots post three years of experimentation, more so significantly in case of VC, NOV-2, NOV-3, BF, FYM- 1 and FYM-2 plots, with respect to control. The results indicated towards increase in total soil available nutrient content (i.e. N, P, K and S) under application of different types of organic soil inputs during the three year project period (fig. 27).

Microbial status of soil samples from different treatment plots

Microbial activity is probably the most important factor that controls nutrient re-cycling in soil. This is especially relevant for organic agriculture where an efficient soil nutrient dynamics is the key towards maintenance of crop productivity. Analysis of soil samples pre and post three years of experimentation showed an increase in soil microbial population in all the treatment plots post application of organic soil inputs (fig. 28). Especially in case of bacterial population significant increase was noted in case of plots receiving Novcom compost (i.e. NOV-1, 2 & 3 plots) as compared to control as well as plots (table 15A and 15B) receiving other types of organic soil inputs (except in case of NOV-2 w.r.t. FYM-2). Increase in the population of nitrogen converters in soil i.e. ammonifiers, nitrosomonas and nitrobacter (irrespective of the type of organic soil input applied) indicates the scope for better nitrogen transformation and plant availability as well as lower loss potential. Similarly increase in the population of phosphate solubilizing bacteria (PSB) in all the treatment plots (more so significantly in the plots receiving Novcom compost i.e. NOV-1, NOV-2 & NOV-3 w.r.t. control) might cause a positive influence towards phosphate availability in the acid tea soils.

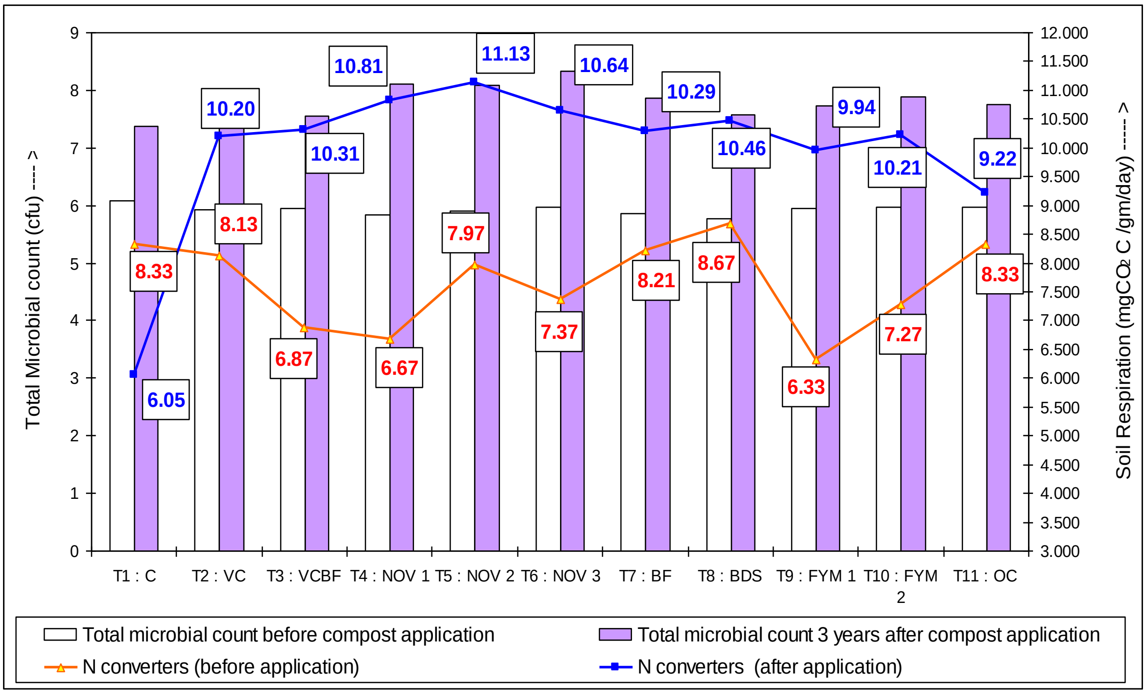


Fig. 28 : Variation of soil microbial count and soil microbial respiration under different organic soil inputs before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

Table 15A : Variation in soil microbial population under application of different types of organic soil inputs.

Treatments	Time of Sampling	Bacteria	Fungi	Actino.[1]	Amm.[2]	Nitroso.[3]	Nitrobac.[4]	PSB[5]	Soil Resp.*
		Soil Microbial Population (in $\log_{10}$ value) < ---- per gm moist soil ---- >							
T_1 : C	Before Initiation of Experiment	5.968	5.230	4.954	2.851	3.355	3.602	4.028	8.33
	After completion of experiment (3 years)	6.377	5.311	4.981	4.053	4.095	4.090	3.998	7.72
T_2 : VC	Before Initiation of Experiment	5.806	5.114	4.954	2.808	3.426	3.572	4.000	8.13
	After completion of experiment (3 years)	7.586	5.668	5.394	5.031	4.914	5.000	4.306	10.20
T_3 : VCBF	Before Initiation of Experiment	5.799	5.322	4.845	2.743	3.263	3.505	3.903	6.87
	After completion of experiment (3 years)	7.531	5.942	5.503	4.879	4.832	5.092	4.359	10.31
T_4 : NOV-1	Before Initiation of Experiment	5.602	5.301	5.000	2.773	3.228	3.445	4.014	6.67
	After completion of experiment (3 years)	8.111	6.209	5.935	5.114	4.301	6.050	4.747	10.81
T_5 : NOV-2	Before Initiation of Experiment	5.623	5.398	5.079	2.743	3.230	3.486	4.213	7.97
	After completion of experiment (3 years)	8.072	6.031	5.855	5.091	4.903	5.751	4.898	11.13
T_6 : NOV-3	Before Initiation of Experiment	5.839	5.230	4.903	3.032	3.201	3.579	4.125	7.37
	After completion of experiment (3 years)	8.322	5.855	5.896	4.879	5.014	5.747	4.863	10.64

[1]Actinomycates, [2] Ammonifiers, [3] Nitrosomonas, [4] Nitrobacter, [5] Phosphate solubilizing bacteria, * Soil respiration **_Contd.._**

Table 15B : Variation in soil microbial population under application of different types of organic soil inputs.

Treatments	Time of Sampling	Soil Microbial Population (in log_{10} value)							
		Bacteria	Fungi	Actino.[1]	Amm.[2]	Nitroso.[3]	Nitrobac.[4]	PSB[5]	Soil Resp.*
		< ------------------------------ per gm moist soil ------------------------------ >							
T_7 : BF	Before Initiation of Experiment	5.662	5.301	4.845	2.792	3.154	3.424	4.213	8.21
	After completion of experiment (3 years)	7.857	5.942	5.600	5.026	4.255	5.668	4.357	10.29
T_8 : BDS	Before Initiation of Experiment	5.477	5.204	5.114	3.145	3.191	3.523	4.308	8.67
	After completion of experiment (3 years)	7.568	5.855	5.714	4.962	4.255	5.518	4.420	10.46
T_9 : FYM-1	Before Initiation of Experiment	5.653	5.544	4.845	2.783	3.322	3.627	3.669	6.33
	After completion of experiment (3 years)	7.724	6.156	5.554	5.158	5.114	5.525	4.259	9.94
T_{10} : FYM-2	Before Initiation of Experiment	5.771	5.447	4.845	2.771	3.322	3.587	3.903	7.27
	After completion of experiment (3 years)	7.875	6.062	5.503	5.258	4.255	5.155	4.041	10.21
T_{11} : OC	Before Initiation of Experiment	5.724	5.518	4.845	2.741	3.315	3.544	3.985	8.33
	After completion of experiment (3 years)	7.756	5.748	5.156	5.279	4.954	5.347	3.949	9.22
CD (P = 0.5)	***2009***	***0.59***	***0.40***	***0.65***	***1.43***	***0.97***	***0.95***	***0.87***	***4.27***
	2012	***0.21***	***0.52***	***0.37***	***0.49***	***0.54***	***1.02***	***0.46***	***2.05***

[1]Actinomycates, [2] Ammonifiers, [3] Nitrosomonas, [4] Nitrobacter, [5] Phosphate solubilizing bacteria, * Soil respiration

Variation in soil N-dynamics under application of different types of organic soil inputs

Nitrogen is the most important element required by tea and accounts for about 4.0 percent dry weight of the shoots. Nitrogen transformation in soil primarily depends upon the soil-microbial activity, which is once again greatly influenced by the quality of applied organic soil inputs. For balanced plant nutrition, the dynamics of readily available– N in soil, which comprises both Ex. NH_4^+ and Ex. (NO_2+NO_3) forms, is more important. Readily available- N was found to increase significantly in all the treatment plots (w.r.t. control) post application of organic soil inputs, except in case of oil cake, which recorded lower value even as compared to pre- input applied soil sample. This might be due to the very low C/N ratio of oil cake leading to rapid microbial decomposition and fixation of N within microbial tissue, which shall be slowly available with time. Simultaneously fixed- NH_4^+ content was found to decrease in case of all the treatment plots (with few exceptions) post three years of experimentation, which might be due to enhanced microbial transformation of such fixed forms under organic environment.

Exchangeable NH_4^+– N was found to increase in most of the treatment plots (including control) post application of organic soil inputs (table 16A & 16B). Percent increase was highest in Biodynamic compost (32.33 percent) treated plots followed by plots receiving vermi compost (27.80 percent) and Novcom compost (25.41 percent). Percent increase in exchangeable (NO_2+NO_3) – N, was found to be highest in the plots receiving Biodynamic (121.57 percent) compost closely followed by Novcom compost (115.57 percent) applied plots (fig. 29). Tea plants require both Ex.- NH_4^+ and Ex.- (NO_2+NO_3) forms i.e. the readily available– soil N pool to meet its N requirement (Jianyun *et al*., 2007). Percent increase in the value of readily available– N was found to be highest in case of Biodynamic compost (104.33 %) closely followed by vermi compost (97.72 %) applied plots (fig. 30). In case of total mineral- N, which comprises both readily available and fixed inorganic- N, highest increase was recorded in plots receiving Novcom compost (50.96 %) followed by Biodynamic compost (44.85 %) and vermi compost (30.57 %) treated plots.

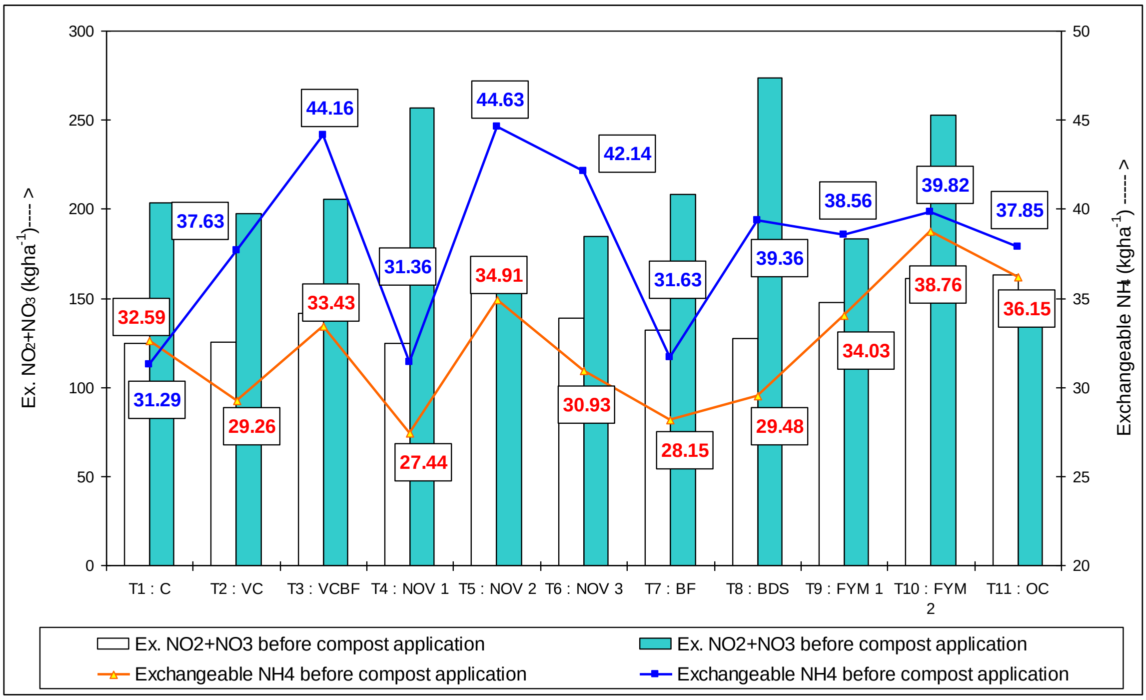


Fig. 29: Variation of exchangeable- (NO_2+NO_3) & NH_4^+ in soil under application of different organic soil inputs before and post 3 years of experiment under FAO-CFC-TBI Project at Maud T.E., Assam.

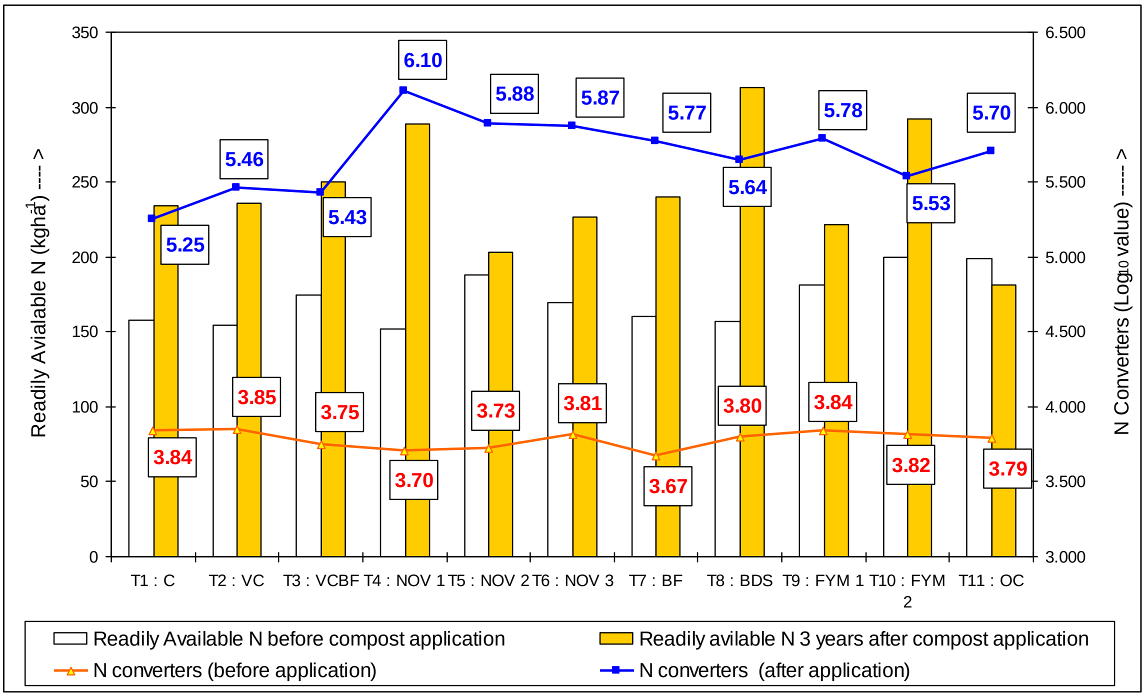


Fig. 30: Variation of readily available- N and N converters in soil under application of different types of organic soil inputs before and post 3 years of experiment under FAO-CFC-TBI Project at Maud T.E., Assam.

Table 16A : Variation in different forms of N in soil under application of different types of organic soil inputs.

Treatments	Time of Sampling	Different forms of N ($kgha^{-1}$)						
		Readily Av. N	Total Min. N	Exch. + Non Exch. NH_4	Exch. NH_4	Fixed NH_4	Exch. (NO_2+NO_3)	ND*
T_1 : C	Before Initiation of Experiment	157.44	311.30	186.45	32.59	153.86	124.84	0.51
	After completion of experiment (3 years)	132.08	289.09	188.30	31.29	157.01	100.79	0.46
T_2 : VC	Before Initiation of Experiment	154.54	291.74	166.46	29.26	137.20	125.28	0.53
	After completion of experiment (3 years)	235.45	378.26	180.44	37.63	142.81	197.82	0.62
T_3 : VCBF	Before Initiation of Experiment	174.69	337.96	196.70	33.43	163.27	141.26	0.52
	After completion of experiment (3 years)	249.98	413.47	207.65	44.16	163.49	205.82	0.60
T_4 : NOV-1	Before Initiation of Experiment	152.17	284.06	159.33	27.44	131.89	124.73	0.54
	After completion of experiment (3 years)	288.51	439.04	181.89	31.36	150.53	257.15	0.66
T_5 : NOV-2	Before Initiation of Experiment	187.81	351.37	198.48	34.91	163.57	152.89	0.53
	After completion of experiment (3 years)	203.33	358.22	199.52	44.63	154.89	158.70	0.57
T_6 : NOV-3	Before Initiation of Experiment	169.75	325.91	187.09	30.93	156.16	138.82	0.52
	After completion of experiment (3 years)	226.76	363.16	178.54	42.14	136.40	184.62	0.62

Table 16B : Variation in different forms of N in soil under application of different organic soil inputs.

Treatments	Time of Sampling	Different forms of N (kgha^{-1})						
		Readily Av. N	Total Min. N	(Ex.+Non Ex.) NH_4	Ex. NH_4	Fixed NH_4	Ex. (NO_2+NO_3)	ND*
T_7 : BF	Before Initiation of Experiment	160.23	297.54	165.46	28.15	137.31	132.08	0.54
	After completion of experiment (3 years)	239.63	360.25	152.25	31.63	120.62	208.00	0.67
T_8 : BDS	Before Initiation of Experiment	157.05	301.30	173.73	29.48	144.25	127.57	0.52
	After completion of experiment (3 years)	313.37	433.11	159.10	39.36	119.74	274.01	0.72
T_9 : FYM-1	Before Initiation of Experiment	181.62	335.92	188.32	34.03	154.30	147.59	0.54
	After completion of experiment (3 years)	221.84	368.11	184.82	38.56	146.27	183.28	0.60
T_{10} : FYM-2	Before Initiation of Experiment	199.58	369.18	208.36	38.76	169.61	160.82	0.54
	After completion of experiment (3 years)	292.31	466.14	213.65	39.82	173.83	252.49	0.63
T_{11} : OC	Before Initiation of Experiment	199.05	366.63	203.72	36.15	167.58	162.91	0.54
	After completion of experiment (3 years)	181.53	378.54	234.86	37.85	197.01	143.68	0.48
CD (P = 0.5)	***2009***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
	2012	***60.43***	***54.10***	***47.40***	***NS***	***59.3***	***51.47***	***0.13***

*ND : Nitrogen Dynamics (Readily Available N/ Total Mineralizable N)

Interrelation between crop yield and soil quality parameters.

To evaluate the interrelationship between crop response and soil quality parameters, total 22 soil parameters (analyzed during this study) were correlated with crop yield and significantly positive correlation was found in case of 8 soil quality parameters (table 17). As per the data revealed from table 5, crop yield was positively and significantly correlated with electrical conductivity (0.439**), cation exchange capacity (0.468**), available- N (0.339*), total mineralizable- N (0.396*), total ammonia (0.358*), fixed ammonia (0.366**), total ammonifiers (0.363*) and soil respiration (0.358*). The study indicated that improvement of these soil quality parameters might influence the crop performance and regular application of quality compost helped to improve soil quality.

Table 17 : Correlation coefficient between Yield and Soil Quality Parameters.

	Parameter	Correlation coefficient
Crop Yield Vs	Electrical Conductivity	0.439**
	Cation Exchange Capacity	0.468**
	Available Nitrogen	0.339*
	Total Mineralizable N	0.396*
	Total NH_4	0.358*
	Fixed NH_4	0.366*
	Total Ammonifiers	0.363*
	Soil Respiration	0.358*

** Significant at 1% level; * Significant at 5 % level

Relationship among different Soil Quality Parameters

Relationship among soil quality parameters are given in table 18. Soil pH is one of the important components of soil quality. Especially in acid soil, minor change in soil pH affects nutrient availability (Naqvi *et al.*, 1999). Soil pH was positively and significantly correlated with available- phosphate (r = 0.351*), available- sulphate (r = 0.559**), total bacteria (r = 0.568**), fungi (r = 0.473**), actinomyctes (r = 0.490**) and soil respiration (r = 0.472**) (table 18). Significantly higher correlation between the different types of soil microbes and soil pH indicated that in the acid tea soil, slight improvement of soil pH can influence proliferation of the native microbial population. Similar observation was noticed by Basu *et al*. (2011) in their study of acid soils.

Table 18 : Relationship among different soil physicochemical, fertility and biological parameters.

Correlation coefficient	*pH*	*EC*	*CEC*	*Organic carbon*	*Av. N*	*Av. Phosphate*	*Av. Potash*	*Av. Sulphate*	*Total bacteria*	*Total fungi*	*[1]Total Act.*	*Total PSB*
EC	-0.077	-										
CEC	-0.040	0.509**	-									
Org. carbon	0.056	0.109	0.171	-								
Av. N	0.118	0.631**	0.539**	0.177	-							
Av. Phosphate	0.351*	0.619**	0.451**	0.058	0.653**	-						
Av. Potash	0.307	0.531**	0.242	-0.032	0.821**	0.656**	-					
Av. Sulphate	0.559**	0.408*	0.137	0.053	0.622**	0.525**	0.817**	-				
Total bacteria	0.568**	0.503**	0.322	-0.097	0.392*	0.635**	0.521**	0.616**	-			
Total fungi	0.473**	0.510**	0.529**	-0.034	0.689**	0.555**	0.553**	0.568**	0.514**	-		
[1]Total Act	0.490**	0.556**	0.204	-0.185	0.436**	0.612**	0.587**	0.666**	0.722**	0.670**	-	
Total PSB	0.281	0.442**	0.034	-0.355*	0.257	0.455**	0.528**	0.555**	0.702**	0.435**	0.863**	-
[2]Soil Resp.	0.472**	0.587**	0.287	0.045	0.697**	0.655**	0.825**	0.835**	0.589**	0.677**	0.740**	0.611**

[1]Total Act[1] : Total Actinomycetes; [2]Soil Resp.: Soil Respiration; ** Significant at 1% level; * Significant at 5% level

Cation exchange capacity also showed positive and significant correlation with available- N (r = 0.539**) and available- phosphate (r = 0.451**). Significant and positive correlation among soil available nutrient and soil microbial population indicated their role in the availability of soil nutrients and the phenomenon in acid tea soil has a significant impact on crop productivity. Hoorman and Islam (2010) in their study indicated role of microbes in the availability of soil nutrients.

Relationship among different forms of N and N-converters

Soil- N converters play an important role in the conversion of soil nitrogen especially organic forms to exchangeable and readily available forms, for plant uptake (Rosswall, 1976; Hofman and Cleemput, 2004). Table 19 showed the relationship between different forms of nitrogen in soil and the soil– N converters. Research has indicated that with enhancement in the population of soil– N converters availability of exchangeable- NH_4 and exchangeable- NO_2+NO_3 increases in soil (Bramley and White, 1990). Correlation study indicated positive and significant interrelation between total mineral nitrogen and N converters *viz.* total ammonifiers (r = 0.505**) and nitrobactor (r = 0.663**). Similarly total and fixed- NH_4^+ was positively and significantly correlated with total ammonifiers (r = 0.711** and r = 0.711** respectively) which might indicate the role of ammonifiers in the mineralization of ammonia from organic matter.

Table 19 : Relationship among different forms of N and N-converters.

Correlation coefficient	*Readily Av. N*	*[1]Total min. N*	*Total NH_4*	*Exchangeable NH_4*	*Fixed NH_4*	*Ex. NO_2+NO_3*	*[2]Total amm.*	*[3]Total Nitro.*
Readily Av. N	-							
Total mineralizable N	0.741**	-						
Total (Non exch +exch) NH_4	-0.261	0.443**	-					
Exchangeable NH_4	-0.046	0.124	0.412*	-				
Fixed NH_4	-0.269	0.447**	0.983**	0.239	-			
Ex. NO_2+NO_3	0.989**	0.710**	-0.317	-0.193	-0.299	-		
Total ammonifiers	0.010	0.505**	0.711**	0.232	0.711**	-0.025	-	
Total nitrosomonas	-0.748**	-0.631**	0.143	0.307	0.091	-0.780**	-0.184	-
Total nitrobactor	-0.006	0.663**	0.073	-0.103	0.099	0.009	0.319	-0.225

[1]Total min. N : Total Mineralizable N; [2]*Total amm* : Total ammonifiers; [3]*Total Nitro* : Total Nitrosomonas;

** Significant at 1% level; * Significant at 5% level

Formulation of Soil Development Index (SDI)

Soil development index (SDI) is actually soil audit, which can enable the production of 'Soil Resource Map'. Soil resource map is again like the 'Soil Balance Sheet' of individual tea estate, which emphasizes soil productivity potential. Its importance and necessity exist in all the tea estates but has special relevance for organic tea plantation. Soil audit every year will confirm the impact and effectivity of the Soil Management Protocol undertaken. Any improvement in SDI shall be reflected in crop performance, hence; it is the first essential step towards meeting sustainable organic tea production.

In case of tea plantations, where there may be significant heterogeneity in soil character of individual sections, assessment of SDI can help in the identification of priority areas, which if attended effectively might significantly influence the productivity of entire garden. Assessment of SDI is of special relevance in case of Darjeeling plantations where sustenance of productivity is a critical issue considering the shallow soil depth, large variance in sectional topography of individual gardens; along with environmental factors that produce a significant influence on the surrounding soil ecology.

Hence, a simple and easily understood index for quantifying soil development is requisite for the tea planters to assess the soil development rate under any specific soil management programme/ compost application. The index should quantitatively indicate crop response in relation to the soil management programme undertaken. SDI was formulated using soil physicochemical, fertility and biological parameters. Twenty different quality parameters *viz.* soil pH, EC, organic carbon, C.E.C, Available NPKS, total bacteria, fungi, actinomycetes, ammonifiers, nitrobactor, nitrosomonas, phosphate solubilizing bacteria, readily available- N, total mineralizable- N, total- NH_4^+, exchangeable- (NO_2+NO_3), were used to calculate soil development index (SDI).

$$\text{Soil Development Index (SDI)} = \frac{a}{n^2}\left\{\sum_{n=1}^{n}\frac{100(X_1 - C_1)}{C_1} + \frac{100(X_2 - C_2)}{C_2} + \cdots + \frac{100(X_n - C_n)}{C_n}\right\}$$

Where X = Soil Quality parameters after Experimentation; C = Value of individual Soil Quality Parameter before Experimentation ; a = no. of Soil Quality Parameters showing increased over initial value.

Analytical values of the selected parameters before initiation of experiment in 2009 and after 3 consecutive years of compost application (i.e. in 2011) were then used as per the following formula to calculate soil development index under different treatments.

SDI was highest in case of Novcom compost (NOV-1) applied plots (SDI : 45.39) followed by NOV-3 (SDI : 32.65), VCBF (SDI : 30.28) and VC (SDI : 30.06) treatments. Highest SDI value obtained under Novcom compost indicated maximum soil quality development post compost application. The effectivity of Novcom compost might be due to its higher quality as well as its high self-generated microbial potential. The finding further corroborated with highest crop yield under NOV-1, as compared to the performance obtained under rest all other types of compost (fig. 31). The finding once again supported the hypothesis that organic soil management helps to rejuvenate soil quality which in turn helps to sustain crop productivity.

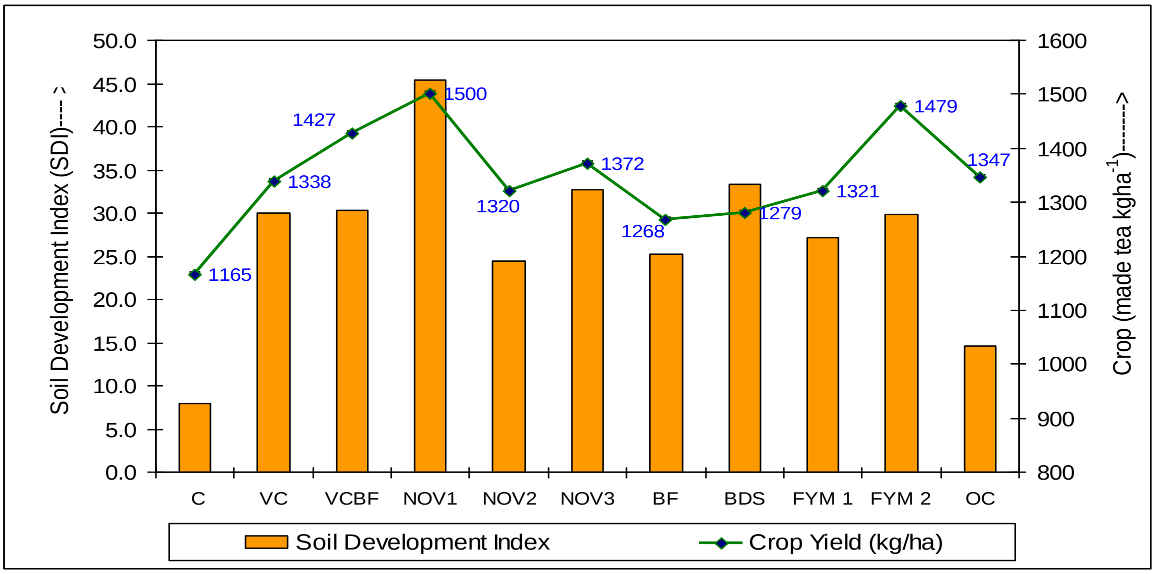


Fig. 31: Comparative Study of Soil Development under different types of organic soil inputs at Maud T. E. (Assam) over a period of 3 years.

Also there was no significant change in soil quality index, when bio-fertilizer was added to vermi compost. The findings again questioned the effectivity of adding microbial formulations in soil, which provided no insurance of crop but incurred huge cost. Similar views were shared by different workers (Thies 1990; Laditi *et al.*, 2012; Anonymous 1979; Garrett, 1956), according to whom success of inoculated soil microbial population in present form is case specific and the effort fails most of the time because it is in flagrant contradiction to the ecological axiom that population is a reflection of the habitat, and that any change due to plant introduction without change of the habitat must be a transient one. At the same time sole application of oil cake might support crop performance to an extent and for the first few years, but has very little role in soil quality development as supported by the SDI (14.64) scoring, which was last among all the treatments, except control.

Correlation of Soil Development Index with Crop Performance

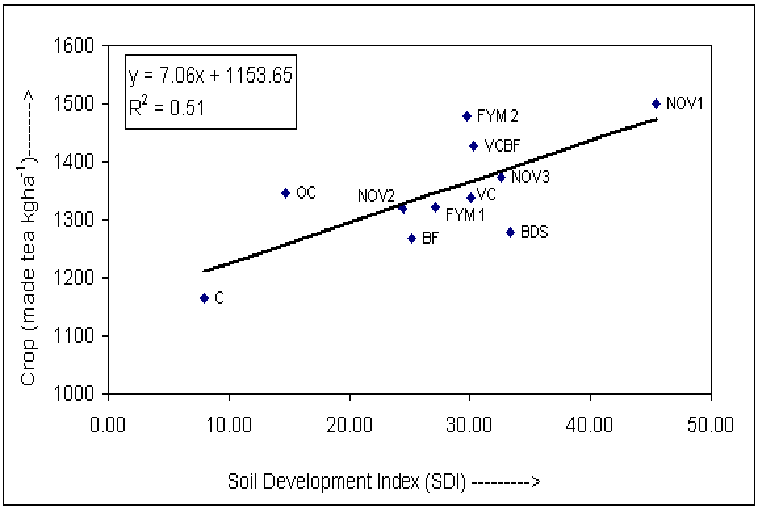


Fig. 32: Relationship between SDI and crop yield with application of different types of compost.

Soil development index will be representative only if it correlated with respective crop performance. The positive and significant (r = 0.716**) correlation obtained between SDI and crop performance, indicated that it can be used as an effective tool to judge soil quality in relation to crop performance as well as to assess the competence of soil management programme towards achieving desired development, especially in acid tea soils. The trend line (fig. 32) also showed close relationship between SDI and crop response.

Temporal Variation of Soil Development Index (SDI) under Application of Different Types of Organic Soil Inputs.

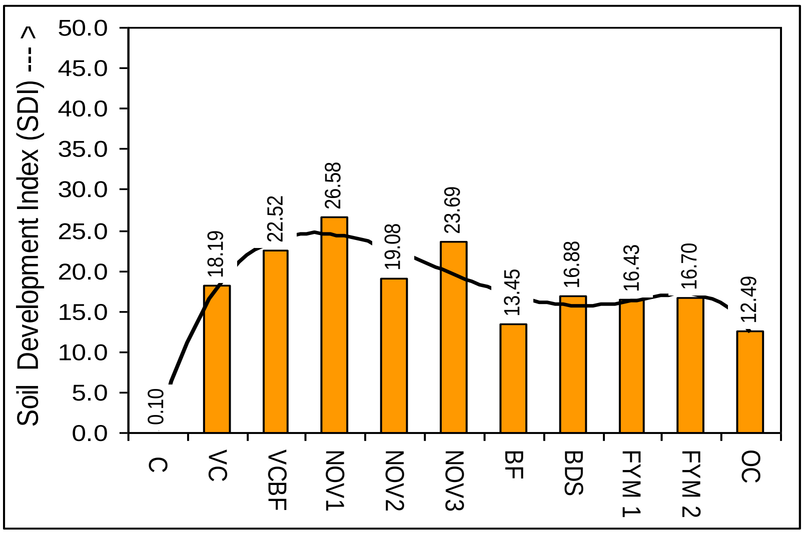


Fig 33 : Comparative study of SDI (2009 to 2010) under different types of organic soil input application.

Temporal variation in soil development under application of different types of organic soil input was studied and is represented by figure 33, 34 and 35. The figures not only indicated year wise variation in soil development but also depicted

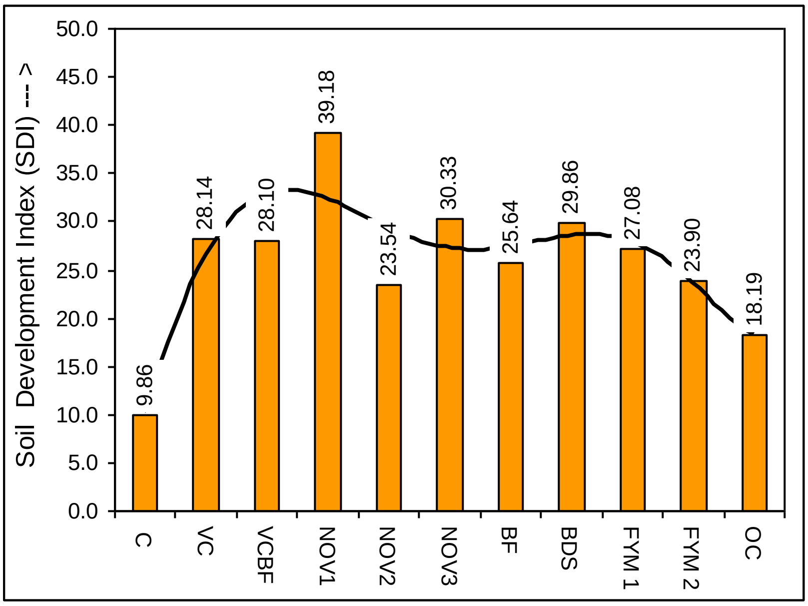


Fig 34 : Comparative study of SDI (2009 to 2011) under different organic soil input application.

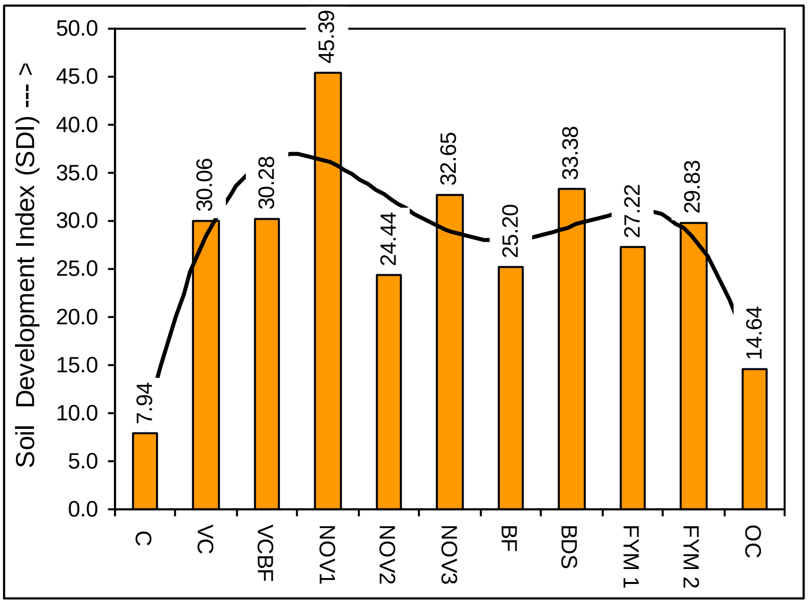


Fig 35 : Comparative study of SDI (2009 to 2012) under different organic soil input application.

its performance consistency under application of different types of organic soil inputs. In the first year (2009 to 2010) highest SDI was obtained under NOV-1 followed by NOV-3 and VCBF. After two years of compost application, SDI under NOV-1 was considerably higher than other treatments. Similar SDI values were obtained for NOV-3, BDS, VCBF and VC treated plots. Post application of organic soil inputs for 3 consecutive years, the SDI curve under different treatments followed almost similar trend as observed during 2nd year.

The findings gave some clear indications regarding the potentials of different types of organic soil input towards achieving rejuvenation of soil quality. NOV-1 treatment demonstrated clear superiority over rest other treatments. BDS, NOV-3, VCBF, VC and FYM-2 showed similar potentials but the most significant finding was that no additional benefit was obtained when vermicompost was applied in combination with bio-fertilizer as indicated by the almost similar SDI values scored under VC and VCBF application.

Pic. 40 : Field visit of Dr. T. C. Chaudhuri, Project Coordinator at Maud T.E.

Pic. 41: Professors from Calcutta Univ. visit Novcom Composting site at Maud T.E.

Pic. 42 : Visit of IFOAM personnel at Maud T.E. under FAO-CFC-TBI Project.

Pic. 43 : Visit of Mr. R. Padmanaban, Member of 'Inhana Advisory Board'.

Soil Quality Indexing through Minimum Data Set and Principle Component Analysis to Assess effectivity of different Organic Soil Inputs towards Soil Quality Development *vis-a-vis* Crop Response

Generation of Minimum Data set (MDS) and its screening through principle component analysis (PCA) is the new weapon in statistical armoury. The method was used to test the effectivity of different organic soil inputs (with variable dosage) in terms of crop productivity and soil development. The huge data set was first reduced to form minimum data set (MDS) through a series of univariate and multivariate statistical methods. This was followed by Principle Component Analysis (PCA) for each statistically significant variable to choose representative variables. To reduce redundancy, Pearson's Correlation Coefficients were done to determine the strength of the relationships among variables. Then MDS was validated and indicator transformation (scoring) was done in linear scoring methods. The indicators were then integrated into Soil Quality Indices (SQI).

In the study, both additive SQI of MDS variables and weighted additive SQI of MDS variables indicated NOV-1 as the best treatment or organic soil input. This was followed by study of relationship between observed and estimated yield under different organic soil inputs using multiple regression analysis. Close interrelation (as revealed from analysis) clearly indicated towards positive relationship between soil quality development and crop response.

Table 20: The Model Treatments

T1 : Control (C)
T2 : Vermi compost (VC)
T3 : Vermi compost + Microbial Formulations for Soil Management (VCBF)
T4 : Novcom Compost 1 (NOV-1)
T5 : Novcom Compost 1 (NOV-2)
T6 : Novcom Compost 1 (NOV-3)
T7 : Microbial Formulations for Soil Management (BF)
T8 : Biodynamic Soil Input (BDS)
T9 : Farm Yard Manure 1 (FYM-1)
T10 : Farm Yard Manure 2 (FYM-2)
T11 : Oil Cake (OC)

However to get a method for judging the system, a well-structured step by step framework was used for calculating soil quality index with analysis of a large numbers of soil parameters/indicators. The details of the parameters analysed are given below:

Table 21 : Soil Quality Parameters analysed

Following variables were measured on 0, 60 and 150 days post organic soil input application for 3 consecutive years i.e. 2009-2012 and on 0 day of 2012-13.

Code	Name	Code	Name
S1	pH	*S12*	Exchangeable NH_4
S2	EC	*S13*	Fixed NH_4
S3	CEC	*S14*	Exchangeable NO_2+NO_3
S4	Organic carbon	*S15*	Total bacterial count
S5	Available N	*S16*	Total fungal count
S6	Available Phosphate	*S17*	Total actinomycetes count
S7	Available Potash	*S18*	Total ammonifiers
S8	Available Sulphate	*S19*	Total nitrosomonas
S9	Readily Available N	*S20*	Total nitrobactor
S10	Total mineralizable N	*S21*	Total PSB
S11	Total NH_4 (exchangeable + non exchangeable)	*S22*	Soil respiration

This was followed by rigorous screening of few indicators (minimum data-set/master variables) from a pool of indicators using few statistical tools (as given below) and their subsequent union to get the unique value called **SOIL QUALITY INDEX (SQI)**. The details of how the master variables were screened and integrated into a combinable soil quality index are given below.

STATISTICAL METHOD

Data screening and choosing representative variables

The data was reduced to a minimum data-set (MDS) of soil quality indicators through a series of univariate and multivariate statistical methods using SPSS 10.0 software. Parametric (Randomized Complete Block Design) statistical method was used to identify indicators with significant treatment differences for each day of study resulting in 10 sets of analysis. For each set Duncan's test ($P<0.05$) was followed to find out the best treatment(s) for each day of observation. Duncan test results are displayed beside mean values of all 22 variables as included in table 21. All 22 variables were subjected to factor analysis with varimax rotation technique ith Kaiser normalization. Rotated component matrix (table 22) containing component loadings corresponding to eigen values more than 1 were further subjected to marking of each variable for its highest loading, indifferent of extracted factors. All variables within each factor will be highly associated and any variable either for its highest loading among all highly loaded variables or depending upon its easy time or cozy effective measurement, were selected in Minimum Data Set (MDS). It is clear that following such procedure will reduce redundancy and rule out spurious groupings among the highly weighted variables within each factor. Well-correlated variables were considered redundant and were thereby candidates for elimination from the data-set. The choice among well-correlated variables could also be based on practicality (i.e., ease of sampling, cost, and interpretability).

Indicator transformation (scoring)

After determining the variables for the MDS, every observation of each MDS indicator was transformed for inclusion in the SQI methods examined. Linear scoring technique was used for this purpose. In this technique, indicators were ranked in ascending or descending order depending on whether a higher value was considered "good" or "bad" in terms of soil function. For 'more is better' indicators, each observation was divided by the highest observed value such that the highest observed value received a score of 1. For 'less is better' indicators, the lowest observed value (in the numerator) was divided by each observation (in the denominator) such that the lowest observed value received a score of 1. For some indicators, such as pH, BD, available P etc. observations were scored as 'higher is better' up to a threshold value (e.g. pH 6.5) then scored as 'lower is better' above the threshold.

Indicator integration into indices

The additive index as a summation of the scores from MDS indicators were expressed in the form of stacked bars for all 11 treatments and also for all 10 periods of study. Higher index scores were assumed to mean better soil quality and so from the treatments the ones with higher altitudes will be preferred.

Results:

Mean results of all 22 variables as soil parameters studied for 10 periods during 2009-12 along with Duncan's test results were interpreted. All 22 variables were subjected to FA where 5 factors were extracted with the criteria of eigen values more than 1. These factors could explain 77.94% of the total variance. Only those highly loaded variables indifferent of factors were identified and within each column highest of all identified loadings were marked bold for MDS. But keeping the importance of the variable in mind sometimes such MDS variables were substituted with other variables for higher association with the MDS if and only if they are in the same factor.

In present study factor 1 is dominated by S3, S4, S15, S18, S19, S20, S21 and S22, which are highly correlated among themselves. Here S18 could have been the MDS variable. But S4 (OC) is selected for its overall importance in the study. Again factor 2 is represented by highly correlated variables like S10, S11, S12 and S13. S11 (total NH_3) is our natural selection for MDS and it is retained. Factor 3 is represented by highly correlated variables like S2, S5, S6, S7 and S8. S8 would have been our natural selection for MDS. But it is replaced by S6 (P_2O_5) for its importance in the total study. Factor 4 is represented by highly correlated variables like S1, S9 and S14. Here S14 is substituted by S9 (readily available N) as MDS variable for its importance. Factor 5 is represented by highly correlated variables like S16 and S17. S16 (fungi) is our natural selection for MDS and it is retained for its importance in the study of soil quality.

So our MDS for this study were OC, total NH_3, P_2O_5, readily available- N and fungi. Linear indexing method of study was used on these MDS variables.

Linear indexing:

After MDS selection all MDS member variables were adjudged for their importance towards soil health. We found that all MDS variables are best in their higher manifestation for soil health and this criterion was used for linear indexing. Stacked bars were drawn for all 10 periods of observations separately and included in Fig. 36 to 45.

Table 22 : Rotated Component Matrix

	Factor				
Variable	**1**	**2**	**3**	**4**	**5**
S1	-0.197	-0.103	-0.035	0.509	0.304
S2	0.204	0.254	0.434	0.330	0.211
S3	0.589	0.400	0.332	0.272	-0.217
S4	0.661	0.413	0.108	0.175	0.173
S5	0.500	0.172	0.548	0.206	0.088
S6	0.172	0.240	0.755	0.281	0.025
S7	0.186	0.323	0.734	-0.028	0.212
S8	0.204	0.184	**0.778**	0.190	-0.157
S9	0.295	0.192	0.296	0.846	0.057
S10	0.228	0.764	0.351	0.450	0.030
S11	0.203	**0.933**	0.253	-0.044	-0.009
S12	0.547	0.616	0.133	-0.058	-0.029
S13	0.087	0.924	0.260	-0.035	-0.003
S14	0.109	-0.025	0.262	**0.912**	0.071
S15	0.873	0.200	0.160	0.103	0.256
S16	0.139	0.020	0.033	0.075	**0.910**
S17	0.257	0.006	0.059	0.240	0.868
S18	**0.896**	-0.050	0.247	0.182	0.069
S19	0.886	0.206	0.080	-0.044	-0.016
S20	0.874	0.150	0.266	0.117	0.027
S21	0.778	0.232	0.068	-0.050	0.177
S22	0.643	-0.124	0.323	-0.025	0.380
Eigen value	*5.938*	*3.533*	*3.030*	*2.515*	*2.131*
% of Variance	*26.989*	*16.059*	*13.771*	*11.430*	*9.687*
Cumulative %	*26.989*	*43.048*	*56.819*	*68.249*	*77.935*

Stacked bar involving additive SQI of MDS variables which revealed the best treatments or organic soil input with higher peaks / 1

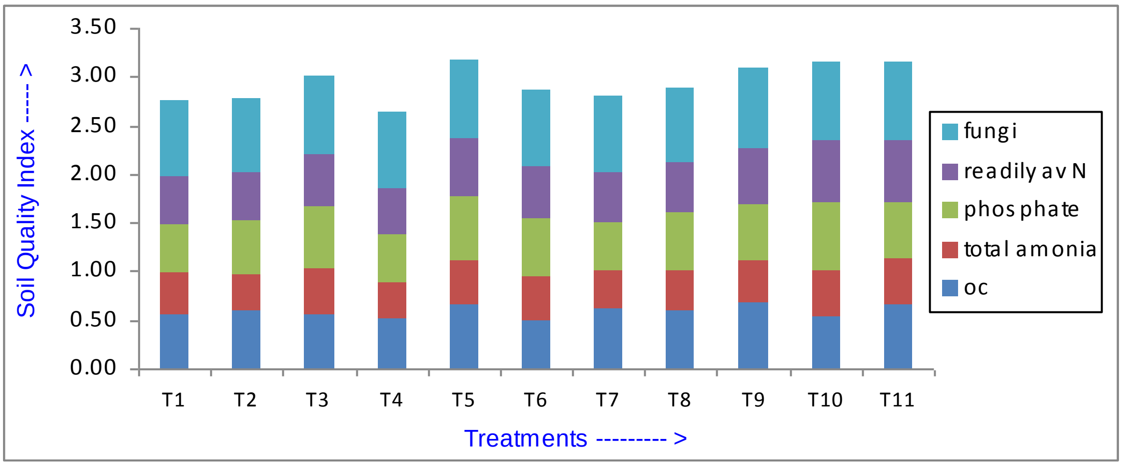


Fig.36: Day 0 of year 2009-10

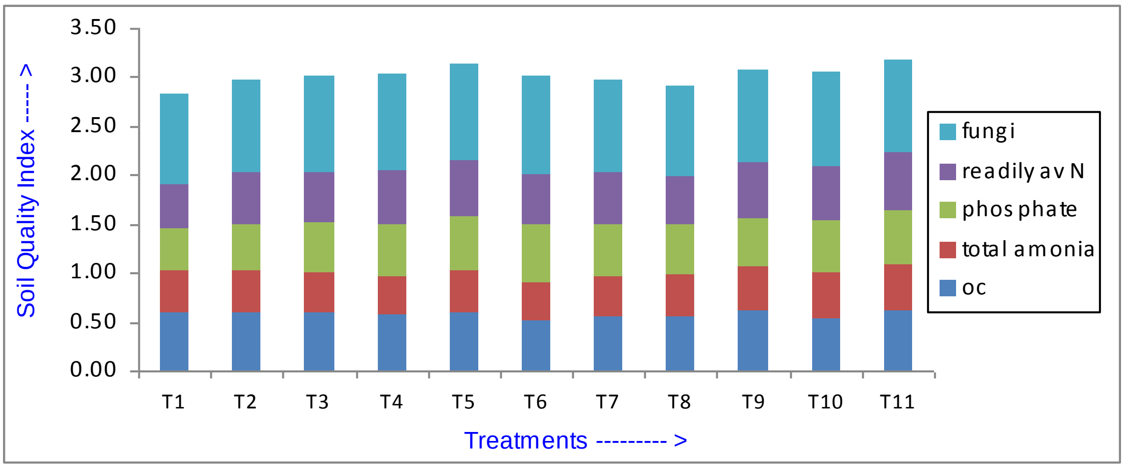


Fig. 37: Day 60 of year 2009-10

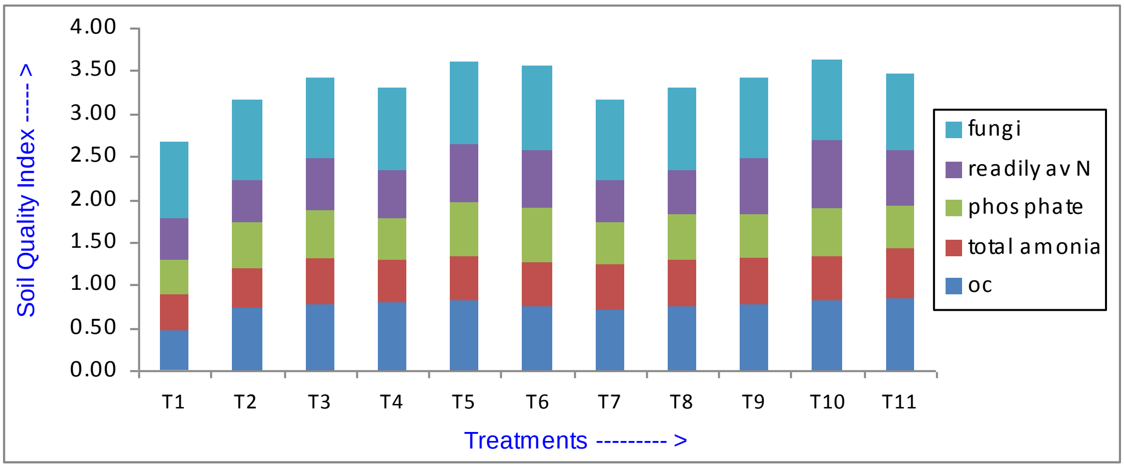


Fig. 38: Day 150 of year 2009-10

Stacked bar involving additive SQI of MDS variables which revealed the best treatments or organic soil input with higher peaks / 2

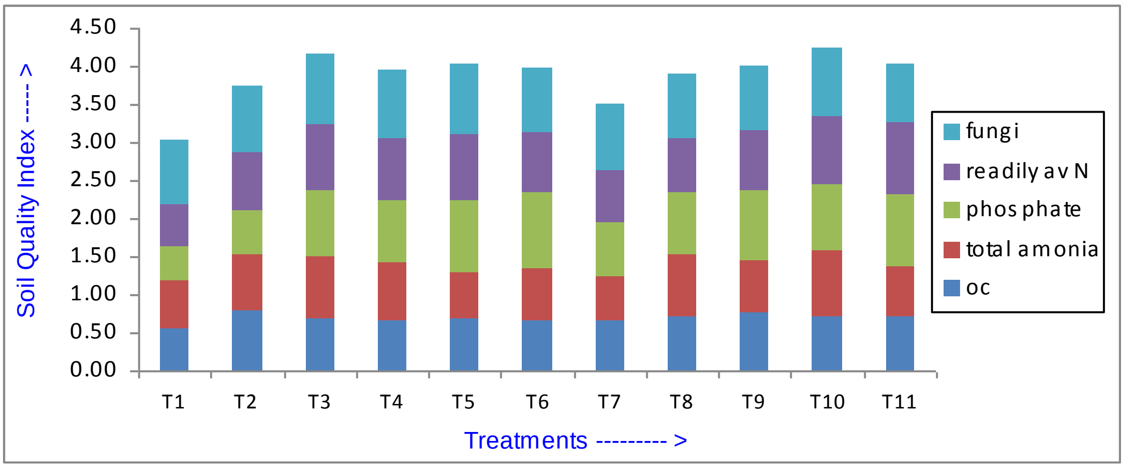


Fig. 39: Day 0 of year 2010-11

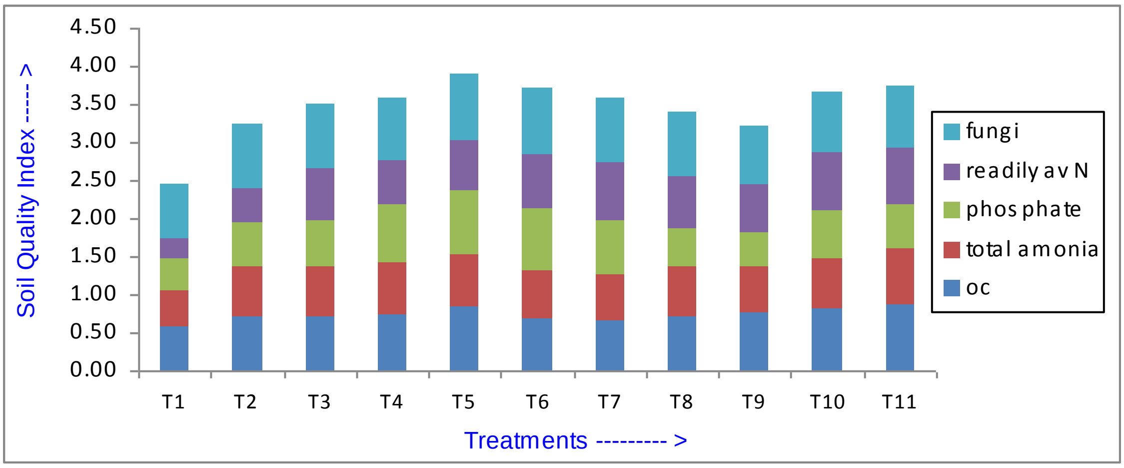


Fig. 40: Day 60 of year 2010-11

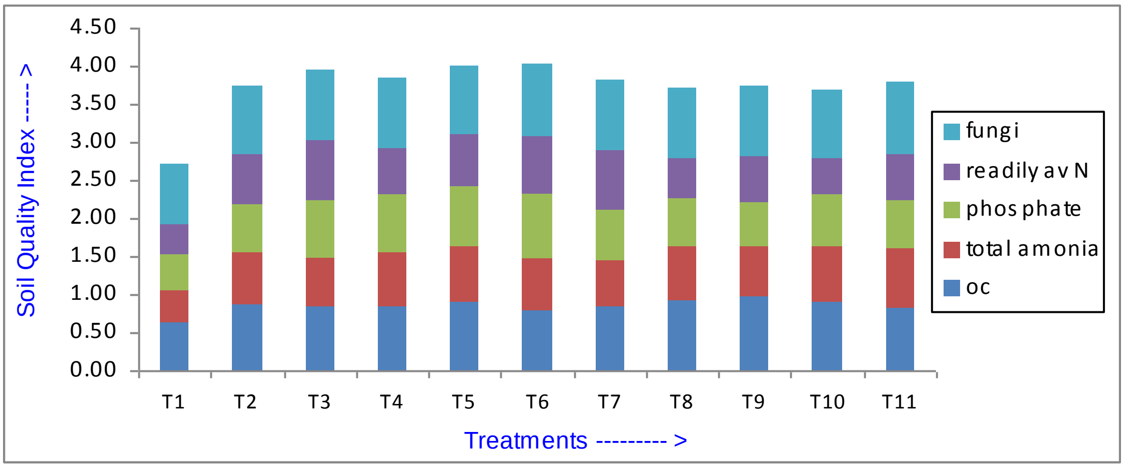


Fig. 41 : Day 150 of year 2010-11

Stacked bar involving additive SQI of MDS variables which revealed the best treatments or organic soil input with higher peaks / 3

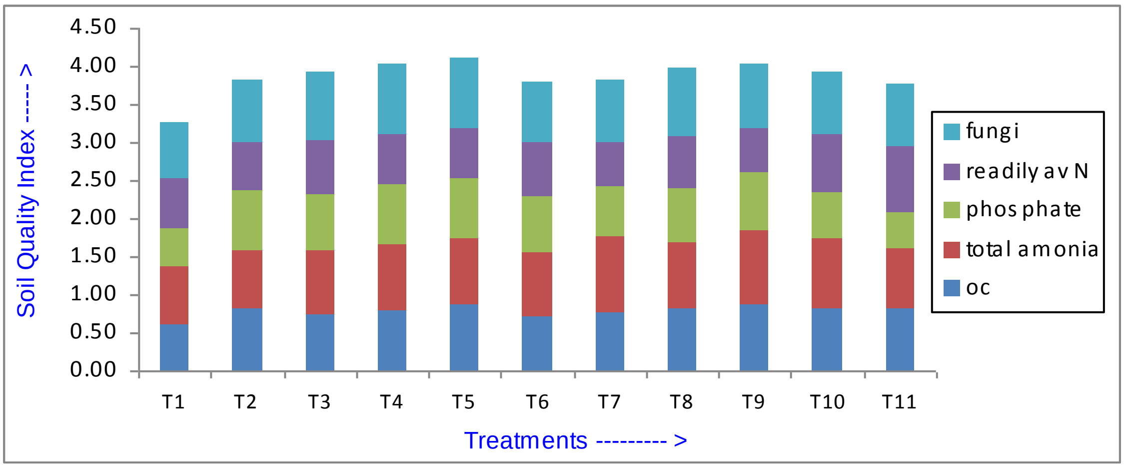


Fig. 42: Day 0 of year 2011-12

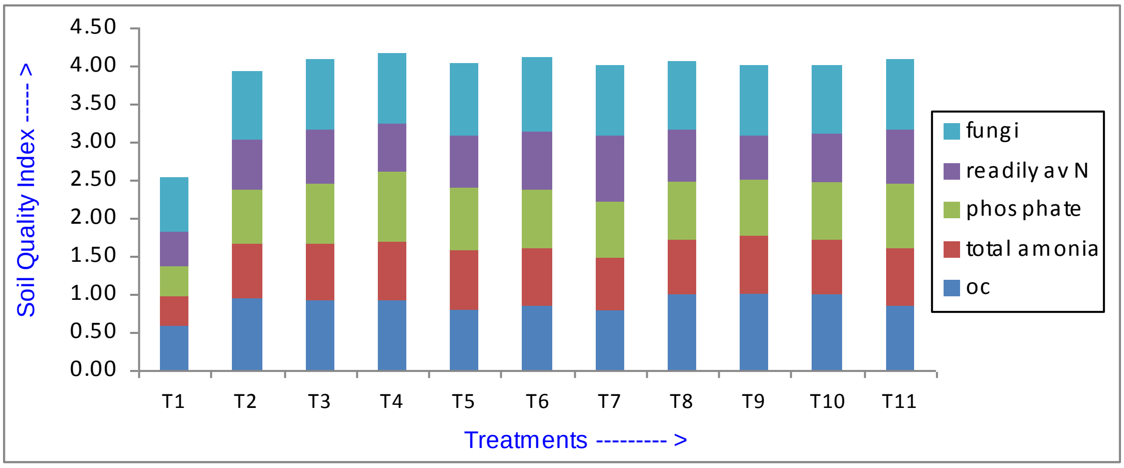


Fig. 43: Day 60 of year 2011-12

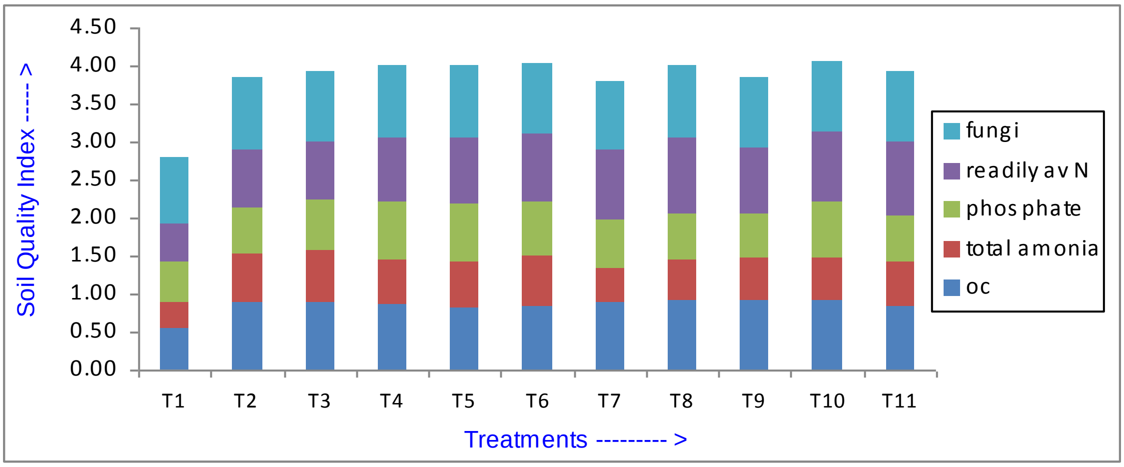


Fig. 44 : Day 150 of year 2011-12

Stacked bar involving additive SQI of MDS variables which revealed the best treatments or organic soil input with higher peaks

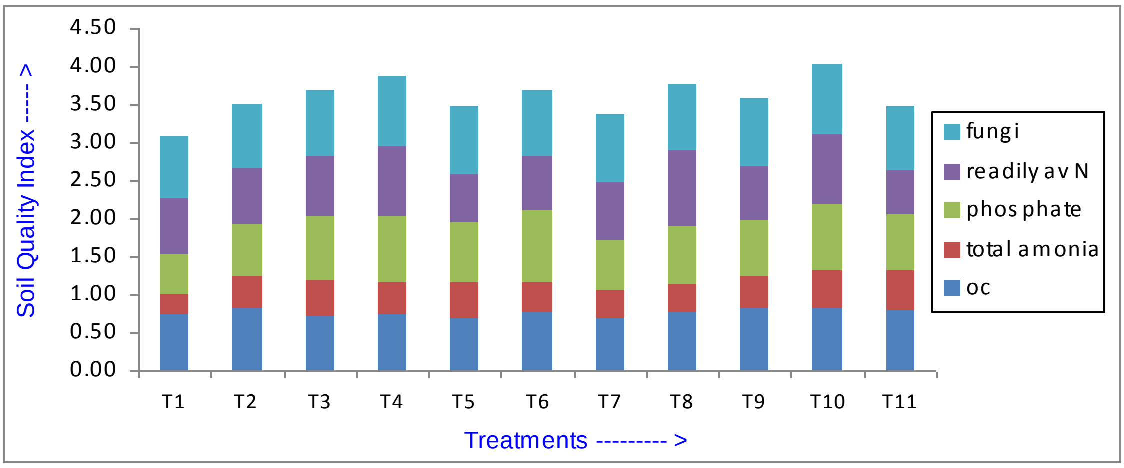


Fig. 45: Day 0 of year 2012-13

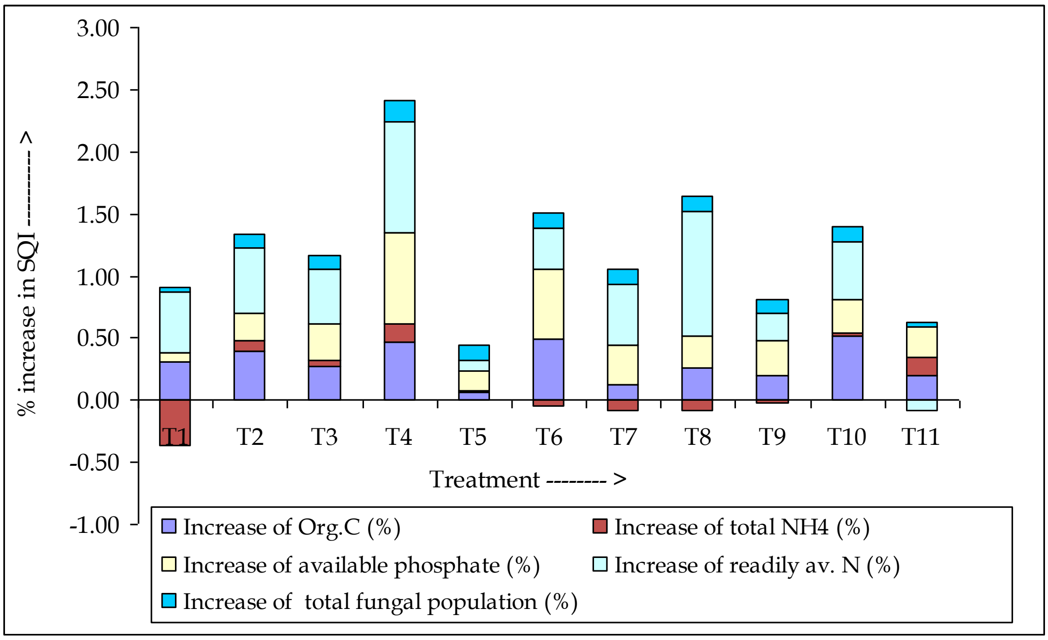


Fig. 46: Percent increase in MDS variables for comparison of the relative contribution of 11 treatments towards upliftment of soil health.

Evaluation of the degree of increase in selected soil quality parameters showed that cumulative percent increase was highest in case of T4 (NOV-1) follwed by T8 (BDS), T6 (NOV-3), T10 (FYM-2) and T2 (VC) respectively. The results indicated development of soil quality under Novcom compost was most effective in comparision to other organic soil inputs (Fig. 46).

Development of Organic Tea Nursery under Different Packages of Practice under FAO-CFC-TBI Project.

Brief Summary

Nursery (using seed variety TS-463) was initiated in 2009 under five different organic 'Packages of Practice' with one control. Objectivity of the experiment was to assess the potential of different organic packages towards development of healthy planting material.

The selected treatments were Biodynamic package of practice (BD), Conventional organic practice (CO), Inhana Rational Farming Technology (IRF), Microbial formulations for soil and plant (MI), and Vermi compost + Conventional organic practice (VCO),

Quality of tea seedlings grown under different organic packages were evaluated using various agronomic parameters (shoot height, stem diameter, root mass, and shoot/ root ratio etc.) and indices (Specific leaf area, Leaf N content, Plant Strength, Dickson quality index etc.).

Dickson quality index, which quantified the overall morphological development of seedlings; was highest in case of IRF (1.41) treated seedlings followed by MI (1.27) and CO (1.21) treatments.

Better and consistent growth performance as well as better survival chances and speedier growth (post transplantation) was observed under IRF management as indicated by the high values obtained both in case of agronomic parameters and indices. Irrespective of IRF, other organic packages of practice like MI and CO also showed higher performance as compared to VCO and BD.

Development of Organic Tea Nursery under Different Packages of Practice under FAO-CFC-TBI Project.

Introduction

Nursery is the backbone of any good tea garden; however successful development of Nursery under organic management is still considered as a challenging job. Under this project, a nursery (using seeds) was initiated in 2009.

Tea seed variety 463 was used and five different 'Packages of Practice' (with one control) were taken as treatment for the experiment. About 300 saplings were segregated, made into batches of 50 numbers and each batch was managed as per specific package of practice for one year, to assess their effectivity towards development of healthy planting material.

Objective

1. To achieve low/ no mortality.
2. Development of more number of natural laterals.
3. To achieve plantable stage within a short span of time.

Methodology

Among the five different packages of practice, besides recommendation for tube filling, only IRF and BD offered solutions before initiation of sand bed treatment, while the rest packages gave protocol starting from two leaf stage. Hence, in case of all treatments (except Inhana Rational Farming and Biodynamic Package of Practice) healthy seeds were selected, soaked overnight in water and then transferred to sand bed after air drying. In case of Inhana Rational Farming (IRF) the seeds were soaked in Inhana Seed solution overnight and under Biodynamic Package of Practice (BD) the seeds were treated with CPP using 2% jaggery solution, before air drying and transferring to sand bed. Comparative effectivity of IRF and BD 'Pre-Germination Seed Treatment Protocol' was evaluated in terms germination percent (GP), germination index (GI), emergence percent (EI) and emergence Index (EI) as per the methodology of Yang *et al*. (2005). Germination speed was assessed in terms of Bartlett's Rate Index (BRI) as per the methodology of Barlett (1973) and seed vigour as per the methodology of Abdul-Baki and Anderson (1973).

The cracked seeds were then transferred to plastic tubes and raised under different organic packages. Standard cultural practices *viz.* demossing and weeding were done for all the packages.

Analysis of different agronomic parameters of tea seedlings (90, 180 and 270 days after germination) under different packages of practice was also taken up and Dickson quality index (Dickson *et al.*, 1960) was calculated to evaluate the quality of tea seedlings. Morphological characteristics *viz.* shoot height, stem diameter, root mass, and shoot/ root ratio were also measured for grading seedlings under different organic packages in the nursery.

Treatment Details : Nursery experiment /1.

Sl.	Package of Practice		Treatment details
1.	**Conventional Organic Practice (CO)**	**:**	**Tube Filling Operation :** Metarrhizium enriched (@ 100 grams in 20 kg of compost) Indigenous compost (FYM) was mixed in the soil at 75:25 ratio, before tube filling. **Spraying :** Once, the plant reached two to three leaf stage, they were monitored regularly for pest incidence and sprayed using different herbal concoctions as per Expert recommendations.
2.	**Biodynamic Package of Practice (BD)**	**:**	**Tube Filling Operation :** Soil was mixed with Biodynamic compost at 75:25 ratio, before tube filling. **Spraying :** Once, the plant reached two to three leaf stage, different Biodynamic formulations were sprayed at regular interval along with pest/ disease management as per requirement on the basis of the Expert recommendations.

Continued …

Treatment Details : Nursery experiment /2.

Sl.	Package of Practice		Treatment details
3.	**Inhana Rational Farming (IRF)**	:	**Tube Filling Operation :** Soil was mixed with Novcom compost at 70:30 ratio, before tube filling. **Spraying :** Once, the plant reached two to three leaf stage, different Inhana solutions were sprayed at regular interval along with pest/ disease management on requirement basis as per Schedule provided by Inhana Biosciences.
4.	**Microbial Formulations for Soil & Plant (MI)**	:	**Tube Filling Operation :** In each tube 5 g city compost organic fertilizer induced with N fixing bacteria & PSB as well as 1 g of Bio-NPK (combination of *Bacillus, Pseudomonas, Azotobacter and Azospirillum*) was mixed with soil. **Spraying :** Once, the plant reached two to three leaf stage, they were sprayed at regular interval using microbial growth promoter along with pest/ disease management on requirement basis as per Expert recommendations.
5.	**Vermicompost + Conventional Organic Practice (VCO)**	:	**Tube Filling Operation :** Soil was mixed with vermicompost at 70:30 ratio, before tube filling. **Spraying :** Once, the plant reached two to three leaf stage, they were monitored regularly for pest incidence and sprayed using different herbal concoctions as per Expert recommendations.
6.	**Control (C)**	:	**Tube Filling Operation :** Normal garden soil was used for tube filling. **Spraying :** Once, the plant reached two to three leaf stage, they were sprayed with plain water at regular interval and also in case of any pest incidence.

Table 23 : Physicochemical properties and fertility status of soil of nursery tube before and after experiment under FAO-CFC-TBI Project.

Details of experiment	pH	EC (dSm^{-1})	Org. C %	Av- N	Av - P_2O_5	Av - K_2O	Av - SO_4^{2-}
				< -------- ppm --------- >			
Physicochemical & fertility parameters of soil before initiation of experiment.							
-	4.87	0.065	1.31	365.07	21.48	132.18	40.45
Physicochemical & fertility parameters of soil under different packages of practice post completion of experiment.							
C	5.10	0.064	1.30	363.78	20.26	113.49	40.34
CO	5.29	0.087	1.54	385.73	29.57	163.60	78.00
BD	5.53	0.078	1.64	413.95	35.18	151.25	67.70
VCO	5.36	0.109	1.63	457.86	37.50	170.80	50.12
MI	4.98	0.068	1.32	373.18	23.28	139.15	42.68
IRF	5.60	0.105	1.68	466.67	33.97	190.40	55.92

Physicochemical properties and fertility status of tube soils before initiation and post three years of experiment under different packages of practice was analyzed and is presented in table 23. pH of the soil was moderately acidic with moderate organic carbon status. Average value of available- N, P, K and S were 365.07 ppm, 21.48 ppm, 132.18ppm and 40.45 ppm respectively ranging between moderate and high status. Except in case of control and MI treatment, for all other organic packages, compost was mixed with tube soil on 25 to 30 percent by weight as per suggestion of the respective protocol.

Post experiment pH of all the tube soils except control and MI increased considerably, which might be due to the basic characteristics of the applied compost. Soil nutrients in terms of available- N, P, K and S under all the treatments (except control) ranged between 373.18 to 466.67 ppm, 23.28 to 37.50 ppm, 139.15 to 190.40 ppm and 42.68 to 78.00 ppm respectively, meeting the moderate to high status range. The findings clearly indicated improvement in soil fertility status in all the tubes irrespective of the type of treatment.

Results & Discussion

Evaluation of the Effectivity of 'Pre-Germination Seed Treatment Protocol'

Assessment of the effectivity of Biodynamic and IRF 'Pre-Germination Seed Treatment Protocol' towards seed cracking (as compared to control) was done in terms of germination percent, germination speed, germination index, emergence percent, emergence index and seed vigour. About 6.79 and 10.41 percent more cracked seeds were witnessed post seed treatment under Biodynamic and IRF protocol as compared to general soaking with water (fig. 47) in control tubes.

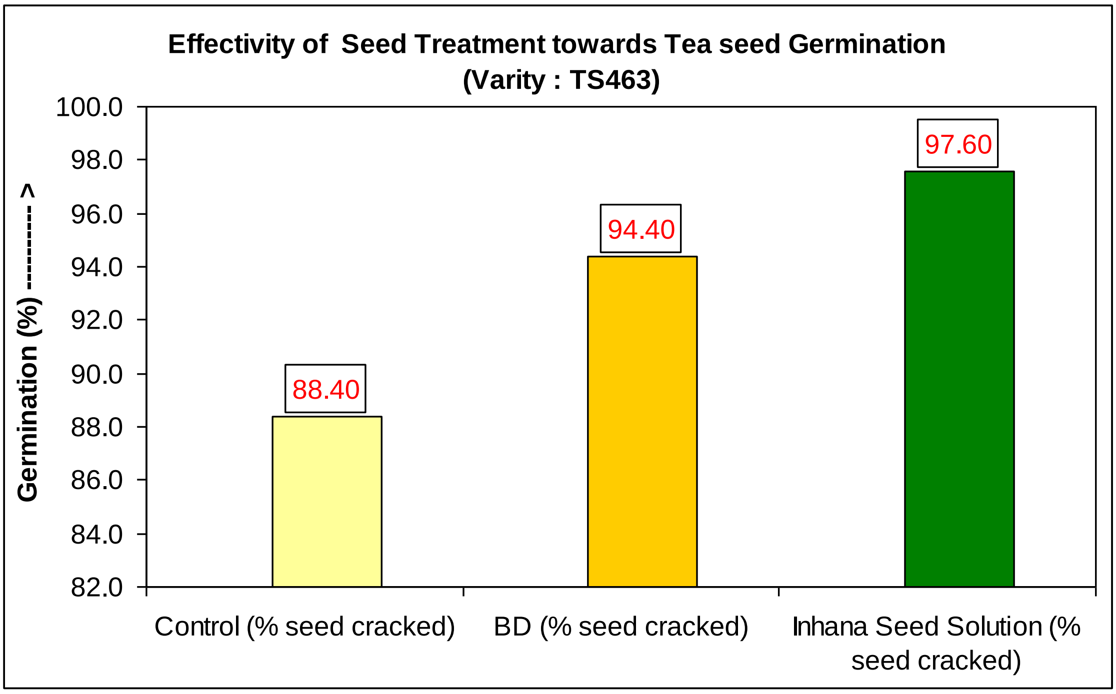
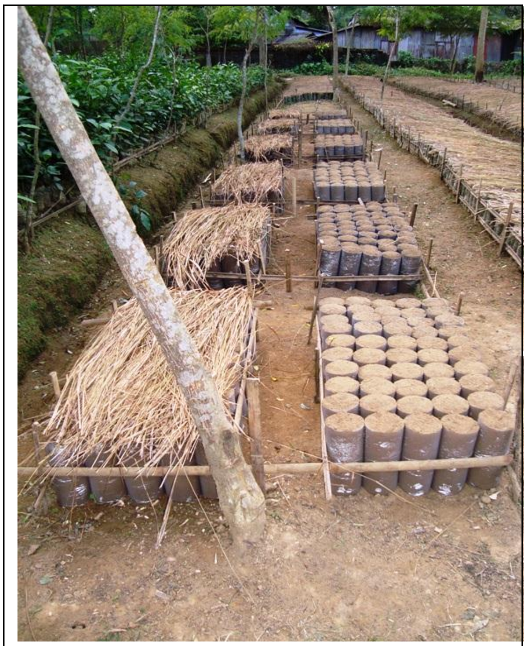


Fig. 47: Comparative assessment of the effectivity of organic seed treatment protocol under FAO-CFC-TBI Project at Maud T.E., Assam.

Germination percent (fig. 48) of the tea seeds was highest under IRF seed treatment (97.60 %) followed by BD seed treatment (94.40 percent). Similar observation was made in case of germination speed (fig. 49), germination index (fig. 50), emergence percent (fig. 51) and emergence index (fig. 52), which indicated the effectivity of IRF package. Thirusenduraselvi and Jerlin (2007) also recorded relative effectivity of pre-germination seed treatment towards emergence percentage of the seeds.

Pic. 44 : Tea seeds were placed in sand bed for cracking.

Pic. 45 : Tube filling operation at Nursery site in Maud T.E.



Pic. 46 : Mulching of tubes with straw after transplanting of cracked seeds.

Pic. 47 : Growth of tea seedlings (0 to 60 days)

Pic. 48 : Nursery Experiment under FAO-CFC-TBI Project at Maud T.E.

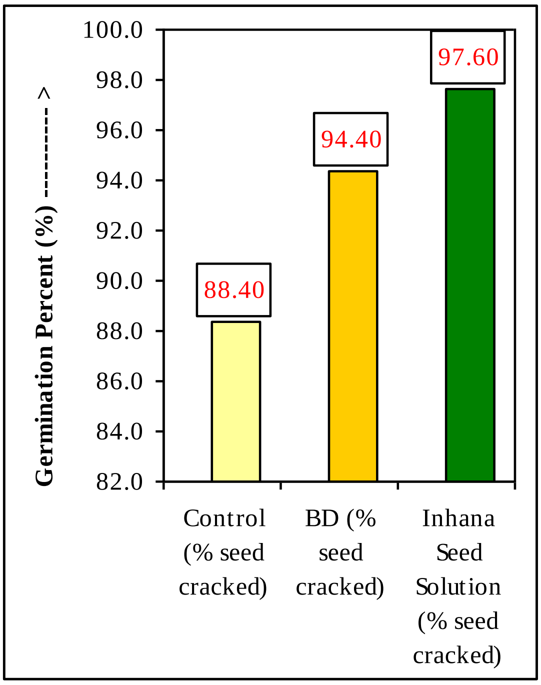


Fig. 48: Germination Percent of tea seedlings (variety: TS 463).

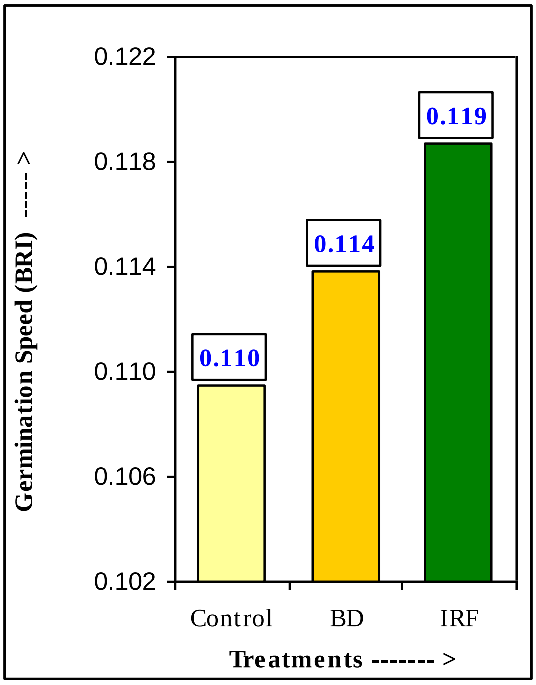


Fig. 49: Germination Speed of tea seedlings (variety: TS 463).

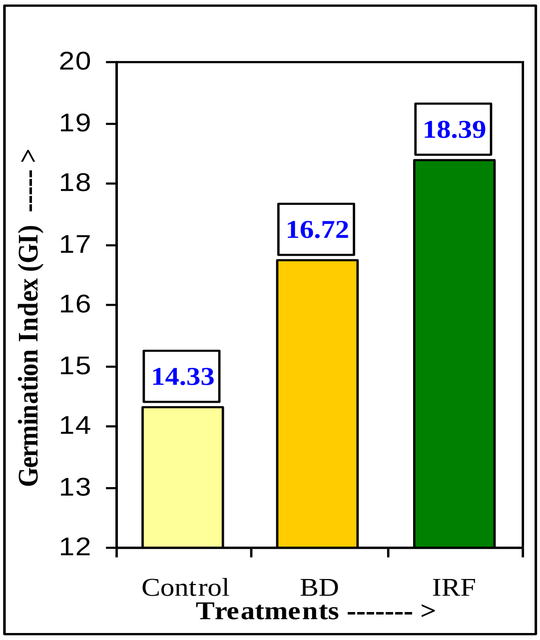


Fig. 50: Germination Index of tea seedlings (variety: TS 463).

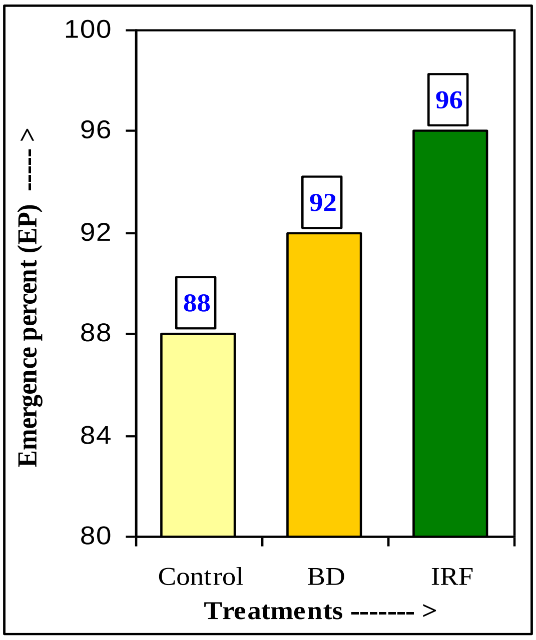


Fig. 51: Emergence Percent (EP) of tea seedlings (variety: TS 463).

Seed vigour as represented by Seed Vigour Index (SVI) is an important quality parameter which needs to be (fig. 53) assessed in order to supplement germination and viability tests to gain insight into the performance of a seed lot in the field. The seed lot showing higher SVI is considered to be more vigorous and plays an important role towards early establishment of crop (Singh *et al.*, 2000). Highest value of SVI was obtained under IRF (5.73) once again confirming the effectivity of IRF pre-germination seed treatment protocol towards better germination and vigorous seedling growth.

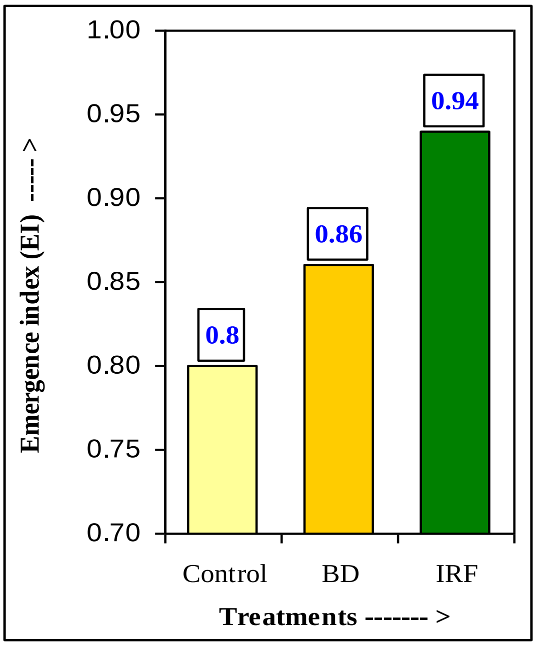


Fig. 52: Emergence Index (EI) of tea seedlings (variety: TS 463) under treatment in FAO-CFC-TBI Project.

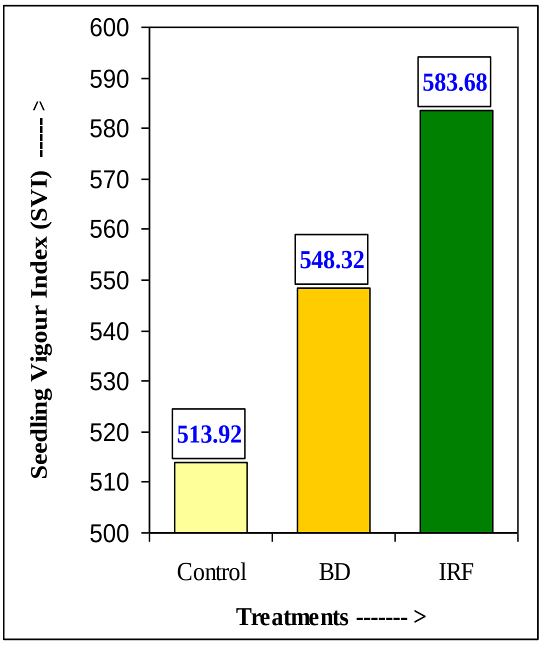


Fig. 53: Seedling Vigour Index (SVI) of tea seedlings (variety: TS 463) under treatment in FAO-CFC-TBI Project.

Evaluation of effectivity of different organic packages towards seedling growth and quality towards speedy recovery of ready planting material.

Quality of tea seedlings have great commercial significance as it determines their post planting survival rate under hostile environmental conditions and growth performance thereafter. More recently, several studies demonstrated that seedling survival was positively affected by nursery practices aimed at increasing seedling vigour (Oliet *et al.*, 2004). Quality of tea seedlings was analyzed using different agronomic parameters (90, 180 and 270 days after germination) and through assessment of Dickson quality index.

Assessment of Morphological Attributes **:**

Agronomic parameters (table 24 and 25), such as seedling shoot height and diameter are often used as indicators of seedling quality and predictors of field response (Rose *et al.*, 1990; Dey and Parker, 1997) because they are relatively simple to measure (Racey 1985; Thompson 1985) and correlate well with field success (Kaczmarek and Pope, 1993a; Dey and Parker, 1997).

Seedling height at the time of out-planting can greatly influence growth rate in the field (Duryea, 1984). Shoot length of the nursery seedlings were highest under IRF (68.76 cm) followed by MI (63.14 cm) and BD (63.14 cm) packages. However, stem diameter (often referred to as root collar diameter or caliper) has often been considered the best single predictor of field survival and growth. (Thompson 1985).

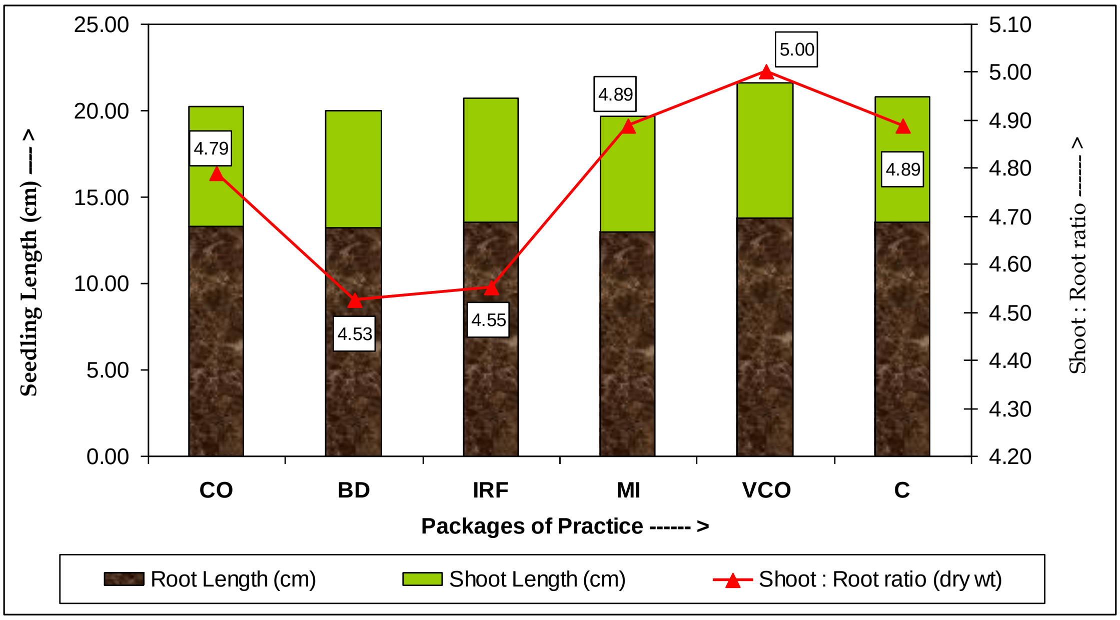


Fig. 54: Shoot & root length of 90 day seedlings.

Schmidt-Vogt (1981) in his study showed that seedlings with larger root-collar diameters (which tend to be larger stock) have better out-planting success. In this respect Johnson (1976) reported that planting seedlings with stem caliper of 8 mm or greater, increased survival rate and early growth. Stem girth was highest under IRF management indicating better growth potential of seedlings, as compared to other packages of practice.

Root mass has recently been recognized as one of the most important factors critical to field performance. Hermann (1964) in his study showed that survival of seedlings with poor root systems was significantly lower than that of seedlings with good root systems regardless of shoot-height class. Root length and root dry weight, which indicated the development of root system showed higher value under IRF (root length and root dry weight 42.64 cm and 6.48 g respectively) followed by CO (root length and root dry weight 39.17 cm and 5.46g respectively) and BD (root length and root dry weight 39.15 cm and 5.41g respectively) packages.

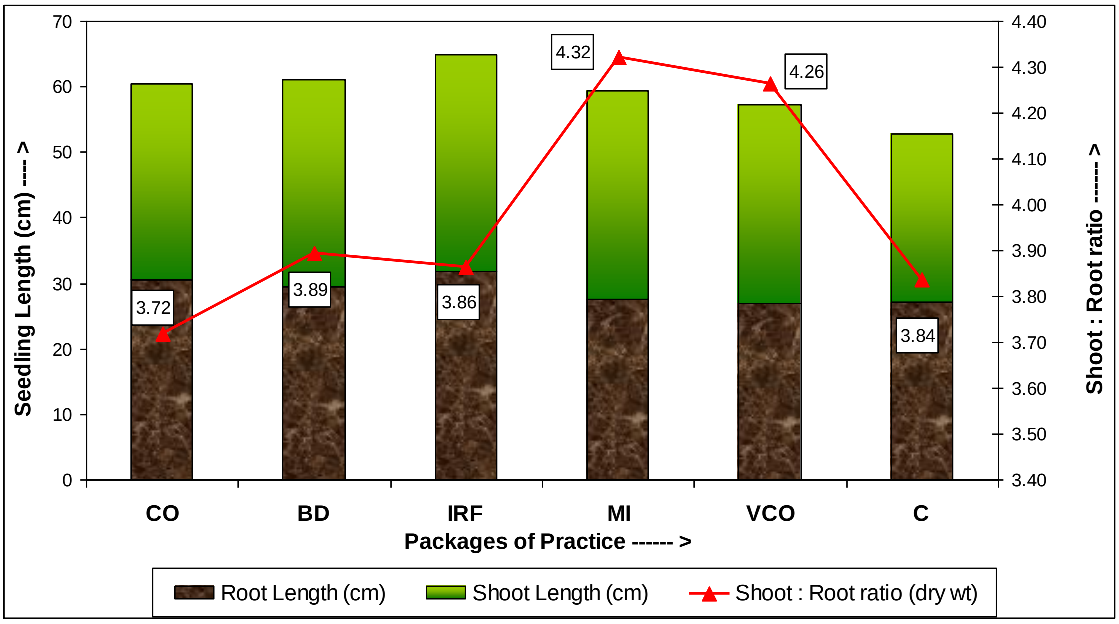


Fig. 55: Shoot & root length of 180 day seedlings.

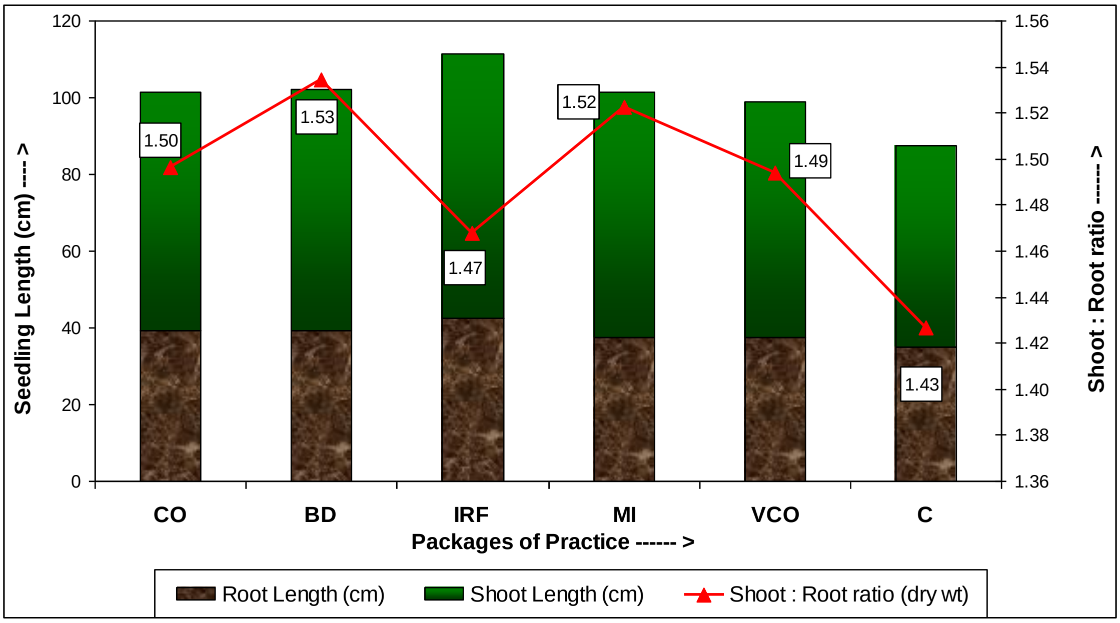


Fig. 56: Shoot & root length of 270 day seedlings.

Shoot/ Root ratio on dry weight basis is an indicator of the balance between transpirational area (shoot) and water absorbing area (root) of the seedlings. Shoot/ root ratio drastically increased with seedling age irrespective of the management undertaken (fig. 54, 55 and 56). A good quality seedling must have an appropriate shoot/ root ratio of 2:1 or less (Haase, 2007). Shoot/ root ratio of all the mature seedlings (270 days) were well within the standard reference range irrespective of the type of treatment.

Assessment of Seedling Growth Indices **:**

Several other agronomic and quality indices related to seedling growth were also studied and some of the important components *viz.* Specific leaf area (SLA), Leaf N content (LNC), Plant Strength and Dickson quality index are given in fig. 10A, 10B, 10C and 10D.

Specific Leaf Area (SLA) is an index of the 'leafiness of the leaf' i.e. a measure of density or relative thinness, which involves an assessment of the leaf's area in relation to its dry weight (Hunt, 1978; Hunt *et al*, 2002). Specific leaf area is strongly associated with the relative growth rate of the plant species (Wright and Westoby, 2000). Specific leaf area (cm^2/mg) was highest (fig. 57) in case of VCO and IRF (0.173 cm^2/mg) closely followed by CO and MI (0.171 cm^2/mg) packages. Specific leaf area increased with increase of leaf area (LA) and it should be considered as the consequence of shoot- N accumulation and not the reverse if we consider that shoot- N represents N availability for leaf expansion (Hirose *et al*., 1997).

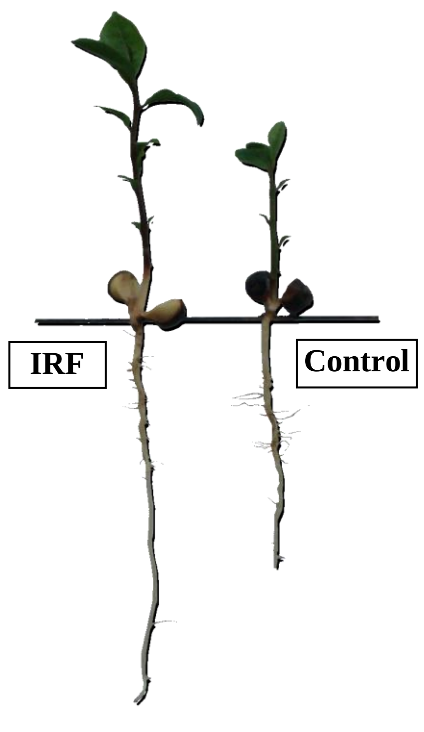
Plant N uptake, regardless of the source of N supply, is regulated by shoot N and C. Receipt of positive signal from photosynthesis C supply and a negative one from organic N that is re-circulating from shoot to root through the phloem (Forde, 2002), acts as a N satiety signal. Therefore, the proportionality between LA expansion and shoot N accumulation can be explained by the fact that LA expansion (i) increases the photosynthetic activity of the plant that provides larger quantities of C compounds to roots for supporting their N uptake activity and (ii) increases the capacity of plants to store organic N in leaves as in Rubisco (Millard, 1988). This last action is crucial to avoid the depletion of root N uptake capacity by re-circulating N compounds such as amino acids.

Table 24 : Age wise variation in agronomic parameters of tea seedlings under different organic 'Packages of Practice'.

Sl. No.	TS-463	90 days (Average of 5 samples)						180 days (Average of 5 samples)					
		CO	**BD**	**IRF**	**MI**	**VCO**	**C**	**CO**	**BD**	**IRF**	**MI**	**VCO**	**C**
1	Shoot Length (cm)	6.92	6.81	7.18	6.72	7.83	7.31	29.98	31.46	33.12	31.74	30.26	25.63
2	Root Length (cm)	13.29	13.21	13.57	12.97	13.78	13.52	30.57	29.57	31.81	27.61	26.93	27.17
3	Leaf (No.)	5.40	4.60	4.80	5.10	5.20	5.00	14.20	12.80	15.20	14.60	13.80	12.80
4	Girth (cm)	1.06	1.08	1.10	1.06	1.04	1.00	1.73	1.66	1.79	1.73	1.68	1.46
5	Branch (No.)	1.30	1.00	1.50	1.60	1.00	1.30	1.60	1.80	2.00	2.20	1.40	1.30
6	Shoot wt. (fresh) (g)	1.59	1.59	1.71	1.54	1.76	1.58	10.21	10.28	11.68	10.8	10.01	7.37
7	Leaf wt. (fresh) (g)	1.58	1.34	1.43	1.49	1.52	1.46	6.28	5.65	6.73	6.45	6.1	5.65
8	Root wt. (fresh) (g)	0.56	0.56	0.59	0.54	0.56	0.53	3.92	3.64	4.24	3.54	3.36	2.94
9	Total wt. (fresh) (g)	3.73	3.49	3.73	3.57	3.84	3.57	20.41	19.57	22.65	20.79	19.47	15.96
10	Leaf area (cm^2)	80.11	59.80	60.64	70.14	70.78	60.81	267.24	252.03	292.45	277.69	260.82	214.78
11	Shoot wt. (dry) (g)	0.48	0.49	0.52	0.47	0.54	0.48	2.91	2.92	3.34	3.07	2.84	2.09
12	Root wt. (dry) (g)	0.19	0.19	0.20	0.18	0.19	0.18	1.21	1.12	1.31	1.09	1.03	0.92
13	Leaf wt. (dry) (g)	0.43	0.37	0.39	0.41	0.41	0.40	1.59	1.44	1.72	1.64	1.55	1.44
14	Total wt. (dry) (g)	1.10	1.05	1.11	1.06	1.14	1.06	5.71	5.48	6.37	5.8	5.42	4.45
15	Shoot N (%)	1.84	1.93	1.89	1.93	1.86	1.91	1.74	1.7	1.67	1.69	1.63	1.64
16	Root N (%)	2.01	1.97	2.03	2.04	1.96	2.01	1.8	1.75	1.76	1.78	1.72	1.72
17	Leaf N (%)	3.36	3.44	3.41	3.39	3.35	3.38	3.12	3.08	3.14	3.08	3.16	3.01

Table 25: Agronomic parameters of tea seedlings (age: 270 days) under different organic 'Packages of Practice'.

Parameters	Different Organic Packages of Practice					
	CO	**BD**	**IRF**	**MI**	**VCO**	**C**
Shoot Length (cm)	62.18	63.14	68.76	63.71	61.39	52.38
Root Length (cm)	39.17	39.15	42.64	37.59	37.45	35.09
Leaf (No.)	27.40	28.10	30.30	26.40	23.70	19.10
Total Leaf area (cm^2)	623.62	633.09	698.11	599.81	544.39	420.96
Girth (cm)	2.00	1.98	2.18	2.11	1.89	1.62
Branch (No.)	2.10	2.20	2.40	2.40	1.70	1.50
Stem wt. (dry)(g)	4.53	4.56	5.47	4.91	4.23	3.11
Root wt. (dry)(g)	5.46	5.41	6.48	5.53	4.94	3.96
Shoot/ Root ratio	1.50	1.53	1.47	1.52	1.49	1.43
Leaf wt. (dry)(g)	3.64	3.74	4.04	3.51	3.15	2.54
Total wt. (dry)(g)	13.63	13.71	15.99	13.95	12.32	9.61



Pic. 49 : Development of shoot and root of tea seedlings (variety : TS-463) 60 days after germination.

Leaf N content expressed in mmol N/g or seedling nutrient status can affect seedling physiological factors which are related to out-planting survival, hence is a well known parameter for determining seedling quality (Landis 1985). The amount of nitrogen in the leaves is one of the primary plant properties that determine the rate of photosynthesis (Berendse and Aerts, 1987). Mooney *et al.* (1981) found a linear relationship between the rate of photosynthesis per unit of leaf area and the nitrogen concentration in the leaves of several plant species. Leaf nitrogen content (mmol N/g) was highest (fig 58) in case of IRF (4.52 mmol N/g) followed by BD (4.13 mmol N/g) and CO (3.97 mmol N/g) treated seedlings.

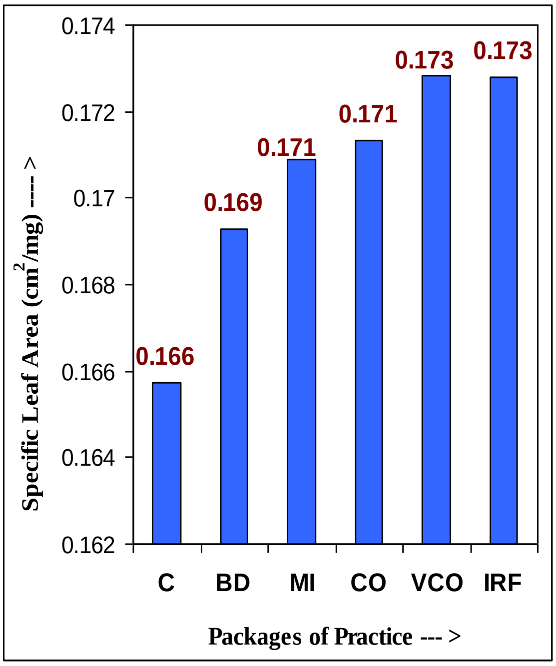


Fig. 57: Comparative study of Specific Leaf Area (SLA) of tea seedlings under different organic packages of practice.

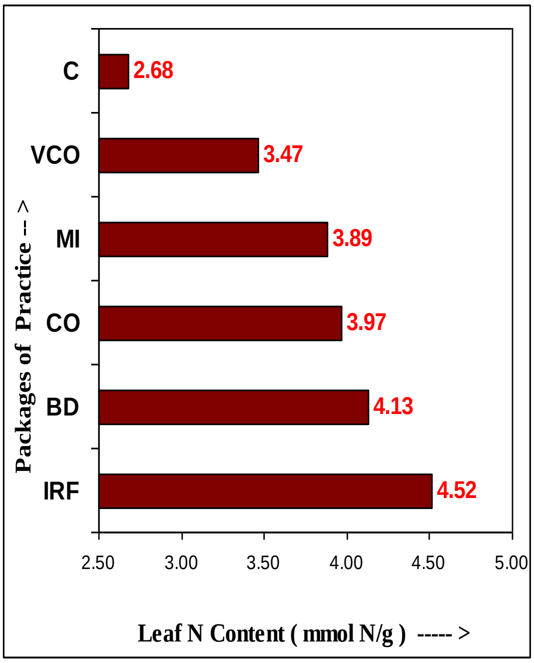


Fig. 58: Comparative study of Leaf- N Content in tea seedlings under different organic packages of practice.

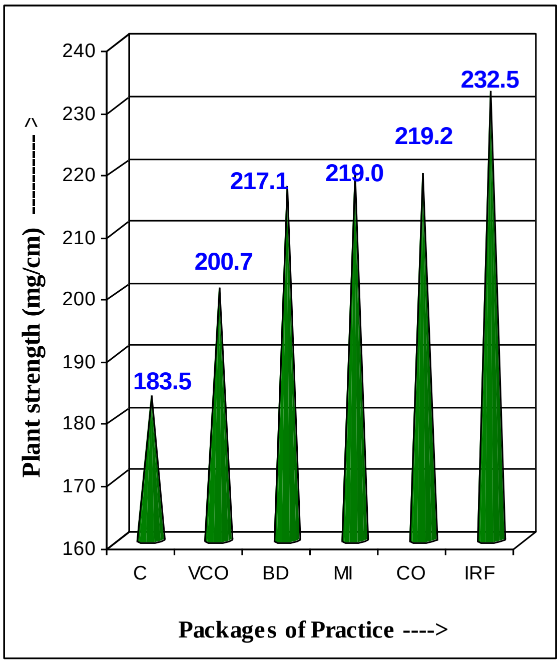


Fig. 59: Comparative study of Plant Strength under different organic packages of practice.

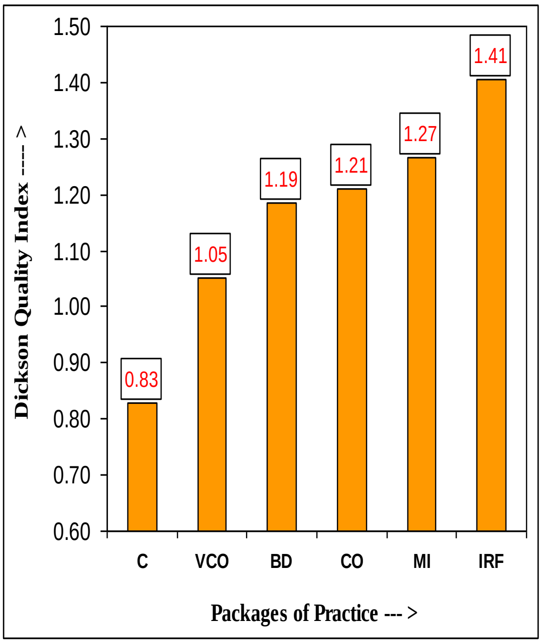
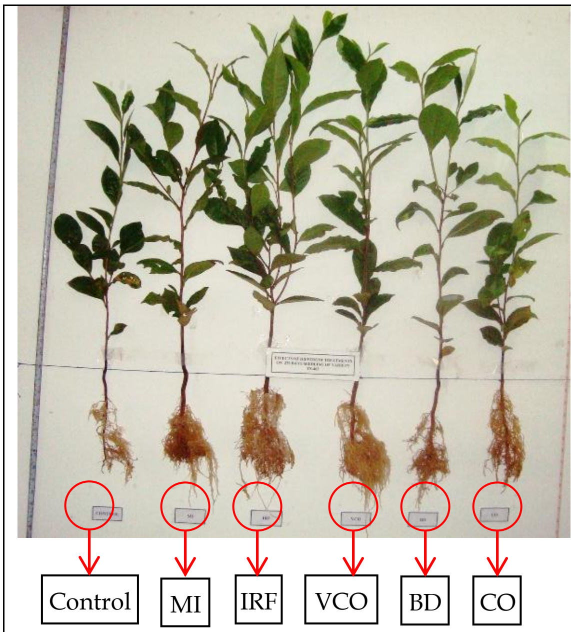


Fig. 60: Comparative study of Dickson Quality Index under different organic packages of practice.

Plant Strength described as dry matter per unit height of seedlings can also be used as an indicator of growth response (Ponmurugan and Baby, 2007). Plant strength was calculated on the basis of total dry weight and height of the plant following the methodology of Maskina *et al*. (1984). Plant strength was found to be distinctly higher (fig. 59) under IRF management (232.5 mg/cm) followed by CO (219.20 mg/cm), MI (219.0 mg/cm) and BD (217.1 mg/cm) packages.

Dickson quality index (Dickson *et al.*, 1960) was devised by evaluating how well a number of possible combinations of morphological parameters predicted seedling quality and thereby selecting the best combination. In a subsequent test, this index was able to predict quality based on nutrient environment (soil fertility) in which the seedlings were grown (Dickson *et al.*, 1960[b]). The index was successfully used by Roller (1976) to differentiate between plantable and non-plantable containerized seedlings. Several other workers *viz.* Roller (1976) and Ritchie (1984) used Dickson quality index to evaluate seedling quality due to its simplicity and high predictability with post transplantation performance. Dickson quality index was highest (1.41) in case of IRF treated seedlings followed by MI (1.27) and CO (1.21) packages (fig. 60). The results indicated that comparatively higher quality of tea seedlings with better survival chances and speedier post field transplanted growth can be obtained under Inhana Rational Farming (IRF) as compared to the rest other packages.

Pic. 50: Tea seedlings (TS-463) of 60 days under different organic packages.



Pic. 51 : Tea seedlings (TS-463) of 270 days under different organic packages.

Pic. 52: Tea seedlings under IRF nursery management package.

Pic. 53: Growth of Jalinga sectional seeds at Maud T.E.

Pic. 54 : Mature tea seedlings under different organic packages.

Evaluation of Different Organic 'Package of Practice' in New Tea Plantation under FAO-CFC-TBI Project (2009 to 2012)

Brief Summary

Potential of the different organic 'Packages of Practice' towards new tea plantation management was evaluated in terms of successful establishment of young tea seedlings and early growth potential or attaining the commercial plucking stage.

Eight different organic packages (with control) were selected for the experiment viz. Biodynamic Package of Practice (BD), Conventional Organic Practice with Indigenous compost @ 13.5 ton/ha (CO), Inhana Rational Farming Technology with 2.6 ton Novcom Compost (IRF-1) and with 8.0 ton Novcom Compost (IRF-2), Microbial Formulations i.e. Bio-fertilizer + Bio-pesticides + Bio-growth promoter (MI), Vermicompost @ 9.4 ton/ha + Conventional Organic Practice (VCO), Vermicompost @ 9.4 ton/ha + Microbial Formulations i.e. Bio-fertlizer + Bio-pesticides + Bio-growth promoter (VMI)

Agronomic parameters were measured under different growth phase of plantation i.e. just after de-centering, before initiation of tipping operation and six months after first frame formation (FFP).

*'PLANT DEVELOPMENT INDEX (PDI)' was formulated to quantify the enhancement in different agronomic parameters by a single value depicting overall plant development. Highest PDI was obtained under IRF-2 package. Strong correlation (r= 0.872**) between PDI and yield performance under the different packages indicated that PDI can be used as an effective tool for predicting crop response under different management practice.*

The newly planted tea saplings attained pluckable stage within a short period of 18 months under all the different packages, however; yield performance was found to be distinctly higher in case of IRF and VCO packages as compared to all others.

Evaluation of economics (in terms of VCR revealed highest benefit under IRF packages (VCR: 4.92 and 5.63 in case of IRF-2 and IRF-1 respectively) while the other packages failed to ensure economic sustainability in new plantation mainly due to high input cost without proportionate returns.

Evaluation of Different Organic 'Package of Practice' in New Tea Plantation under FAO-CFC-TBI Project (2009 to 2012)

Introduction:

New plantation forms the nucleus of any tea garden, which if managed effectively can give exponential returns over time. Moreover, future productive potential of any tea bush primarily depends on the care fostered on the newly planted saplings in order to ensure successful on- field survival and balanced growth, i.e. an activated physiology for efficient nutrition and effective host-defense mechanism. However, under chemical farming practice the new plants become fertilizer sensitive, prone towards pest and disease infestation and on the other hand often fail to survive when exposed to harsh chemical pesticides.

At the same time successful replanting programme in organic remains a hard attained objective. This is because the young plants generally suffer from insufficient nutrition due to depleted soil fertility along with slow acting and often poor quality organic manure. Physiological stress in the plants becomes widely apparent; thereafter they fail to recover in case of any pest/ disease attack more so because organic formulations are much weaker options. To ensure successful establishment of new plantation under organic management, a comprehensive protocol comprising of guideline for soil, plant and pest/ disease management, will be requisite. The following study at Maud tea estate (Assam), India under FAO-CFC-TBI Project (2009-2012); was taken up to evaluate different organic methods/ 'Packages of Practice' towards effective management of new tea plantation leading to their successful establishment and early growth potential.

Objective :

To reinstate the natural potential of future plantations, through sustained organic management from juvenile stage.

Methodology :

The selected section was planted with Guatemala and left for rejuvenation for a period of 18 months, post which soil samples were collected and analyzed for their fertility status. Planting pits were made at interval of 120 cm X 75 cm. Experiment was laid out using randomized block design with 8 treatments, replicated 3 times (Fig. 61). Treatment wise specific soil input i.e. vermicompost, FYM, Biodynamic compost, Novcom compost, Bio-fertilizer etc.

were applied in the respective planting pits followed by planting of healthy plants of 16 to 18 inches height. The plants were raised as per the guidelines under different packages of practice for new plantation management. Effectivity of the different packages was evaluated in terms of ensuring maximum survival rate, balanced growth, early growth potential, i.e. commercial plucking stage as well as soil rejuvenation.

Soil samples were collected from each treatment plot before initiation of experiment and 60, 90 and 150 days post application of soil inputs, for analyzing their physicochemical properties, fertility status and microbial potential.

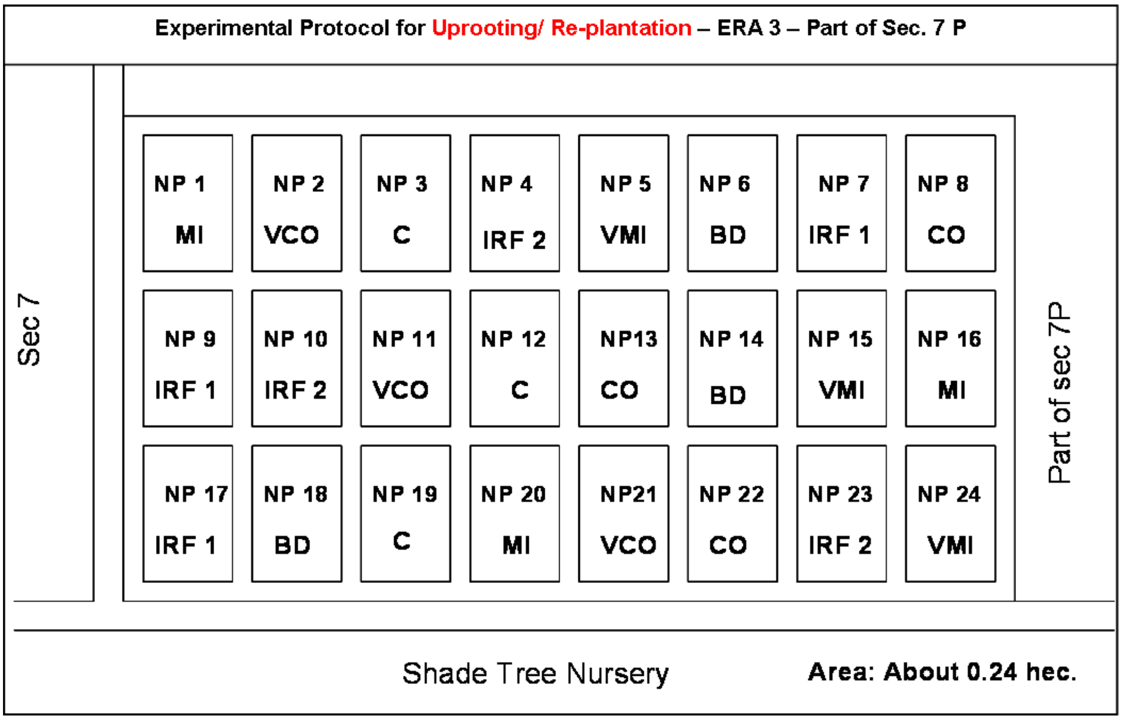


Fig. 61 : Layout of Experimental Research Area – 2 (ERA-3) for evaluation of different Organic Packages of Practice in Young Tea Plantation.

Treatment Details :

T_1 :	Control (C).
T_2 :	Vermi compost @ 9.4 ton/ ha + Herbal concoctions for pest and disease management (VCO).
T_3 :	Vermi compost @ 9.4 ton/ ha + Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK) + Bio-growth promoter + Bio-pesticides (VMI).
T_4 :	(Novcom compost @ 2.6 ton/ha + Elemental-S + Rock Phosphate) + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-1).
T_5 :	(Novcom compost @ 8.0 ton/ha + Elemental-S + Rock Phosphate) + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-2).
T_6 :	Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK) + Bio-growth promoter + Bio-pesticides (MI).
T_7 :	Biodynamic compost @ 10 ton/ ha + Cow Pat Pit + Cow horn manure + Biodynamic package for plant management (BD).
T_8 :	Indigenous compost/ Farm Yard Manure (FYM) @ 13.5 ton/ ha + Herbal concoctions for pest and disease management (CO).

Development of agronomic indices under different organic packages of practice in new tea plantation.

Different agronomic parameters *viz*. plant height, number of leaves, number of branches and plant girth were measured under different growth phase of the plantation, i.e. just after de-centering, before initiation of tipping operation and six months after first frame formation (FFP). After de-centering growth in terms of plant height (up to Ist tipping) was similar under all the different packages except control and MI. Number of leaves, which is directly related to the plant photosynthetic capacity or growth potential was higher in case of IRF packages (both IRF-2 and IRF-1) as compared to all others (table 26). Number of branches is important in terms of plucking table formation and number of plucking points which are closely related to the yield potential of plant. Number of branches after six months of FFP operation indicated the stage of frame formation and was highest in case of IRF-2 (62.0) closely followed by VCO (58.4) and IRF-1 (51.6). Plant girth indicating dry matter reserve *vis-a-vis* bush health and was distinctly higher in case of IRF-2 (9.79 cm) followed by VMI (9.11 cm), BD (9.09 cm) and VCO (9.06 cm).

Correlation coefficient among crop yield and different agronomic parameters under each treatment was also done and the results indicated that crop yield was highly and positively correlated with number of leaves (r = 0.778**) and number of productive branches (r = 0.912**).

Formulation of Plant Development Index (PDI)

Different agronomic parameters *viz.* plant height, girth, number of leaves etc., which indicate bush health also reflect the effect of management undertaken that ultimately influence the bush yield potential. However, to understand comparative plant development by a single value, plant development index was formulated utilizing easily measurable agronomic parameters.

Plant Development Index (PDI)

$$= \frac{1}{n}\left\{\sum_{n=1}^{n} \frac{100(X_1 - C_1)}{C_1} + \frac{100(X_2 - C_2)}{C_2} + \cdot \cdot \cdot \cdot + \frac{100(X_n - C_n)}{C_n}\right\}$$

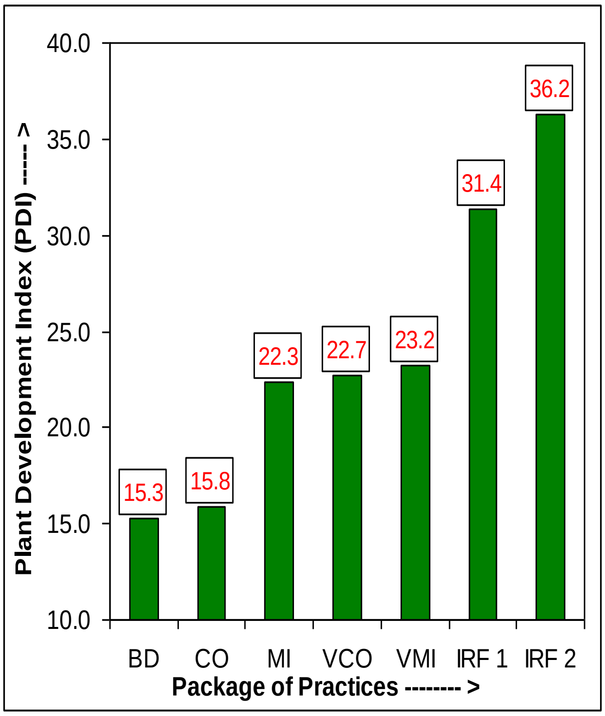
Where X = Agronomic Parameter; C = Control

In the present study four parameters *viz.* plant height, number of leaves, number of branches and plant girth were considered and cumulative impact of these parameters were measured through Plant Development Index (PDI).

Plant development index (PDI) under each growth stage was calculated and net change in PDI value between two growth phases were evaluated (fig. 62, fig. 63 and fig. 64). Net agronomic development in terms of PDI was highest in case of IRF-2, under all the growth phases, which clearly indicated its better effectivity towards optimum growth of tea seedlings post plantation as compared to the rest other organic packages. Relationship among crop performance and plant development index is shown in figure 65. Strong correlation was observed between PDI and yield performance under the top four best performing packages of practice i.e. IRF-2, IRF-1, VCO and CO. Correlation coefficient between crop yield and PDI indicated significant and positive correlation (r= 0.872**).

Table 26: Variation in agronomic indices under different growth stages of new tea plantation under different organic packages of practice.

Growth stage	Packages of Practice							
	C	IRF-2	IRF- 1	VCO	CO	BD	VMI	MI
Plant height (cm)								
During Plantation (30.10.2009)	63.34	63.22	63.05	63.25	63.31	63.63	63.24	63.51
After De-centering (13.5.2010)	32.61	29.72	32.69	30.64	32.94	29.53	30.94	32.80
Before 1st tipping (05.08.2010)	45.43	53.37	51.73	51.30	51.41	50.10	49.16	47.23
6 months after FFP (03.01.2012)	61.24	60.87	61.21	59.87	60.52	62.02	60.38	61.05
No. of leaves								
During Plantation (30.10.2009)	23.40	26.70	24.10	22.90	22.30	21.70	24.10	24.80
After De-centering (13.5.2010)	16.62	17.00	16.96	17.22	20.00	16.11	14.67	14.22
Before 1st tipping (05.08.2010)	38.84	70.22	67.22	59.33	63.44	55.44	50.67	46.89
6 months after FFP (03.01.2012)	285.65	390.33	376.56	307.89	318.00	324.11	313.67	269.33
No. of branches								
During Plantation (30.10.2009)	2.40	2.30	2.30	2.10	2.50	2.40	2.20	2.10
After De-centering (13.5.2010)	2.83	3.80	3.00	2.56	3.09	3.56	3.22	3.67
Before 1st tipping (05.08.2010)	6.00	13.33	10.00	10.22	10.56	8.68	8.56	7.67
6 months after FFP (03.01.2012)	38.90	62.00	51.60	58.40	51.60	49.60	43.00	44.20
Plant girth (cm)								
During Plantation (30.10.2009)	2.00	2.11	2.00	1.98	2.06	2.11	2.11	2.22
After De-centering (13.5.2010)	2.64	3.35	3.14	3.25	3.08	3.00	3.24	3.19
Before 1st tipping (05.08.2010)	3.38	4.26	3.86	4.03	3.82	3.81	4.10	3.89
6 months after FFP (03.01.2012)	8.36	9.79	8.56	9.06	8.67	9.09	9.11	8.56



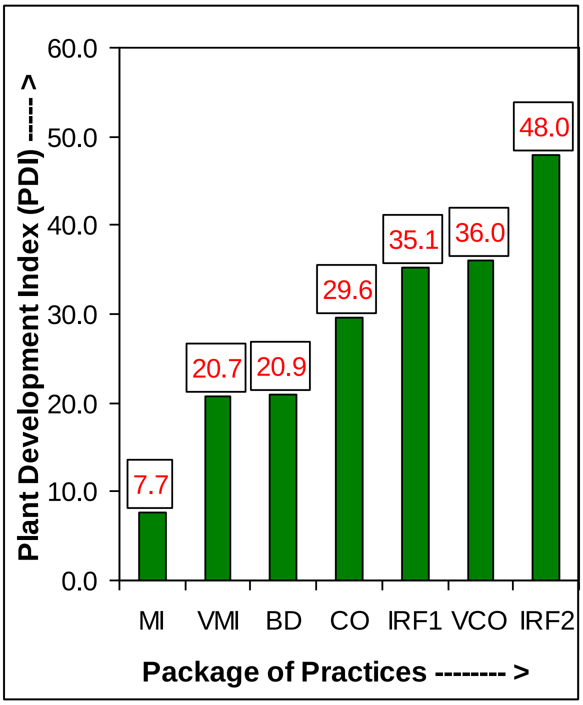
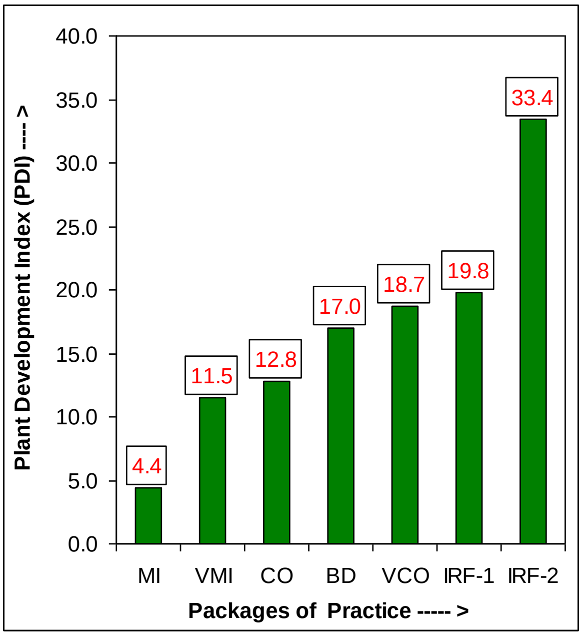


Fig. 62: Comparative Study of Management Impact on Net Agronomic Development of New Plantation (From plantation to 180 days – i.e. before de-centering)

Fig. 63: Comparative Study of Management Impact on Net Agronomic Development of New Plantation (After De-centering to 1st tipping)



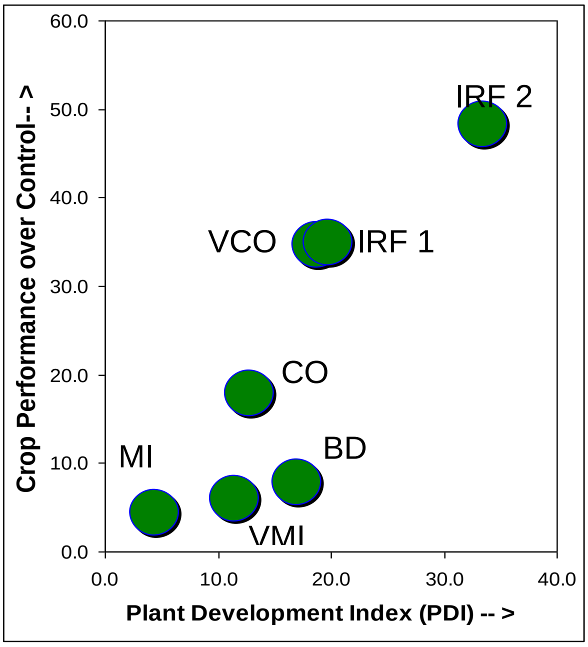


Fig. 64: Comparative Study of Management Impact on Agronomic Development of New Plantation (6 months after FFP).

Fig. 65: Comparative study of Agronomic Development *vis-a-vis* Crop Performance in New Plantation (After FFP, 25 rounds within 6 months)

Evaluation of different organic packages of practice in terms of crop performance and economics.

1st Production Year

Proper soil management along with effective plant management practice with focus towards activation of plant physiology is necessary for successful establishment of new plantation. However, due to lack of proper guidelines achieving success in this respect is still a Herculean task. In the present study newly planted tea saplings attained pluckable stage within a short period of 18 months under all the different packages. Green leaf per bush (fig. 66) varied from 320 gm to 216 gm. However, yield performance was found to be distinctly higher in case of IRF and VCO packages as compared to rest others (table 27).

Table 27: Ranking of different packages of practice in terms of crop efficiency & cost per hectare in new plantation (1st Production Year).

Rank	Packages of Practice	Crop Efficiency			Cost / ha	VCR[2]
		Yield (kg/ha)	% over control	RAE[1]		
1.	Inhana Rational Farming with 9 ton Novcom Compost (IRF- 2)	956	48.1	100.00	12,596	4.92
2.	Inhana Rational Farming with 3 ton Novcom Compost (IRF- 1)	870	34.7	72.26	7,952	5.63
3.	Vermi compost + Conventional Organic Practice (VCO)	868	34.4	71.61	39,759	1.12
4.	Indigenous compost + Conventional Organic Practice (CO)	760	17.7	36.77	13,825	1.65
5.	Biodynamic Package of Practice (BD)	695	7.7	15.81	14,270	0.69
6.	Vermicompost + Microbial Formul. for Both Soil & Plant (VMI)	684	5.8	12.26	64,919	0.12
7.	Microbial Formulation for both Soil and Plant Management (MI)	673	4.2	8.71	27,319	0.20

[1]RAE : Relative agronomic effectiveness, [2]VCR : value cost ratio

Note : *Quantity of soil inputs is same as given in case of mature tea plantation.*

Planted : *Oct. 2000,* ***De-centering :*** *May, 2010 (7 months),* ***Ist FFP :*** *March 2011 (16 months), Initiation of* ***Plucking :*** *May 2011 (at 18 months)* ***Duration :*** *6 months (25 rounds), Bush Population : 12,800/ha; VCR was calculated considering Made tea @ Rs. 200/ kg.*

Another significant finding is that although crop performance under IRF-2 was only about 13 percent higher

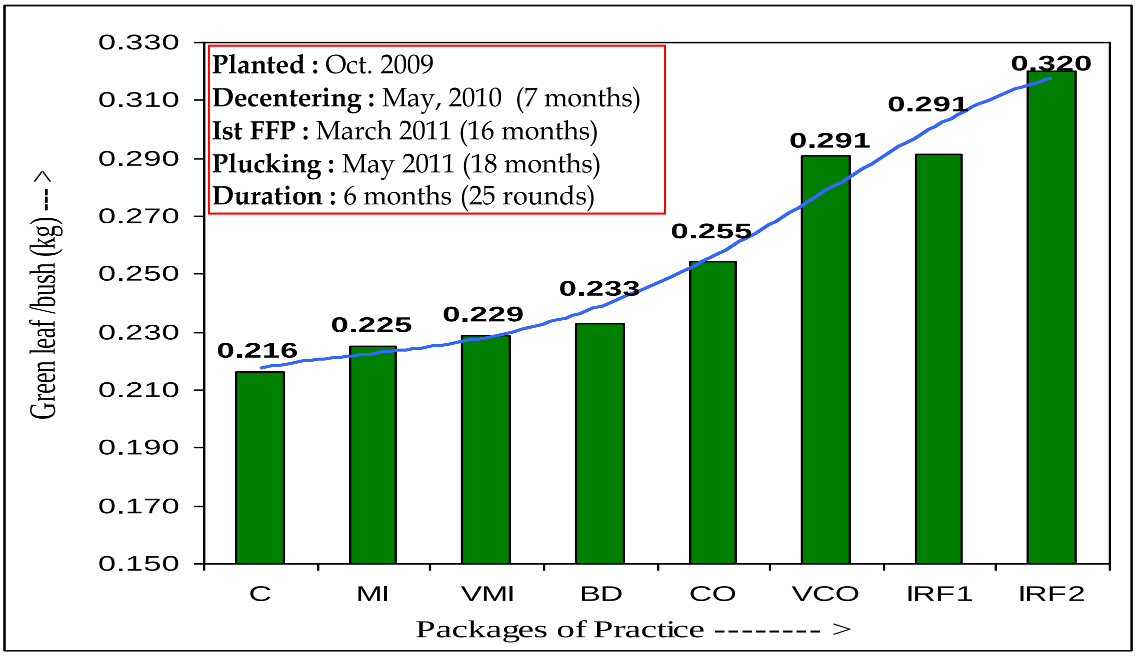


Fig. 66: Comparative Crop Performance under Different Organic Packages of Practice (**<u>1st Production Year</u>**) in New Plantation under FAO-CFC-TBI Project at Maud T.E.

than VCO, it was obtained at a comparatively lower cost (lower by 68 percent). Value cost ratio indicated highest economic sustainability under IRF packages. Also except IRF (VCR: 4.92 and 5.63 in case of IRF-2 and IRF-1 respectively), other packages of practice failed to ensure economic sustainability in new plantation mainly due to high input cost without proportionate returns.

2nd Production Year

The prime objectivity of new tea plantation is to achieve commercial plucking stage as early as possible. In conventional tea estates a minimum of 3 to 4 years is required to achieve the stage, which gets further prolonged in case of organic management. The newly planted areas grown under conventional organic practice in Maud T.E. (i.e. before undertaking the project), took not less than 5 years to attain the commercial plucking stage (i.e. crop yield equal or more than average yield of the garden).

In the 2nd production year made tea yield of new plantation varied from 1759 to 2240 kg/ha with highest yield under IRF-2 treatment of (table 28). Green leaf per bush was highest in case of IRF-2 (751 gm/bush) followed by VCO (718 gm/bush) ≈ IRF-1 (718 gm/bush) and CO (661 gm/bush) packages respectively (fig. 67). Crop response under different organic packages followed a similar trend as observed during the 1st production year, which further corroborates the respective potential of the different packages towards new plantation management. In terms of Value cost ratio (VCR), the IRF packages once again demonstrated similar performance as observed during 1st production year. However, during this year besides IRF; packages like VCO, CO and BD also ensured economic sustainability.

Table 28: Ranking of different packages of practice in terms of crop efficiency & cost per hectare in new plantation (2nd Production Year).

Rank	Packages of Practice	Crop Efficiency Yield (kg/ha)	Crop Efficiency % over control	RAE[1]	Cost/ ha	VCR[2]
1.	Inhana Rational Farming with 9 ton Novcom Compost (IRF- 2)	2240	31.61	100.00	12,196	8.82
2.	Inhana Rational Farming with 3 ton Novcom Compost (IRF- 1)	2140	25.73	81.41	7,552	11.60
3.	Vermi compost + Conventional Organic Practice (VCO)	2140	25.73	81.41	39,771	2.20
4.	Indigenous compost + Conventional Organic Practice (CO)	1971	15.80	50.00	9,948	5.41
5.	Biodynamic Package of Practice (BD)	1948	14.45	45.72	13,948	3.53
6.	Vermicompost + Microbial Formul. for Both Soil & Plant (VMI)	1848	8.58	27.14	63,663	0.46
7.	Microbial Formulation for both Soil and Plant Management (MI)	1759	3.35	10.59	26,063	0.44

[1]RAE : Relative agronomic effectiveness, [2]VCR : value cost ratio

Note : *Initiation of 2nd year* ***Plucking :*** *24th March 2012,* ***Duration :*** *7 months (24 rounds), Bush Population : 12,800/ha ; Bushes were given rest from November, 2012 for final FFP operation; VCR was calculated considering Made tea @ Rs. 200/ kg.*

At the same time economic returns under VMI and MI packages were once again low due to their comparatively poor crop performance and relatively high cost of cultivation.

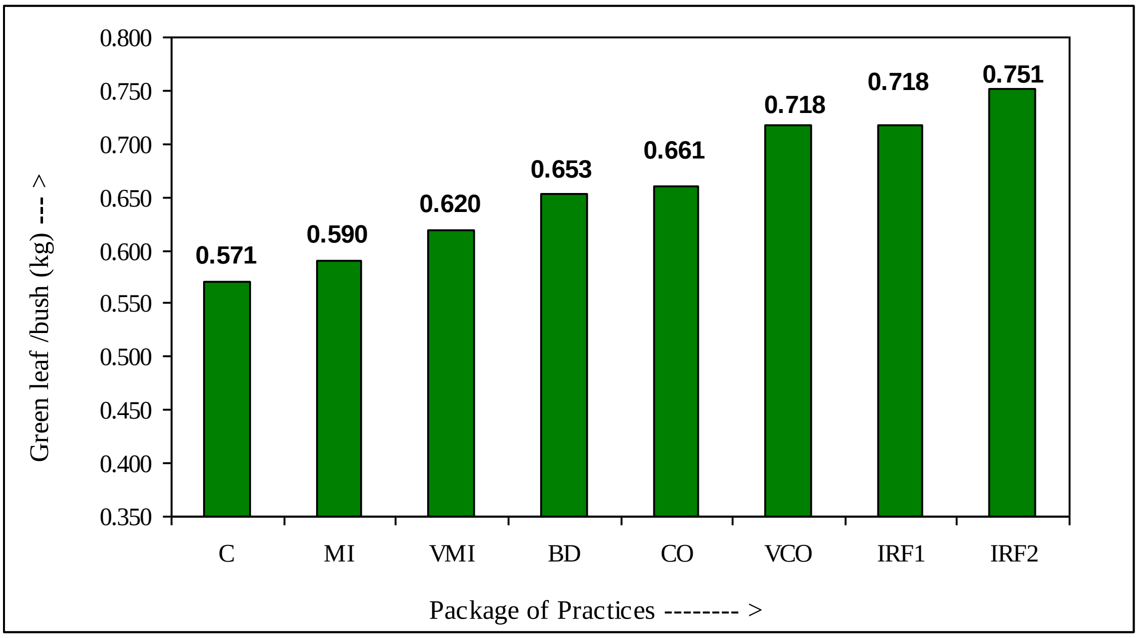


Fig. 67: Comparative Crop Performance under Different Organic Packages of Practice (**<u>2nd Production Year</u>**) in New Plantation under FAO-CFC-TBI Project at Maud T.E.

In the 2nd production year, average yield from new plantation experiment (irrespective of the type of treatment), crossed the average production mark of 1382 kg/ha of Maud T.E. as obtained during 2007 to 2011 (fig 68).

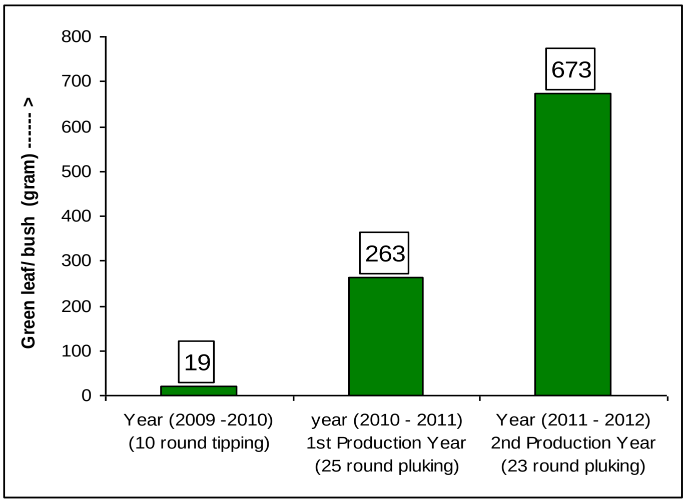


Fig. 68: Crop growth potential under organic management.

The findings clearly indicated that new plantation can be more successfully raised under organic management as compared to conventional chemical practices, provided good quality planting material is selected along with proper spacing as well as timely and effective management of soil, weeds and pest/ diseases.

Pic. 55: Plantation of tea seedlings under new plantation experiment at Maud T.E., Assam

Pic. 56: Mulching after planting of tea seedlings.

Pic. 57: Spraying in different treatment plots under new plantation experiment at Maud T.E., Assam

Pic. 58: Sprinkler irrigation in New Plantation experiment at Maud T.E., Assam.

Pic. 59: De-centering operation in new tea plantation experiment at Maud T.E., Assam.

Pic. 60: De-centered new tea plants at Maud T.E., Assam.

Variation in soil quality under different organic packages of practice (2009 to 2011) in New Tea Plantation.

Soil physical properties :

Soil physical properties *viz.* particle size distribution, textural class, bulk density, particle density, percent pore space, maximum water holding capacity, water in air dry soil and volume expansion were analyzed for all the soil samples (Table 29). The results indicated sandy clay loam soil texture in all the experimental plots where sand, silt and clay varied from 47.78 to 55.23, 15.29 to 22.39 and 28.60 to 32.90 percent respectively. Bulk density of the soils varied from 1.16 to 1.30 gcm^{-3} where as particle density, maximum water holding capacity and percent pore space varied from 2.02 to 2.31 $g\ cm^{-3}$, 40.02 to 46.62 percent and 39.19 to 46.17 percent respectively.

Variation in electrochemical properties of soils :

Variation in electrochemical properties of soils in terms of pH, electrical conductivity and cation exchange capacity were studied before initiation of experiment and after 3 years i.e. post completion of experiment (Table 30). Tea plant being acid loving thrives well at an optimum pH of 4.5–5.5. In this respect soil of all the experimental plots were found to be strongly to moderately acidic in reaction with 4.42 to 4.67 pH value. After application of compost for three consecutive years, pH showed an increasing trend in most of the experimental plots but did not change significantly. Through their cation exchange capacity, organic acids and base functional groups the different types of compost provided much of the pH buffering capacity of soil. This might be the reason behind no major fluctuation in soil pH in the different treatment plots. This is of special significance considering that in chemical gardens pH correction is required frequently due to increase in soil acidity with continuous application of chemical fertilizers. Electrical conductivity (EC) of soil (except in salt effected problematic soil), as reflected by the nutrient status in soil solution showed increased value post application of the different types of organic soil inputs. The findings might also indicate steady mineralization of nutrients from the different input sources.

Table 29 : Physical characteristics of soil in the different plots before initiation of experiment.

Treatment	Depth (cm)	Particle size distribution (%)			Texture	Bulk density	Particle density	% pore space	Max WHC (%)	Water in air dry soil (%)	Volume expansion (%)
		Sand	Silt	Clay		< --- gcm^{-3}	------ >				
T_1 : C	0- 25	50.67	20.29	29.03	scl*	1.19	2.09	40.16	45.18	2.85	9.16
	25- 50	47.78	22.39	29.83	scl	1.20	2.12	43.19	43.22	2.69	9.08
T_2 : VCO	0- 25	55.23	16.17	28.60	scl	1.16	2.04	39.19	44.32	2.81	9.08
	25- 50	54.60	15.33	30.07	scl	1.15	2.03	40.78	41.76	2.70	9.05
T_3 : VMI	0- 25	52.02	15.34	32.63	scl	1.21	2.18	42.16	46.22	3.16	10.17
	25- 50	53.47	15.36	31.17	scl	1.20	2.13	40.29	43.18	3.02	9.32
T_4 : IRF-1	0- 25	52.65	15.29	32.07	scl	1.17	2.07	41.22	43.18	2.92	9.87
	25- 50	52.11	17.09	30.80	scl	1.15	2.06	40.32	40.19	2.89	9.38
T_5 : IRF-2	0- 25	52.33	19.07	28.60	scl	1.15	2.11	40.76	42.22	2.98	9.92
	25- 50	52.31	18.86	28.83	scl	1.16	2.06	39.18	40.02	2.79	9.51
T_6 : MI	0- 25	50.98	17.56	31.47	scl	1.17	2.18	41.62	43.18	2.87	9.91
	25- 50	50.98	17.69	31.33	scl	1.18	2.02	40.16	40.06	2.72	9.62
T_7 : BD	0- 25	48.63	21.07	31.63	scl	1.29	2.29	45.22	45.67	3.19	10.62
	25- 50	51.51	15.59	32.90	scl	1.18	2.15	40.16	41.22	2.82	9.38
T_8 : CO	0- 25	49.86	20.71	29.43	scl	1.30	2.31	46.17	46.62	3.22	10.60
	25- 50	50.79	18.84	30.37	scl	1.22	2.19	41.22	40.98	2.87	9.52
CD (P = 0.5)		***NS***	***NS***	***NS***	**-**	***0.11***	***0.12***	***3.09***	***2.60***	***0.35***	***0.84***

*scl : sandy clay loam

Table 30 : Variation in soil physicochemical and fertility parameters post application of different packages of practice.

Treatments	Before Initiation of Experiment							After completion of experiment (3 years)						
	pH (H_2O)	EC (dSm^{-1})	Org. C (%)	Av. N	Av. P_2O_5	Av. K_2O	Av. SO_4^{2-}	pH (H_2O)	EC (dSm^{-1})	Org. C (%)	Av. N	Av. P_2O_5	Av. K_2O	Av. SO_4^{2-}
				< ---------------- $kgha^{-1}$ --------------- >							< ---------------- $kgha^{-1}$ ------------- >			
T_1 : C	4.58	0.031	0.96	398.27	30.24	162.62	40.10	4.63	0.026	0.93	351.23	56.60	152.30	32.69
T_2 : VCO	4.51	0.030	0.94	371.62	43.04	182.95	46.39	4.52	0.032	1.17	418.92	66.40	196.50	51.44
T_3 : VMI	4.42	0.034	0.76	391.27	24.62	155.85	42.57	4.56	0.036	1.05	424.76	68.79	182.96	53.90
T_4 : IRF-1	4.52	0.037	0.98	404.55	38.19	182.95	36.81	4.59	0.040	1.11	451.27	60.43	194.11	51.57
T_5 : IRF-2	4.55	0.026	0.90	409.25	19.87	182.96	36.81	4.67	0.036	1.24	487.67	62.04	202.95	50.14
T_6 : MI	4.63	0.026	0.86	384.16	37.08	169.40	26.24	4.60	0.024	1.10	402.67	49.21	159.64	30.14
T_7 : BD	4.48	0.033	0.94	412.38	32.01	176.18	26.12	4.47	0.035	1.02	443.39	39.87	184.20	36.37
T_8 : CO	4.67	0.025	0.78	407.68	20.31	176.18	30.36	4.56	0.028	1.03	464.74	46.95	206.18	42.60
CD (P = 0.5)	***0.12***	***NS***	***0.15***	***24.09***	***11.43***	***NS***	***10.85***	***0.16***	***0.008***	***0.12***	***34.63***	***9.79***	***18.35***	***11.91***

Variation in soil fertility :

Variation in soil fertility parameters *viz.* organic carbon, available- N, available- P_2O_5, available- K_2O and available- SO_4^{2-} were studied before initiation and post completion of experiment (Table 30) after three years. Presently retention of soil organic matter is a matter of serious concern and thereby the prime criteria behind prioritization of organic soil management. The benefits of increasing soil organic matter include carbon sequestration and an increase in the capacity of the soil to store water and nutrients. The organic carbon content in the experimental plots ranged from 0.76 to 0.98 percent and was found to increase post application of organic soil inputs under different treatments. Post three years of experimentation 8.51 to 38.55 percent increase in soil organic carbon was observed under different treatments, where the increase was found to be significant under IRF-2 and VCO packages as compared to BD (Fig. 69).

Nitrogen, an important nutrient for vegetative propagation in tea plantation was of medium status in the different experimental plots, varying from 371.6 to 412.4 $kgha^{-1}$. Available- N content in soil increased only minimally (4.8 to 19.2 percent) post application of different organic soil inputs for a period of three years. However, the degree of increase in available- N was found to be significant in case of IRF-2, CO, IRF-1 and BD treated plots as compared to plots receiving microbial formulations i.e. MI package.

Available phosphate in the treatment plots were of low status (according to the range suggested by Bhattacharya, 1998) varying from 19.87 and 43.04 $kgha^{-1}$. After three consecutive years of experiment, available phosphate status increased substantially in the different treatment plots (except control), which might indicate positive influence of organic soil inputs towards higher availability of phosphate in acid tea soils. The available $H_2PO_4^{2-}$ ions get attracted to positive charges that develop under acid conditions on the surfaces of Fe and Al oxides. This adsorbed $H_2PO_4^{2-}$ anion form outer sphere complexes with Fe and Al oxides but are subjected to anion exchange with certain anions such as OH^-, SO_4^{2-} or organic acids ($R\text{-}COO^-$). Thus availability of such adsorbed $H_2PO_4^{2-}$ may be increased by increasing the amount of organic acids capable of replacing $H_2PO_4^{2-}$ through addition of organic matter/ compost in soil, thereby increasing the phosphate availability for plants.

Table 31: Variation in soil microbial population post application of different packages of practice.

Treatments	Before Initiation of Experiment			After completion of experiment (3 years)		
	Total Bacterial Count	Total Fungal Count	Total Actinomycetes count	Total Bacterial Count	Total Fungal Count	Total Actinomycetes count
	< - - - - - - - - - - - - c.f.u per gm moist soil (log_{10} value) - - - - - - - - - - - - - - - >					
Control Plots						
T_1 : C	6.736	5.797	5.635	6.889	5.817	5.851
T_2 : VCO	6.706	5.911	5.627	8.230	6.410	5.837
T_3 : VMI	6.673	5.966	5.681	7.949	6.706	5.861
T_4 : IRF-1	6.939	6.096	5.754	8.269	6.922	6.074
T_5 : IRF-2	6.837	6.006	5.791	8.365	7.042	6.089
T_6 : MI	6.605	5.954	5.649	8.303	6.245	5.686
T_7 : BD	6.621	6.094	5.760	8.037	6.698	5.863
T_8 : CO	6.723	5.918	5.724	7.542	6.738	5.921
CD (P = 0.5)	***0.283***	***0.294***	***NS***	***0.1253***	***0.248***	***0.476***

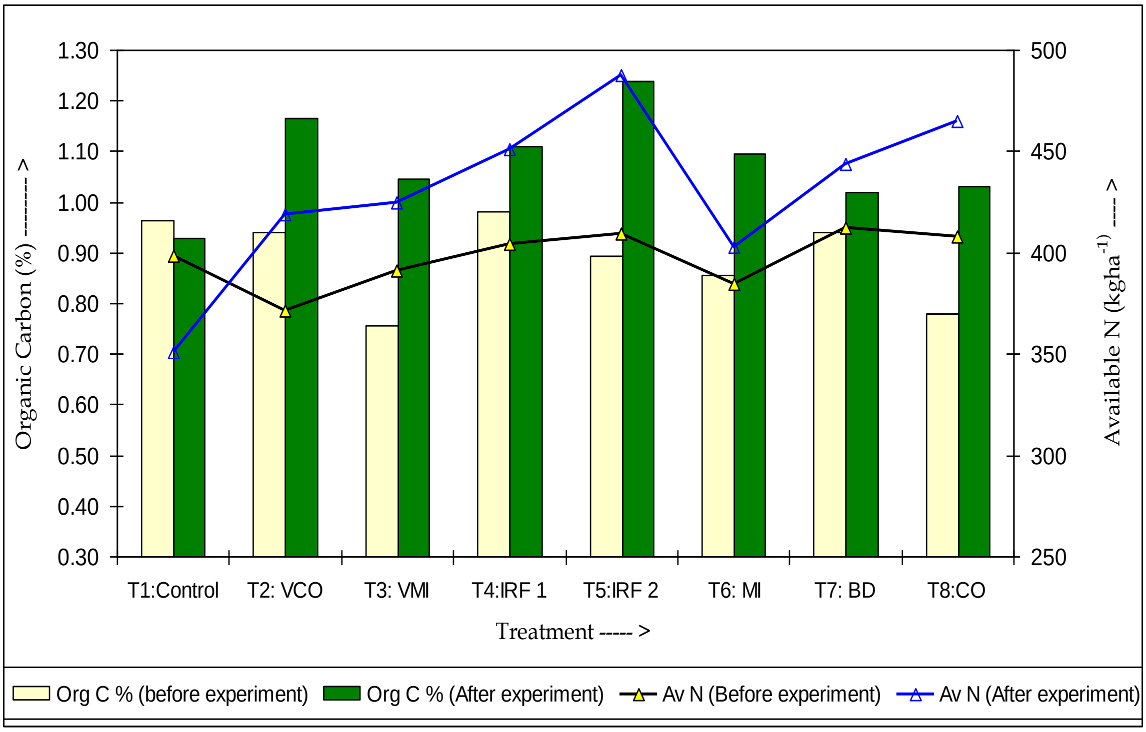


Fig. 69 : Variation in soil organic carbon and available- N status before and post three years of experimentation in New Tea Plantation at Maud T.E., Assam under FAO-CFC-TBI Project.

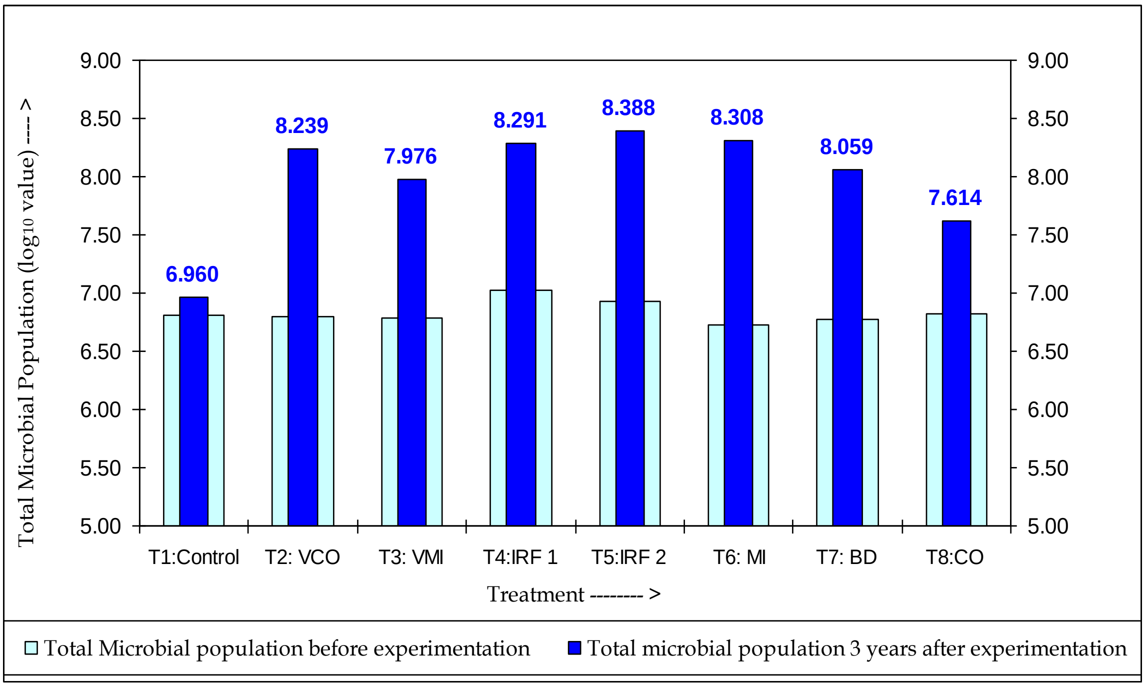


Fig. 70: Variation is soil microbial population before and post three years of experimentation in New Tea Plantation at Maud T.E., Assam under FAO-CFC-TBI Project.

Potassium, which makes up 1.5-2.0 percent of dry matter in tea leaves (Verma, 1997, 1993; Wu Xun *et al*., 1997), also has special relevance towards frame formation in young plants. In new plantation experiment, available potash varied from 155.8 to 182.9 kgha^{-1} in the different treatment plots. Post application of different organic packages of practice potash status in soil increased slightly by 4.5 to 17.4 percent. However, significant difference in treatment effect was observed considering that packages like CO and IRF-2 influenced higher development of potash status in soil as compared to other packages like MI and VMI. Similar upliftment of potash status under organic soil management was also documented by Vasanthi and Kumaraswamy (2000) and Gill (1995).

Available sulphate varied from 26.12 to 46.39 kgha^{-1} in the different treatment plots, before initiation of experiment. Application of different organic packages of practice for a period of three years was found to have positive influence on available- SO_4 status in acid tea soils as indicated by 10.9 to 67.9 percent increase in its value in the different treatment plots.

Variation in soil microbiological status

Microbial activity is probably the most important factor that controls nutrient re-cycling in soil. The phenomenon is of special relevance in young tea plantation where a balanced supply of nutrients is requisite for successful on-field survival and healthy growth of the young plants in order to ensure greater resistance against pest/ diseases and an early productive stage. In general, soil microbial population (total bacteria, fungi and actinomycetes) was found to increase post application of different packages, where highest increase was observed in case of IRF-2 plots as compared to others (Table 31, Fig. 70). The higher proliferation of microbes under IRF might be due to application of Novcom compost, which was found to contain huge population of microbes generated naturally during the composting process.

Variation in soil fertility index

Soil fertility index was developed considering the status of available NPKS and their respective requirement in tea plantation (Annexure III). After 3 years of organic soil management , soil fertility index was found to be highest in IRF- 2 treatment plots (177.71) followed by plots receiving CO (167.79), IRF-1 (167.39) and VCO (162.17) packages (Fig. 71).

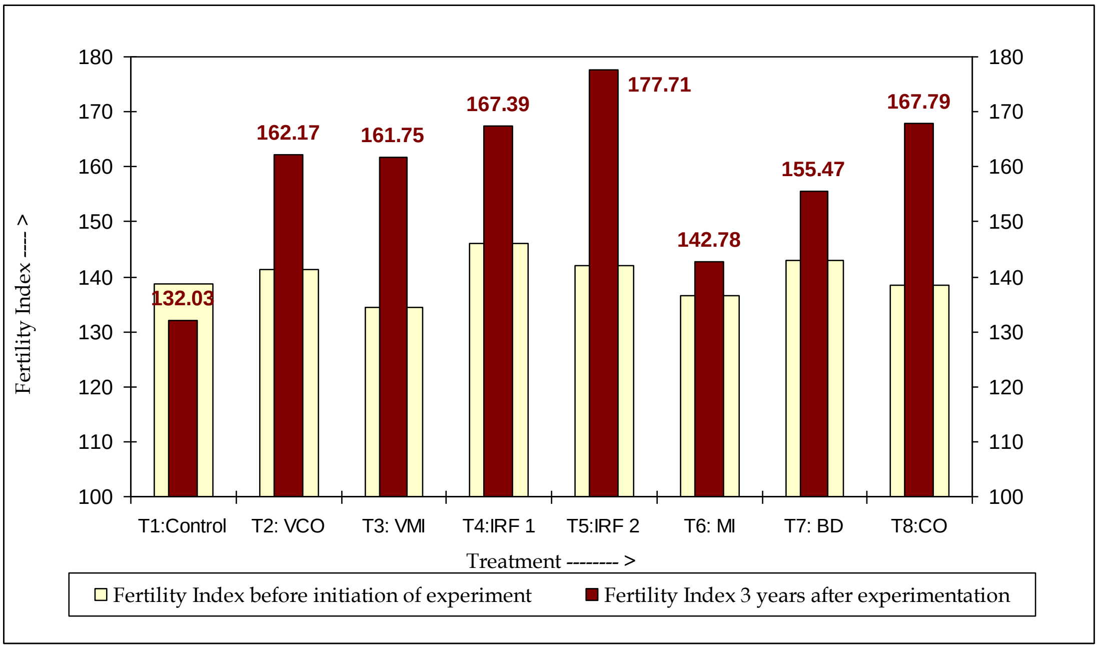


Fig. 71: Fertility index (FI) before and post three years of experimentation at Maud T.E., Assam under FAO-CFC-TBI Project.

Pic. 61: View of plot receiving IRF-1 treatment under New Plantation Experiment at Maud T.E., Assam under FAO-CFC-TBI Project.

Soil Development Index (SDI) and its relationship with crop performance.

Soil development index was utilized to assess the overall variation in soil quality under different packages of practice in new tea plantation. Nine soil quality parameters *viz.* pH, EC, organic carbon, available- N, available- P_2O_5, available- K_2O, total bacteria, fungi and actinomycetes; were used as per the following formula to calculate SDI under different treatments.

$$\text{Soil Development Index (SDI)} = \frac{a}{n^2}\left\{\sum_{n=1}^{n} \frac{100(X_1 - C_1)}{C_1} + \frac{100(X_2 - C_2)}{C_2} + \cdots + \frac{100(X_n - C_n)}{C_n}\right\}$$

Where X = Soil Quality parameters after Experimentation; C = Value of individual Soil Quality Parameter before Experimentation ; a = no of Soil Quality Parameters showing increased over initial value.

SDI was highest in case of plots receiving IRF-2 (SDI: 40.37) followed VMI (SDI: 31.48), CO (SDI : 27.45), IRF-1 (SDI: 17.58) and VCO (SDI: 15.28) packages (Fig. 72). SDI under Inhana Rational Farming was comparatively higher than the next best performing package indicating its effective role towards organic soil management leading to speedy soil rejuvenation. The finding was also corroborated by the highest crop performance obtained under this package in new tea plantation.

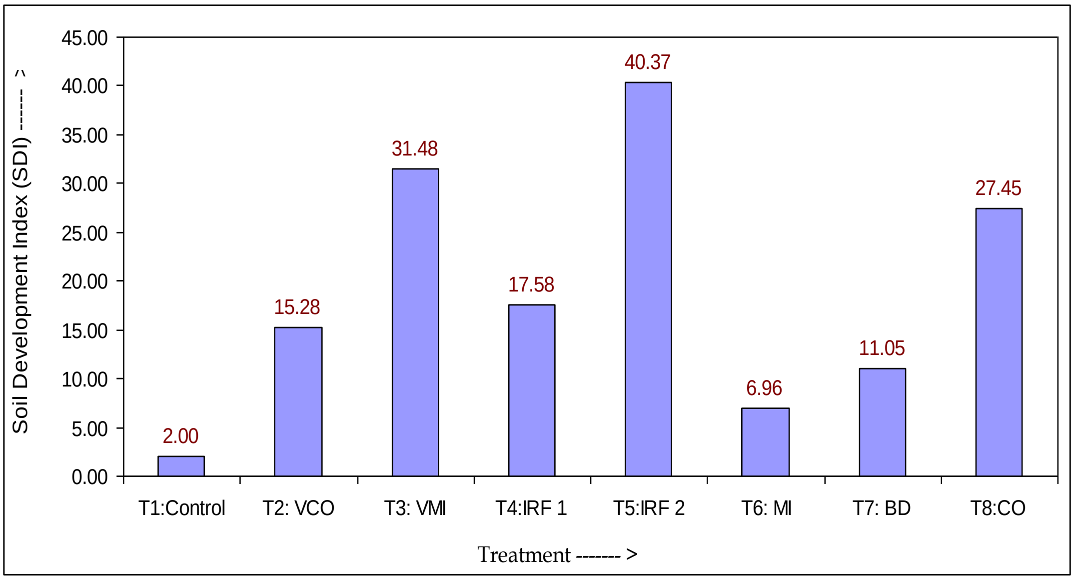


Fig. 72: Soil Development Index (SDI) under different Organic Packages of Practice in New Tea Plantation experiment at Maud T.E., Assam under FAO-CFC-TBI Project.

Table 32 : Relationship among different soil physicochemical, fertility and biological parameters.

Correlation coefficient	pH	EC	Organic carbon	Av. N	Av. Phosphate	Av. Potash	Av. Sulphate	Total bacteria	Total fungi
Electrical conductivity	-0.182								
Organic carbon	0.203	0.397*							
Available- N	-0.028	0.573**	0.627**						
Available Phosphate	0.286	0.367	0.407*	-0.046					
Available Potash	-0.132	0.579**	0.561**	0.865**	0.149				
Available Sulphate	-0.012	0.758**	0.542**	0.523**	0.724**	0.705**			
Total bacteria	-0.116	0.472**	0.816**	0.596**	0.168	0.437*	0.415*		
Total fungi	-0.056	0.754**	0.584**	0.948**	0.089	0.826**	0.653**	0.632**	
Total Actinomycetes	0.263	0.607**	0.336	0.544**	0.199	0.564**	0.500*	0.149	0.596**

** Significant at 1% level; * Significant at 5 % level

Pic. 62: View of bush development under IRF-2 & VCO packages and ring application of compost before mulching operation, in New Plantation Experiment.

Pic. 63: Tea Board & TRA officials, Personnel of Inhana Biosciences & Project Fellow visiting the site of New Plantation experiment.

Pic. 64: Broadcasting of compost in New Plantation experiment.

Pic. 65: Project fellow recording agronomic parameters of bushes (treatment wise) under New Plantation experiment.

Relationship among different Soil Quality Parameters

Relationship among the different soil quality parameters are given in table 32. Soil organic carbon was positively and significantly correlated with available-N (r = 0.627**), available- phosphate (r = 0.407*), available potash (r = 0.561**), available- sulphate (r = 0.542**), total bacteria (r = 0.816**) and total fungi (r = 0.584**). Soil organic carbon is the storehouse of all nutrients and also serves as the food reserve for microflora population. Hence, the close correlation of organic carbon with available nutrient status and soil microbial population is quite expected. Also significantly positive correlation obtained between soil microbial population and available nutrient status indicated the role of former towards nutrient mineralization in soil.

Table 33 : Correlation coefficient between Yield and Soil Quality Parameters.

	Parameter	Correlation coefficient
Crop Yield Vs	pH (H_2O)	0.176 NS
	Electrical Conductivity	0.500*
	Organic carbon	0.740**
	Available Nitrogen	0.581**
	Available Phosphate	0.344 NS
	Available Potash	0.585**
	Available Sulphate	0.525**
	Total Bacteria	0.473*
	Total Fungi	0.533**
	Total Actinomycetes	0.510**

** Significant at 1% level; * Significant at 5 % level; NS : Not Significant

Interrelation between crop yield and soil quality parameters.

Evaluation of the correlation between soil quality and crop response revealed positive and significant interrelationship between the two (Table 33). Positive and significant correlation of crop yield was obtained with soil electrical conductivity (0.500*), organic carbon (0.740**), available- N (0.581**), available- K_2O (0.585**), available- SO_4 (0.525**), total bacteria (0.473*), total fungi (0.533**) and total actinomycetes (0.510**). The study indicated that positive crop response could be obtained through improvement of these quality parameters, which can be achieved through regular application of good quality compost.

Evaluation of Different Organic 'Packages of Practice' in Young Tea Plantation under FAO-CFC-TBI Project (2009 to 2011)

Brief Summary

To find out an effective pathway for achieving healthy and productive young tea seven different organic packages of practices (with control) were evaluated for their potential in terms of crop efficiency as well as soil quality rejuvenation. The packages of practice or treatments were same as taken for New Plantation experiment.

Crop yield followed similar trend as observed in case of New Plantation experiment and recorded highest value under IRF-2 (made tea: 807 kgha^{-1}) package. Yield under IRF-2 was 55.2 percent higher than control and about 25.6 percent higher than the next best performing package of practice i.e. VMI (653 kgha^{-1}). The third highest yield was obtained under IRF-1 and VCO, which recorded almost similar crop (made tea: 619 & 618 kgha^{-1} resp.) followed by BD (593 kgha^{-1}), Co (567 kgha^{-1}) and MI (556 kgha^{-1}) packages.

Value cost ratio (VCR), which is excess revenue generated per unit rupee invested; followed similar trend as observed in case of New Plantation experiment indicating highest economic sustainability under IRF-2 (4.37) followed by IRF-1 (2.33) package. Value cost ratio in case of other organic packages varied between 0.25 and 1.02, indicating economic vulnerability considering that VCR < 2.00 has been indicated by Agricultural economists as the critical mark below which there is no necessary risk coverage against investment towards input cost.

Evaluation of the variation in soil quality under different packages of practice in terms of Soil Development Index (SDI) indicated highest value in case of plots receiving IRF-2 (SDI: 227.84) followed IRF-1 (SDI: 112.34), VMI (SDI : 87.35), BD (SDI: 61.92) and VCO (SDI: 20.46) packages.

Evaluation of Different Organic 'Packages of Practice' in Young Tea Plantation under FAO-CFC-TBI Project (2009 to 2011)

Introduction

Young tea area often plays a contributory role towards sustenance/ increment of crop productivity of any garden. Hence, to ensure high yielding garden, effective management of young tea is crucial in order to enable conditions for the plants to attain optimum yield potential. At the same time when limitations of chemical practices are widely apparent, switching over to organic management system from the early stage shall not only serve to curtail the associated negativities but also enlist the plants to a favourable environment to encourage vigorous growth as well as to increase their longevity.

However, effective rearing of young tea under organic management still forms a major challenge due to chemical fertilizer sensitive clonal plants, the present improper soil dynamics as well as recurring pest/disease problems, which pose a wide array of limitations that are much difficult to address under organic system. The following study at Maud tea estate (Assam), India under FAO-CFC-TBI Project (2008-2011); was taken up to evaluate different organic methods/ 'Packages of Practice' towards yield performance of young tea as well as soil quality rejuvenation.

Objective

To bring forth the most effective organic method/ 'Packages of Practice' that can ensure healthy and productive young tea.

Methodology

In Young tea experiment (plantation age 3 to 6 years) field trial was laid out selecting the same organic methods/ 'Packages of Practice' as treatments; that were evaluated for effectivity under new plantation experiment. Experiment was laid out as per randomized block design (RBD) with eight treatments and three replications (Fig. 73). Effectivity of the different packages was evaluated in terms of yield achieved over control, year wise yield progression towards meeting the target and finally economic viability.

Soil samples were collected from each treatment plot before initiation of experiment and 60, 90 and 150 days post application of soil inputs, for analyzing their physicochemical properties, fertility status and microbial potential.

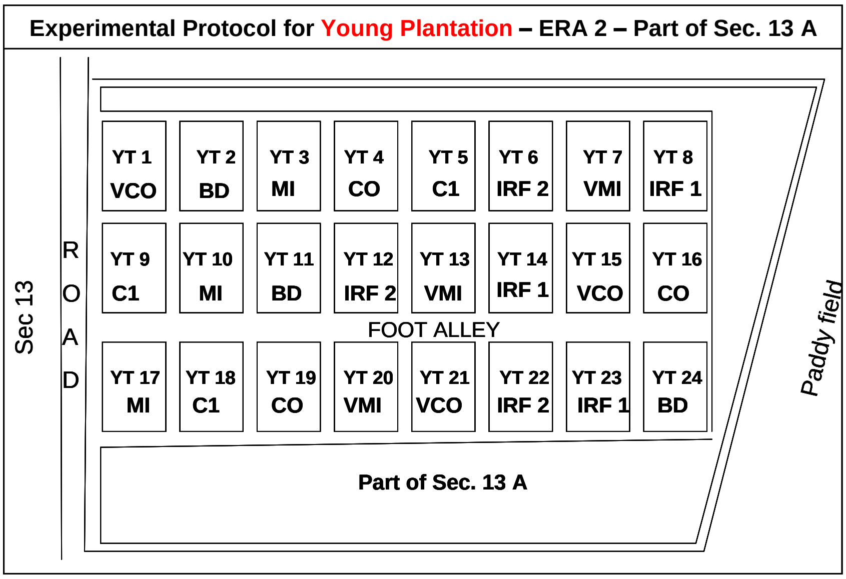


Fig. 73 : Lay out of Experimental Research Area – 2 (ERA-2) for evaluation of different Organic Packages of Practice in Young Tea.

Treatment Details :

T_1	:	Control
T_2	:	Vermi compost @ 9.4 ton/ ha + Herbal concoctions for pest and disease management.
T_3	:	Vermi compost @ 9.4 ton/ ha + Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK) + Bio-growth promoter + Bio-pesticides.
T_4	:	Novcom compost @ 2.6 ton/ha + Elemental-S + Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management.
T_5	:	Novcom compost @ 8.0 ton/ha + Elemental-S + Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management.
T_6	:	Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK) + Bio-growth promoter + Bio-pesticides.
T_7	:	Biodynamic compost @ 10 ton/ ha + Cow Pat Pit + Cow horn manure + Biodynamic package for plant management.
T_8	:	Indigenous compost/ Farm Yard Manure (FYM) @ 13.5 ton/ ha + Herbal concoctions for pest and disease management.

Evaluation of the effectivity of Different Organic 'Packages of Practice' (POP) in terms of Yield Performance and Agronomic Efficiency of Young Tea.

Comparative evaluation of the effectivity of different POP in terms of crop yield (fig. 74) revealed most promising results under IRF-2 (made tea: 807 $kgha^{-1}$), which was 55.2 percent higher than control and about 25.6 percent higher than the next best performing package i.e. VMI (made tea: 653 $kgha^{-1}$). The difference in crop performance among IRF and other treatments is clearly understood by the value of relative agronomic effectiveness (RAE), which were less than 50 in case of other packages of practice (table 34). Cost incurred per ha followed the same trend as new plantation experiment, being lowest in case of IRF-1 (Rs. 8,485/ ha) followed by CO (Rs. 12,792/ ha), IRF-2 (Rs. 13,129/ ha) and BD (Rs. 14,377/ ha). Value cost ratio (VCR) which takes into account both crop performance and cost incurred showed highest economic sustainability under IRF-2 (4.37) followed by IRF-1 (2.33). Value cost ratio in case of other organic packages varied between 0.25 and 1.02 and were significantly lower than IRF packages.

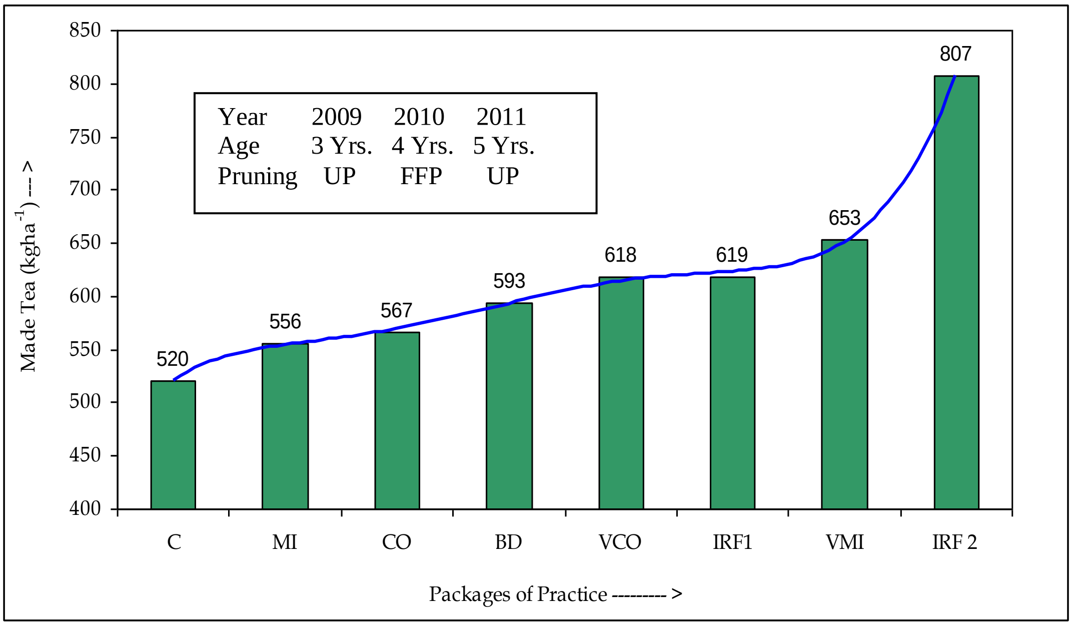


Fig. 74: Average Crop Performance (2009 - 2011) under Different Organic Packages of Practice in Young Tea under FAO-CFC-TBI Project at Maud T.E, Assam.

Table 34: Ranking of different packages of practice in terms of crop efficiency and cost per hectare in young tea.

Rank	Packages of Practice	Crop Efficiency			Cost/ ha (Rs.)	VCR[2]
		Yield (kg/ha)	% over control	RAE[1]		
1.	Inhana Rational Farming with 9 ton Novcom Compost (IRF-2)	807	55.2	100.00	13,129/-	4.37
2.	Vermi compost + Microbial Formulation for Both Soil & Plant Management (VMI)	653	25.6	46.34	66,257/-	0.40
3.	Inhana Rational Farming with 3 ton Novcom Compost (IRF-1)	619	19.0	34.49	8,485/-	2.33
4.	Vermi compost + Conventional Organic Practice (VCO)	618	18.8	34.15	40,023/-	0.49
5.	Biodynamic Package of Practice (BD)	593	14.1	25.44	14,377/-	1.02
6.	Indigenous compost + Conventional Organic Practice (CO)	567	9.0	16.38	12,792/-	0.73
7.	Microbial Formulation for both Soil and Plant Management (MI)	556	6.9	12.54	28,657/-	0.25

[1]RAE : Relative agronomic effectiveness, [2]VCR : value cost ratio

Note : *Quantity of soil inputs under different POP were calculated on plant– N requirement basis i.e. for giving 60kg N, except for the soil inputs which had fixed recommended dosage like BF, BD and FYM-2. Actual dosage was calculated based on N and moisture percent in the soil input. Novcom compost was applied in combination with 40 kg Elemental-S & 80 kg Rock phosphate per hectare. In case of soil mgt. using Biodynamic compost, CPP @ 12.5 kg/ ha and Cow horn manure (15 ltr. soln/ ha) was also used. Pruning: UP - FFP - UP; Bush Population: 7065/ha; Age: 3 - 5 years; VCR was calculated considering Made tea @ Rs. 200/ kg.*

Table 35: Impact of different packages of practice on crop performance of young tea (3+ to 6+ years) under different pruning.

Treatment	**Unpruned (2009)**			**First Frame Formation (2010)**			**Unpruned (2011)**		
	Yield (kgha^{-1})	% over control	RAE[1]	Yield (kgha^{-1})	% over control	RAE	Yield (kgha^{-1})	% over control	RAE
T1 : C	1062	0.00	0.00	1619	0.00	0.00	4013	0.00	0.00
T2 : VCO	1568	47.62	73.15	2121	47.28	50.29	4260	6.15	12.36
T3 : VMI	1608	51.32	78.84	1880	24.57	26.13	4918	22.54	45.29
T4 : IRF-1	1493	40.53	62.26	1948	30.99	32.96	4521	12.65	25.41
T5 : IRF-2	1754	65.13	100.00	2618	94.02	100.00	6011	49.78	100.00
T6 : MI	1186	11.68	17.94	1838	20.65	21.96	4127	2.82	5.67
T7 : BD	1387	30.58	46.98	1914	27.80	29.57	4334	7.99	16.04
T8 : CO	1310	23.29	35.78	1681	5.78	6.15	4301	7.18	14.42
CD (P = 0.5)	***450.48***	*-*	*-*	***NS***	*-*	*-*	***520.83***	*-*	*-*

[1]RAE : Relative Agronomic Effectiveness

Green leaf yield of young tea under different packages of practice was documented from 2009 to 2011 (3 years) under different pruning operations (table 35). Crop load was found to increase under different packages with progress of time. In the 1st year highest yield was obtained in case of IRF-2 (1754 $kgha^{-1}$) followed by VMI (1608 $kgha^{-1}$) and VCO (1568 $kgha^{-1}$) packages. In the second and third year also IRF-2 showed highest crop performance, however; while VCO scored over VMI in 2010, the trend was once again reversed in 2011. Three years assessment of yield under different packages and under different pruning operations revealed most consistence performance under IRF-2 followed by VMI package.

Relative agronomic effectiveness (RAE), which measures the comparative effect of management practice; was also calculated for different POP with respect to IRF-2 (since highest yield was obtained under this package, hence; RAE under IRF-2 is considered as 100). As compared to IRF-2, wide variation in RAE was noted for different POP with progress of time. While in the 1st year only three packages *viz.* VMI, VCO and IRF-1 scored above 50, during 2nd year only VCO barely scored the 50 mark, while in the 3rd year none of these three packages performed even closely. MI and CO packages performed poorly during all the three years while BD although scoring close to the 50 mark in 2009; failed to perform similarly during the next two years. The results once again substantiated the consistent and best crop performance under IRF-2.

Agronomic efficiency of plants under different packages of practice (AE_{POP}) is a useful measure of management effect as it provides an index that quantifies total economic output relative to the utilization of system resources. It was calculated as the excess green leaf divided by the cost of package, and expressed in $gmRs.^{-1}$. In 2009, highest AE_{POP} was observed under IRF-2 (53.28 $gmRs.^{-1}$) closely followed by IRF-1 (51.60 $gmRs.^{-1}$). Evaluation of the AE_{POP} value obtained for the different packages of practice in 2010 and 2011 also indicated higher and consistent performance of IRF packages as compared to others (table 36). Agronomic efficiency can be increased by increasing plant physiological efficiency along with activation of soil-plant-nutrient dynamics. Hence, the results obtained in IRF-2 plots might be due to improvement in soil dynamics due to enhanced microbial proliferation and activity post application of Novcom compost containing huge population of self- generated microbes.

Table 36: Agronomic efficiency and related cost for young tea (3+ to 6+ years) development under different packages of practice and different pruning operations.

Treatment	Unpruned (2009)			First frame formation (2010)			Unpruned (2011)		
	AE_{POP}[1] (gmRs.$^{-1}$)	Cost (Rs.ha^{-1})	VCR[2]	AE_{POP} (gmRs.$^{-1}$)	Cost (Rs.ha^{-1})	VCR	AE_{POP} (gmRs.$^{-1}$)	Cost (Rs.ha^{-1})	VCR
T1 : C	-	-	-	-	-	-	-	-	-
T2 : VCO	12.61	40154	0.58	12.64	39760	0.59	6.16	40154	0.28
T3 : VMI	8.29	65838	0.38	3.89	67094	0.18	13.75	65838	0.64
T4 : IRF-1	51.60	8352	2.37	37.64	8752	1.76	60.82	8352	2.83
T5 : IRF-2	53.28	12996	2.46	74.58	13396	3.49	153.76	12996	7.17
T6 : MI	4.41	28238	0.21	7.44	29494	0.35	4.02	28238	0.18
T7 : BD	22.80	14270	1.05	20.25	14592	0.95	22.49	14270	1.05
T8 : CO	13.69	18108	0.63	6.20	9937	0.30	27.92	10331	1.30

[1] AE_{POP} : Agronomic efficiency under different Packages of Practice is expressed in gram/Rs. ; [2]VCR : Value Cost Ratio

Pic. 66 : Different treatment plots under young tea experiment, FAO-CFC-TBI Project- at Maud T.E.; Assam.

Pic. 67 : View of young tea plantation selected for experiment under FAO-CFC-TBI Project at Maud T.E., Assam.

Evaluation of the effectivity of Different Organic 'Packages of Practice' (POP) in terms of Economics.

Value cost ratio is (VCR) used as an important tool to assess economic sustainability of any management system. Value cost ratio was distinctly higher in case of IRF packages during all the three years irrespective of the type of pruning operation. Other packages of practice *viz.* VCO and VMI which registered 2nd best crop performance, scored very low (less than 1.00) VCR, which depicted economic vulnerability if at all adopted mainly due to high cost of vermi compost. Economically sustainable organic farming will be possible only through adoption of the package of practice, which can influence significant crop response but at a relatively lower cost.

Evaluation of young tea Performance under 'Package of Practice' Experiment *vis-à-vis* under General Garden Practice i.e. Sec. 13A of Maud T.E.

Crop performance under top four packages of practice in the experimental area of Sec. 13A of Maud T.E. was compared with the yield obtained from balance

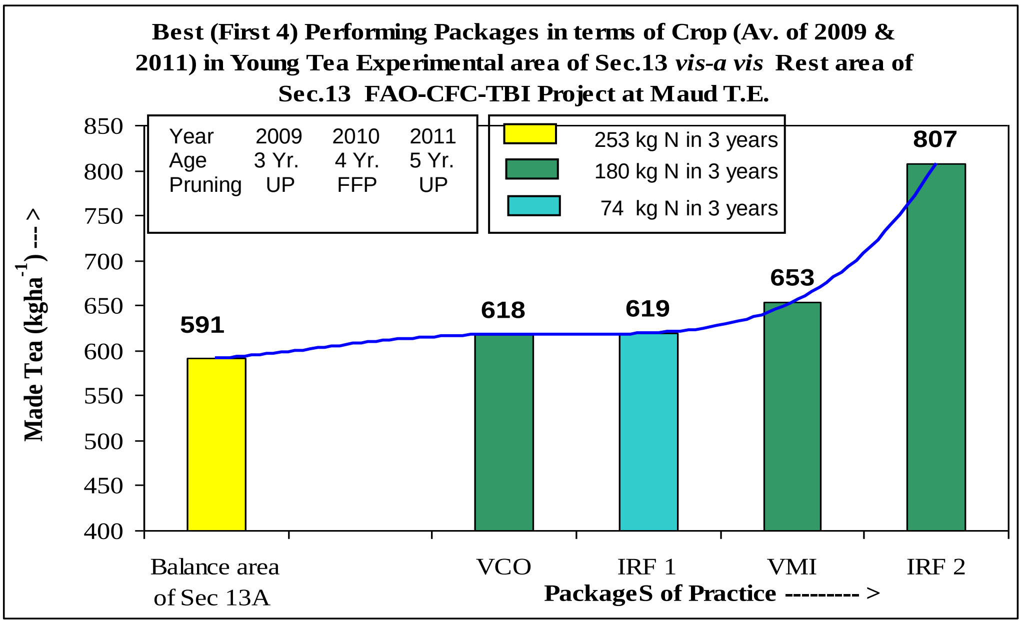


Fig. 75: Variation in crop performance under top 4 packages in experimental area of Sec. 13A (under application of different on-farm compost) *vis-a-vis* in balance area of Sec. 13A (applied with outsourced manure and oil cake), under FAO-CFC-TBI Project at Maud T.E.; Assam.

portion of the same section (fig. 75). Interestingly, even when total 253 kg N was given (using outsourced manure and oil cake) in the balance portion of the section as compared to only 180 kg under different treatments (i.e. IRF-2, VMI and VCO) in the experimental area, crop yield in balance area (591 kg/ha) was only 13% higher than that obtained under control plot (520 kg/ha) in the experimental area. Moreover, despite getting 29% lower amount of N, yield in IRF-2 and VMI plots (in the experimental area); were 36 and 10 percent higher the crop obtained from the rest section.

The finding once again conclusively established better crop and cost efficiency under application of on-farm produced good quality compost (as done under IRF-2) as compared to off- farm bulky/ concentrated organic manure, which was applied in the balance area of section 13A.

Variation in Soil Quality under Different Organic Packages of Practice (2009 to 2011) in Young Tea Plantation.

Variation in soil physical properties

Soil physical properties *viz.* particle size distribution, textural class, bulk density, particle density, percent pore space, maximum water holding capacity, water in air dry soil and volume expansion were analyzed and is represented in Table 37. The textural class is important because size of the soil particles determines whether the soil is light, medium or heavy and their suitability for plant growth and proliferation of roots (Barua and Dutta, 1961). The results indicated that soil texture of all the experimental plots was sandy clay loam where sand, silt and clay varied from 43.98 to 55.97, 13.86 to 24.44 and 27.68 to 35.22 percent respectively. Bulk density of the soils varied from 1.18 to 1.26 g cm^{-3} where as particle density, maximum water holding capacity and percent pore space varied from 2.21 to 2.32 g cm^{-3}, 42.12 to 43.84 percent and 43.16 to 47.36 percent respectively following the same trend as bulk density.

Variation in electrochemical properties of soils

Variation in electrochemical properties of soils in terms of pH, electrical conductivity and cation exchange capacity was studied before initiation of experiment and after 3 years i.e. post completion of experiment (Table 38). Tea is calcifuge that is it does not tolerate alkaline (basic) soil. Therefore the most important criteria for tea is soil acidity. The upper pH range in which tea will thrive is 6.0–6.5, optimum pH being 4.5–5.5. Soil of all the experimental plots were strongly to moderately acidic in reaction pH varying from 4.54 to 4.66. After application of compost for three consecutive years, pH of the soil samples did not change significantly, however; an increasing trend was observed in most of the cases. Though only slight increase (from 0.29 to 5.0 percent) in pH value was observed post compost application in the different plots, but it is of special relevance for tea plantation; where corrective management is required frequently due to increase in soil acidity under regular application of chemical fertilizers. Electrical conductivity (EC) reflected the soluble nutrient status in soil solution. The values were found to increase in general post compost application, which might indicate efficient nutrient mineralization from compost source.

Cation exchange capacity (CEC) of the soil samples were of low to medium range (according to the range suggested by Ilaco, 1985) varying between 9.69 and 12.18 cmol $(p^{+})kg^{-1}$. Increase in CEC value was noticed with compost application, where the percent increase was highest (20.85%) in IRF-2 plots closely followed by plots receiving CO (15.06 %) package. Increasing trend of CEC value in the different experimental plots (as compared to control) indicated the upliftment of soil fertility post compost application. Similar results were obtained by McConnell *et al.*, (1994), who observed increase in CEC in most mineral soils due to compost application and thereby reduced leaching of fertilizer nutrients.

Table 37 : Physical characteristics of soil in the different treatment plots.

Treatment	Depth (cm)	Particle size distribution (%)			Texture	Bulk density	Particle density	% pore space	Max WHC (%)	Water in air dry soil (%)	Volume expansion (%)
		Sand	Silt	Clay		< --- gcm^{-3}------ >					
T_1 : C	0- 25	50.19	16.12	33.69	scl	1.24	2.25	44.81	42.27	5.09	9.65
	25- 50	52.61	16.94	30.45	scl	1.22	2.21	45.03	43.07	4.95	10.96
T_2 : VCO	0- 25	50.02	17.40	32.58	scl	1.25	2.26	44.16	42.62	4.99	10.37
	25- 50	53.85	17.28	28.87	scl	1.23	2.24	45.88	42.62	4.98	10.26
T_3 : VMI	0- 25	45.14	22.39	32.47	scl	1.25	2.32	45.18	43.72	4.97	10.96
	25- 50	52.30	18.09	29.61	scl	1.23	2.28	47.14	43.68	5.08	10.62
T_4 : IRF-1	0- 25	46.14	20.67	33.19	scl	1.22	2.24	45.23	42.16	4.87	10.02
	25- 50	46.37	18.41	35.22	sc	1.26	2.30	45.75	44.16	4.96	11.05
T_5 : IRF-2	0- 25	49.92	18.30	31.78	scl	1.20	2.22	45.52	42.92	4.71	10.42
	25- 50	48.46	17.55	33.99	scl	1.22	2.26	46.30	43.84	5.11	10.80
T_6 : MI	0- 25	43.98	24.44	31.58	cl	1.21	2.23	43.16	42.12	4.81	9.98
	25- 50	48.54	19.96	31.50	scl	1.21	2.21	47.36	43.52	5.01	11.09
T_7 : BD	0- 25	51.47	16.06	32.47	scl	1.22	2.26	47.22	43.16	5.13	10.92
	25- 50	53.17	19.15	27.68	scl	1.18	2.24	45.82	44.92	5.02	10.81
T_8 : CO	0- 25	51.98	13.86	34.16	scl	1.23	2.21	45.67	43.29	5.11	10.57
	25- 50	55.97	15.68	28.35	scl	1.19	2.29	46.91	44.97	4.98	10.60
***CD** (P = 0.5)*		***NS***	***6.80*** ***NS***	***NS***	**-**	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

Table 38: Variation of electrochemical properties of soil post application of different packages of practice.

Treatments	Before Initiation of Experiment			After completion of experiment (3 years)		
	pH (H_2O)	EC (dSm^{-1})	CEC cmol(p+)kg^{-1}	pH (H_2O)	EC (dSm^{-1})	CEC cmol(p+)kg^{-1}
T_1 : C	4.61	0.025	11.39	4.62	0.024	10.56
T_2 : VCO	4.56	0.040	11.55	4.55	0.024	11.91
T_3 : VMI	4.54	0.025	11.35	4.84	0.029	12.05
T_4 : IRF 1	4.64	0.030	12.18	4.60	0.041	12.43
T_5 : IRF 2	4.60	0.030	9.69	4.63	0.046	11.71
T_6 : MI	4.66	0.025	10.03	4.66	0.027	10.42
T_7 : BD	4.63	0.030	10.05	4.66	0.030	10.86
T_8 : CO	4.57	0.030	10.03	4.78	0.044	11.54
***CD* (*P* = 0.5)**	***0.12***	***NS***	***2.30***	***0.25***	***NS***	***2.17***

Variation in soil fertility

Variations in soil fertility parameters *viz.* organic carbon, available- N, available- P_2O_5, available- K_2O and available- SO_4^- were studied before initiation of experiment and after 3 years i.e. post completion of experiment (Table 39). Organic carbon content of soil is considered to be one of the most important quality parameter because it binds the mineral particles into granules, which increases the water holding capacity of soil. Loss of organic matter from soil is a cause for concern for chemical tea gardens because organic matter contributes to soil quality in many ways. Because of the many useful effects on soil quality, retention of soil organic matter is of high priority towards sustainable soil management. The benefits of increasing soil organic matter include carbon sequestration and an increase in the capacity of the soil to store water and nutrients. The organic carbon content in the experimental plots ranged from 0.70 to 0.84 percent and was found to increase (except in case of control) post application of organic soil inputs under the different packages of practice. Percent increase in organic carbon varied significantly (32.47 to 72.60) in the different treatment plots (Fig. 76), where highest increase was found in case of CO followed by IRF-2 package of practice.

Nitrogen is considered to be the most important nutrient for tea in terms of vegetative growth as well as reproductive propagation (Kathiravetpillai and Kulasegaram, 1980). In general, soil in different treatment plots were medium in available- N (as per the rating of Bhattacharya, 1998), which ranged between 379.61 and 406.37 $kgha^{-1}$ before initiation of experiment. In all the treatment plots (except control), available- N was found to increase only minimally post application of different packages of practice (Fig. 77). Available phosphate in the treatment plots were of low to medium status (according to the range suggested by Bhattacharya, 1998) and ranged between 35.20 and 48.41 $kgha^{-1}$ before initiation of experiment. After three consecutive years of experiment, available phosphate status increased from 0.72 to 49.14 percent in the different treatment plots (except control), which might indicate positive influence of organic soil inputs towards higher availability of phosphate in acid tea soils. The effect might be due to slow availability of phosphate through release of organic acids from compost, which reduce the capacity of soil minerals to fix P, as also suggested by Vasanthi and Kumaraswamy (2000) and Sim *et al.* (1991).

Potassium is the second major nutrient for tea after nitrogen and makes up 1.5-2% of the dry matter in tea leaves (Verma, 1997, 1993; Wu Xun *et al*., 1997). Available potash varied within 154.49 and 184.75 $kgha^{-1}$ in the different treatment plots before initiation of experiment. Post experiment, potash status was found to increase from 0.01 to 15.01 percent in the different treatment plots (with few exceptions). Similar compost application effects were also obtained by Vasanthi and Kumaraswamy (2000) and Gill (1995), who recorded increase in the availability of K with increase in CEC of the soils.

Available sulphate varied between 8.79 and 16.00 $kgha^{-1}$ in the different treatment plots before initiation of experiment. Post three year application of organic soil inputs, available sulphate status increased considerably in all the treatment plots (except control plot), which indicated favourable influence of compost towards higher availability of sulphate in acid tea soils. As discussed earlier, compost application caused an increase in soil microbial population, which in turn increased sulphate availability in soil.

Soil fertility index was developed to understand the potential of soil towards meeting the nutrient requirement of tea plant (in terms of overall availability of N, P, K & S). An increasing trend of index value was obtained with application of compost, being highest under IRF-2 plots followed by plots receiving VMI, IRF-1 and BD (Fig. 78) packages.

Table 39 : Variation in fertility status of soils under different packages of practice.

Treatments	Before Initiation of Experiment					After completion of experiment (3 years)				
	Org. C (%)	Av. N	Av. P_2O_5	Av. K_2O	Av. SO_4^{2-}	Org. C (%)	Av. N	Av. P_2O_5	Av. K_2O	Av. SO_4^{2-}
		< ---------------- $kgha^{-1}$ ---------------- >					< ---------------- $kgha^{-1}$ ---------------- >			
T_1 : C	0.84	400.60	39.65	171.27	10.19	0.74	303.28	30.40	143.52	16.73
T_2 : VCO	0.77	397.15	38.00	166.34	11.33	1.02	400.43	46.71	175.08	38.83
T_3 : VMI	0.78	388.41	48.41	154.49	10.74	1.10	406.25	48.76	178.14	40.87
T_4 : IRF-1	0.79	395.26	35.20	184.75	16.00	1.13	402.31	42.13	189.73	44.41
T_5 : IRF-2	0.82	397.76	41.45	177.38	10.96	1.25	424.21	61.82	182.95	45.00
T_6 : MI	0.70	379.61	47.68	160.70	9.32	1.01	389.45	47.30	160.71	31.92
T_7 : BD	0.79	380.33	45.38	174.32	10.20	1.11	397.19	50.98	176.18	38.17
T_8 : CO	0.73	406.57	36.36	166.22	8.79	1.26	414.59	40.53	195.14	42.30
***CD** (P = 0.5)*	***0.14***	***24.09***	***11.43***	***30.02***	***5.85***	***0.15***	***66.66***	***19.48***	***38.53***	***18.93***

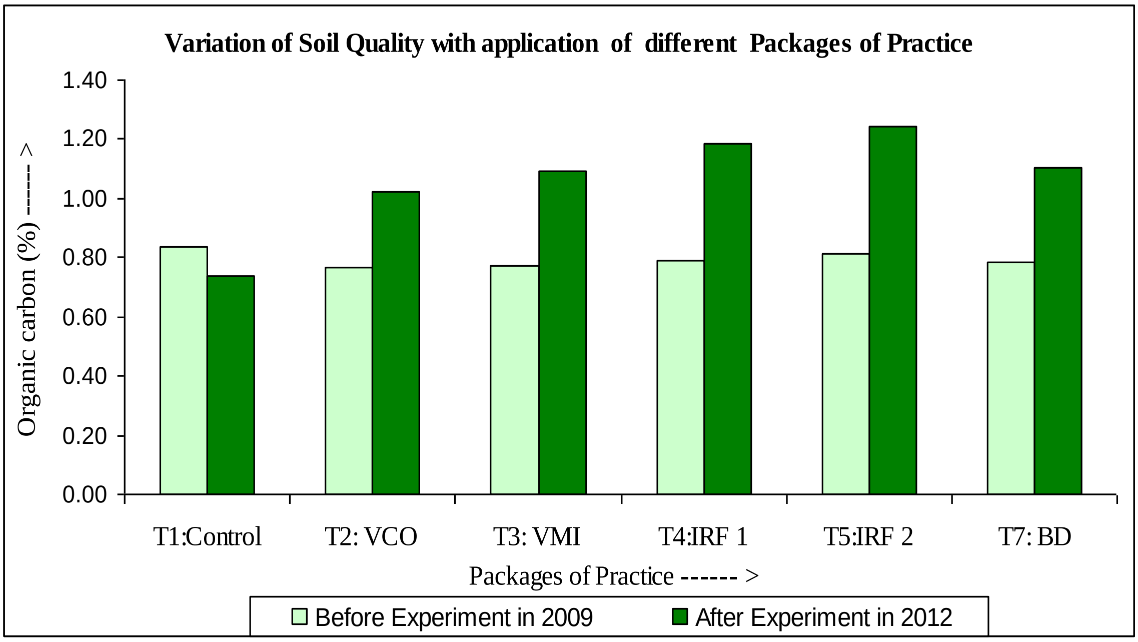


Fig. 76: Variation of soil organic carbon before and after 3 years of experimentation at Maud T.E., Assam; under FAO-CFC-TBI Project.

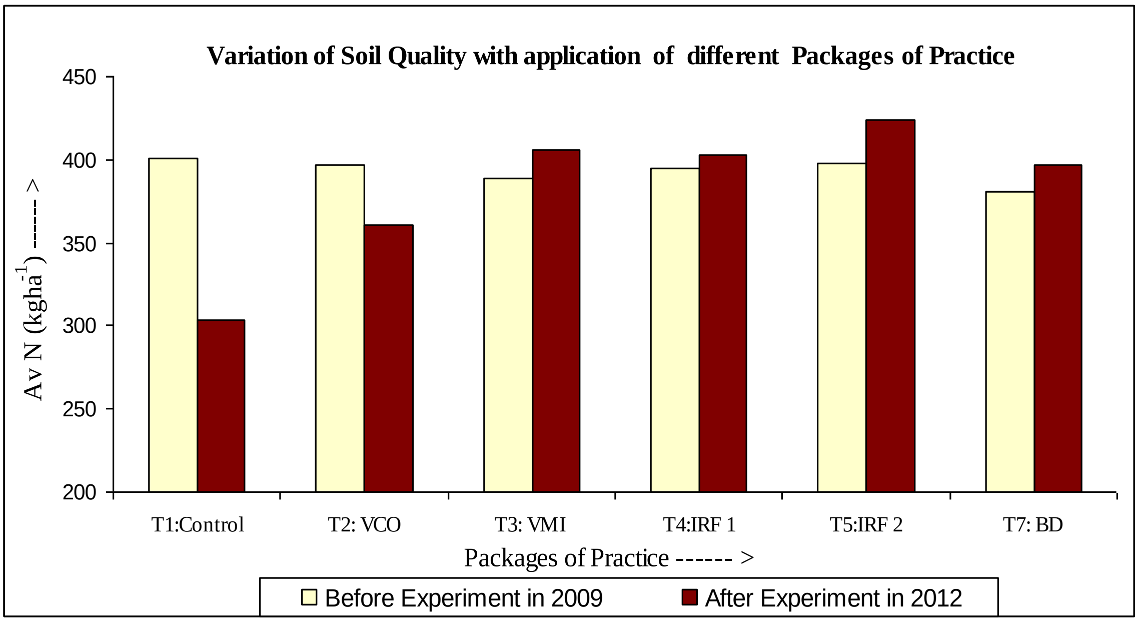


Fig. 77 : Variation of soil available- N before initiation and after 3 years of experimentation at Maud T.E., Assam; under FAO-CFC-TBI Project.

Variation in soil microbiological status

Microbial activity is probably the most important factor that controls nutrient re-cycling in soil. Microorganisms participate in disintegration and decomposition processes leading to release of nutrients trapped in plant and animal debris, rock and minerals along with synthesis and release of hormones

Table 40 : Soil microbial population before and after completion of experiment under different packages of practice.

Treatments	Before Initiation of Experiment			After completion of experiment (3 years)		
	Total Bacterial Count	Total Fungal Count	Total Actinomycetes count	Total Bacterial Count	Total Fungal Count	Total Actinomycetes count
	< - - - - - - - - - - c.f.u. per gm moist soil ($\log_{10}$ value) - - - - - - - - - - >					
T_1 : C	6.398	5.326	4.888	6.367	4.463	4.475
T_2 : VCO	6.339	5.431	5.026	8.209	4.923	5.033
T_3 : VMI	6.384	5.252	5.171	8.068	4.973	5.037
T_4 : IRF-1	6.266	5.128	4.954	8.122	5.051	5.051
T_5 : IRF-2	6.316	5.244	4.925	8.412	5.322	5.194
T_6 : MI	6.539	5.470	4.932	8.120	4.543	4.622
T_7 : BD	6.318	5.465	4.959	8.103	4.659	4.735
T_8 : CO	6.298	5.407	4.893	8.064	4.783	4.667
***CD** (P = 0.5)*	***0.28***	***0.29***	***0.57***	***0.33***	***0.39***	***0.35***

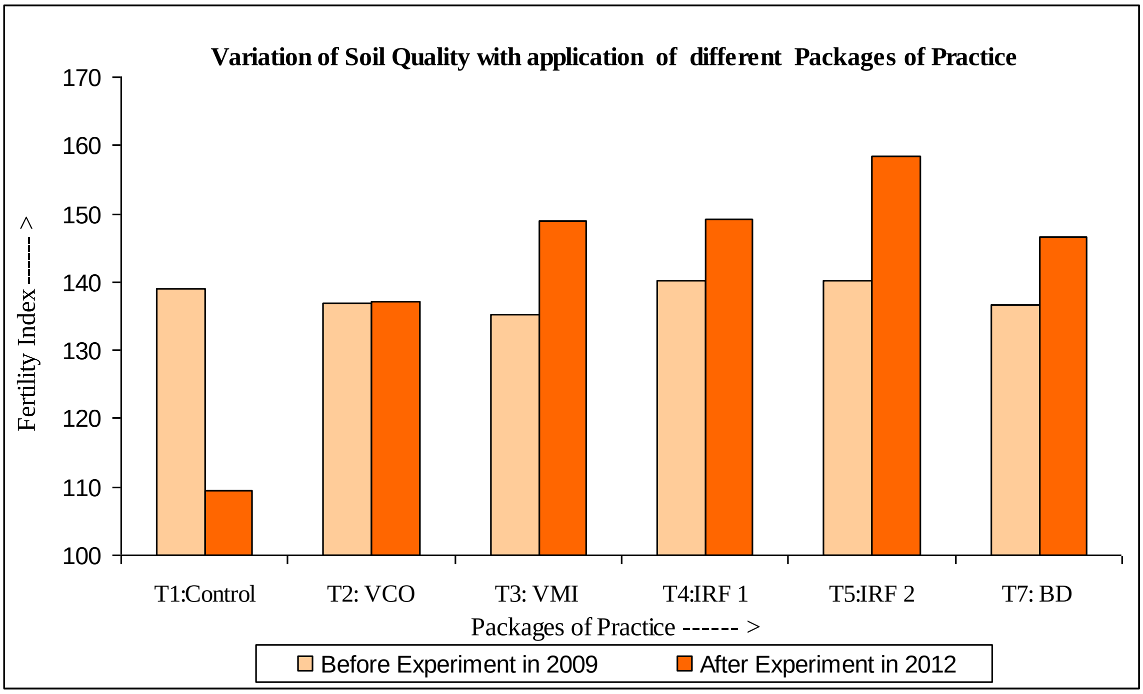


Fig. 78 : Variation of soil fertility index before initiation and after 3 years of experimentation at Maud T.E., Assam;, under FAO-CFC-TBI Project.

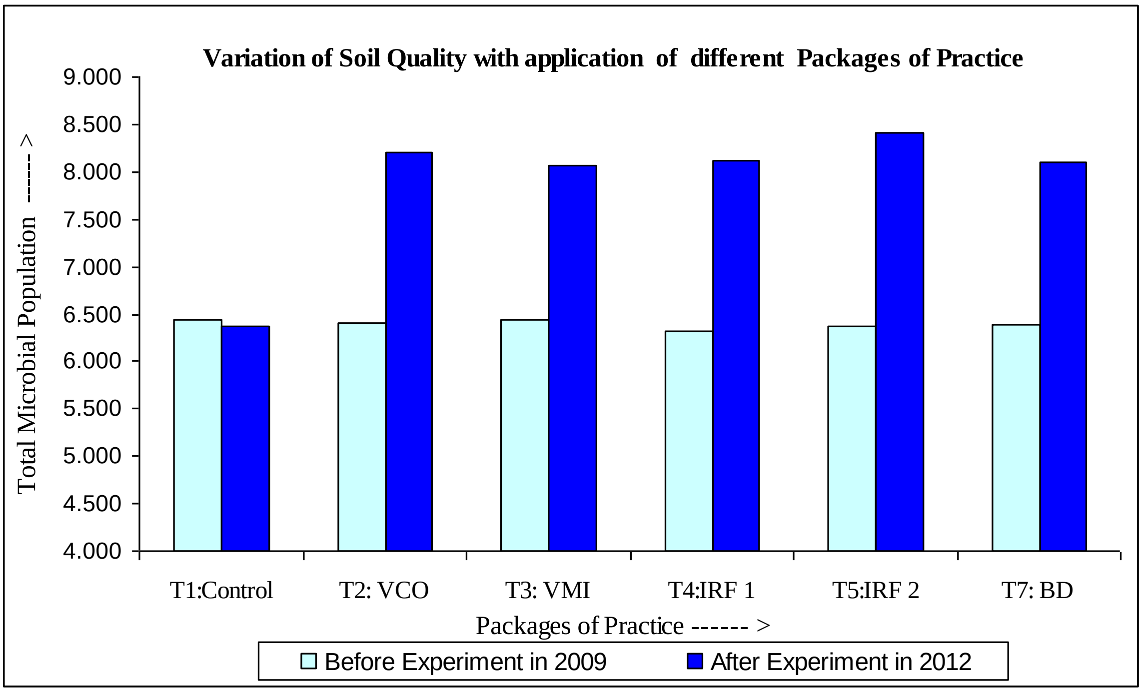


Fig. 79 : Variation of soil microbial population before initiation and after 3 years of experimentation at Maud T.E., Assam; under FAO-CFC-TBI Project.

that are essential for plant growth (Gogoi *et al.*, 2003). Soil microbial population in terms of total bacteria, fungi and actinomycetes, were studied for the different treatment plots in order to assess changes in their population before and after three years application of organic soil inputs (table 40) under different packages of practice. In general, soil microbial population (total population of soil bacteria, fungi and actinomycetes) was found to increase post treatment (Chitravadivu *et. al.,* 2009), where highest increase was observed in case of IRF-2 plots as compared to others (Fig. 79). This might be due to the creation of favourable environment for natural proliferation and activity of native soil microbes as influenced by huge population of self- generated microbes within Novcom compost, that was used for soil management under IRF-2 package.

Relationship among different soil quality parameters

The inter-relationship between different soil quality parameters is presented in table 41. Soil Organic carbon was positively and significantly correlated with cation exchange capacity (0.576**), available- N (r = 0.655**), available-phosphate (r = 0.466**), available potash (r = 0.653**), available- sulphate (r = 0.623*), total bacteria (r = 0.849**), fungi (r = 0.738**), and actinomyctes (r = 0.657**). As Soil Organic carbon is the storehouse of all the nutrients, significantly high correlation between soil organic carbon and other soil quality parameters indicated the effectivity of soil management under the different organic packages of practice. Bationo *et al.* (2006) also observed similar findings, which indicated that application of compost increased soil organic carbon status leading to higher soil fertility. On the other hand, organic carbon reserve is the food reserve of microbial community and thus close correlation between organic carbon and soil microbial population is quite expected.

Cation exchange capacity was also found to be positively and significantly correlated with available macro nutrients, indicating its strong relationship with soil fertility.

Significant and positive correlation among soil available nutrient and soil microbial population indicated their role in the availability of soil macro nutrients and the phenomenon has special relevance towards crop productivity in acid tea soils. Hoorman and Islam (2010) in their study also indicated the role of microbes in the availability of soil nutrients.

Table 41 : Relationship among the physicochemical, fertility and biological parameters of soil.

Correlation coefficient	pH	EC	Organic carbon	CEC	Av. N	Av. Phosphate	Av. Potash	Av. Sulphate	Total bacteria	Total fungi
EC	0.237	-								
Organic carbon	0.244	0.706**	-							
CEC	0.138	0.487*	0.576**	-						
Av. N	0.395	0.655**	0.919**	0.470*	-					
Av. Phosphate	0.120	0.466*	0.667**	0.313	0.762**	-				
Av. Potash	0.190	0.653**	0.919**	0.726**	0.819**	0.531**	-			
Av. Sulphate	0.217	0.623**	0.914**	0.724**	0.878**	0.726**	0.938**	-		
Total bacteria	0.091	0.394	0.849**	0.453*	0.863**	0.776**	0.783**	0.873**	-	
Total fungi	0.012	0.617**	0.738**	0.747**	0.659**	0.691**	0.764**	0.809**	0.637**	-
[1]Total Act	-0.015	0.481*	0.657**	0.784**	0.621**	0.709**	0.728**	0.804**	0.683**	0.942**

[1]*Total Act : Total Actinomycetes; ** Significant at 1% level; * Significant at 5 % level*

Interrelation between crop yield and soil quality parameters.

To evaluate the inter-relationship between soil quality and crop response, ten soil quality parameters (analyzed during this study) were correlated with crop

Table 42 : Correlation coefficient between Yield and Soil Quality Parameters.

	Parameter	Correlation coefficient
Crop Yield *Vs*	pH (H_2O)	0.072 NS
	Electrical Conductivity	0.518**
	Organic carbon	0.375 NS
	Cation Exchange Capacity	0.514**
	Available Nitrogen	0.492*
	Available Phosphate	0.701**
	Available Potash	0.403*
	Available Sulphate	0.566**
	Total Bacteria	0.378 NS
	Total Fungi	0.672**
	Soil Actinomycetes	0.687**

*** Significant at 1% level; * Significant at 5 % level; NS : Not Significant*

yield. Eight parameters were found to be positively and significantly related to crop yield (Table 42). Positive and significant correlation of crop yield was obtained with electrical conductivity (0.518**), cation exchange capacity (0.51488), available- N (0.492*), available- P_2O_5 (0.701**), available- K_2O (0.403*), available- SO_4 (0.566**), total fungi (0.672**) and total actinomycetes (0.687*). The study indicated that improvement in these quality parameters might positively influence crop performance, which can be achieved through regular application of good quality compost.

Soil Development Index (SDI) and its relation with crop performance.

The overall variation in soil quality under different packages of practice over a period of three years was assessed using soil development index. SDI was formulated using soil physicochemical, fertility and biological parameters. Ten different quality parameters *viz.* soil pH, EC, organic carbon, C.E.C, available-N, available- P_2O_5, available- K_2O, total bacteria, fungi and actinomycetes; were used as per the following formula to calculate soil development index under different treatments.

$$\text{Soil Development Index (SDI)} = \frac{a}{n^2} \sum_{n=1}^{n} \left\{ \frac{100(X_1 - C_1)}{C_1} + \frac{100(X_2 - C_2)}{C_2} + \cdots + \frac{100(X_n - C_n)}{C_n} \right\}$$

Where X = Soil Quality parameters after Experimentation; C = Value of individual Soil Quality Parameter before Experimentation ; a = no of Soil Quality Parameters showing increased over initial value.

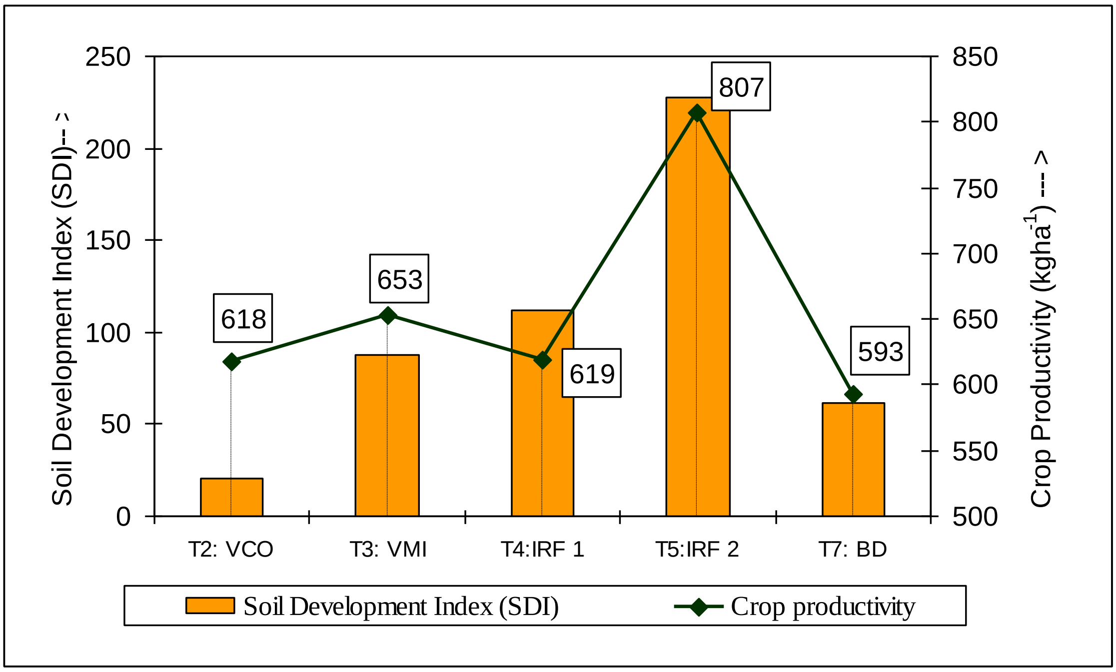


Fig. 80 : Variation of Soil Development Index before initiation and after 3 years of experimentation at Maud T.E., Assam; under FAO-CFC-TBI Project.

SDI was highest in case of plots receiving IRF-2 (SDI: 227.84) followed IRF-1 (SDI: 112.34), VMI (SDI : 87.35), BD (SDI: 61.92) and VCO (SDI: 20.46) packages (Fig. 80). SDI under Inhana Rational Farming Packages were distinctly higher than the next best performing treatment indicating effective organic soil management under the former, leading to speedy soil rejuvenation. The finding was further corroborated by better crop performance under IRF packages, the highest yield being obtained under IRF-2 package of practice.

Evaluation of Organic 'Packages of Practice' for Ecologically and Economically Sustainable Tea (Mature Tea) Cultivation under FAO-CFC-TBI Project at Maud T.E., Assam

Brief Summary

To find out an effective pathway for sustainable tea cultivation in a cost effective manner along with restoration of soil quality, ten organic packages of practice (with control) were taken as treatments to evaluate their potential in mature tea plantation.

The different packages were : Biodynamic (BD), Conventional Organic Practice with Indigenous compost @ 13.5 ton/ha (CO), Inhana Rational Farming Technology with 2.6 ton Novcom Compost (IRF-1), with 8 ton Novcom Compost (IRF-2), with 4 ton Novcom Compost (IRF-3) and with 5.1 ton Novcom Compost (IRF-4); Microbial Formulations i.e. Bio-fertilizer+ Bio-pesticides+ Bio-growth promoter (MI), Vermicompost @ 9.4 ton/ha + Conventional Organic Practice (VCO), Vermicompost @ 9.4 ton/ha + Microbial Formulations (VMI), Vermicompost @ 9.4 ton/ha + Microbial Formulations i.e. Bio-pesticides+ Bio-growth promoter (VMIP).

IRF-2, IRF-4 and VMI accomplished the target yield (i.e. 1220 kg made tea/ ha considering average yield of Maud T.E. for last 5 years) recording a crop efficiency of 113.3, 110.0 and 103.5 percent respectively; while VMIP performed just close to the target (98.9 %). Rest all other packages viz. BD, CO, MI and VCO failed to achieve the target crop and scored even less than 25 percent higher crop as compared to control.

Cost/ kg made tea were lowest for IRF packages followed by CO, while inclusion of vermicompost jacked up the respective package cost by many folds. Low crop performance under CO neutralized it suitability for adoption as favoured by the low package cost.

Agronomic Efficiency (NUE), which among other factors depends upon the nutrient uptake and utilization efficiency of plant or conversely the state of plant physiology was assessed to score the different organic packages as per N expensed for unit crop production. Highest NUE was obtained under IRF packages followed by VMI, VMIP and VCO. The highest crop yield along with high NUE under IRF-2 indicated an effective management approach towards activation of plant physiology.

High SDI under IRF packages as compared to rest all other packages was corroborated by the highest increase in soil- N content and population of N converters in these plots.

Evaluation of Organic 'Packages of Practice' for Ecologically and Economically Sustainable Tea (Mature Tea) Cultivation under FAO-CFC-TBI Project at Maud T.E., Assam

Introduction

Sustainable tea cultivation, although being the most persistent and critical issue for the Indian tea industry; has remained unachievable even under incremental dose of chemical fertilizers. The age old bushes, continuous stress on plants due to multiple vegetative propagation, limited scope for soil rejuvenation, soil acidity or improper nutrient dynamics along with unresolved pest and disease infestation lead to complex problems, which are much different and difficult to address as compared to other crops. No wonder success has remained elusive even under organic farming practices.

In case of tea plantations soil management cost comprises more than 50 percent of the total expense on inputs moreover; effective organic soil management is a challenging task in such problematic acid soils. However, there has been no comprehensive and scientific guideline for identification of organic soil input quality and their application dosage depending on quality variations, which has a direct bearing on the related expenses considering that it is the quality of compost, which determines the application quantity *vis-à-vis* the economics. Moreover, fertilizer sensitive tea clones, comprising major portion of tea plantation suffer from depressed physiological functioning under application of ordinary compost and slow reacting organic inputs. In such a scenario a comprehensive organic method/ 'Package of Practice' that provide guidelines for effective plant management programme along with scientific soil management practices can perhaps bring about the desired sustainability.

The following study at Maud tea estate (Assam), India under FAO-CFC-TBI Project, 2008-2011; was taken up to evaluate the different organic methods/ 'Packages of Practice' towards yield performance, soil quality rejuvenation as well as economics.

Objective

To bring forth the most effective organic method/ 'Package of Practice' that can ensure sustainable organic tea production along with scope for soil quality rejuvenation, but most importantly at an affordable cost.

Methodology

Field experiment was laid out where the available organic methods *viz.* Biodynamic Farming (BD) and Inhana Rational Farming (IRF), as well as organic inputs *viz.* vermicompost, bio-fertilizers, bio-pesticides, herbal formulations, etc., were selected as treatments (Fig. 81).

The organic methods selected were those that are practiced in organic tea gardens in India on large scale. Also the organic inputs selected for evaluation were the ones popular in Indian tea industry or Indian agriculture (for attending their respective criteria), and these inputs were not studied individually but combined to form different 'Packages of Practice' based on scientific rationale.

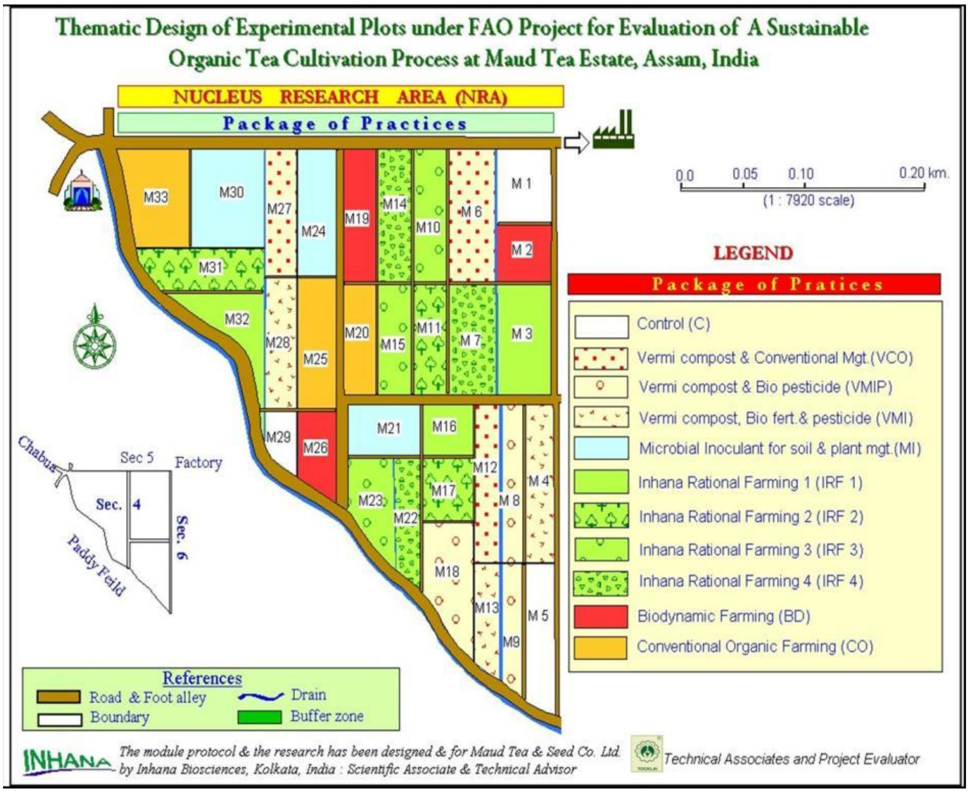


Fig. 81: Lay out of Nucleus Research Area (NRA) for evaluation of different Organic Packages of Practice in mature tea plantation under FAO-CFC-TBI project at Maud T.E., Assam.

The experiment was laid out as per IBD or Incomplete Block Design, with eleven treatments and three replications. The 'Packages of Practice' were evaluated in terms of meeting the target yield (1220 kg/ ha i.e. last 5 years average yield of the garden) as well as their efficiency over control and finally in terms of their economic viability.

Soil samples were collected from each treatment plot before initiation of experiment and 60, 90 and 150 days post application of soil inputs, for analyzing their physicochemical properties, fertility status and microbial potential.

Treatment Details

T_1	:	Vermicompost @ 9.4 ton/ ha + Herbal concoctions for pest and disease management (VCO).
T_2	:	Vermicompost @ 9.4 ton/ ha + Bio-growth promoter + Bio-pesticides (VMIP).
T_3	:	Vermicompost @ 9.4 ton/ ha + Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK) + Bio-growth promoter + Bio-pesticides (VMI).
T_4	:	Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK) + Bio-growth promoter + Bio-pesticides (MI).
T_5	:	Novcom compost @ 2.6 ton/ha + Elemental-S + Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-1).
T_6	:	Novcom compost @ 8.0 ton/ha + Elemental-S + Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-2).
T_7	:	Novcom compost @ 4.0 ton/ha + Elemental-S + Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-3).
T_8	:	Novcom compost @ 5.1 ton/ha + Elemental-S + Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-4).
T_9	:	Biodynamic compost @ 10 ton/ ha + Cow Pat Pit + Cow horn manure + Biodynamic package for plant management (BD).
T_{10}	:	Indigenous compost/ Farm Yard Manure (FYM) @ 13.5 ton/ ha + Herbal concoctions for pest and disease management (CO).
T_{11}	:	Control (C).

Evaluation of the effectivity of different organic 'Packages of Practice' (POP) in terms of yield performance of Mature Tea.

Highest crop performance was obtained in case of IRF- 2 (1374 kg made tea/ha) followed by IRF-4 (1369 kg made tea/ha), VMI (1299 kg made tea/ha), VMIP (1235 kg made tea/ha) and VCO (1158 kg made tea/ha) respectively. Among all the treatments only the first three *viz.* IRF-2, IRF-4 and VMI accomplished the target yield (crop efficiency: 113.3%, 110.0% and 103.5% respectively) while VMIP performed just close to the target (98.9 %). Rest all other packages *viz.* BD, CO, MI and VCO failed to achieve the target crop and scored even less than 25 percent higher crop as compared to control.

Lowest yield performance under MI (excluding control) indicated very nominal impact of the microbial formulations (bio-fertilizers and bio-pesticides) towards effective plant nutrition as well as pest management. The results bear a strong conformity with the findings of Martin and Ervin (1952) regarding the relative inefficiency of inoculated microbes under unfavourable environmental conditions. Addition of vermicompost with MI package certainly boosted up crop efficiency by influencing 22% increase in made tea/ ha, but also caused an additional hike of 131 percent over MI package cost or 408 % higher cost than IRF-2 package.

Information on relative agronomic effectiveness (RAE) of tea plants under different organic packages of practice could assist in selection of the most effective package thereby leading to economic crop production. As highest crop production was obtained in case of IRF-2, taking its yield as reference (RAE : 100), the next best treatment (IRF-4) had the relative agronomic effectiveness of 98.83 percent followed by VMI (82.48 percent) and VMIP (67.52 percent). RAE in case of all other organic packages was less than 50 percent. The results clearly indicated the relative effectiveness of IRF packages over rest other organic packages of practice.

Duncan's new multiple range test (MRT) to explain crop yield.

Duncan's new multiple range test (MRT) is a multiple comparison procedure developed by David B. Duncan in 1955 and is commonly used in agronomy and other agricultural research. Duncan's MRT belongs to the general class of multiple comparison procedures that use the studentized range statistic q_r to compare sets of means. Duncan's new multiple range test (MRT) is a variant of the Student–Newman–Keuls method that uses increasing alpha levels to calculate the critical values in each step of the Newman–Keuls procedure. Duncan's MRT attempts to control family wise error rate (FWE) at $\alpha ew = 1 - (1 - \alpha pc)\ k - 1$ when comparing k, where k is the number of groups. This results in higher FWE than unmodified Newman–Keuls procedure which has FEW of $\alpha ew = 1 - (1 - \alpha pc)\ k/2$. David B. Duncan developed this test as a modification of the Student–Newman–Keuls method that would have greater power. Duncan's MRT is especially protective against false negative (Type II) error at the expense of having a greater risk of making false positive (Type I) errors.

Table 43 : Crop performance under different organic packages of practice in Mature tea (2009 to 2011).

Treatment	Crop Yield ($kgha^{-1}$)		
	2009	2010	2011
T1 : VCO	6519.62^{abc}	2947.64^{ab}	5470.71^{ab}
T2 : VMIP	7041.51^{abc}	3156.29^{ab}	5726.08^{ab}
T3 : VMI	7415.40^{abc}	3119.30^{ab}	6219.88^{ab}
T4 : MI	5495.69^{bc}	2878.17^{ab}	5353.96^{ab}
T5 : IRF1	7329.45^{ab}	3152.93^{ab}	5546.96^{ab}
T6 : IRF2	6235.41^{abc}	4210.77^{a}	7260.13^{a}
T7 : IRF3	6518.23^{abc}	3252.09^{ab}	6345.64^{ab}
T8 : IRF4	7509.02^{a}	3527.32^{ab}	6624.86^{ab}
T9 : BD	5137.38^{c}	2871.36^{ab}	5846.35^{ab}
T10 : CO	6417.85^{abc}	3014.27^{ab}	4870.35^{b}
T11 :C	5107.21^{c}	2468.17^{b}	4631.45^{b}

To evaluate the effectivity of different packages of practice towards sustained crop performance in mature tea plantation, field trial was laid out following Incomplete Block Design (IBD) depending upon land situation and natural boundaries; with 11 treatments replicated 3 times. ANOVA technique meant for IBD was used and treatment effect when found significant were farther subjected to Duncan's Test ($p < 0.05$) to compare all 11 treatment means due to all character under study.

Evaluation of the crop performance under different packages of practice in the year 2009 following Duncan's test indicated significantly higher yield under IRF-4 as compared to MI, BD and control (table 43). However, it was having homogenous mean results with remaining treatments. However, in 2010 and

2011 crop performance was found to be significantly higher under IRF-2 package as compared to control.

Evaluation of the effectivity of different organic 'Packages of Practice' (POP) in terms economics.

Comparative study of the cost of inputs under different organic packages of practice showed that IRF-4 (table 44) incurred lowest expense per hectare (Rs. 11,302/-) followed by CO (Rs. 12,954/-), IRF-2 (Rs. 13,796/-), BD (Rs. 14,914/-), MI (Rs. 28,657/-), VCO (Rs. 40,184/-), VMIP (Rs. 46,832/-) and VMI (Rs. 66,257/-) packages. It is clearly indicated from the data that inclusion of vermi compost caused up to six times higher cost as compared to the package with lowest cost (IRF-4). While the low cost along with high yield efficiency in case of IRF packages indicated their potential for large scale adoption, the low cost of CO was neutralized by the comparatively lower yield efficiency of 98.2 percent.

However, impact of packages towards both crop performance and associated cost can be better understood from cost/ kg made tea and value cost ratio (VCR). Cost/ kg made tea was lowest in case of IRF-4 (Rs. 8.26/-) followed by IRF-2 (Rs. 10.04/-) and CO (Rs. 11.68/-) packages. Assessment of the variation in crop yield and the related cost under different organic packages of practice (fig. 82) clearly indicated the best option for sustained crop production.

Value cost ratio, which indicated the excess revenue generated per unit rupee invested; is generally used to assess the economic sustainability under different management practices. The scope of sustainability increased with increase in the ratio value.

$$\text{Value Cost Ratio (VCR)} = \frac{\text{Value of increased yield obtained}}{\text{Cost of fertilizer used}}$$

Table 44 : Ranking of different organic packages of practice in terms of crop efficiency & cost per hectare for mature tea.

Rank	Package of Practice	Crop Efficiency				Economics of Packages of Practice		
		Yield (kg/ha)	Over Target (1220 kg/ha)	Over control	RAE[1]	Cost / ha	Cost/kg made tea	Value Cost Ratio (VCR)[2]
1.	Inhana Rational Farming with 8 ton Novcom Compost (IRF-2)	1374	113.3 %	45.2%	100.00	Rs. 13,796/-	Rs. 10.04/-	6.20
2.	Inhana Rational Farming with 5.1 ton Novcom Compost (IRF-4)	1369	110.0 %	44.8%	98.83	Rs. 11,302/-	Rs. 8.26/-	7.49
3.	Vermicompost+Microbial Formulation for Both Soil & Plant (VMI)	1299	103.5 %	37.3%	82.48	Rs. 66,257/-	Rs. 51.01/-	1.07
4.	Vermicompost + Microbial Formulation for Plant (VMIP)	1235	98.9 %	30.5%	67.52	Rs. 46,832/-	Rs. 37.92/-	1.23
5.	Vermicompost + Conventional Organic Practice (VCO)	1158	92.8 %	22.4%	49.53	Rs. 40,184/-	Rs. 34.70/-	1.06
6.	Indigenous compost + Conventional Organic Practice (CO)	1109	89.2 %	17.2%	38.08	Rs. 12,954/-	Rs. 11.68/-	2.52
7.	Biodynamic Package of Practice (BD)	1075	87.4 %	13.6%	30.14	Rs. 14,914/-	Rs. 13.87/-	1.73
8.	Microbial Formulation for both Soil and Plant Management (MI)	1065	86.2 %	12.5%	27.80	Rs. 28,657/-	Rs. 26.91/-	0.83

[1]RAE : Relative agronomic effectiveness, [2]VCR : value cost ratio

Note : *Among IRF packages of practice, results of best two packages was included in the table. Quantity of various soil inputs were calculated on plant–N requirement basis i.e. for giving 60kg N; except for those packages which had fixed recommended dosage like BF, BD, FYM-2. Actual dosage was calculated based on N and moisture % in the soil input. Novcom compost was applied in combination with 40 kg Elemental-S & 80 kg Rock phosphate per hectare. In case of soil management using Biodynamic compost, CPP @ 12.5 kg/ ha and Cow horn manure (15 ltr. soln/ ha) was also used. Pruning : UP - Corrected LP - UP ; Bush Population : 10930/ha ; Age : 11-14 years; VCR was calculated considering Made tea @ Rs. 200/ kg*

Value cost ratio of IRF-2 and IRF- 4 (6.20 and 7.49 respectively) packages were distinctly higher than all other packages of practice, which showed that the IRF packages could provide an economically sustainable road map for organic tea production.

Comparatively low values obtained in case of other packages (*viz.* VMI, VMIP, VCO and MI), especially MI (VCR-0.83) indicated not only lowest yield but more importantly high to very high package cost. Low VCR obtained in case of CO and BD even after having lower package cost was primarily due to poor crop efficiency. Agricultural economists have also pointed out that VCR < 2.00 cannot provide the necessary risk coverage against investment towards input cost (Kelly, 2006; CIMMYT, 1988; Morris, *et al.*, 2007; Pender, 2009). VCR < 2.00 as obtained for most of the organic packages of practice except IRF-4, IRF-2 and CO; indicated their economic vulnerability towards crop loss or market downfall.

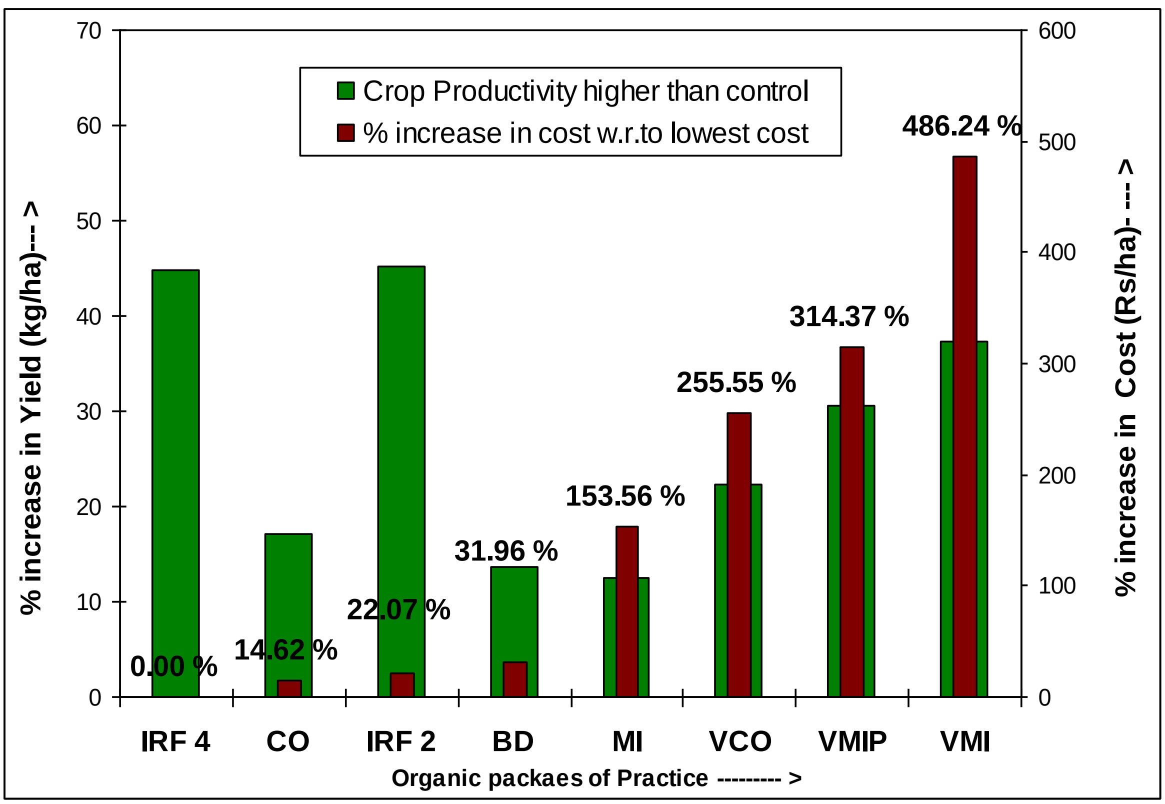


Fig. 82 : Comparative study of percent crop increase and associated cost under different Organic Packages of Practice in mature tea plantation.

Agronomic efficiency of tea plants under Different Organic 'Packages of Practice'.

Agronomic efficiency (NUE-AE) expressed by relative yield increase per unit of N applied and partial factor productivity (NUE-PFP) expressed as crop yield per unit N applied (Roberts, 2008) are indicative of the degree of economic and soil/ plant efficiency towards use of nutrient inputs. It is therefore of major importance to identify the critical steps controlling plant N use efficiency (NUE). This NUE can be divided into two processes: uptake efficiency (NupE; the ability of the plant to remove N from the soil as nitrate and ammonium ions) and the utilization efficiency (NutE; the ability to use N to produce grain yield).

Table 45 : Agronomic indices to determine nutrient use efficiency in terms of compost N application under different organic packages of practice.

Treatment	Nutrient Use Efficiency				
	(AE_{CN})	(PFP_{CN})	(PE_{CN})	(RE_{CN})	(RAE)
Inhana Rational Farming with 9 ton Novcom Compost (IRF-2)	24.44	18.32	34.87	16.36	100.00
Inhana Rational Farming with 6 ton Novcom Compost (IRF-4)	47.22	35.57	34.91	31.50	99.18
Vermicompost + Microbial Formulation for Both Soil & Plant (VMI)	18.83	16.13	33.09	13.24	82.69
Vermicompost + Microbial Formulation for Plant (VMIP)	16.52	16.46	34.12	11.27	67.59
Vermicompost + Conventional Organic Practice (VCO)	12.14	15.44	31.20	9.07	49.68
Indigenous compost + Conventional Organic Practice (CO)	5.74	9.12	32.90	4.07	38.10
Biodynamic Package of Practice (BD)	5.97	11.68	31.82	4.40	29.95

Hence, NUE of a crop should be considered not only as a function of soil texture, climate conditions, interactions between soil and bacterial processes (Walley *et al.*, 2002; Burger and Jackson, 2004) and the nature of organic or inorganic N sources

(Schulten and Schnitzer, 1998), but also in terms of the management approach taken towards development of plant physiology. This is because especially under organic, effective plant management programme leading to the activation of plant physiology plays a determinant role in efficient nutrient uptake and their utilization by plants.

Agronomic efficiency (AE_{CN}) and Partial Factor Productivity of Applied Compost N (PFP_{CN}) was highest (table 45) in case of IRF- 4 (47.22 *kg green leaf kg N Applied*$^{-1}$ *and 35.57 kg made tea kg N Uptake*$^{-1}$), followed by IRF- 2 (24.44 *kg green leaf kg N Applied*$^{-1}$*and 18.32 kg made tea kg N Uptake*$^{-1}$) and VMI (18.83 *kg green leaf kg N Applied*$^{-1}$ *and16.13 kg made tea kg N Uptake*$^{-1}$) packages. Higher agronomic efficiency in case of IRF-4 is mainly due to lowest dose of N applied while lowest agronomic efficiency under CO package is due to the highest quantity N application. Evaluation of agronomic efficiency and PFP_{CN} for the rest other packages of practice (where almost similar dose of N was applied), indicated highest value under IRF-2 treatment indicating its positive influence towards better soil-plant functioning leading to highest N efficiency. The fact is well corroborated with the highest crop response, obtained in case of IRF-2 package of practice.

Physiological efficiency of compost- N (PFP_{CN}) under different packages of practice indicate the relative effectiveness of the management practice towards plant physiology activation. This is because higher physiological efficiency entails effective translocation, assimilation and redistribution of N for use in crop growth (Kanampiu *et al.*, 1997). The PFP_{CN} varied from 34.91 to 31.20 *kg made tea kg N Uptake*$^{-1}$ among the different treatments, where highest value was obtained in case of Inhana Rational Farming packages of practice.

Crop Recovery Efficiency of Applied Compost N (RE_{CN}) depends largely on the degree of congruence between plant N demand and the available supply of N from applied fertilizer or organic N sources. Consequently, optimizing the timing, quantity, and availability of applied N is the key for achieving high RE (Dobermann, 2005). RE_{CN} was highest in case of IRF packages, which once again indicated an effective plant management programme leading to efficient soil-plant-nutrient dynamics. Relative agronomic effectiveness (RAE) was calculated for different treatments taking yield under highest performing package (i.e. IRF in terms of crop performance) as reference (RAE : 100). RAE was found to be on the higher side only under VMI package (82.69 %), while VCO, CO and BD packages scored merely 49.68 %, 38.10 % and 29.95 % respectively.

Impact of Plant Management Practice under Different Organic Packages, towards Agronomic Efficiency of Mature Tea Plantation.

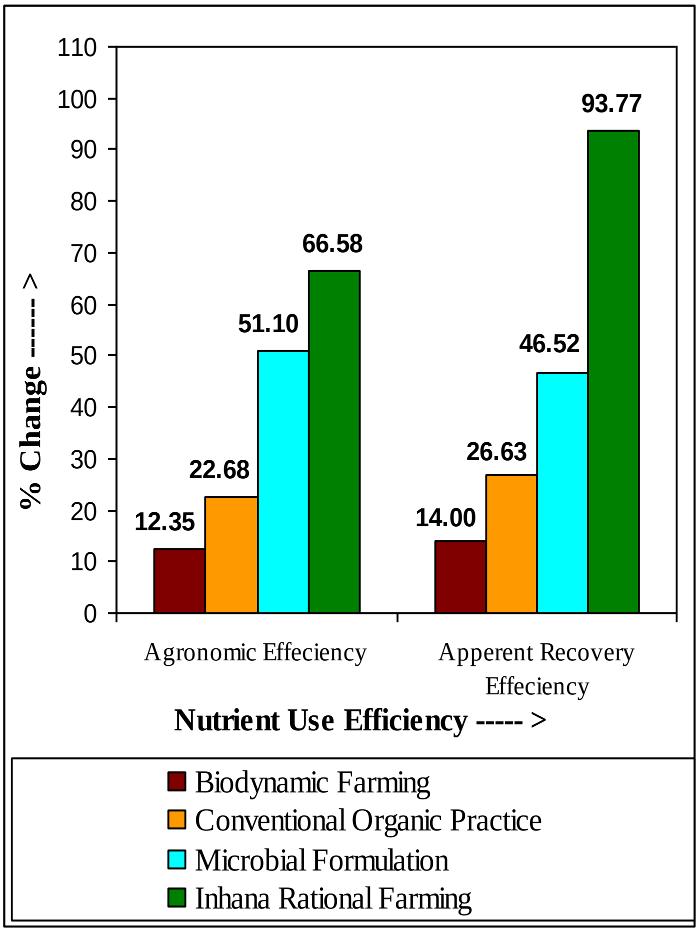
Improvement in compost use efficiency entails improvement of yield (Olsen and Sommers, 1982), especially increase in nitrogen use efficiency (NUE, as assessed through agronomic and relative agronomic efficiency), which plays an essential role in cutting down the production costs (Silspoor and Momayezi, 2006). Increase in compost use efficiency can be brought about by different methods e.g. increasing compost quality, alter application method and post application management, changing application time/ dose; and most importantly improving the physiological efficiency of plants, which is reflected in its agronomic efficiency.

Hence, comparative assessment of the agronomic efficiency of mature tea under different organic packages of practice (i.e. both soil and plant management) *vis-à-vis* under only specific soil management i.e., from 'Soil Input Experiment' (same organic soil input with same dosage in both cases), was done. Table 46 represents the agronomic efficiency (AE_{CN}) and crop recovery efficiency of applied compost N (RE_{CN}) under different organic packages of practice *vis-à-vis* under specific soil management. Any increase in the value of AE_{CN} and RE_{CN} under organic package as compared to that obtained under only soil management, shall indicate the positive influence of plant management towards activation of plant physiology.

In general nutrient use efficiency in terms of AE_{CN} was found to increase with the addition of plant management along with soil management practice i.e. under comprehensive organic package of practice. The highest increase of AE_{CN} (Fig. 83) was influenced by Inhana plant management practice under IRF packages (105.42) followed by bio-pesticides and microbial growth promoter as applied under MI package (66.91). Increase of agronomic efficiency under application of microbial formulations indicated, that they were more suited for plant management as compared to soil quality development.

Table 46 : Impact of plant management on agronomic efficiency of mature tea plants.

Impact of plant management of	Treatments	Nutrient Use Efficiency		% change in Nutrient Use Efficiency	
		(AE_{CN})	**(RE_{CN})**	**(AE_{CN})**	**(RE_{CN})**
Inhana Rational Farming (IRF)	Novcom compost-1 (NOV-1) (@ 8 ton/ha)	19.13	12.69	27.74	28.86
	Inhana Rational Farming with 8 ton Novcom Compost (IRF-2)	24.44	16.36		
	Novcom compost-3 (NOV-3) (@ 5.1 ton/ha)	22.99	12.18	105.42	158.67
	Inhana Rational Farming with 5.1 ton Novcom Compost (IRF-4)	47.22	31.50		
Biodynamic Farming (BD)	Biodynamic compost (BDS) (@ 10 ton/ha)	5.31	3.86	12.35	14.00
	Biodynamic Package of Practice (BD)	5.97	4.40		
Microbial Formulation	Vermi Compost + Biofertilizer (VCBF)	13.92	9.77	35.29	35.61
	Vermicompost + Microbial Formulation for Both Soil & Plant (VMI)	18.83	13.24		
	Vermi compost (VC) (@ 9.4 ton/ha)	9.90	7.16	66.91	57.42
	Vermicompost + Microbial Formulation for Plant (VMIP)	16.52	11.27		
Conventional Organic Practice	Indigenous compost-2 (FYM 2) (@13.5ton/ha)	11.05	8.36	-48.04	-51.34
	Indigenous compost + Conventional Organic Practice (CO)	5.74	4.07		
	Vermi compost (VC) (@ 9.4 ton/ha)	9.90	7.16	22.68	26.63
	Vermicompost + Conventional Organic Practice (VCO)	12.14	9.07		



**(-)ve observation in one set under conventional organic practice was omitted for average calculation.*

Fig. 83: Impact of plant management on nutrient use efficiency of mature tea under different organic POP.

Higher value of AE_{CN} under IRF packages indicated most economic expense of compost- N for crop production. Agronomic efficiency of N can be increased by increasing plant uptake and decreasing N losses from the soil-plant system (Amanullah and Lal, 2009). Hence, the results obtained in these plots might be due to (i) improvement in soil-nutrient dynamics due to enhanced microbial proliferation and activity in these plots as influenced by the high self- generated microbial population within Novcom compost and (ii) enhancement of plant physiological functioning due to application of energized and potentized botanical solutions under Inhana plant management practice. Crop recovery efficiency of applied compost N (RE_{CN}) is defined as the amount of nutrient in the crop as a ratio of the amount applied or available. The value depends largely on the degree of congruence between plant N demand and the available supply of N from applied fertilizer or organic N sources. Consequently, optimizing the timing, quantity, and availability of applied N as well as activation of the plant physiology is the key towards achieving high RE (Dobermann, 2005). RE_{CN} was also highest in case of IRF packages, which once again indicated an effective plant management programme leading to efficient soil-plant-nutrient dynamics.

Variation in soil quality under different Organic Packages of Practice in mature tea plantation.

Top and sub soil samples were collected before initiation of experiment and then periodically i.e. 60, 90 and 150 days post application of soil inputs during each year i.e., from 2009 to 2011. The samples were analyzed for twenty different quality parameters *viz.* pH, electrical conductivity, cation exchange capacity, organic carbon, available- N, P, K, S, different forms of N, N-converters as well as total bacteria, fungi, actinomycetes and phosphate solubilizing bacteria.

Soil physical properties

Measurement of soil texture, bulk density, water holding capacity etc. provides useful indications regarding the state of soil compactness, translocation of water, air and root transmission. The soil of the experimental plots was found to be medium textured i.e. clay loam in nature with bulk density ranging from 1.15 to 1.25 gcm^{-3} (table 47). Water holding capacity of the soil, which provides information on the ability of soils for storing water and its subsequent availability to the crops varied between 38.7 and 49.2 percent.

Variation in electrochemical properties of soil

pH is an important criteria that directly regulates the nutrient availability in soil solution, and indirectly so by altering the soil micro-flora make-up, which play a primary role in maintaining the soil-plant- nutrient dynamics. In general soil of the experimental plots was found to be strongly acidic in reaction (table 48), pH varying from 4.25 to 4.59, and increased slightly post three years of experimentation. Electrical conductivity of the soils ranged from 0.037 to 0.063 dSm^{-1}. Cation exchange capacity (C.E.C.) of the soil were of low to medium range varying from 13.85 to 18.08 cmol $(p+)kg^{-1}$. Increase in CEC value of soil (although insignificantly) was noticed post three years of experimentation, except in case of plots receiving VMI package as compared to control plots.

Variation in soil fertility status

Soil fertility, which indicated the ability of soil reserves to supply adequate levels of essential nutrients needed for plant growth, affects agricultural productivity and sustainability. Especially sustenance and upliftment of the soil organic carbon levels forms the primary objective of organic management practices. The organic carbon content in the experimental plots ranged from 0.68 to 0.94 percent. Post three years of experimentation the values were found to increase slightly in the different treatment plots (Fig. 84) except in case of plots receiving CO and IRF-2 packages where significant increase was noticed over control *vis-a-vis* rest others. The high soil organic carbon values in CO plots might be due to the high dose of compost application in these soil at the rate of about 13.5 ton/ha (table 49).

The relevance of nitrogen in vegetative propagated crop like tea is well understood. However, effective nitrogen management under organic practice is still felt to be a difficult task considering the low nutrient content and slow releasing potential of most of the available organic soil inputs. The soils of the experimental plots were found to be medium in available-N, varying from 413.8 to 474.8 $kgha^{-1}$. Post three years of experimentation available-N content in soil was found to increase (except in case of control). However, significant increase was noted only in case of IRF-2 and IRF-4 plots followed by MI, as compared to control and rest other treatment plots (Fig. 85). The higher availability of soil- N in IRF plots might indicate better N mineralization in these soils under influence of Novcom compost, which contained a huge population of self- generated microbes.

Available- P_2O_5 is the most limiting nutrient in acid soil. At the same time their inherently low status in available organic soil inputs makes it a difficult nutrient for supplementation under organic practice. The only effective pathway remains to energize the soil microflora population in order to enable natural mineralization from soil reserve. Available-P_2O_5 in the treatment plots were of low status ranging between 18.3 and 33.8 $kgha^{-1}$. However, post three years of experimentation phosphate status was found to increase under application of different packages (discussed earlier) more so significantly in case of IRF-4 and BD plots, as compared to control (Fig. 86).

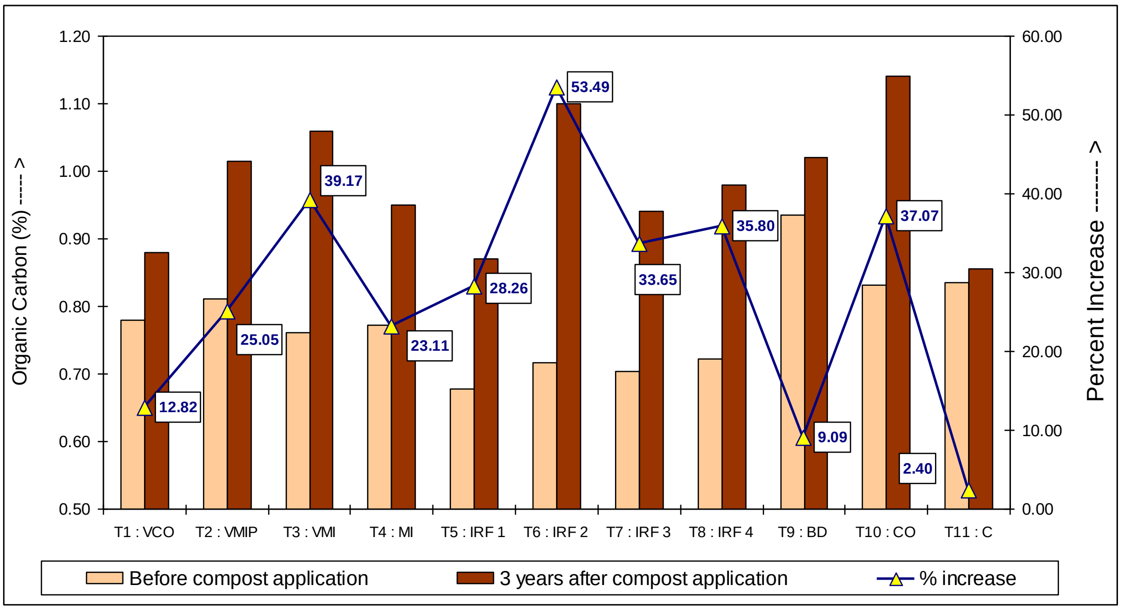


Fig. 84: Variation in soil organic carbon values under different Organic Packages of Practice before and after 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

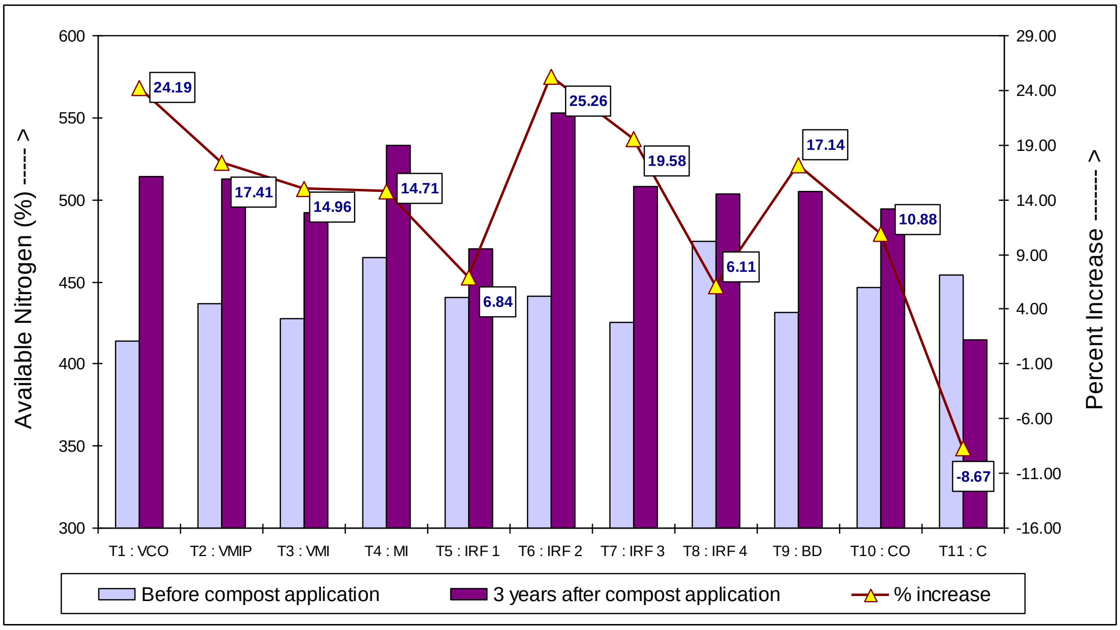


Fig. 85: Variation in soil available-N under application of different Organic Packages of Practice before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

Table 47 : Physical characteristics of soil in the different treatment plots before initiation of experiment.

Treatment	Depth (cm)	Particle size distribution (%) Sand	Silt	Clay	Texture	Bulk density (gcm^{-3})	Particle density (gcm^{-3})	% pore space	Max. WHC (%)	Water in air dry soil (%)	Volume expansion (%)
T_1 : VCO	0- 25	32.88	35.45	31.67	cl	1.18	2.12	43.81	38.70	1.87	9.83
	25- 50	33.57	33.53	32.90	cl	1.17	2.04	42.43	43.95	1.92	9.14
T_2 : VMIP	0- 25	25.57	38.67	35.77	cl	1.22	2.31	47.44	47.35	2.32	9.87
	25- 50	28.77	37.13	34.10	cl	1.24	2.24	44.99	45.40	2.35	10.98
T_3 : VMI	0- 25	31.77	34.93	33.30	cl	1.18	2.31	47.82	48.15	2.49	10.26
	25- 50	33.77	35.53	32.37	cl	1.23	2.25	45.39	46.06	2.68	11.24
T_4 : MI	0- 25	34.03	30.40	35.57	cl	1.23	2.23	44.77	45.38	2.25	10.90
	25- 50	35.10	30.87	34.03	cl	1.21	2.15	43.78	44.45	1.98	9.88
T_5 : IRF-1	0- 25	31.10	36.27	32.63	cl	1.15	2.22	47.80	49.25	3.39	9.47
	25- 50	33.77	33.73	32.50	cl	1.16	2.11	44.51	47.12	3.49	10.47
T_6 : IRF-2	0- 25	29.35	36.49	34.17	cl	1.21	2.36	48.58	48.54	2.90	10.00
	25- 50	29.63	37.07	33.30	cl	1.23	2.31	46.86	46.62	2.48	10.45
T_7 : IRF-3	0- 25	31.77	33.67	34.57	cl	1.20	2.32	47.56	47.63	2.72	9.34
	25- 50	31.23	34.07	34.70	cl	1.25	2.27	45.33	44.69	2.72	10.02
T_8 : IRF-4	0- 25	26.91	38.55	34.53	cl	1.17	2.18	46.21	47.99	2.16	9.94
	25- 50	28.12	37.71	34.17	cl	1.17	2.12	44.34	45.97	3.24	9.63
T_9 : BD	0- 25	28.53	38.90	32.57	cl	1.21	2.21	45.12	45.88	1.92	10.34
	25- 50	28.57	37.27	34.17	cl	1.22	2.25	46.22	45.40	2.76	9.93
T_{10} : CO	0- 25	34.90	32.20	32.90	cl	1.22	2.34	48.07	47.48	1.58	9.64
	25- 50	36.77	29.80	33.43	cl	1.22	2.31	46.99	46.41	1.13	9.74
T_{11} : C	0- 25	23.93	44.50	31.57	cl	1.20	2.23	46.32	47.62	3.10	10.02
	25- 50	24.47	43.63	31.90	cl	1.21	2.21	44.69	45.91	3.20	10.54

Table 48 : Variation in electrochemical properties of soil under application of different organic packages of practice.

Treatments	Before Initiation of Experiment			After Completion of Experiment (3 years)		
	pH (H_2O)	EC (dSm^{-1})	CEC cmol $(p^+)kg^{-1}$	pH (H_2O)	EC (dSm^{-1})	CEC cmol $(p+)kg^{-1}$
T_1 : VCO	4.37 ^{ab*}	0.037 ^{NS}	16.99 ^{NS}	4.44 ^{cd}	0.054 ^{b}	18.18 ^{ab}
T_2 : VMIP	4.47 ^{ab}	0.045 ^{NS}	16.99 ^{NS}	4.49 ^{b}	0.043 ^{d}	18.47 ^{ab}
T_3 : VMI	4.55 ^{ab}	0.042 ^{NS}	15.45 ^{NS}	4.58 ^{a}	0.042 ^{d}	18.62 ^{a}
T_4 : MI	4.42 ^{ab}	0.063 ^{NS}	15.10 ^{NS}	4.39 ^{ef}	0.055 ^{b}	17.15 ^{ab}
T_5 : IRF-1	4.35 ^{ab}	0.055 ^{NS}	15.64 ^{NS}	4.49 ^{b}	0.062 ^{a}	18.14^{ab}
T_6 : IRF-2	4.37 ^{ab}	0.055 ^{NS}	15.61 ^{NS}	4.40 ^{def}	0.063 ^{a}	17.55 ^{ab}
T_7 : IRF-3	4.25 ^{b}	0.063 ^{NS}	13.85 ^{NS}	4.37 ^{f}	0.052^{b}	17.92 ^{ab}
T_8 : IRF-4	4.30 ^{ab}	0.045 ^{NS}	15.66 ^{NS}	4.42 ^{de}	0.048 ^{c}	18.01 ^{ab}
T_9 : BD	4.47 ^{ab}	0.050 ^{NS}	18.08 ^{NS}	4.24 ^{g}	0.038 ^{e}	18.13 ^{ab}
T_{10} : CO	4.59 ^{a}	0.050 ^{NS}	14.77 ^{NS}	4.47 ^{bc}	0.061 ^{a}	17.02 ^{ab}
T_{11} : C	4.44 ^{ab}	0.038 ^{NS}	17.18 ^{NS}	4.39 ^{ef}	0.032 ^{f}	16.68 ^{b}

**Duncan test ($p < 0.05$)*

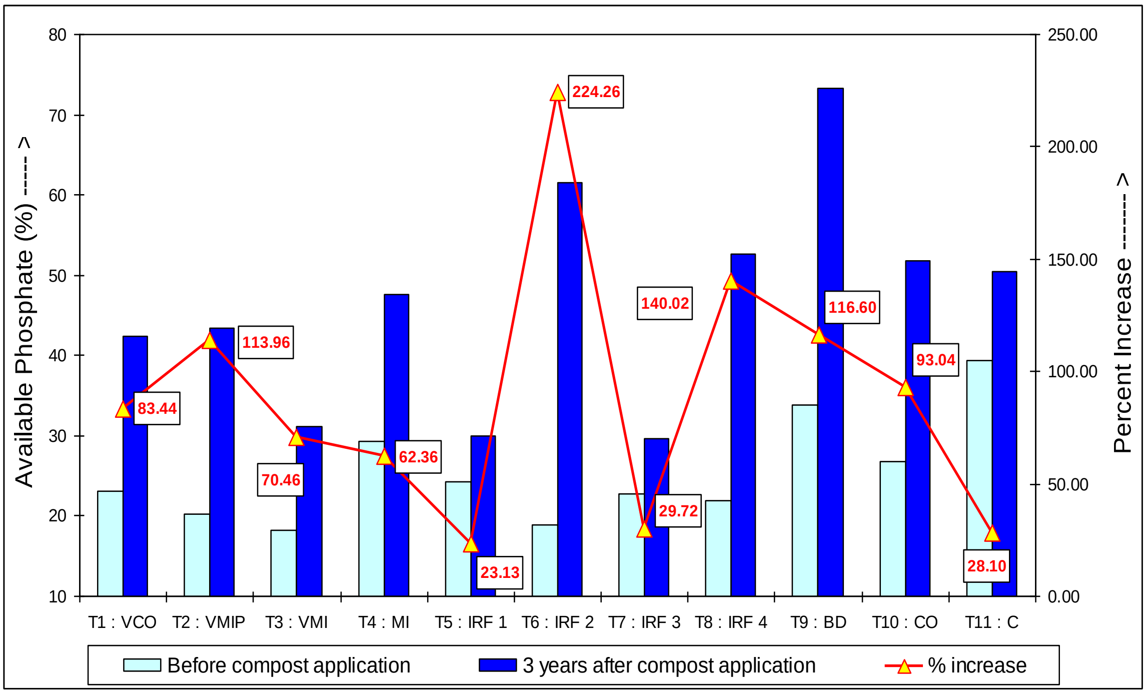


Fig. 86: Variation in soil available- P_2O_5 under application of different Organic Packages of Practice before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

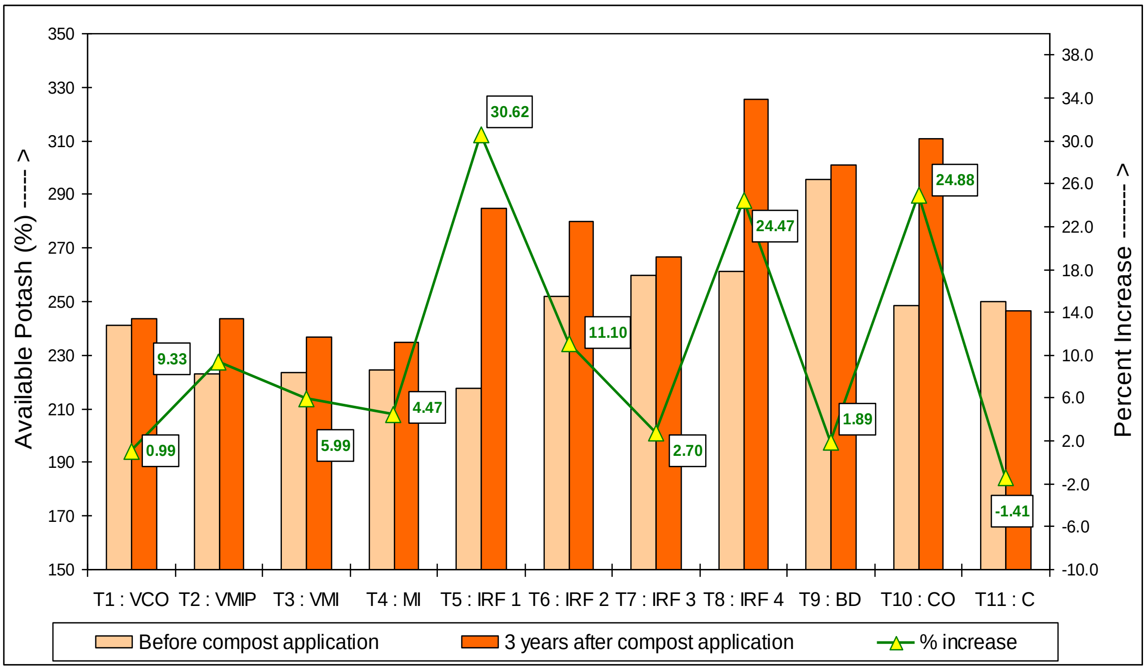


Fig. 87: Variation in soil available- K_2O under application of different Organic Packages of Practice before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

Available-K_2O in the different treatment plots varied from 217.8 to 295.4 $kgha^{-1}$. The values were found to increase slightly under application of different packages of practice for a period of three years (Fig. 87). However, the increase in potash status followed the same trend as observed in case of available-N and P_2O_5 being significant in case of plots receiving IFR-4 package (as compared to control). Available- varied from 9.3 to 28.3 $kgha^{-1}$ and the values increased in all the plots post three years of experimentation. However, significant increase was noticed only in case of plots receiving CO package, as compared to control and all other treatments.

Total nutrient content in terms of available N+P+K+S and its relationship with soil CEC was studied under different packages of practice (Fig. 88). In all cases (except control), soil CEC value increased under organic soil management and bore a close relationship with soil nutrient content.

Variation in soil microbiological status

Microbial activity is probably the most important factor that controls nutrient re-cycling in soil. Soil microflora is limited in acid tea soil, at the same time remains specifically important for sustained tea production, which can be obtained only through a regular and balanced supply of nutrients. Analysis of soil samples pre and post three years of experimentation showed an increase in soil microbial population in all the plots receiving different types of organic packages of practice (fig. 89). However, significant increase was noticed only in case of plots receiving IRF packages as compared to rest all other treatments including control (table 50A & 50B). Bacterial population was found to increase significantly in the plots receiving IRF-2. The high population of nitrosomonas and nitrobacter in IRF-1 treated plots indicated the scope for better nitrogen transformation and plant availability in these soils. At the same time considering that the soil in all experimental plots are inherently low in phosphate status, increase in the population of phosphate solubilizing bacteria (PSB) in soil post application of different organic packages of practice (more so significantly in the plots receiving IRF-3 package) might cause a positive influence towards phosphate availability in these acid tea soils as indicated in fig 90.

Total nutrient content in terms of available N+P+K+S also showed close positive relationship with total microbial count (Fig. 91). The finding indicated that consistent organic soil management programme helped to enhance soil microbial population which in turn played an important role towards better nutrient mineralization in soil.

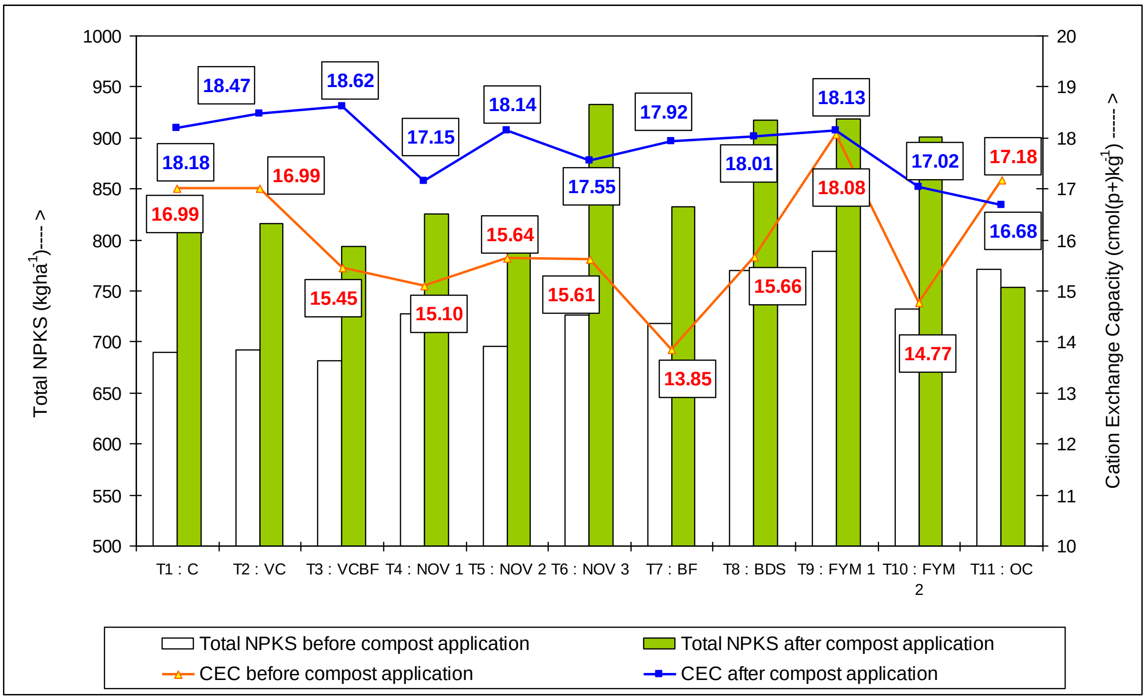


Fig. 88: Variation in soil available- NPKS and cation exchange capacity (CEC) under different Organic Packages of Practice before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

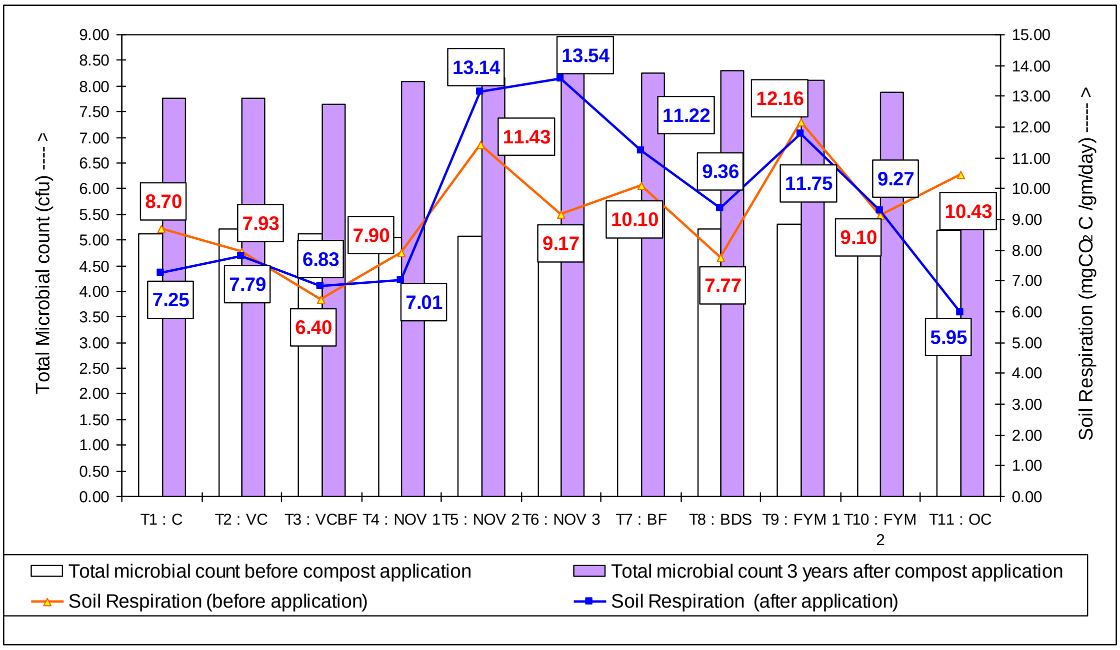


Fig. 89: Variation of soil microbial count and soil microbial respiration under different organic packages of practice before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

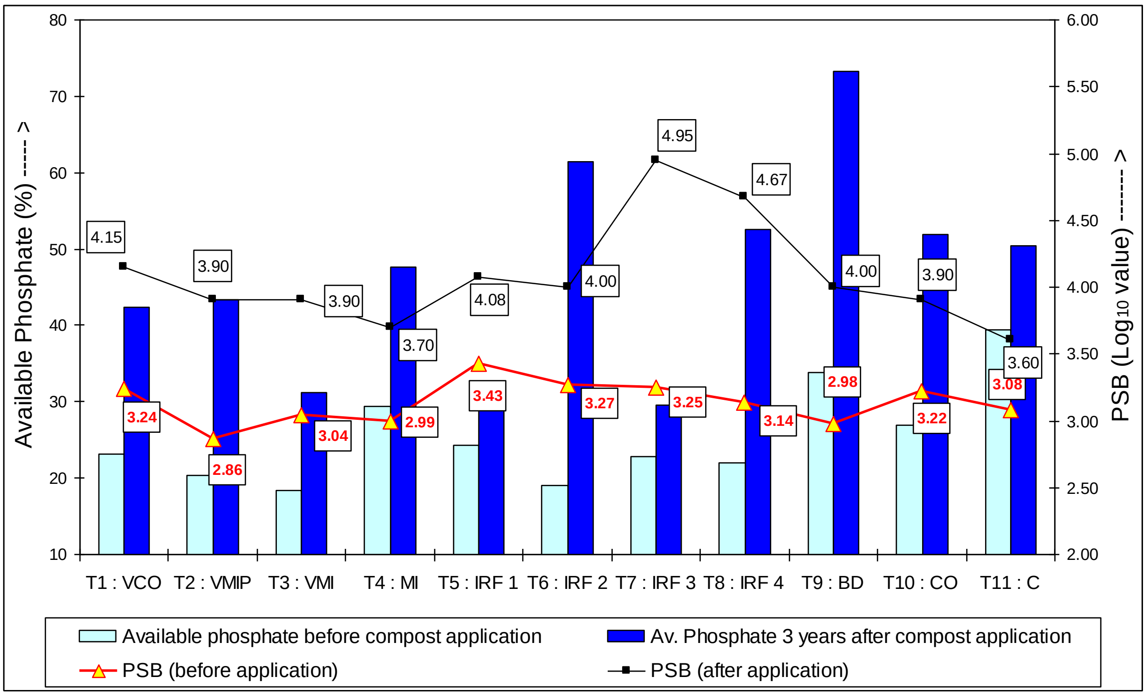


Fig. 90 : Variation in soil available- P_2O_5 and phosphate solubilizing bacteria (PSB) under different Organic Packages of Practice before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

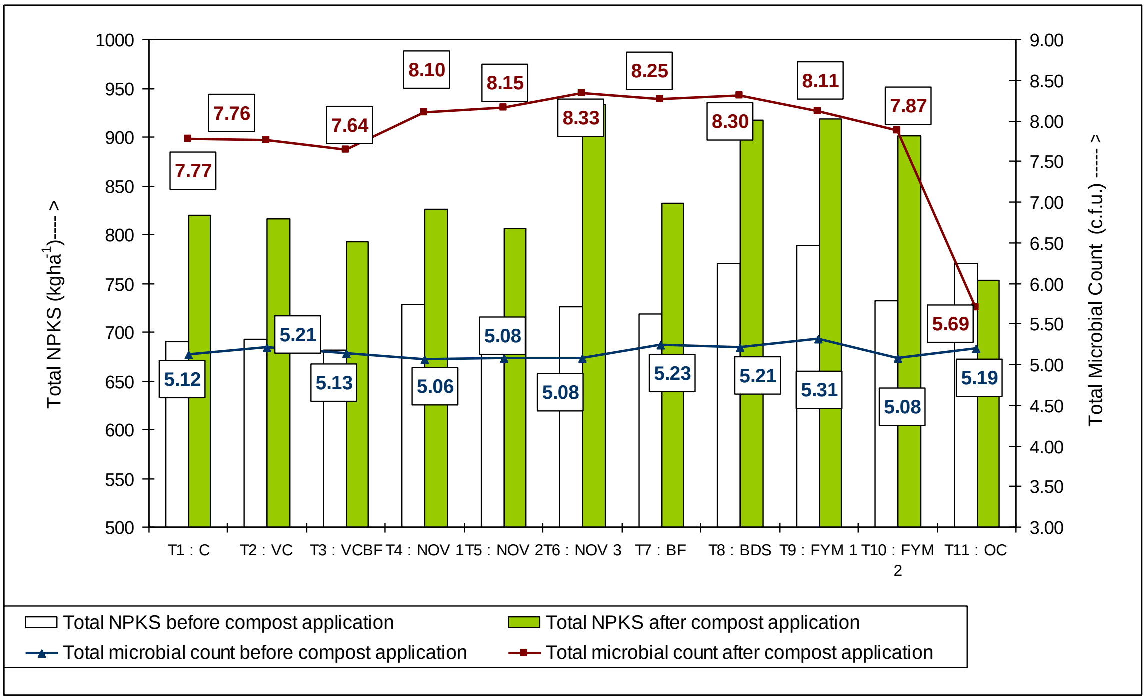


Fig. 91 : Variation of total NPKS and soil microbial count under different organic packages of practice before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

Table 49 : Variation in soil fertility under different organic packages of practice.

Treatments	Before Initiation of Experiment					After Completion of Experiment (3 years)				
	Org. C (%)	Av. N	Av. P_2O_5	Av. K_2O	Av. SO_4^{2-}	Org. C (%)	Av. N	Av. P_2O_5	Av. K_2O	Av. SO_4
		< ------------------ kgha^{-1} ------------------ >					< ------------------ kgha^{-1} ---------------- >			
T_1 : VCO	0.78 ^{ab}	413.81 ^{NS}	23.10 ^{cd}	241.28 ^{NS}	12.13 ^{b}	0.88 ^{g}	513.91 ^{c}	42.38 ^{d}	243.70 ^{fg}	19.68 ^{de}
T_2 : VMIP	0.81 ^{ab}	436.36 ^{NS}	20.27 ^{d}	222.88 ^{NS}	12.59 ^{b}	1.02 ^{d}	512.33 ^{cd}	53.37 ^{b}	243.68 ^{fg}	16.08 ^{ef}
T_3 : VMI	0.76 ^{ab}	427.85 ^{NS}	18.31 ^{d}	223.59 ^{NS}	11.77 ^{b}	1.06 ^{c}	491.88 ^{e}	31.20 ^{e}	236.98 ^{fg}	13.12 ^{fg}
T_4 : MI	0.78 ^{ab}	464.80 ^{NS}	29.31 ^{bc}	224.55 ^{NS}	9.34 ^{b}	0.95 ^{f}	533.17 ^{b}	47.59 ^{c}	234.59 ^{g}	10.43 ^{g}
T_5 : IRF-1	0.68 ^{b}	440.13 ^{NS}	24.29 ^{cd}	217.88 ^{NS}	13.06 ^{b}	0.87 ^{g}	470.26 ^{f}	29.91 ^{e}	284.59 ^{d}	20.87 ^{d}
T_6 : IRF-2	0.72 ^{ab}	441.59 ^{NS}	18.96 ^{d}	252.13 ^{NS}	13.77 ^{b}	1.10 ^{b}	553.14 ^{a}	41.48 ^{d}	280.12 ^{d}	38.06 ^{bc}
T_7 : IRF-3	0.71 ^{ab}	425.17 ^{NS}	22.81 ^{cd}	259.88 ^{NS}	10.55 ^{b}	0.94 ^{f}	508.40 ^{cde}	29.59 ^{e}	266.89 ^{e}	35.24 ^{c}
T_8 : IRF-4	0.72 ^{ab}	474.81 ^{NS}	21.92 ^{cd}	261.31 ^{NS}	12.36 ^{b}	0.98 ^{e}	553.82 ^{a}	69.27 ^{a}	325.25 ^{a}	40.24 ^{ab}
T_9 : BD	0.94 ^{a}	431.16 ^{NS}	33.86 ^{ab}	295.40 ^{NS}	28.27 ^{a}	1.02 ^{d}	505.06 ^{cde}	73.33 ^{a}	300.97 ^{c}	39.35 ^{bc}
T_{10} : CO	0.83 ^{ab}	446.21 ^{NS}	26.85 ^{b}	248.70 ^{NS}	10.47 ^{b}	1.14 ^{a}	494.76 ^{de}	51.83 ^{bc}	310.58 ^{b}	44.32 ^{a}
T_{11} : C	0.84 ^{ab}	454.08 ^{NS}	39.41 ^{a}	250.01 ^{NS}	27.49 ^{a}	0.86 ^{g}	414.71 ^{g}	50.49 ^{bc}	246.48 ^{f}	41.55 ^{ab}

**Duncan test ($p < 0.05$)*

Table 50A : Variation in soil microbial population under different organic packages of practice.

Treatments	Time of Sampling	Soil Microbial Population (in log_{10} value)							
		Bacteria	Fungi	Actino.[1]	Amm.[2]	Nitroso.[3]	Nitrobac.[4]	PSB[5]	Soil Resp.*
		< ------------------------------ per gm moist soil ----------------------------- >							
T_1 : VCO	Before Initiation of Experiment	4.820 ab	4.733 bcd	4.088 NS	2.025 ab	2.582 a	2.471 NS	3.243 ab	8.70 NS
	After completion of experiment (3 years)	7.673 e	5.560 de	5.301 ef	5.227 c	4.577 bc	5.254 fg	4.141 c	6.25 d
T_2 : VMIP	Before Initiation of Experiment	4.930 ab	4.801 abc	4.134 NS	2.172 ab	2.235 ab	2.167 NS	2.859 b	7.93 NS
	After completion of experiment (3 years)	7.747 de	6.065 c	5.602 de	5.948 b	5.386 ab	6.419 b	3.884 d	7.12 d
T_3 : VMI	Before Initiation of Experiment	4.838 ab	4.725 bcd	4.100 NS	2.013 ab	2.433 ab	2.492 NS	3.043 ab	6.40 NS
	After completion of experiment (3 years)	7.622 e	6.076 c	5.897 bcd	4.949 c	4.683 bc	5.320 efg	3.895 d	6.83 d
T_4 : MI	Before Initiation of Experiment	4.795 ab	4.581 d	4.155 NS	2.248 ab	2.059 ab	1.839 NS	2.994 ab	7.90 NS
	After completion of experiment (3 years)	8.090 c	5.460 e	6.072 abc	6.322 ab	4.615 bc	5.783 d	3.693 e	7.01 d
T_5 : IRF-1	Before Initiation of Experiment	4.766 b	4.701 bcd	4.052 NS	2.421 ab	1.915 b	1.915 NS	3.429 a	12.43 NS
	After completion of experiment (3 years)	8.148 bc	5.897 c	5.894 bcd	6.702 a	5.317 ab	6.633 a	4.061 cd	13.14 a
T_6 : IRF-2	Before Initiation of Experiment	4.729 b	4.724 bcd	4.115 NS	2.253 ab	2.306 ab	1.978 NS	3.271 ab	10.17 NS
	After completion of experiment (3 years)	8.328 a	6.460 b	6.039 abc	5.985 b	5.305 ab	5.503 e	3.990 cd	13.54 a

Table 50B : Variation in soil microbial population under different organic packages of practice.

Treatments	Time of Sampling	Soil Microbial Population (in log_{10} value)							Soil Resp.*
		Bacteria	Fungi	Actino.[1]	Amm.[2]	Nitroso.[3]	Nitrobac.[4]	PSB[5]	
		< ------------------------------ per gm moist soil ---------------------------- >							
T_7 : IRF-3	Before Initiation of Experiment	4.920 ab	4.893 ab	3.995 NS	2.528 ab	2.379 ab	2.398 NS	3.253 ab	11.10 NS
	After completion of experiment (3 years)	8.235 abc	6.754 a	6.235 ab	6.041 b	5.287 ab	6.251 bc	4.949 a	11.22 b
T_8 : IRF-4	Before Initiation of Experiment	4.896 ab	4.865 abc	3.941 NS	1.965 ab	2.242 ab	2.375 NS	3.138 ab	7.77 NS
	After completion of experiment (3 years)	8.283 ab	6.610 ab	6.341 a	6.004 b	5.177 ab	6.193 c	4.671 b	9.36 c
T_9 : BD	Before Initiation of Experiment	5.010 a	4.939 a	4.176 NS	2.353 ab	2.202 ab	2.291 NS	2.979 ab	13.17 NS
	After completion of experiment (3 years)	8.104 c	5.801 cd	5.767 cd	5.321 c	4.259 c	5.444 ef	3.995 cd	7.08 d
T_{10} : CO	Before Initiation of Experiment	4.784 ab	4.671 cd	4.104 NS	1.838 b	2.010 b	1.906 NS	3.224 ab	9.10 NS
	After completion of experiment (3 years)	7.863 d	5.826 cd	5.301 ef	6.322 ab	5.924 a	5.968 d	3.897 d	6.97 d
T_{11} : C	Before Initiation of Experiment	4.950 ab	4.686 cd	4.192 NS	2.548 a	2.255 ab	2.416 NS	3.082 ab	10.43 NS
	After completion of experiment (3 years)	6.986 f	4.986 f	5.218 f	4.359 d	4.301 c	5.135 g	3.602 e	6.28 d

[1]Actinomycetes, [2] Ammonifiers, [3] Nitrosomonas, [4] Nitrobacter, [5] Phosphate solubilizing bacteria, * Soil respiration

**Duncan test ($p < 0.05$)*

Variation in soil N- Dynamics under Application of Different Organic Packages of Practice.

The importance of soil- N dynamics in vegetative propagated crop like tea becomes all the more critical under organic management, considering the inherently low N content of organic soil inputs. Hence, efficient N supply to plants under organic management can be ensured only through invigoration of soil microflora population that regulates N transformation in soil, along with activation of plant physiology. For balanced plant nutrition, the dynamics of readily available– N in soil, which comprises both Ex. NH_4^+ and Ex. (NO_2+NO_3) forms, is important.

Readily available- N was found to increase slightly (Fig. 92) in all the treatment plots (w.r.t. control), except in case of IRF-2 where significant hike was recorded over all other treatments (table 51A & 51B). Exchangeable NH_4^+– N was also found to increase (Fig. 93) post application of the different packages, and followed the same trend as observed in case of readily available-N, increasing significantly in case of IRF-2; with respect to control as well as all other treatments. Significant increase in soil- N content was recorded in case of all the plots receiving IRF package, followed by BD package applied plots. Simultaneously percent increase in different forms of N was found to be highest in the plots receiving IRF-2 package. Especially in case of readily available– N and exchangeable (NO_2+NO_3)– N, 52.3 and 44.8 percent hike was recorded in these plots, while less that 20 percent increase in the respective values was observed under rest all other treatments.

Pic. 68 : Inter plot vegetative barrier to restrict overlapping of treatment effect.

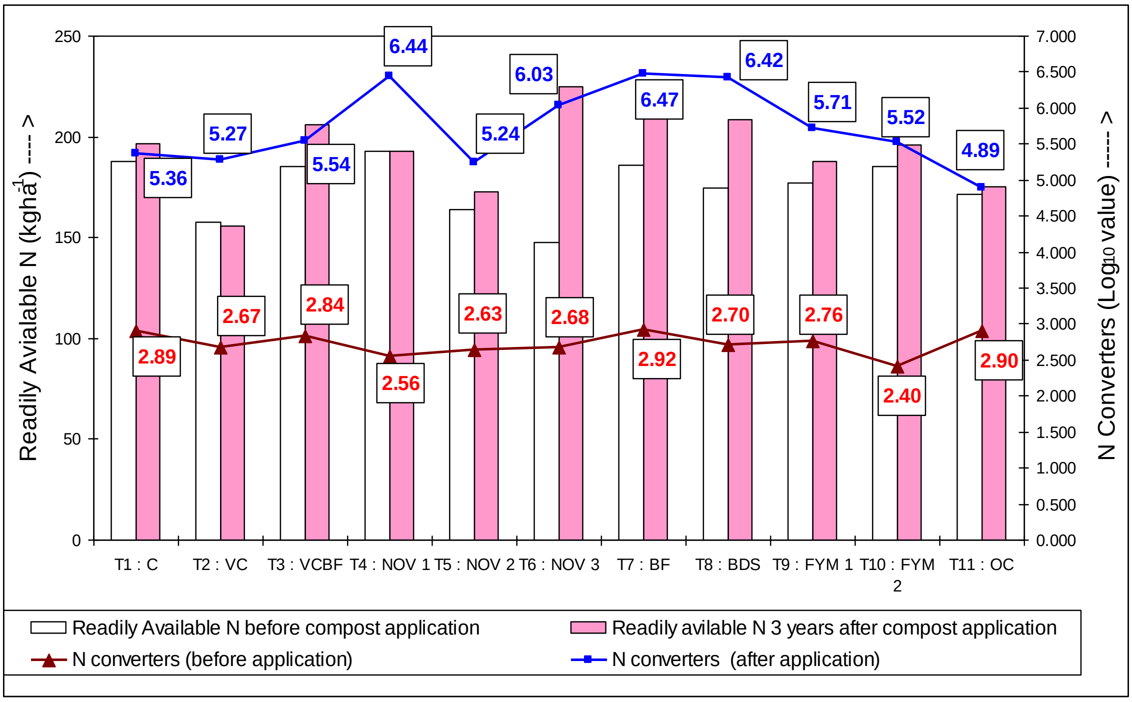


Fig. 92: Variation of readily available- N and N converters in soil under different organic packages of practice before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

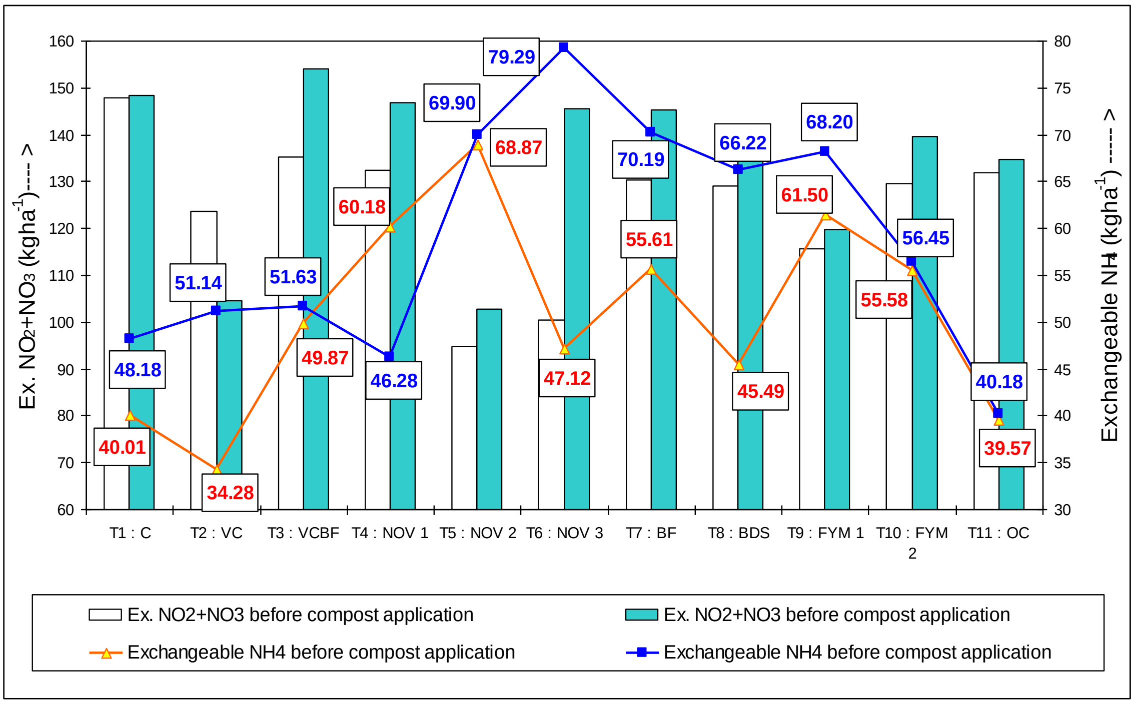


Fig. 93: Variation of exchangeable- (NO_2+NO_3) and exchangeable- NH_4^+ in soil under different organic packages of practice before and post 3 years of experimentation under FAO-CFC-TBI Project at Maud T.E., Assam.

Table 51A : Variation in different forms of N in soil under different organic packages of practice.

Treatments	Time of Sampling	Different forms of N ($kgha^{-1}$)					
		Readily Av. N	Total Min.* N	Exch. + Non Exch. NH_4	Exch. NH_4	Fixed NH_4	Exch. (NO_2+NO_3)
T_1 : VCO	Before Initiation of Experiment	187.80 NS*	231.59 NS	83.81 NS	40.01 NS	43.79 NS	147.79 a
	After completion of experiment (3 years)	196.63 cd	489.09 d	340.64 cd	48.18 d	292.46 bc	148.45 ab
T_2 : VMIP	Before Initiation of Experiment	157.96 NS	203.13 NS	79.45 NS	34.28 NS	45.17 NS	123.68 ab
	After completion of experiment (3 years)	155.80 f	440.28 g	335.62 de	51.14 cd	284.48 cd	104.66 d
T_3 : VMI	Before Initiation of Experiment	184.77 NS	234.44 NS	99.21 NS	49.87 NS	49.67 NS	134.90 ab
	After completion of experiment (3 years)	205.72 bcd	504.25 c	350.16 c	51.63 cd	298.53 b	154.09 a
T_4 : MI	Before Initiation of Experiment	192.56 NS	244.59 NS	112.21 NS	60.18 NS	52.03 NS	132.38 ab
	After completion of experiment (3 years)	193.14 cd	454.54 f	307.68 f	46.28 de	261.40 ef	146.86 ab
T_5 : IRF-1	Before Initiation of Experiment	163.73 NS	213.25 NS	118.38 NS	68.87 NS	49.51 NS	94.87 b
	After completion of experiment (3 years)	172.58 ef	387.02 h	284.34 g	69.90 b	214.44 g	102.68 d
T_6 : IRF-2	Before Initiation of Experiment	147.58 NS	203.99 NS	103.53 NS	47.12 NS	56.41 NS	100.46 ab
	After completion of experiment (3 years)	224.75 a	521.78 a	376.32 b	79.29 a	297.03 bc	145.46 ab

[1] Total mineralizable- N

Table 51B : Variation in different forms of N in soil under different organic packages of practice.

Treatments	Time of Sampling	Different forms of N ($kgha^{-1}$)					
		Readily Av. N	Total Min.[1] N	(Ex.+Non Ex.) NH_4	Ex. NH_4	Fixed NH_4	Ex. (NO_2+NO_3)
T_7 : IRF-3	Before Initiation of Experiment	185.99 ^{NS}	252.12 ^{NS}	121.74 ^{NS}	55.61 ^{NS}	66.13 ^{NS}	130.38 ^{ab}
	After completion of experiment (3 years)	215.52 ^{ab}	471.55 ^{e}	326.22 ^{e}	70.19 ^{b}	256.03 ^{f}	145.33 ^{ab}
T_8 : IRF-4	Before Initiation of Experiment	174.44 ^{NS}	226.88 ^{NS}	97.92 ^{NS}	45.49 ^{NS}	52.43 ^{NS}	128.96 ^{ab}
	After completion of experiment (3 years)	208.24 ^{abc}	481.24 ^{d}	339.22 ^{d}	66.22 ^{b}	273.00 ^{de}	142.02 ^{ab}
T_9 : BD	Before Initiation of Experiment	177.28 ^{NS}	234.46 ^{NS}	118.68 ^{NS}	61.50 ^{NS}	57.18 ^{NS}	115.79 ^{ab}
	After completion of experiment (3 years)	188.08 ^{de}	508.92 ^{bc}	389.04 ^{a}	68.20 ^{b}	320.84 ^{a}	119.88 ^{c}
T_{10} : CO	Before Initiation of Experiment	185.25 ^{NS}	249.48 ^{NS}	119.80 ^{NS}	55.58 ^{NS}	64.22 ^{NS}	129.68 ^{ab}
	After completion of experiment (3 years)	196.08 ^{cd}	517.31 ^{ab}	377.68 ^{b}	56.45 ^{c}	321.23 ^{a}	139.63 ^{ab}
T_{11} : C	Before Initiation of Experiment	170.58 ^{NS}	217.28 ^{NS}	85.27 ^{NS}	39.57 ^{NS}	45.70 ^{NS}	131.01 ^{ab}
	After completion of experiment (3 years)	174.98 ^{e}	435.84 ^{g}	301.04 ^{f}	40.18 ^{e}	260.86 ^{ef}	134.80 ^{b}

Duncan test ($p < 0.05$), [1] Total mineralizable- N

Pic. 69 : Landscape view of experimental plots under mature tea at Maud T.E.

Pic. 70 : New leaf flush after LP operation in 2010 in the experimental plots.

Pic. 71 : Professors of Calcutta University witnessing new leaf flush in the experimental plots.

Variation of Soil Development Index (SDI) under Different Organic Packages of Practice.

Soil development index (SDI) forms an important tool towards preparation of 'Soil Resource Map' of an area and its periodical evaluation enables assessment of the effectivity of soil management practices undertaken. Being positively interrelated, an improvement in SDI shall be automatically reflected in crop performance (Fig. 94). Variation in SDI during three years of experimentation is represented in Fig. 95, 96 & 97.

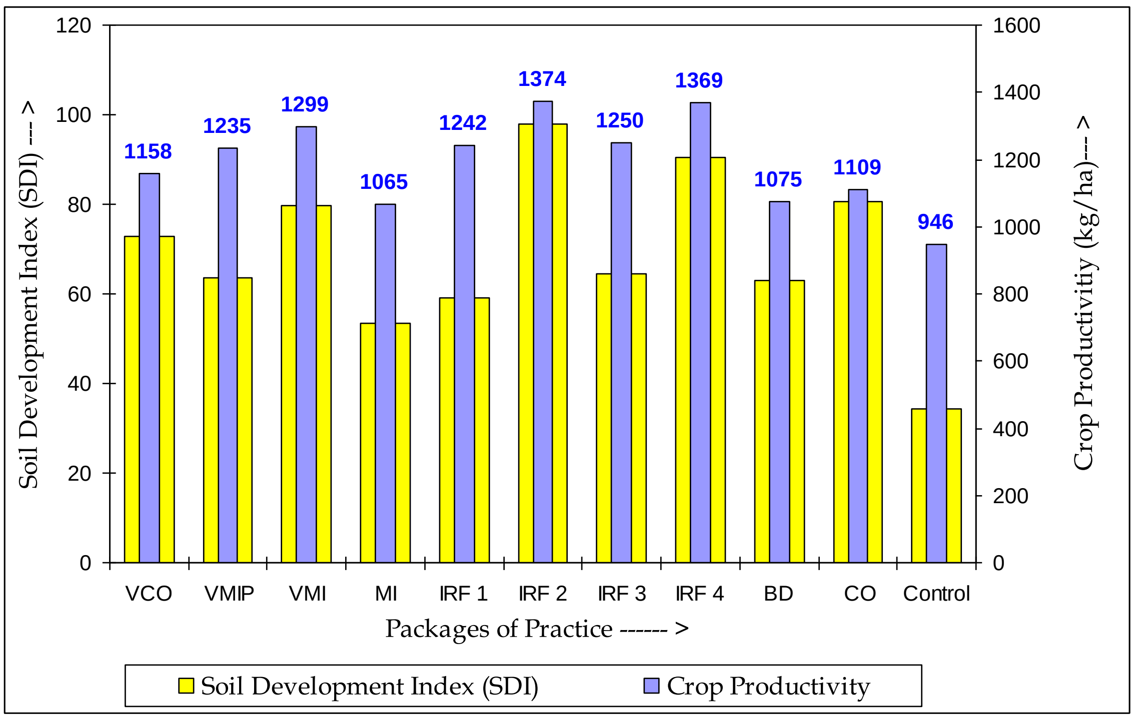


Fig. 94: Comparative Study of Soil Development under different organic Packages of Practice at Maud T. E. (Assam) over a period of 3 years.

Highest SDI was obtained in case of IRF-2 package (SDI: 97.9), followed by IRF-4 (SDI: 90.3), CO (SDI: 80.5), VMI (SDI: 79.7), and VCO (SDI: 72.9). The high SDI under IRF packages might be primarily due to application of highly charged Novcom compost containing huge population of self- generated microbes, along with other practices like *in-situ* composting, application of charged cow dung slurry solution, green manuring etc. The results were corroborated by the findings obtained under soil input experiment (i.e. in Sec. 6A), where highest SDI value was obtained in the plots receiving Novcom compost.

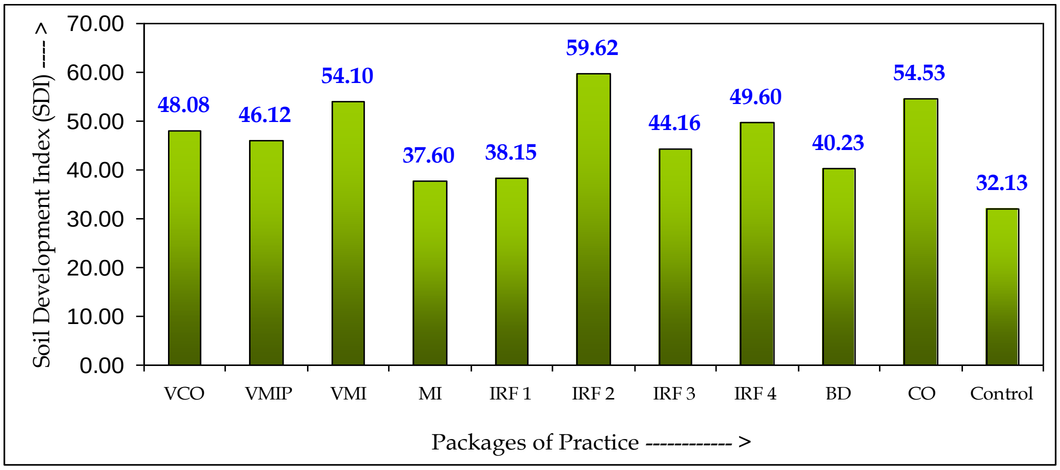


Fig. 95: Variation of Soil Development Index (SDI) under different organic Package of Practice during 2009 to 2010.

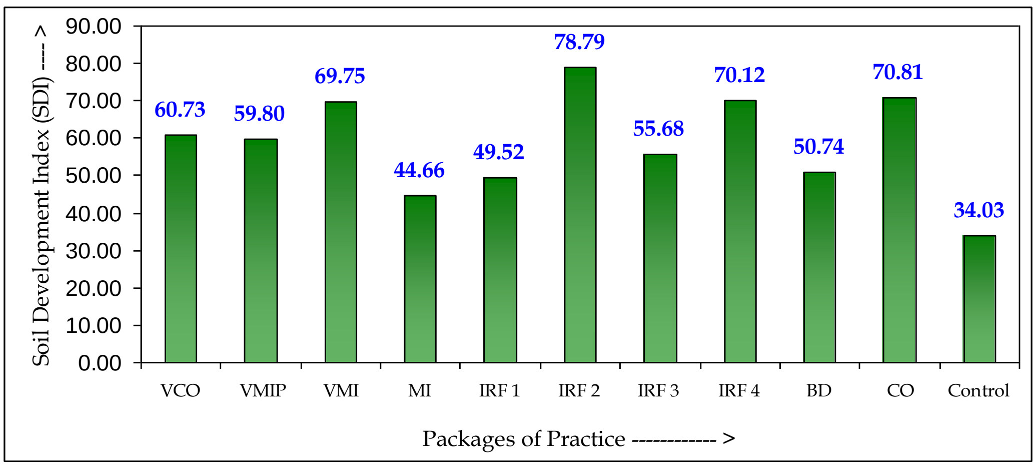


Fig. 96: Variation of Soil Development Index (SDI) under different organic Package of Practice during 2009 to 2011.

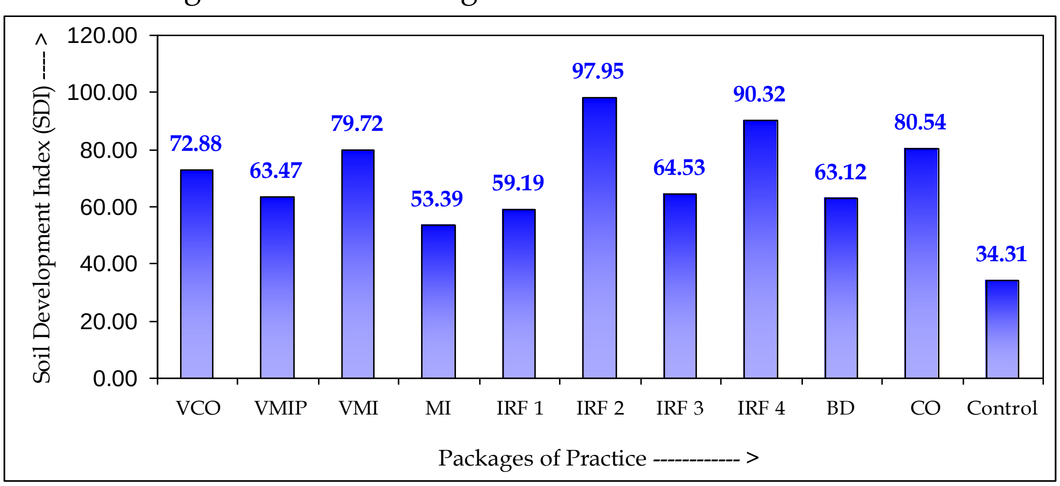


Fig. 97: Variation of Soil Development Index (SDI) under different organic Package of Practice during 2009 to 2012.

Large Scale Effectivity Assessment of the Different Organic Packages of Practice, under Minimal Microclimatic Influences, at Maud T.E. (Assam) in FAO-CFC-TBI Project.

Brief Summary

To study the adaptability potential of different organic packages of practice on large scale basis or in other words their lab to land potential, repetitive study was taken up in mature tea plantation.

The experiment was initiated from 2010 till 2011 using five organic packages as treatments, selected on the basis of their 1st year performance under Packages of Practice experiment in mature tea (i.e., Sec.4) as well as considering their individual relevance in organic tea cultivation.

No specific experimental design was followed and bigger plot size varying from 1.31 to 2.12 ha was taken up to evaluate the performance of different treatments in terms of crop yield, soil development and economics of cultivation in wider reference area.

Average yield of two years indicated consistently high performance of IRF-2 package (93 percent higher crop over control) as also witnessed under all the other package of practice experiments i.e., in new plantation, young tea and mature tea (i.e. Sec. 4). The high crop response was equally supported by the highest development of soil quality under this package as reflected by the highest SDI in comparison to the value obtained for rest other organic packages.

Also the highest crop yield under BD package was contradictory considering its relatively poor performance as recorded under all the other Package of Practice experiments covering different growth stages of tea. Hence, to scientifically evaluate whether the performance was due to some other influencing factor or treatment effect alone, benchmark data (in terms of crop yield) was collected from the same plots in 2012 (when all the plots received similar soil and plant/ pest management programme) and correlated with yield records of 2010 and 2011. The results indicated a depleting gradient of crop yield on shifting from the plot receiving BD package towards the control plot, thereby indicating higher inherent crop potential of the former plot that justified the highest crop yield recorded here.

Large Scale Effectivity Assessment of the Different Organic Packages of Practice, under Minimal Microclimatic Influences, at Maud T.E. (Assam) in FAO-CFC-TBI Project.

Guiding Concept

The experiment was initiated to assess how a particular organic Package of Practice delivers in a larger area as compared to its potential occurring under micro-climatic influence as well as wider heterogeneity in the small experimental plots. The experiment is of special significance for tea cultivation, where the packages performing in the experimental plots have to be applicable and ensure sustainability on larger scale i.e., in the gardens, which mostly spread over few hundred hectare area and also in various zones.

The experiment was initiated from the 2nd year (i.e. 2010) with five organic packages as treatments, selected on the basis of their 1st year performance under Packages of Practice experiment in mature tea (i.e., Sec.4) as well as considering their individual relevance in organic tea cultivation.

Objective

- To study the effectivity of different packages in larger area for wider adaptability.
- To study the difference between micro and macro results (Lab to Land Model).
- To study the degree of variance in performance of different packages due to presence/ absence of micro climatic influencing factors.

Methodology

Field experiment was laid out taking five packages of practice (with control) i.e. BD, VMI, VCO, IRF-1 and IRF-2 as treatments. The packages were evaluated for their performance (in terms of crop yield, soil development and economics) in wider scale to assess their potential for large scale adoptability. No specific design was followed for experimental lay out and bigger plot size varying from 1.31 to 2.12 ha was taken for the different treatments.

Treatment Details

T1	:	Control (C).
T2	:	Vermicompost @ 9.4 ton/ ha + Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK) + Bio-growth promoter + Bio-pesticides (VMI).
T3	:	Novcom compost @ 2.6 ton/ha + Elemental-S + Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-1).
T4	:	Vermicompost @ 9.4 ton/ ha + Herbal concoctions for pest and disease management (VCO).
T5	:	Novcom compost @ 8.0 ton/ha + Elemental-S + Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-2).
T6	:	Biodynamic compost @ 10 ton/ ha + Cow Pat Pit + Cow horn manure + Biodynamic package for plant management (BD).

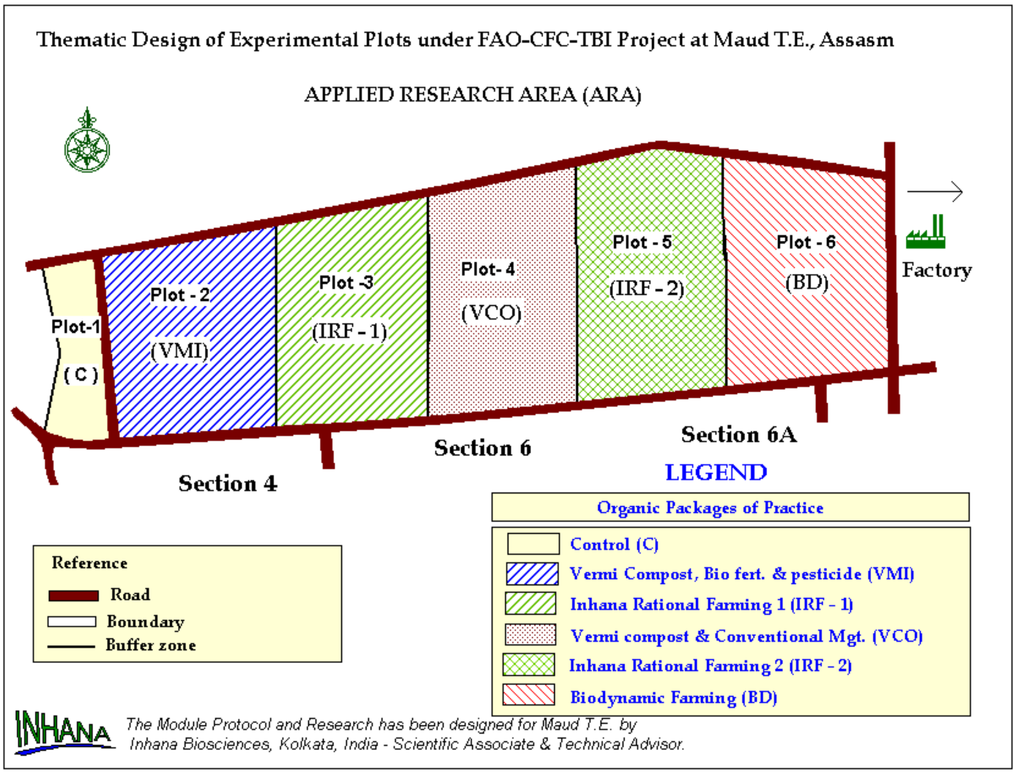


Fig. 98: Lay out of Applied Research Area (ARA) for large scale effectivity assessment of the different Organic Packages of Practice in mature tea plantation; under FAO-CFC-TBI project at Maud T.E. (Assam).

Pic. 72: View of large scale Package of Practice experiment in Mature Tea demarcated as Applied Research Area (ARA) under FAO-CFC-TBI Project, Maud T.E.

Pic. 73: Banner showing the objectivity of large scale Package of Practice experiment in Mature Tea at Maud T.E., Assam.

Large scale evaluation of the effectivity of different Organic 'Packages of Practice' (POP) in terms of yield performance of Mature Tea.

<u>Crop Performance in 2010 & 2011</u>

Crop response in terms of green leaf productivity ($kgha^{-1}$) was recorded under each plucking round from all the six treatment plots. Pruning style followed during 2010 and 2011 were unpruned and DS respectively (as per the Garden Pruning Cycle). Average yield of two years indicated almost at par and high performance of BD and IRF-2 packages which recorded 97 and 93 percent higher crop over control. The other three packages i.e. VMI, VCO and IRF-1 influenced less than 40 percent variations with respect to control (Fig. 99).

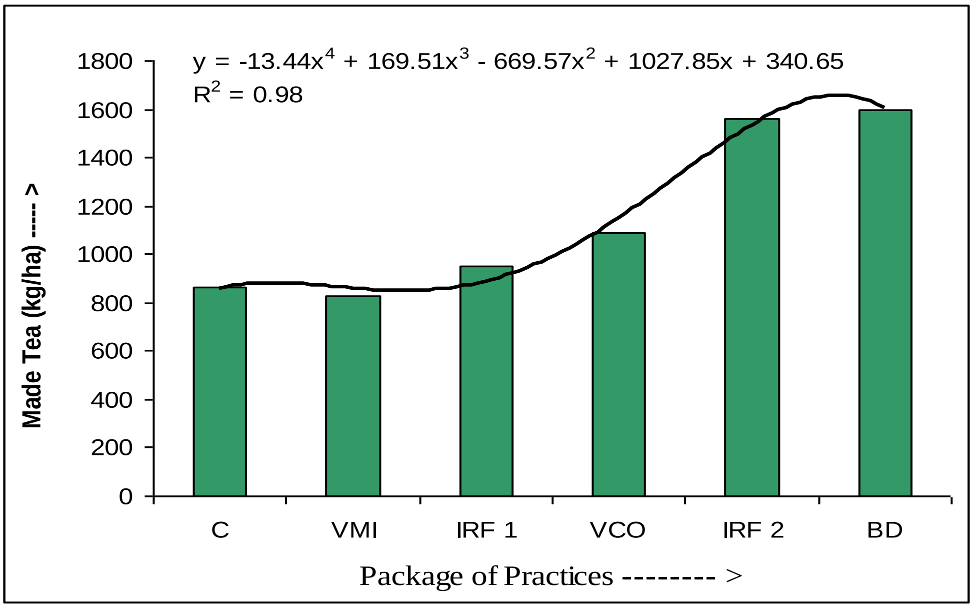


Fig. 99: Comparative evaluation of crop productivity under different organic Packages of Practice under large scale mature tea experiment at Maud T.E., Assam.

Performance of IRF-2 followed a consistent pattern as also observed under all the other experiments covering different growth stages of tea i.e. during 2009 to 2011. However, the high performance of BD package under this large scale experiment came as a surprise considering that it performed poorly under all the experiments i.e. nursery, new plantation, young tea and mature tea (Sec.4). Similarly the poor performance of VMI recorded here was in stark contrast to the potential exhibited under all the other package of practice experiments.

Table 52: Performance of different organic packages of practice in terms of crop efficiency & cost per hectare in large scale mature tea experiment under FAO-CFC-TBI Project.

Package of Practice	Crop Efficiency				Economics of packages of practice (Average of 2010 & 2011)		
	Year 2010 (Unprune)		Year 2011 (Deep skiff)				
	Yield (kg/ha)	Over control	Yield (kg/ha)	Over control	Cost / ha	Cost/kg made tea	Value Cost Ratio (VCR)[1]
T_1 : Control	1045	-	574	-	-	-	-
T_2 : Vermi compost + Microbial Formulation for Both Soil & Plant Management (VMI)	1089	4.21 %	598	4.18 %	Rs. 66,466/-	Rs. 78.80/-	0.10
T_3 : Inhana Rational Farming with 2.6 ton Novcom Compost (IRF-1)	1168	11.77 %	731	27.35 %	Rs. 9,152/-	Rs. 9.64/-	3.05
T_4 : Vermi compost + Conventional Organic Practice (VCO)	1366	30.72 %	805	40.24 %	Rs. 40,233/-	Rs. 37.06/-	1.37
T_5 : Inhana Rational Farming with 8 ton Novcom Compost (IRF-2)	1928	84.50 %	1200	109.06 %	Rs. 13,796/-	Rs. 8.82/-	10.93
T_6 : Biodynamic Package of Practice (BD)	1878	79.71 %	1321	130.14 %	Rs. 15,236/-	Rs. 9.53/-	10.36

[1]VCR : Value cost ratio

Note : *Quantity of various soil inputs were calculated on plant– N requirement basis i.e. for giving 60kg N; except for BD package which had fixed recommended dosage. Actual dosage was calculated based on N and moisture % in the soil input. Novcom compost was applied in combination with 40 kg Elemental-S & 80 kg Rock phosphate per hectare. In case of soil mgt. using Biodynamic compost, CPP @ 12.5 kg/ ha and Cow horn manure (15 ltr. soln/ ha) was also used.*

Pruning : UP - DS ; Bush Population : 13174/ha ; Age : 25 - 26 years; VCR was calculated considering Made tea @ Rs. 200/ kg

The huge variation in crop response under BD and VMI packages under large scale experiment as compared to their potentials recorded under other Package of Practice experiments covering different growth stages of tea definitely indicated towards the presence of some other influence other than treatment effect alone (table 52). Hence for scientific verification, benchmark data (in terms of crop yield) was collected from the same plots for another year i.e. 2012 and further correlated with the yield recorded from the same plots during 2010 and 2011.

Crop Performance in 2012 (HRP)

In 2012, the plots received HRP as per the Garden Pruning Cycle. All the plots (including control) received similar type of soil input with similar dosage (i.e. Novcom cmpost @ 3 ton/ ha) and no other foliar spray except Neem based product was given for pest management in the different treatment plots. Crop response in terms of green leaf productivity (kgha^{-1}) was recorded under each plucking round from all the six plots.

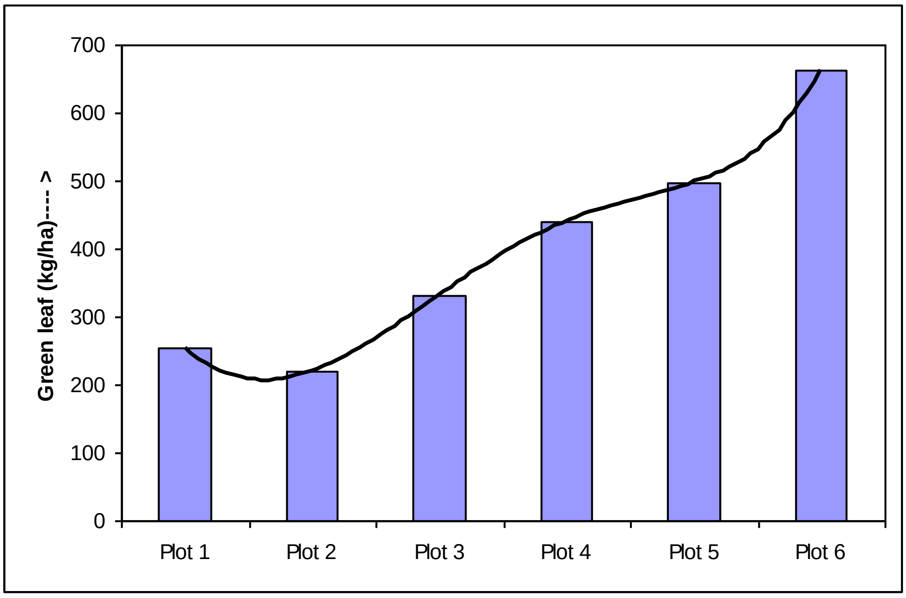


Fig. 100: Comparative evaluation of inherent crop potential in the individual plots under common management programme in Applied Research Area (ARA) at Maud T.E., Assam.

The results indicated a decreasing pattern of crop yield (Fig. 100) i.e. almost a depleting gradient from plot 6 to plot 2, rising slightly for plot 1. The finding definitely indicates higher inherent crop potential of plot 6, which might justify the highest crop yield recorded here under the otherwise poorly performing BD package as documented for package of practice experiments covering different growth stages of tea i.e., nursery, new plantation, young tea and mature tea (Sec. 4). Economics under the different packages was also evaluated and is represented by the following figure 101.

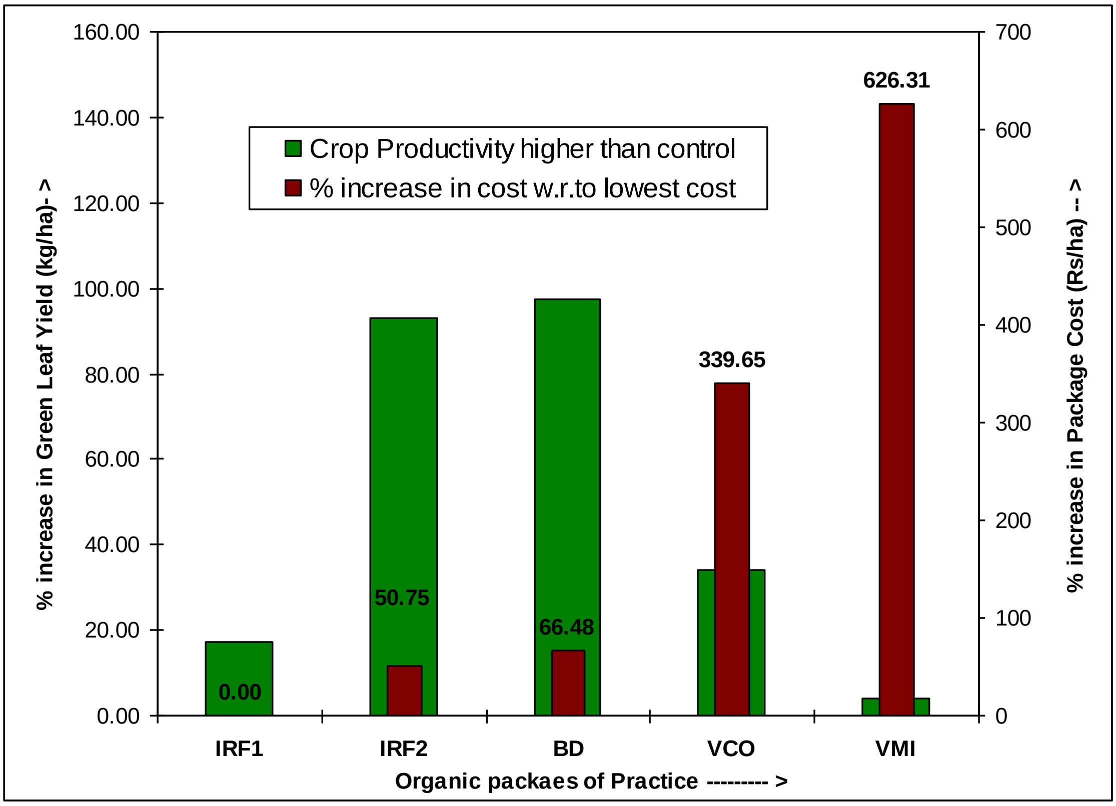


Fig. 101: Comparative study of percent crop increase and associated cost under different packages of practice in mature tea plantation under FAO-CFC-TBI Project at Maud T.E., Assam.

Variation in soil quality under different Organic Packages of Practice in mature tea plantation on large scale basis.

Top and sub soil samples were collected before initiation of experiment and then periodically i.e. 60, 90 and 150 days post application of soil inputs during 2010 and 2011. The samples were analyzed for twenty different quality parameters *viz.* pH, electrical conductivity, cation exchange capacity, organic carbon, available- N, P, K, S, different forms of N, N-converters as well as total bacteria, fungi, actinomycetes and phosphate solubilizing bacteria.

Soil physical properties

Soil physical properties not only act as the basic tool for deciding land use pattern, its evaluation also indicates the impact of the management practice undertaken, being especially relevant for judging the efficacy of organic soil management practices. Soil of the different treatment plots was found to be clay loam in texture with bulk density of 1.26 to 1.31 gcm^{-3} (table 53) and 41.3 to 47.3 percent water holding capacity.

Variation in electrochemical properties of soil

Electrochemical properties *viz.* pH, EC, CEC etc. are important criteria which regulate the availability of soil nutrients *viz.* nitrogen, potassium, phosphorus, etc. in soil solution, which the plants need in specific amounts to grow, thrive, and fight off diseases. Soil of the different treatment plots were found to be strongly acidic in reaction (table 54), pH varying from 4.60 to 4.77, and increased only slightly post two years of experiment. Electrical conductivity of the soils ranged from 0.031 to 0.038 dSm^{-1} with low cation exchange capacity, varying from 11.80 to 13.63 cmol $(p+)kg^{-1}$. Very insignificant increase in CEC value of soil was noticed post completion of experiment, in the different plots (except control).

Variation in soil fertility status

Soil fertility indicates its ability to supply elements essential for plant growth without a toxic concentration of any element that affects crop productivity as well as its disease fighting abilities. Especially organic carbon, which forms a major part of soil organic matter, acts as the store house of nutrients, cations and trace elements that are of importance to plant growth. Organic carbon varied from 0.78 to 0.97 percent in the different treatment plots and increased only slightly post two years of experimentation except in case of plots receiving VCO package and control (table 54).

Nitrogen (N) is a nutrient that is commonly in limited supply especially in acidic soil but at the same time is very important for vegetative propagated crop like tea. Low content of soil available- N (366.9 to 388.3 $kgha^{-1}$) was recorded for the different plots, which was found to increase only slightly post completion of experiment (except control).

P is an essential element for plant growth being involved in many critical plant metabolic functions. Phosphorus management can be difficult in organic production considering low phosphate content of compost/ manures as well as dependency on non-possessed mineral sources, which can often lead to under or over-fertilization of the plants. Available-P_2O_5 in the different treatment plots ranged between 38.0 and 49.6 $kgha^{-1}$. The status increased only slightly post two years of experimentation (except control) in the different treatment plots, except in case of plots receiving IRF-2 package where about 46 percent increment was recorded as compared to the initial value.

Available-K_2O varied from 229.2 to 258.2 $kgha^{-1}$ in the different treatment plots and increased only slightly under application of different packages of practice for a period of two years. Available-SO_4^{2-} in soil varied from 29.3 to 39.9 $kgha^{-1}$ and followed the same trend post completion of experiment, as observed in case of available-N.

Table 53: Physical characteristics of soil in the different treatment plots before initiation of experiment.

Treatment	Depth (cm)	Particle size distribution (%)			Texture	Bulk density	Particle density	% pore space	Max. WHC (%)
		Sand	Silt	Clay		< --- gcm^{-3}------ >			
T_1 : C	0 - 25	36.90	27.90	32.50	Clay loam	1.26	2.28	43.92	41.91
	25 - 50	38.21	28.70	33.10	Clay loam	1.28	2.29	43.62	41.71
T_2 : VMI	0 - 25	30.16	32.70	37.10	Clay loam	1.29	2.30	43.49	41.29
	25 - 50	28.46	32.30	39.20	Clay loam	1.29	2.29	43.62	41.72
T_3 : IRF 1	0 - 25	39.78	27.10	33.10	Clay loam	1.26	2.27	43.91	46.22
	25 - 50	33.02	32.10	34.90	Clay loam	1.26	2.28	43.74	45.19
T_4 : VCO	0 - 25	43.26	21.60	35.10	Clay loam	1.28	2.29	43.81	43.72
	25 - 50	37.76	25.20	37.10	Clay loam	1.29	2.30	43.22	41.76
T_5 : IRF 2	0 - 25	35.00	29.90	35.10	Clay loam	1.29	2.31	43.19	47.29
	25 - 50	39.78	25.10	35.10	Clay loam	1.29	2.30	43.02	44.27
T_6 : BD	0 - 25	37.10	24.30	37.10	Clay loam	1.30	2.32	43.66	43.19
	25 - 50	39.20	25.60	39.20	Clay loam	1.31	2.33	43.71	42.22

Table 54: Variation in soil physicochemical properties and fertility status under different organic packages of practice.

Treatments	Time of Sampling	Soil Physico-chemical and Fertility Parameters							
		pH (H_2O)	EC (dSm^{-1})	CEC (cmol $(p^+)kg^{-1}$)	Org. C (%)	Av. N	Av. P_2O_5	Av. K_2O	Av. SO_4^{2-}
						< ---------------- $kgha^{-1}$ ---------------- >			
T_1 : C	Before Initiation of Experiment	4.77	0.038	12.65	0.97	387.30	44.00	252.68	29.34
	Post 2 years of experiment	4.71	0.032	12.40	0.88	372.66	38.27	224.61	23.74
T_2 : VMI	Before Initiation of Experiment	4.60	0.033	12.24	0.88	374.76	38.04	258.20	39.95
	Post 2 years of experiment	4.76	0.035	14.96	0.92	406.11	40.19	283.84	40.29
T_3 : IRF 1	Before Initiation of Experiment	4.64	0.031	12.21	0.84	366.91	40.08	243.72	28.15
	Post 2 years of experiment	4.74	0.037	13.44	0.87	370.05	49.57	261.45	44.67
T_4 : VCO	Before Initiation of Experiment	4.62	0.032	12.61	0.81	376.32	49.95	229.84	31.55
	Post 2 years of experiment	4.64	0.038	13.76	0.77	381.23	49.51	269.84	49.97
T_5 : IRF 2	Before Initiation of Experiment	4.64	0.031	13.63	0.78	368.11	42.55	229.24	32.55
	Post 2 years of experiment	4.75	0.039	14.40	0.97	387.52	62.30	272.31	40.29
T_6 : BD	Before Initiation of Experiment	4.70	0.035	11.80	0.84	388.28	40.68	242.08	31.14
	Post 2 years of experiment	4.78	0.038	12.96	0.87	395.14	42.48	262.88	34.99

Table 55: Variation in different forms of nitrogen in soil under different organic packages of practice.

Treatments	Time of Sampling	Different forms of N ($kgha^{-1}$)					
		Readily Av. N	Total Min. N	Exch. + Non Exch. NH_4	Exch. NH_4	Fixed NH_4	Exch. (NO_2+NO_3)
T_1 : C	Before Initiation of Experiment	162.70	289.76	176.22	49.16	127.06	113.54
	Post 2 years of experiment	267.75	424.34	233.04	76.45	156.59	191.30
T_2 : VMI	Before Initiation of Experiment	280.09	412.76	189.78	57.11	132.67	222.98
	Post 2 years of experiment	334.90	521.40	261.76	75.26	186.50	259.64
T_3 : IRF-1	Before Initiation of Experiment	274.76	396.22	171.22	49.76	121.46	225.00
	Post 2 years of experiment	350.53	501.76	207.68	56.45	151.23	294.08
T_4 : VCO	Before Initiation of Experiment	246.19	389.59	193.16	49.76	143.40	196.43
	Post 2 years of experiment	337.60	533.12	239.42	43.90	195.52	293.70
T_5 : IRF-2	Before Initiation of Experiment	288.25	456.58	212.11	43.78	168.33	244.47
	Post 2 years of experiment	356.18	546.40	240.40	50.18	190.22	306.00
T_6 : BD	Before Initiation of Experiment	242.91	431.58	245.78	57.11	188.67	185.80
	Post 2 years of experiment	304.66	530.80	276.32	50.18	226.14	254.48

Variation in soil microbiological status

Soil microbial activity is critical not only for effective nutrient re-cycling but also for suppression of the soil borne plant pathogens, thereby ensuring healthy and productive growth of plants. Analysis of soil samples pre and post two years of experimentation showed an increase in the population of different types of soil microbes in all the treatment plots (except control). However, substantial increase in microflora population especially in terms of total bacteria; was noticed only in case of plots receiving IRF-2 package as compared to rest all other treatments including control (table 56). Most importantly the noticeable increase in the population of soil- N converters *viz.* ammonifiers, nitrosomonas, nitrobacter as well as PSB under this package might enable better nitrogen (Fig. 102) and phosphate transformation in soil leading to their efficient availability for plants in these acid tea soils.

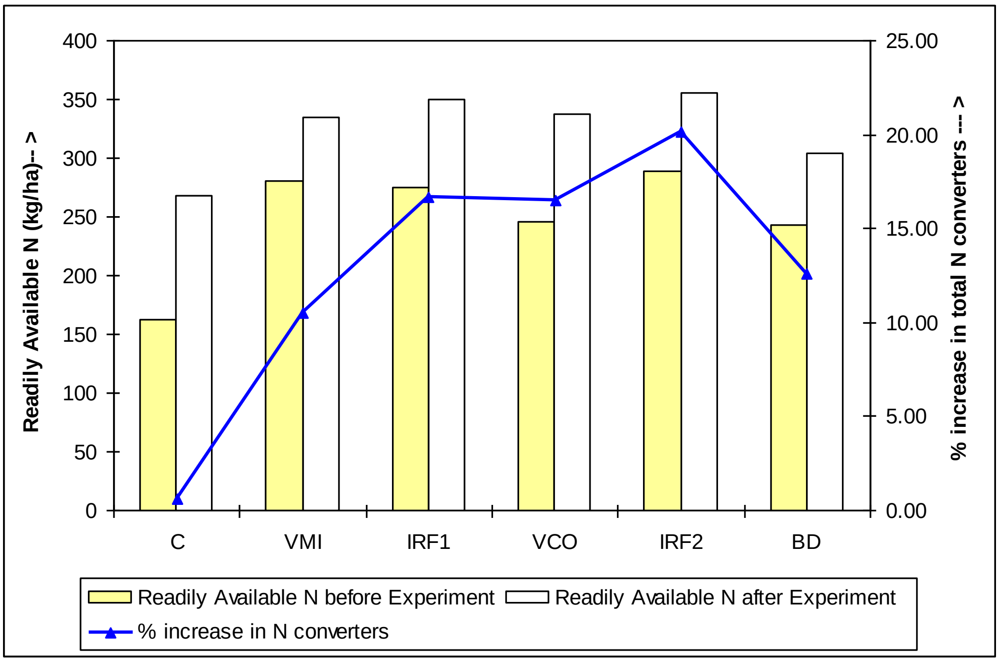


Fig. 102: Variation in readily available- N content of soil with increase in N-converters under different packages of practice before and post 2 years of experimentation under FAO-CFC-TBI Project at Maud T.E. (Assam).

Table 56: Variation in soil microbial population under different organic packages of practice.

Treatments	Time of Sampling	Soil Microbial Population (in log_{10} value)							Soil Respiration ($mgCO_2$-C/g OM/day)
		Bacteria	Fungi	Actino.[1]	Amm.[2]	Nitroso.[3]	Nitrobac.[4]	PSB[5]	
		< ---- per gm moist soil ---- >							
T_1 : C	Before Initiation of Experiment	6.012	5.046	5.079	3.477	4.531	4.638	5.041	8.17
	Post 2 years of experiment	6.033	4.568	4.362	4.079	4.908	4.672	4.672	9.62
T_2 : VMI	Before Initiation of Experiment	6.362	5.067	5.061	3.602	4.591	4.544	5.021	9.22
	Post 2 years of experiment	8.117	5.079	5.255	4.415	5.519	5.000	5.079	12.24
T_3 : IRF-1	Before Initiation of Experiment	6.658	5.022	5.139	3.477	4.389	4.531	4.978	9.06
	Post 2 years of experiment	8.061	5.146	5.342	4.556	5.806	5.176	5.146	12.19
T_4 : VCO	Before Initiation of Experiment	6.712	5.143	5.180	3.653	4.041	4.279	4.746	8.63
	Post 2 years of experiment	8.072	5.255	5.255	4.362	5.146	5.000	5.000	11.69
T_5 : IRF-2	Before Initiation of Experiment	6.648	5.067	5.162	3.544	4.389	4.681	4.681	8.81
	Post 2 years of experiment	8.215	5.398	5.230	4.591	5.806	5.230	5.447	12.48
T_6 : BD	Before Initiation of Experiment	6.638	4.929	5.198	3.699	4.161	4.531	4.732	8.02
	Post 2 years of experiment	7.342	5.204	5.204	4.230	5.505	4.602	4.914	10.84

[1]Actinomycetes, [2] Ammonifiers, [3] Nitrosomonas, [4] Nitrobacter, [5] Phosphate solubilizing bacteria.

The overall variation in soil quality post application of different organic packages of practice was assessed through calculation of soil development index (SDI).

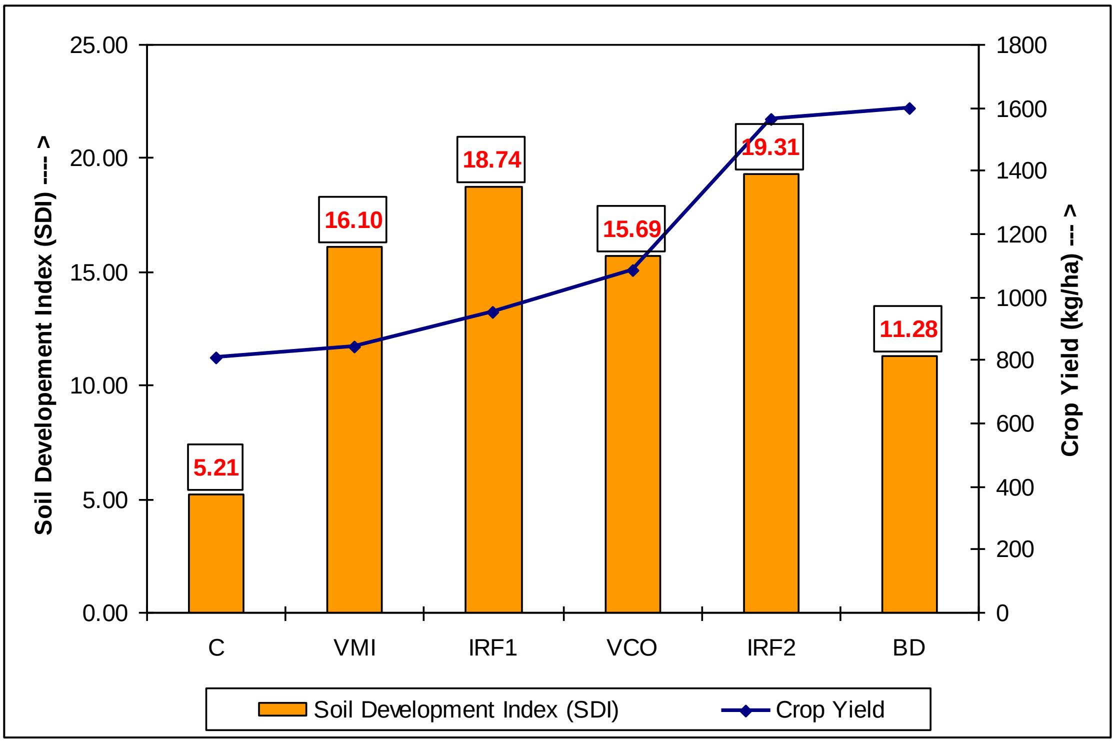


Fig. 103: Comparative study of soil development under different Packages of Practice at Maud T. E. (Assam) over a period of 2 years.

Highest SDI was obtained in case of IRF-2 (SDI: 19.3), followed by IRF-1 (SDI: 18.7), VMI (SDI: 16.1), VCO (SDI: 15.69), and BD (SDI: 11.28) packages (Fig. 103). High SDI values obtained under IRF packages conclusively indicate towards effective soil management programme as also corroborated by the results obtained under soil input experiment (i.e., in Sec.6A where highest SDI value was obtained under Novcom compost application, which forms the soil management component under IRF package) as well as package of practice experiment in new plantation, young tea and mature tea (Sec.4).

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Impact of Inhana Rational Farming (IRF) Package in Rest of the Garden Area of Maud T.E., Assam

Brief Summary

Inhana Rational Farming (IRF) package was adopted and practiced in the entire area (excluding the micro experimental area) of Maud T.E. i.e. in 135 ha area, during 2009 to 2011. While same IRF plant mgt. was taken up during all the three years, different types of organic soil inputs were used for soil mgt. during each year to study their relative effectivity in terms of crop response vis-a–vis application dose and economics.

In the first year, on-farm produced Novcom compost (Average N content- 2.0% and moisture- 60%) was applied @ 3 ton/ha after mixing with 80 kg rock phosphate and 40 kg elemental- S. In the year 2010, outsourced press mud compost (N content- 2.5% and moisture-45%) was applied @ 9 ton/ha, where as in the year 2011, 3 ton castor de-oil cake (N content- 8.0 % and moisture-4.0%) and 1 ton of on-farm produced Novcom compost was applied.

Assessment of crop performance (mature tea) during these three years indicated crop productivity (excluding young tea up to 5 years and HRP sections) of 1440, 1363 and 2001 kg/ha in 2009, 2010 and 2011 respectively. When compared with the productivity of Panitola Circle (i.e. the same tea growing zone where all the gardens are under conventional chemical farming), yield at Maud T.E. was 17.0, 3.5 and 41.0 percent higher in 2009, 2010 and 2011 respectively as compared to 2008. Yield obtained during these three years is of special significance considering that post organic conversion in 1999, crop productivity at Maud T.E. was mostly going downwards.

Crop performance vis-a-vis total cost of inputs indicated that application of off-farm soil input (press mud compost and Castor DOC) or quantitative increase in their dosage (in terms of press mud) only jacked up the cost but could not provide similar incremental benefit on crop productivity.

In case off-farm soil input is concentrated organic manure, it has to be necessarily added with quality compost (as in this case Castor DOC was applied in combination with Novcom compost) to minimize its harmful effect and increase its nutrient utilization efficiency.

At the same time, effective plant management package must be added to off– farm soil inputs for lowering the risk, avoiding losses and increasing the revenue by enhancing plant physiological efficiency.

Impact of Inhana Rational Farming (IRF) Package in Rest of the Garden Area of Maud T.E., Assam

Total Garden Area : 154.58 ha
Total Project Area (Proposed) : 100 ha
Total Experimental Area : about 20 ha.

Excluding the experimental area, the rest 135 (154.5 - 20) ha area of the garden is under Inhana Rational Farming Technology (IRF). The technology comprises three basic steps of management as given below:

SOIL MANAGEMENT :

IN 2009 : Novcom compost prepared in the Garden (Avg. N content- 2.0% and Moisture-60%) was applied @ 3 ton/ha after mixing with 80 kg Rock Phosphate and 40 kg Elemental- S.

The requirement of N was considered as 60 kg/ha (taking average yield of 1500 kg x 4% N content in made tea). Hence considering N and moisture content in Novcom compost the requirement comes to approximately 9.3 tons/ha. However, total N supplied was 20 kg/ha, which was only about 1/3rd of total requirement. The lower dose was given considering the high and naturally generated microbial population within compost ranging from 39 x 10^{16} to 52 x 10^{16} c.f.u., which on application would ensure mineralization of the soil- N for crop sustenance.

IN 2010 : Out sourced Press Mud compost certified by IMO (N content- 2.5% and Moisture-45%) was applied @ 9 ton/ha. Microbial population in the compost ranged from 18 x 10^{10} to 32 x 10^{10} c.f.u.

Now considering N content of the compost its requirement comes to approximately 5.4 tons/ha. Total N supplied was about 100 kg/ ha, which was 1.5 times the actual requirement. The higher dose in the second year was given for observing the following criteria:

i) Qualitative influence of soil inputs on quantity
ii) Influence of microbial potential on soil- N Dynamics

IN 2011 : Out sourced Castor cake (N content- 4.0% and Moisture-5%) @ 3 ton/ha + Novcom compost prepared in the Garden (N content- 1.75% and Moisture-55%) (as per recommendation of Inhana Biosciences) @ 1 ton/ha was applied after mixing with 80 kg Rock Phosphate and 40 kg Elemental- S.

The requirement of N was considered as 60 kg/ha (taking average 1500 kg yield x 4% N content in made tea). Total N supplied was about 130 kg/ ha, which was more than 2 times of the actual requirement. The higher dose in the third year was given considering 50 % less N utilization efficiency in case of oilcake.

PLANT MANAGEMENT :

Plant management was done through the application of various Inhana Solutions (which are potentized and energized botanical solutions) as per the protocol of Inhana Biosciences; for activation of plant physiology.

PEST & DISEASE MANAGEMENT :

Various Inhana solutions, Neem oil, Karanj oil along with concoctions made with cow dung and cow urine etc.; were sprayed for pest control as per requirement. Disease problem like Black Rot was managed by spraying of Inhana Soln. 13.

In figure 104, 105 and 106; detail of spraying (month wise plant management as well as pest and disease management) is given. According to the figure, number of spraying rounds gradually decreased year wise post initiation of project, which reflected the effectivity of the adopted organic practice of Inhana Rational Farming. Figure 107, 108 and 109 represents the month wise management schedule for control of red spider, helopeltis, bunch caterpillar and black rot infestation. Red spider infestation was comparatively more during the month of February to May, while from May to July, the garden faced the problem of helopeltis. The comparatively high black rot infestation of 2010 was probably due to intense rainfall and sub-surface water logging in some problematic sections of the garden during July to September. However, adoption of an effective disease management protocol under Inhana Rational Farming helped in restricting the problem to a lesser magnitude and thereafter its complete control in 2011.

Month wise Spraying Statistics in General Garden Area of Maud Tea Estate under FAO-CFC-TBI Project in the Year 2009 – 2011.

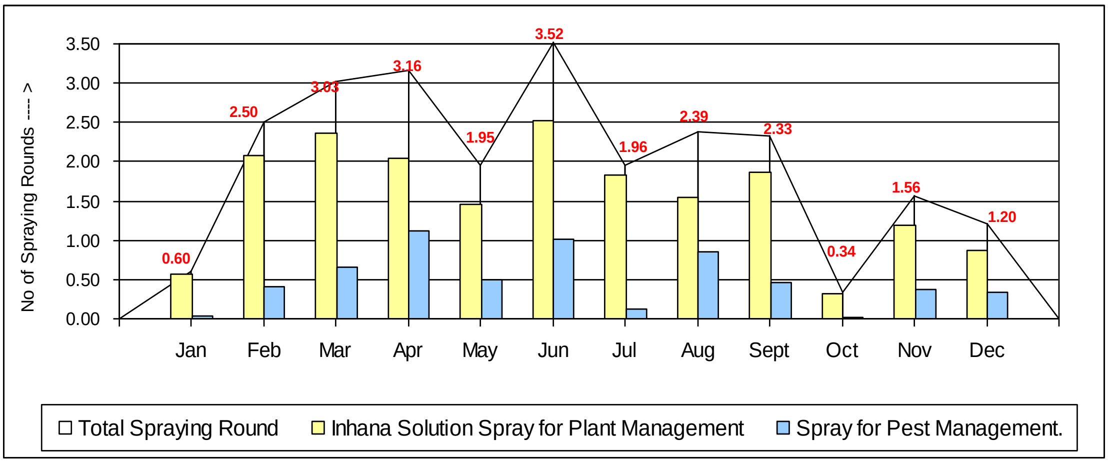


Fig. 104 : Month-wise spraying rounds for plant and pest management during 2009 under Inhana Rational Farming (IRF) in Maud T.E.

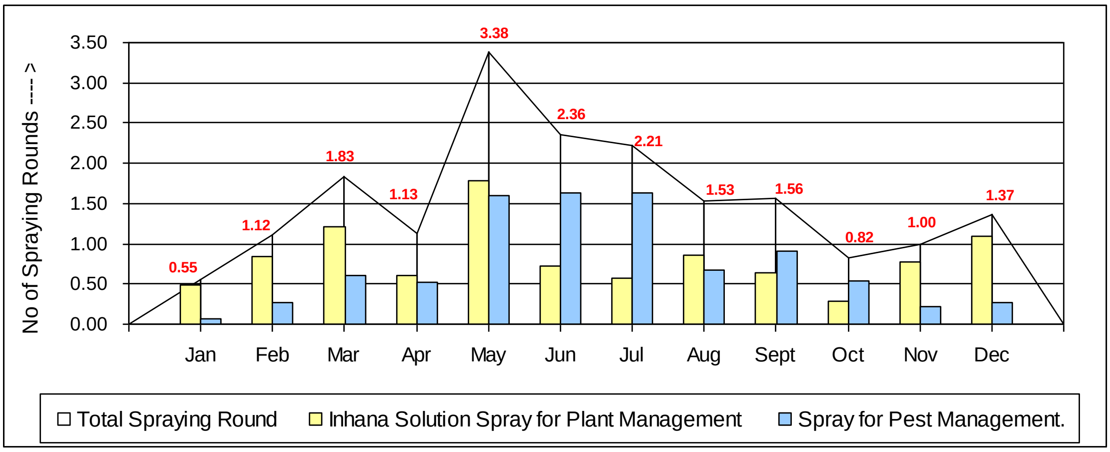


Fig. 105 : Month-wise spraying rounds for plant and pest management during 2010 under Inhana Rational Farming (IRF) in Maud T.E.

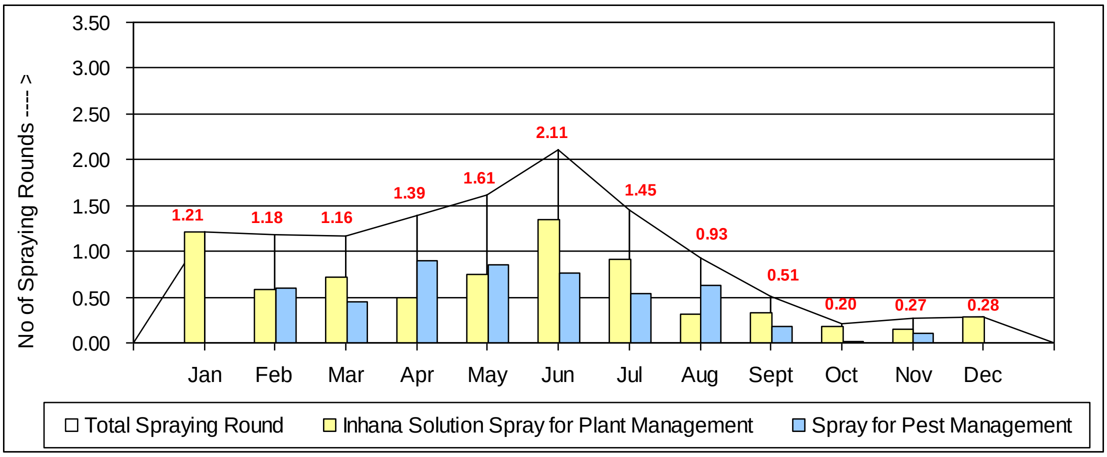


Fig. 106 : Month-wise spraying rounds for plant and pest management during 2011 under Inhana Rational Farming (IRF) in Maud T.E.

Year wise Variation in Monthly Spraying Rounds for Pest and Disease Control in General Garden Area of Maud T.E. under FAO-CFC-TBI Project.

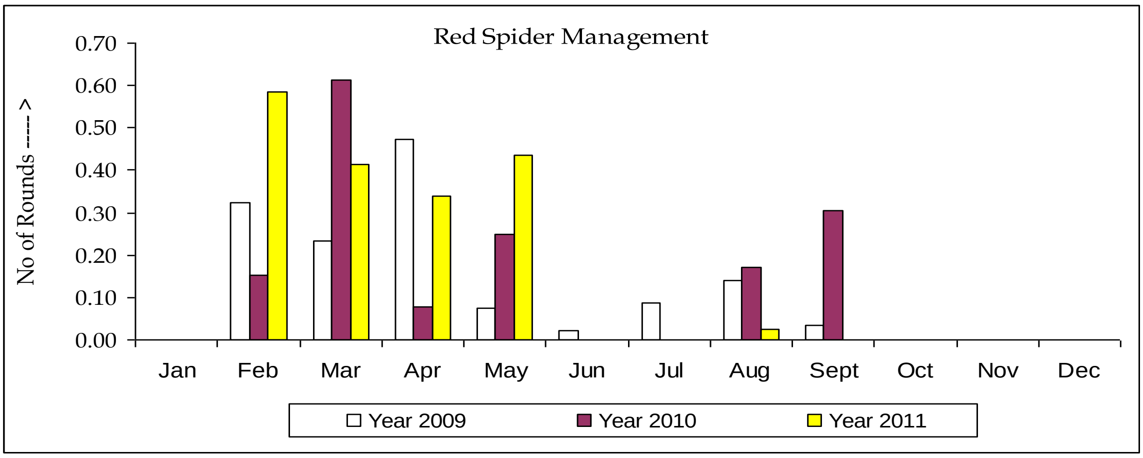


Fig. 107 : Spraying Rounds for Red Spider Management under Inhana Rational Farming (IRF) in Maud T.E..

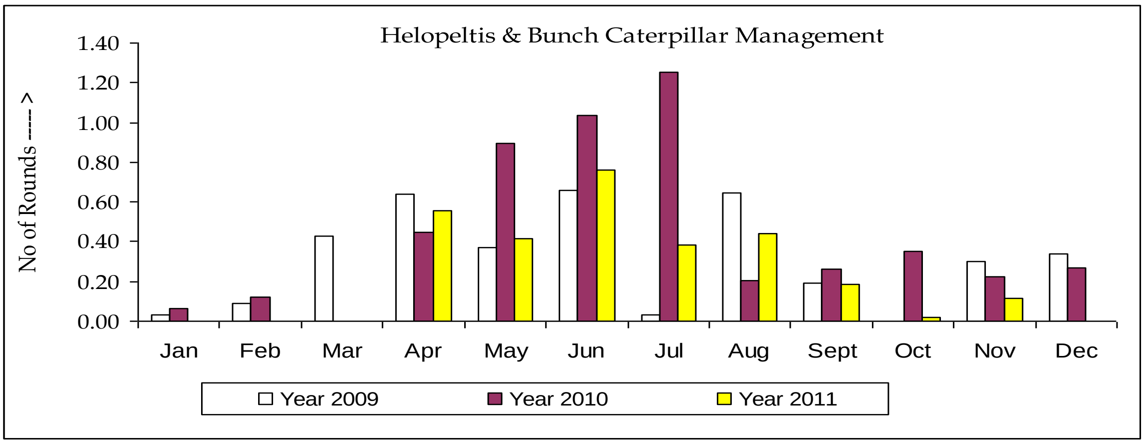


Fig. 108 : Spraying Rounds for Helopeltis and Bunch Caterpillar Management under Inhana Rational Farming (IRF) in Maud T.E.

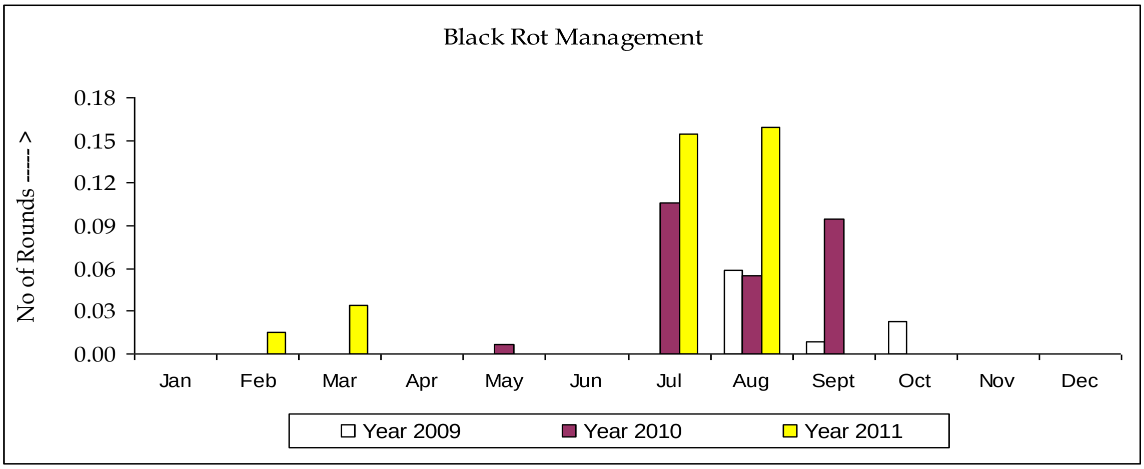
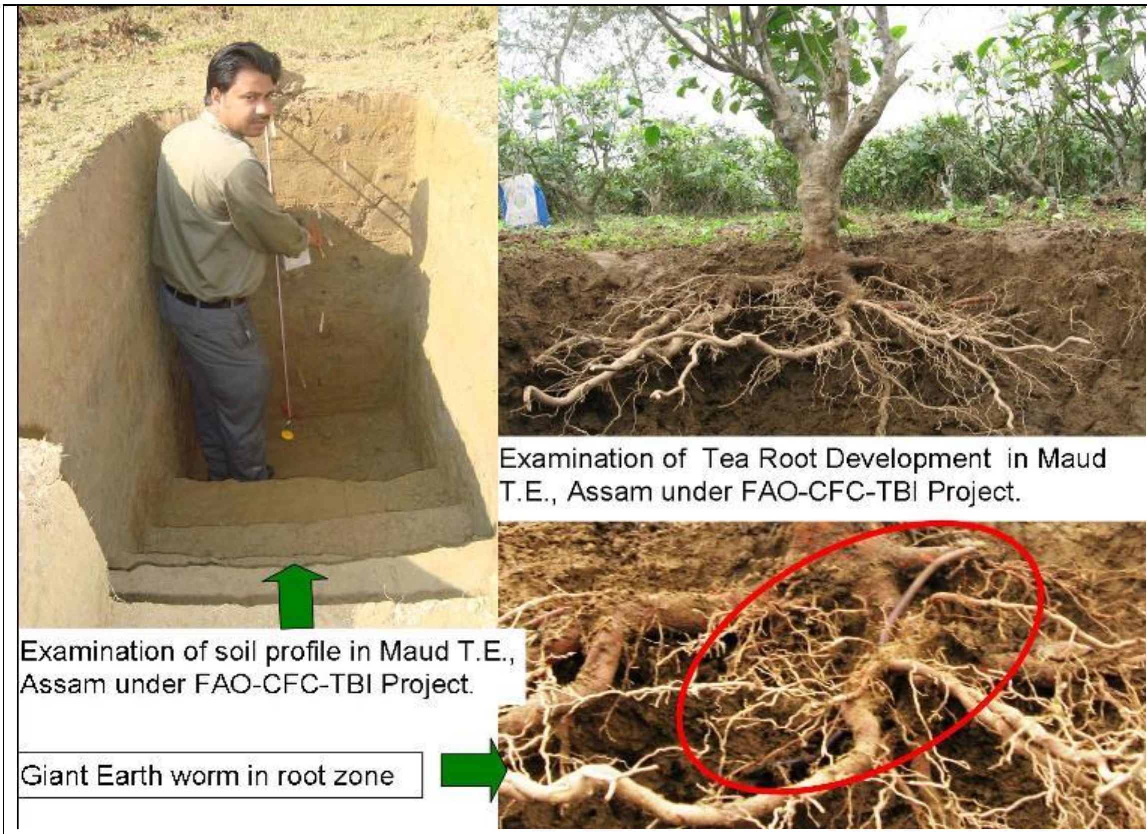


Fig. 109 : Spraying Rounds for Black Rot Management under Inhana Rational Farming (IRF) in Maud T.E.

Pic. 74 : Landscape of Maud Tea Estate, Assam.



Pic. 75: Study of soil profile and root zone in the problematic sections of Maud T.E.

Pic. 76 : Collection of soil samples from sections.

Pic. 77 : Soil sample

Helopeltis (*Helopeltis theivora*) infestation and Management efficiency in Maud T.E. under FAO- CFC–TBI Project during 2009 – 2011.

Tea mosquito bug, *Helopeltis theivora* W. (Hemiptera: Miridae) is one of the major pests of tea causing serious damage to tea plantation with respect to both quantity and quality of tea (Ahmed *et al.*, 1993). About 80% area of the tea plantation in North East India is affected by this pest which reduces 10 – 50% productivity (Gurusubrmanian and Bora, 2007). The insect attack is generally severe during the months of May–September, due to high temperature and rainfall, leading to severe loss of biomass due to curling and drying up of leaves (Chakraborty and Chakraborty, 2005).

Evaluation of the trend of helopeltis infestation in the year 2009, indicated low status in the month of March (during initiation of 1st flush), remaining more or less similar in the month of April. However, the infestation increased from the month of May, becoming moderate to moderately high in the month of May and June respectively (Fig. 110). July was the month of highest intensity, infestation varying from moderately high to High status. Intercultural practice like weed control, ground sanitation, clearing of fences and drainage, part black plucking etc., were taken up along with timely spraying for pest management using neem and karanj oil based concoction in different concentration based on the intensity of infestation. Accordingly the infestation decreased sharply in August, however; from September onwards the garden once again witnessed sporadic pest problem.

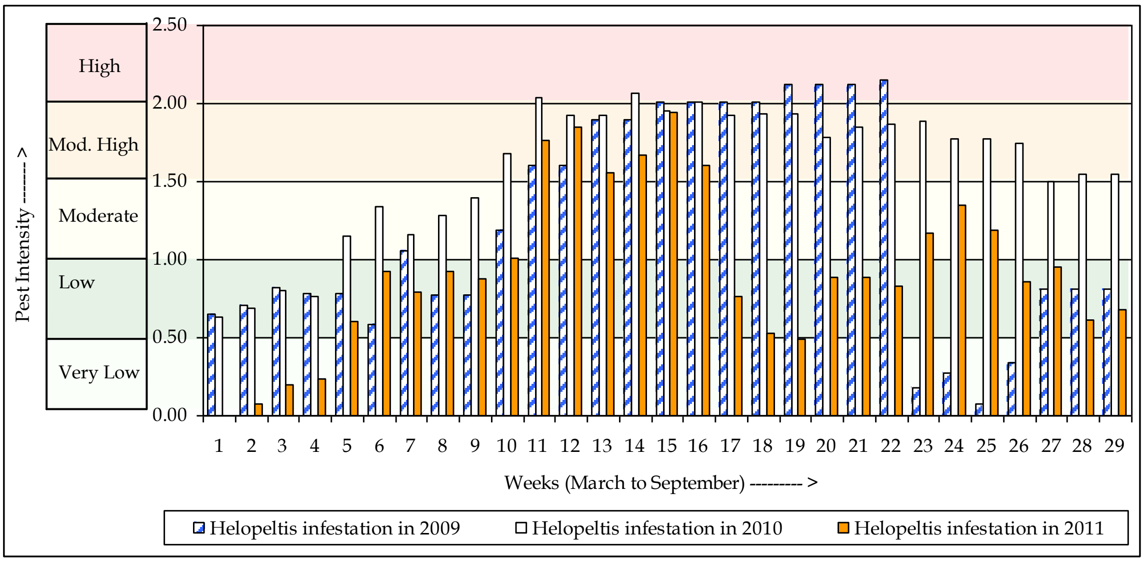


Fig. 110 : Helopeltis infestation at Maud T.E during (Period: March to September) 2009 to 2011.

In 2010, helopeltis became a menace for the entire tea growing zone of Assam. In Maud T.E. the pest initiated on the same note as in 2009, but increased progressively in the month of April becoming moderately high to high by the month of June. Conducive weather conditions helped to increase the infestation, at the same time continuous rainfall lowered the effectivity of pest management programme. However, despite these adversities, the intensity of infestation showed a reducing trend from July onwards. This was a notable phenomenon considering that even the surrounding chemical gardens did not exhibit effective capacity to contain the pest. Though there is lack of sufficient database to substantiate the above fact, however; comparative yield performance in the zone *vis-à-vis* Maud T.E. provided indirect proof regarding effective control of helopeltis under organic management protocol of Inhana Rational Farming Technology. Variation of Helopeltis infestation and respective spraying efficacy is represented in figure 111, 112, 113 and 114.

Variation of helopeltis infestation *vis-a-vis* spraying efficacy.

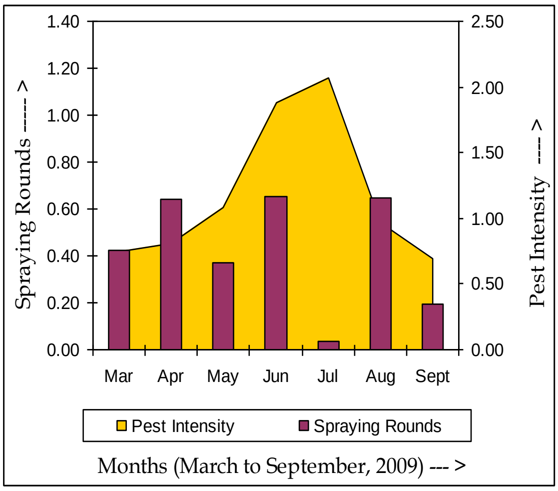


Fig. 111: Helopeltis infestation and pest management programme in 2009.

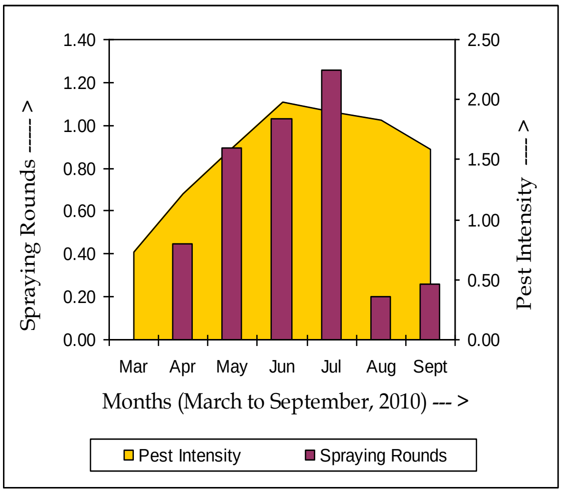


Fig. 112: Helopeltis infestation and pest management programme in 2010.

In 2011, the intensity of helopeltis infestation was much lower than the previous two years. Moderate to moderately high infestation was observed in the month of June, which reduced gradually in July. However, the infestation again showed an increasing trend from the month of September. Even though climate plays a determinant role towards the intensity of pest, however; pest management programme if taken up in an effective and timely manner can ensure to curb the infestation in a successful manner.

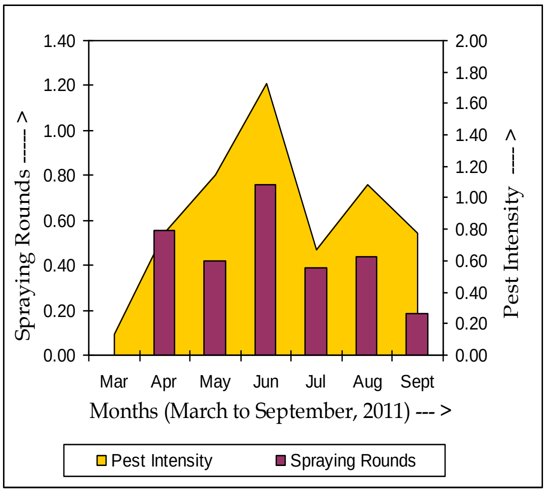


Fig. 113: Helopeltis infestation & pest management programme in 2011

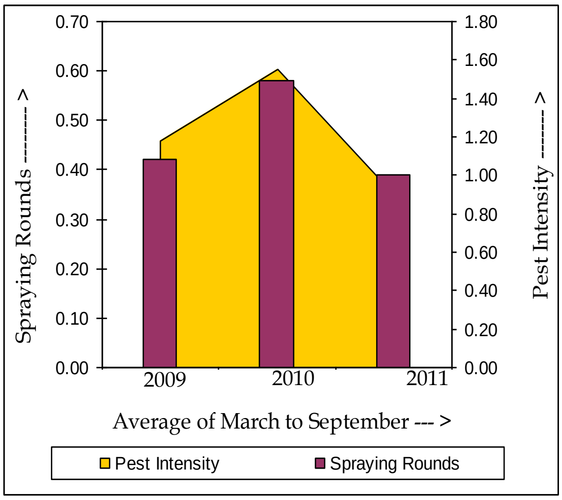


Fig. 114: Helopeltis infestation (on an Average) *vis-à-vis* respective spraying schedule during 2009–11.

Table 57 : Temporal variation of helopeltis infestation at Maud Tea Estate during 2009 to 2011 (March to September).

Pest Status		2009	2010	2011	Remarks
		No. of Weeks			
High	:	8	3	0	In 2010, helopeltis infestation was most severe in entire Assam, which reflected in the statistics of Maud T.E. also. However, the period representing highest intensity was definitely shorter as compared to 2009, which decreased further in 2011. The phenomenon pointed towards better and effective pest management approach under Inhana Rational Farming at Maud T.E.
Mod. High	:	4	17	6	
Moderate	:	2	5	4	
Low	:	11	4	15	
Very Low	:	4	0	4	

Table 57 showed that with the initiation of Inhana Rational Farming in 2009, severity of helopeltis infestation gradually decreased in Maud T.E. by 2011. Variation of green leaf production with intensity of helopeltis infestation is shown in figure 115, 116 and 117. Variation of helopeltis infestation with rainfall intensity is represented in figure 118, 119 and 120; and indicated that higher intensity of rainfall served as a major bottleneck towards effective management of helopeltis infestation.

Helopeltis Infestation *vis-a-vis* Green leaf production at Maud T.E., Assam.

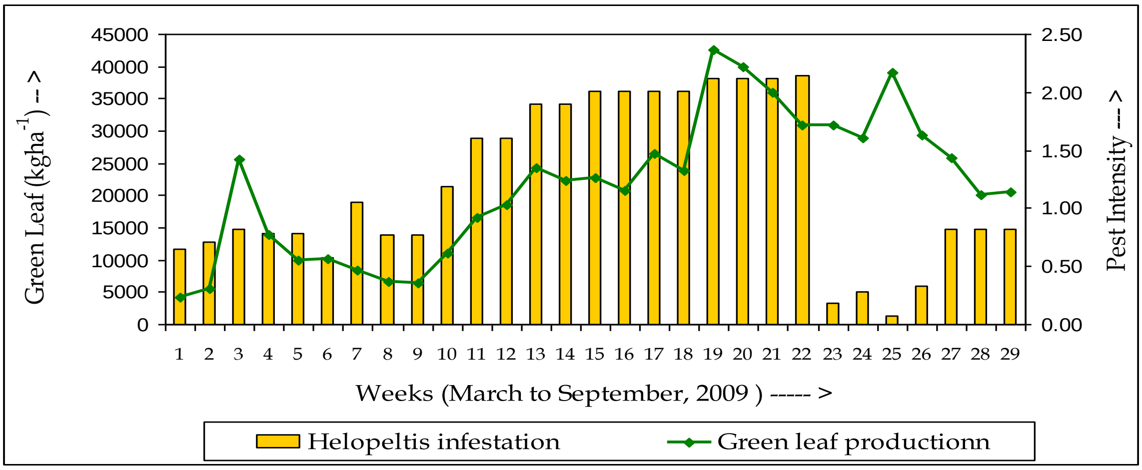


Fig. 115 : Variation of helopeltis infestation *vis-à-vis* green leaf production in 2009 at Maud T.E., Assam.

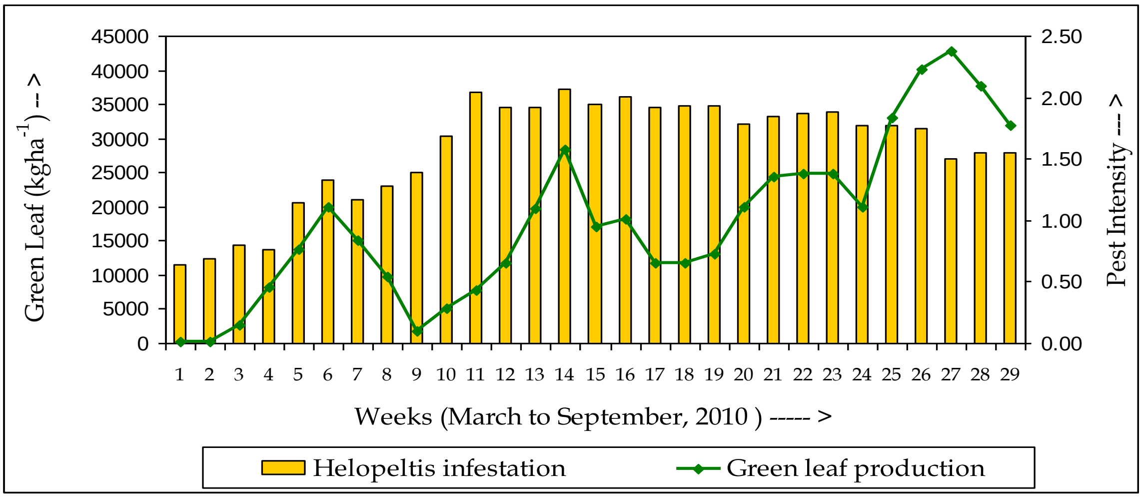


Fig. 116 : Variation of helopeltis infestation *vis-à-vis* green leaf production in 2010 at Maud T.E., Assam.

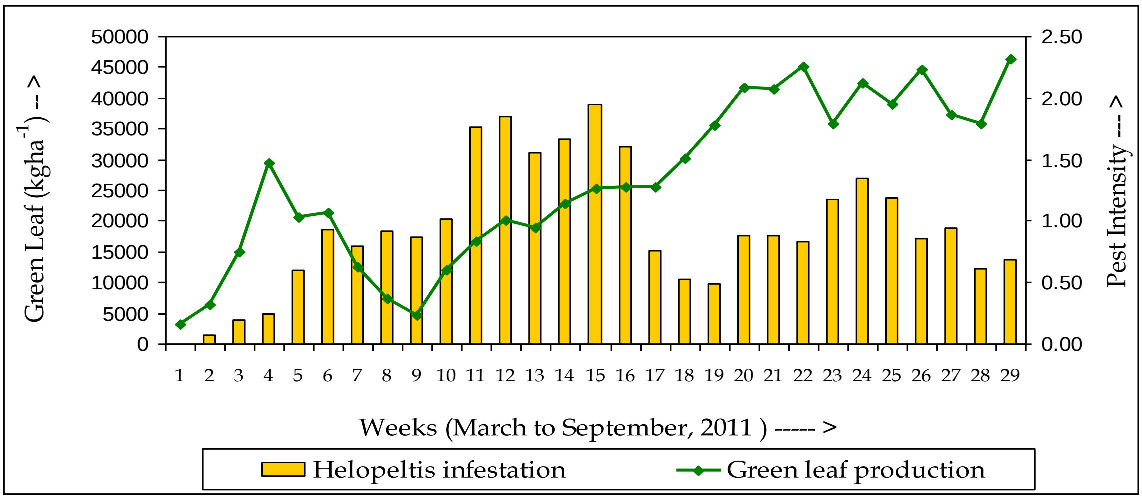


Fig. 117 : Variation of helopeltis infestation *vis-à-vis* green leaf production in 2011 at Maud T.E., Assam.

Rainfall Distribution *vis-à-vis* Helopeltis Infestation pattern at Maud T.E., Assam during 2009 to 2011 (March to September).

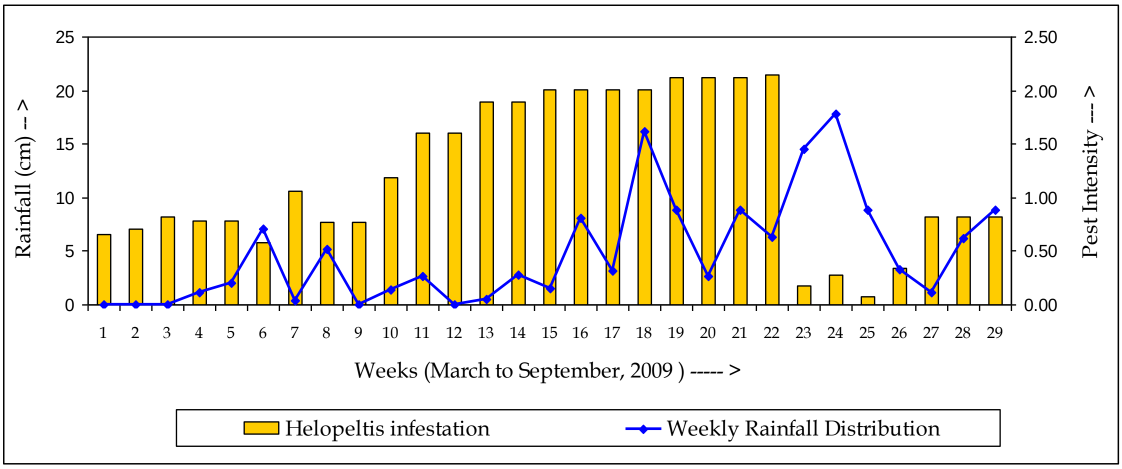


Fig. 118 : Rainfall Distribution *vis-à-vis* Helopeltis Infestation pattern in 2009.

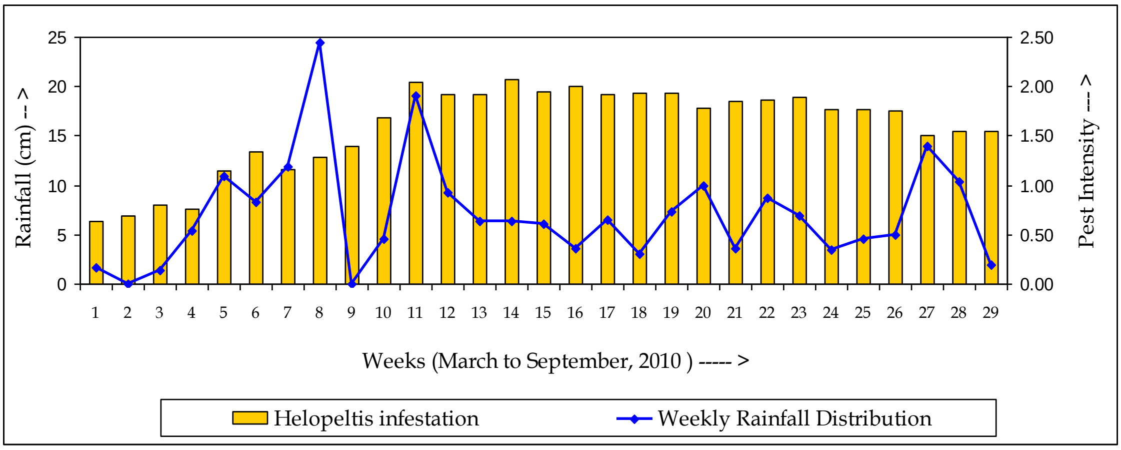


Fig. 119 : Rainfall Distribution *vis-à-vis* Helopeltis Infestation pattern in 2010.

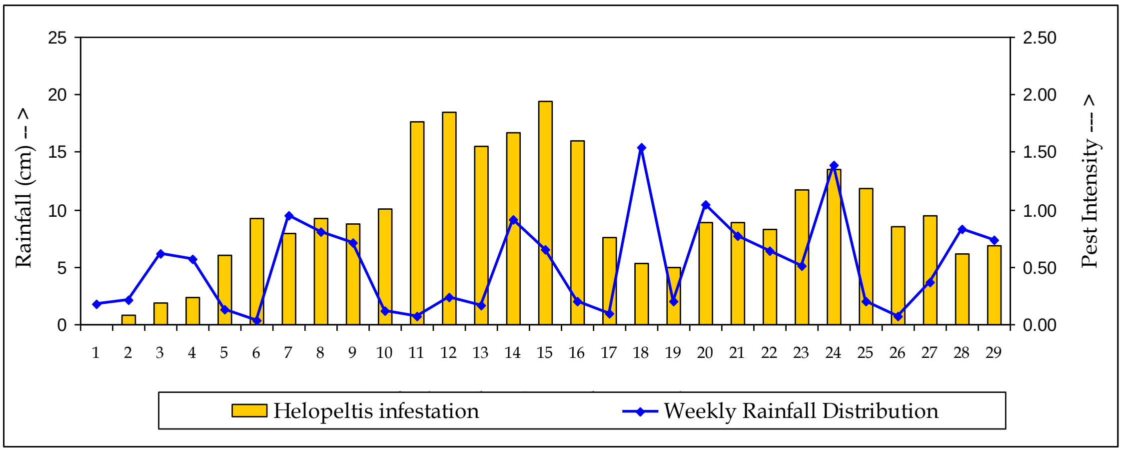


Fig. 120 : Rainfall Distribution *vis-à-vis* Helopeltis Infestation pattern in 2011.

Pic. 78: Soil churning after uprooting as part of soil rejuvenation programme at Maud T.E.

Pic. 79: Plantating of Guatemala as part of soil rejuvenation programme at Maud T.E.

Pic. 80 : Guatemala Plantation

Pic. 81: Transplantation of new tea seedlings at Maud T.E. under FAO-CFC-TBI Project.

Pic. 82: Sprinkler Irrigation in new tea plantation at Maud T.E.

Pic. 83: Temporary shade tree columns in new plantation.

Pic. 84: Application of plastic mulch in new plantation.

Evaluation of pruning status *vis-à-vis* crop performance in general garden area of Maud Tea Estate from 2009 to 2011.

Pruning is one of the most important operations, next to plucking, which directly determines the productivity and quality of tea bushes [Tocklai Tea Research Association (TTRA), 2008; Halder and Mandal, 2009]. It renews the plant, provides stimulus for vegetative growth to divert stored energy for production of growing shoots, corrects past defects in bush architecture, maintains ideal frame height for economic plucking, improves bush hygiene, and reduces the incidence of pests and diseases (Barua, 1969, Dutta *et al*., 2010).

Tea plants are pruned to obtain a given table form and height, to eliminate unnecessary and diseased branches, to rejuvenate the tea plants, and to obtain healthier and better quality tea plants (Yilmaz *et al.,* 2004). In spite of huge crop losses that result from pruning, it is a necessity that has been carried out periodically (TTRA, 2008). Yilmaz *et al.* (2004) reported less yields in tea harvested 50 cm above the ground in the first year, with yields increasing in the subsequent second and third years. Thus, pruning increases tea yields in the long term. If pruning is not done or is delayed, the size and weight of growing shoots on plucking surface decrease, with loss of vigour of growing apices in the long run (TTRA, 2008).

Pruning was also found to affect quality of tea. Mahanta and Baruah (2006) reported that all the pigment contents of black tea, except chlorophyll, were found to be higher in pruned tea leaf than unpruned tea, thus enhancing the quality of made tea. Ravichandran (2003) also reported that the precursors responsible for tea quality, such as polyphenols, were found to increase in the first year and thereafter declined in content with time from pruning.

Pruning pattern of Maud T.E. during 2008 to 2011 is represented in figure 121, 122, 123 and 124. Considering bush health, age, declining productivity and incorrect pruning cycle that was followed during the previous years, special attention was given to pruning programme during the project period, to enhance overall productivity of the garden. However, with the initiation of FAO-CFC-TBI project at the end of the year 2008 there were little options for chalking out a full proof programme for 2009. Hence, during this year, 52.65%, 18.90% and 28.45% of the total bearing area (149.66 ha) were left unprune, light pruned and skipped respectively. During the next two years major focus was given towards rejuvenation of the plantation and thereafter 8.16% and 12.23% of the total area (154.58 ha) was brought under height reduction pruning (HRP)

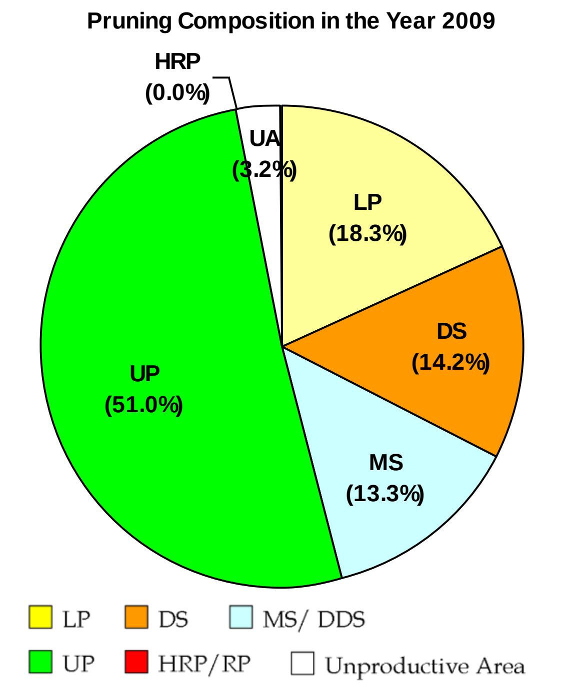


Fig. 121: Pruning Status of Maud T.E., (Assam) in 2009.

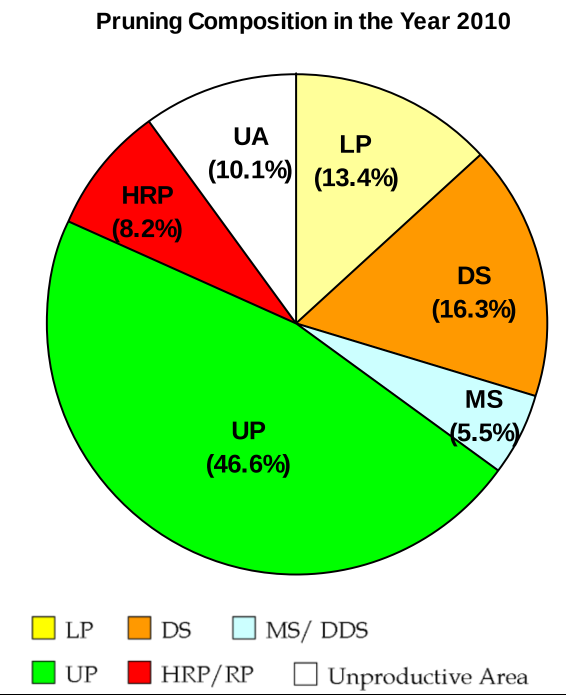


Fig. 122: Pruning Status of Maud T.E., (Assam) in 2010.

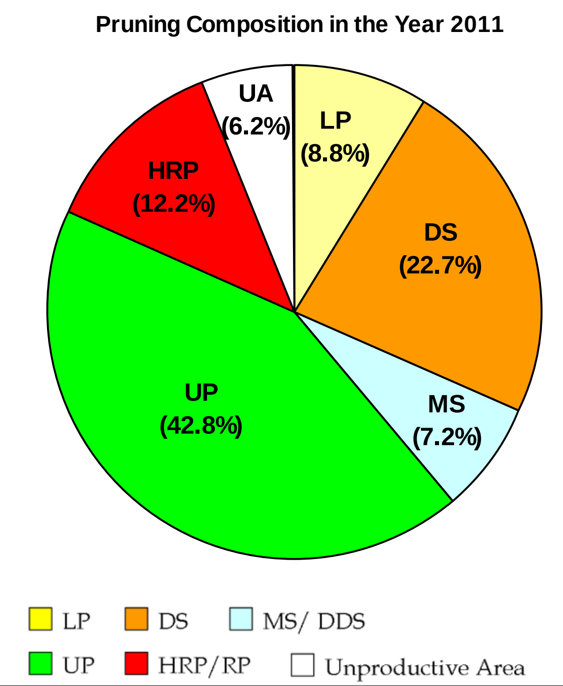


Fig. 123: Pruning Status of Maud T.E., (Assam) in 2011.

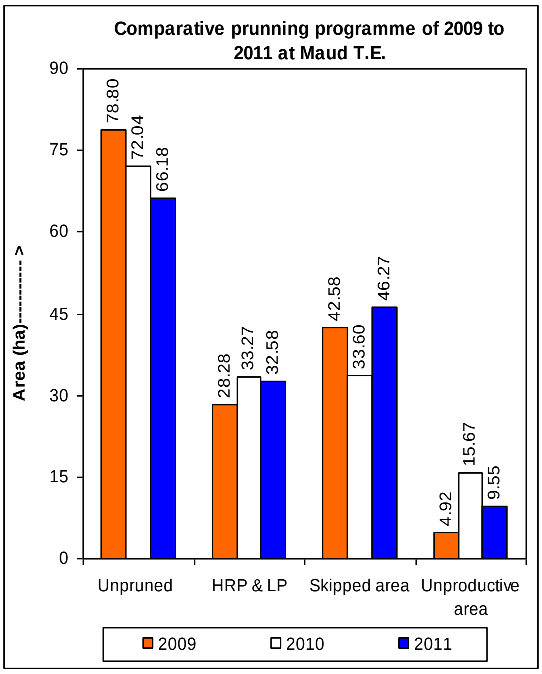


Fig. 124: Year wise variation in Pruning Composition of Maud T.E, Assam.

in 2010 and 2011 respectively. Uprooting and new planting programme was also taken up during these years as indicated by the percent unproductive area during 2010 and 2011 respectively. Considering average crop productivity of the garden (in case all the sections were left unpruned), the yield obtained in 2009, 2010 and 2011 indicated attainment of 87.9, 77.9 and 79.7 percent (respectively) of its total productive potential, during the project period. Lower productivity potential in 2010 and 2011 was primarily due to intensive plant rejuvenation, uprooting and new planting programme, which were taken up to boost up the average productivity of the garden in the coming years.

Year Wise Variation in Yield under Chemical Farming, Organic Conversion & Conventional Organic Farming at Maud T.E.

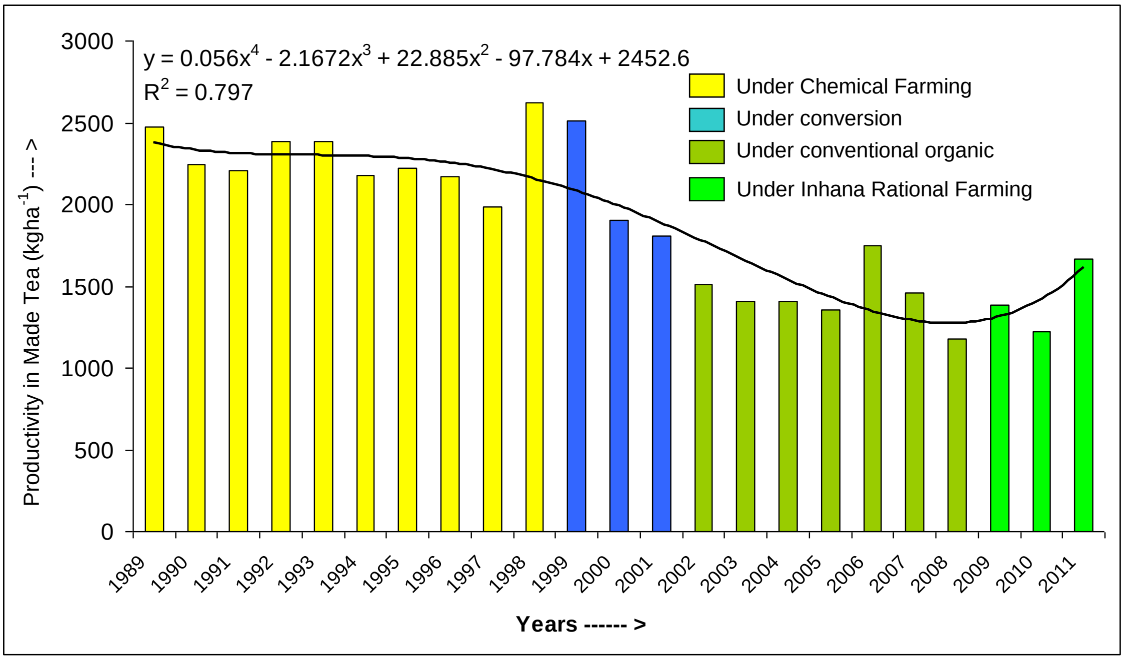


Fig. 125: Variation in made tea productivity (Made Tea) at Maud T.E. under different Management practice from 1989 to 2011.

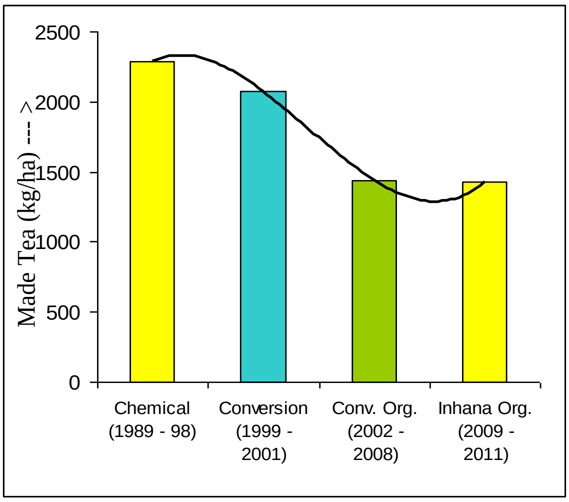


Fig. 126: Average Made Tea Productivity under different Management Practice.

However, the trend is somewhat reversed in 2009, post adoption of Inhana Rational Farming Technology, even without full compliance of its guidelines.

During the last 10 years of chemical practice average productivity of Maud T.E. (in terms of made tea production) was 2287 $kgha^{-1}$. During this decade productivity gradually went down from 2474 $kgha^{-1}$ to 1982 $kgha^{-1}$ (with few exceptions), which clearly indicated the lack of sustainability. During Organic conversion (i.e., during 1999 to 2001), productivity dropped by about 9.3 percent than the last ten years average. However, if crop productivity in 1999 is not taken into account (comparatively higher productivity during this year might be attributed to residual fertilizer effect of previous year), then the yield drop increases further to about 19 percent.

Post organic conversion, productivity in general showed a downhill trend going down from 1513 $kgha^{-1}$ to 1185 $kgha^{-1}$, which is about 22 percent yield drop (Fig. 126). **Hence, the net loss of productivity pre and post chemical practice is about 30 percent.** However, in 2009, 2010 and 2011 about 17.0 percent, 3.5 percent and 41.2 percent respectively (as compared to 2008) increase in productivity was observed under the adoption of Inhana Rational Farming Method. Average productivity under conventional organic farming (2002 – 2008) and Inhana Rational Farming (2009 to 2011) was also similar. However considering the continuously diminishing yield potential of Maud T.E. during the last 20 years, especially sharp yield drop post organic conversion, no further loss in yield during the past three year period (2009 to 2011 under IRF) definitely appears as a notable achievement.

Prune wise productivity under Inhana Rational Farming (IRF) is given in table 58. Productive potential of Maud T.E. during 2009-2011 (i.e., under Inhana Rational Farming) *vis-a-vis* 2008 is shown in figure 127 while crop performance of LP and young tea sections are represented by figure 128 and 129.

Table 58 : Pruning wise made tea productivity at Maud T.E. (2008 to 2011).

Year	2008		2009		2010		2011	
Pruning	Area (ha)	Yield ($kgha^{-1}$)	Area (ha)	Yield ($kgha^{-1}$)	Area (ha)	Yield ($kgha^{-1}$)	Area (ha)	Yield ($kgha^{-1}$)
UP	53.13	1529	71.03	1634	69.2	1441	58.41	2194
LP	32.9	1050	28.28	1098	20.65	1096	13.68	1388
MS	23.73	1261	0	0	8.46	1394	11.18	877
DS	32.13	1361	42.58	1323	25.14	1206	35.09	1753
HRP	0	0	0	0	12.62	602	18.9	492
YT	7.77	34	7.77	385	9.77	227	11.27	1229
Total	149.66	1268	149.66	1379	145.84	1195	148.53	1627

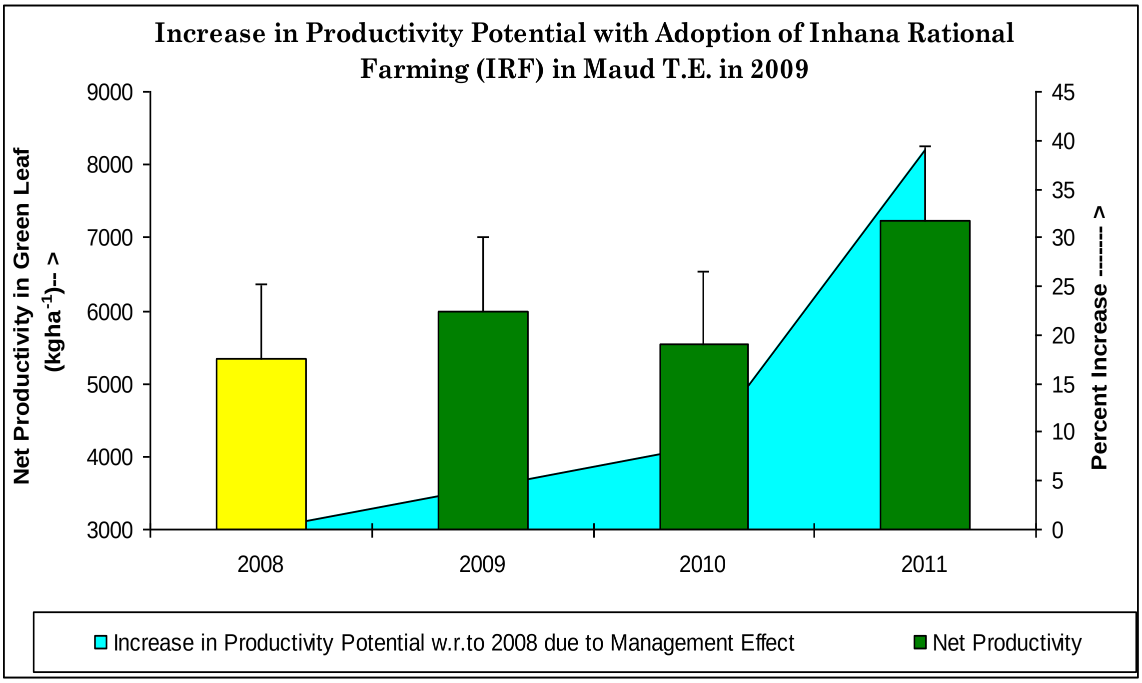


Fig. 127 : Productivity potential of Maud T.E. under Inhana Rational Farming (IRF) during 2009-2011, w.r.t 2008.

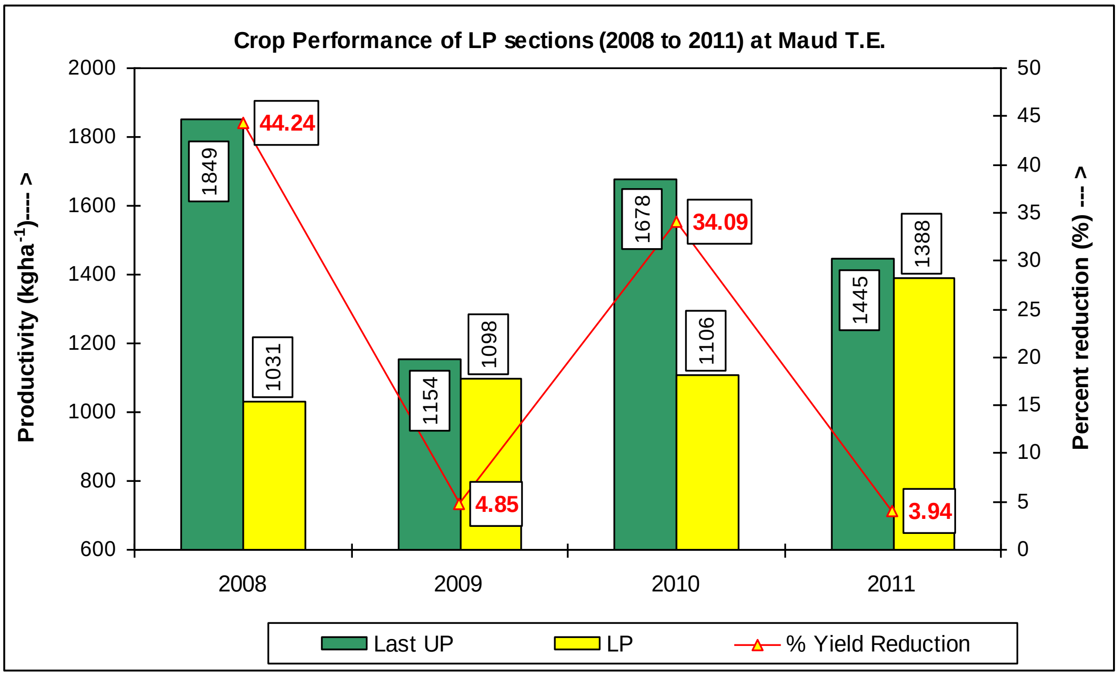
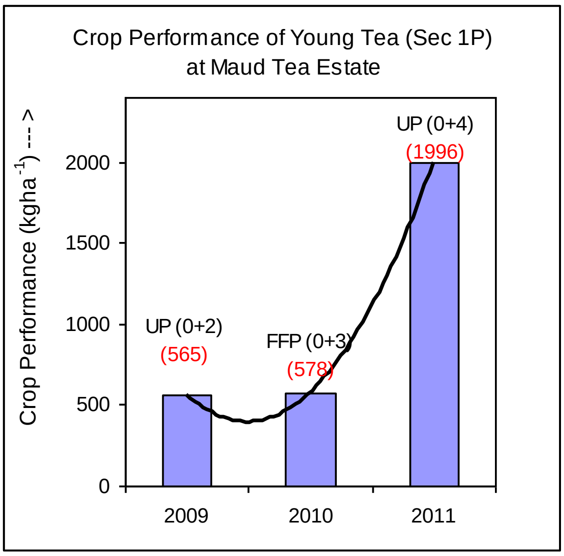


Fig. 128: Year wise variation in crop performance of LP sections at Maud T.E. during 2009 to 2011 under FAO-CFC-TBI Project.



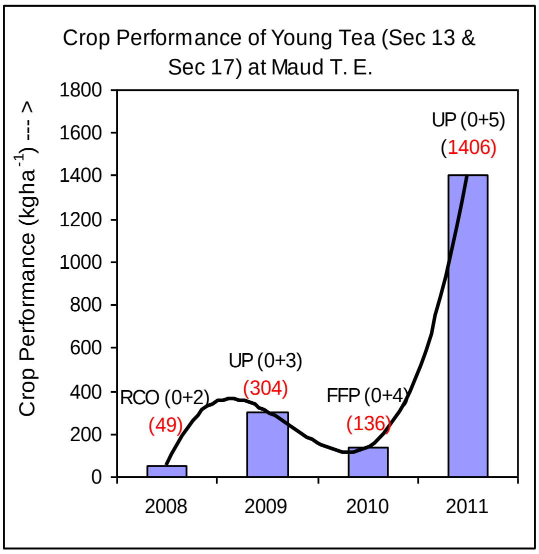


Fig. 129: Year wise performance of two different young tea sections at Maud T.E. during 2009 to 2011 under FAO-CFC-TBI Project.

Pic. 85: Dr. P. Das Biswas, Founder Director of Inhana Biosciences inspecting pruning activity at Maud T.E. under FAO-CFC-TBI Project.

Pic. 86 : New leaf initiation after pruning operation.

Pic 87 : Light prune (LP) operation done in Sec. 6A i.e. under Soil Input Experiment' of FAO-CFC-TBI Project at Maud T.E.

Comparative crop performance at Maud T.E. during 2009 – 2011 (under Inhana Rational Farming) *vis-à-vis* 2008 (under Conventional Organic Farming).

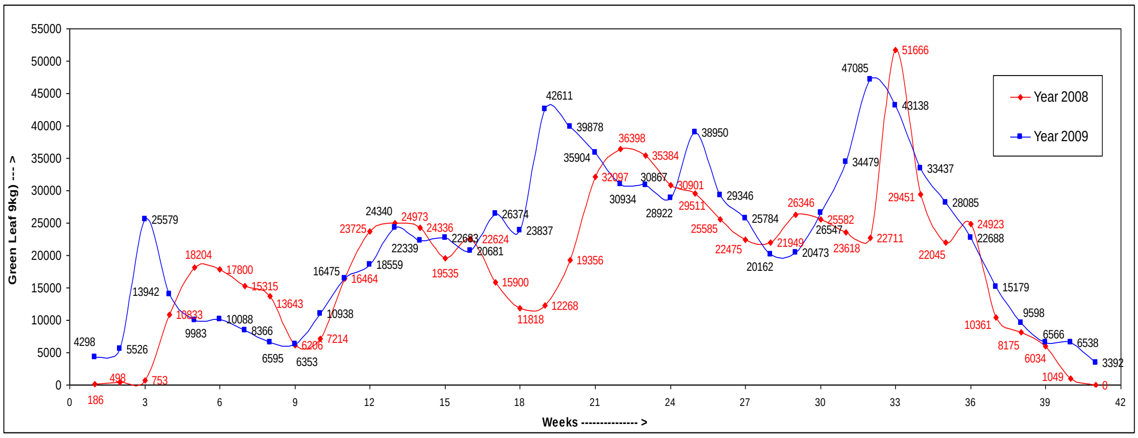


Fig. 130: Variation in green leaf yield under different plucking rounds in 2009 *vis - a -vis* 2008.

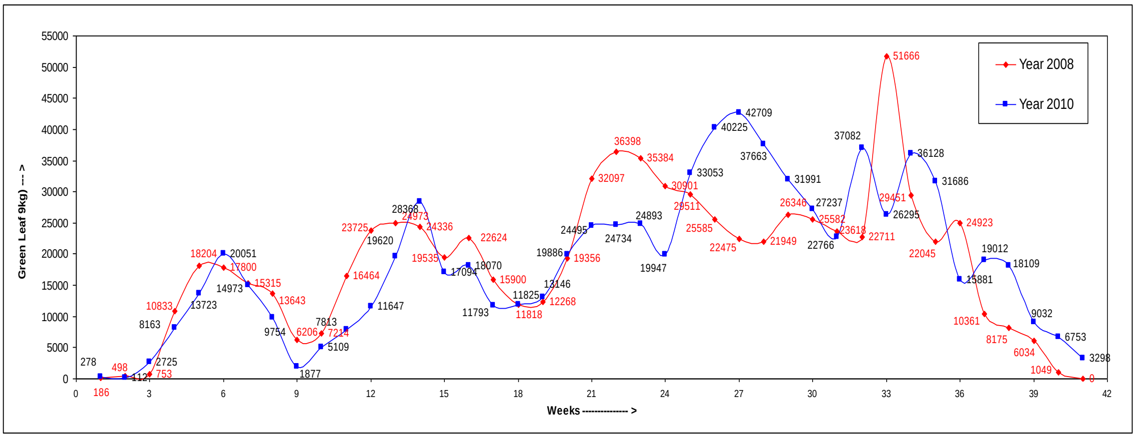


Fig. 131: Variation in green leaf yield under different plucking rounds in 2010 *vis - a -vis* 2008.

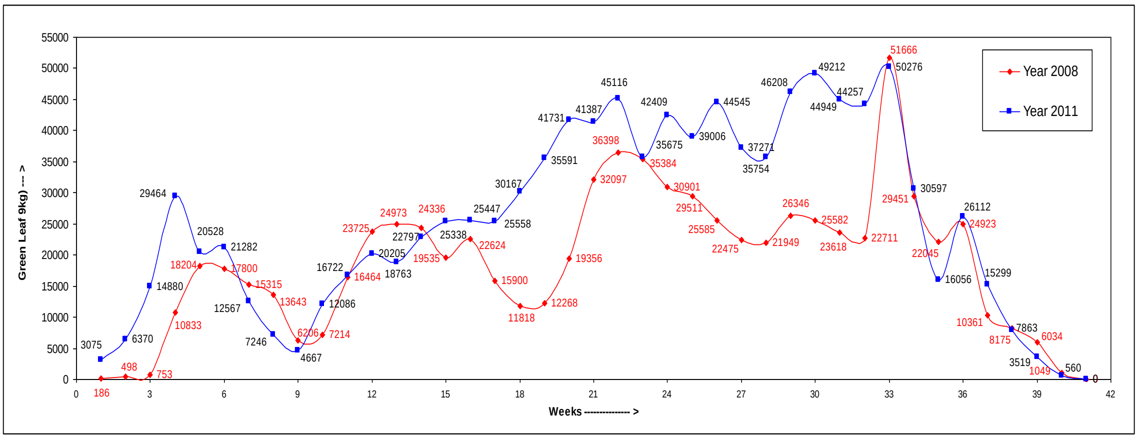


Fig. 132: Variation in green leaf yield under different plucking rounds in 2011 *vis - a -vis* 2008.

Rainfall distribution and cropping pattern of Maud T.E. during 2009 – 2011.

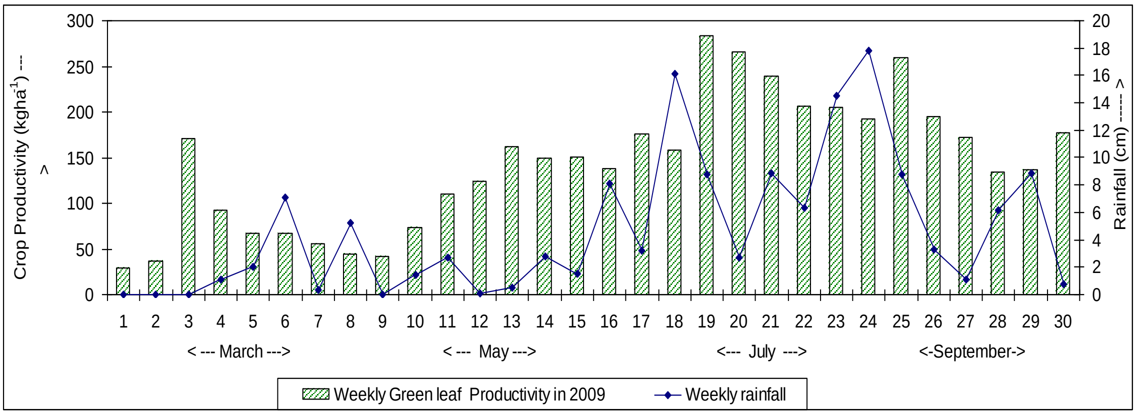


Fig. 133: Rainfall distribution at Maud T.E. in 2009 (during March to December) and its interrelation with green leaf production.

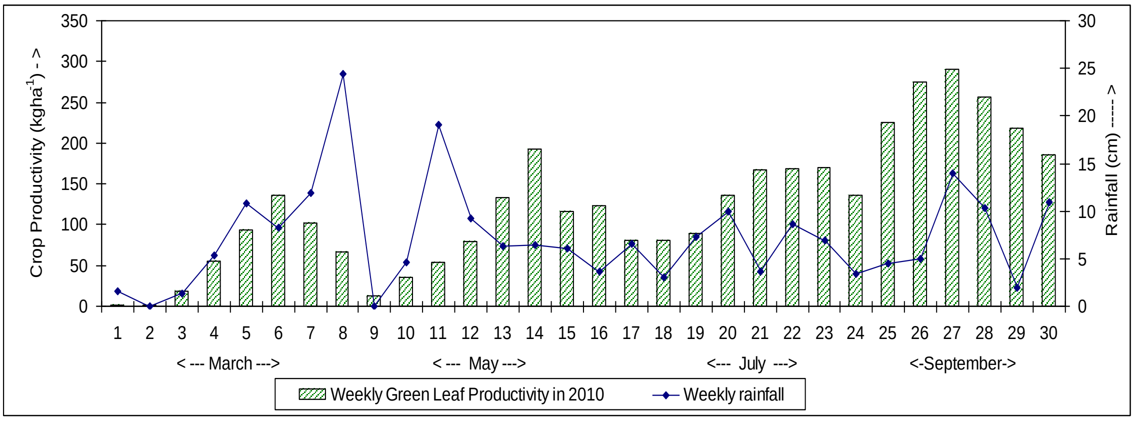


Fig. 134: Rainfall distribution at Maud T.E. in 2010 (during March to December) and its interrelation with green leaf production.

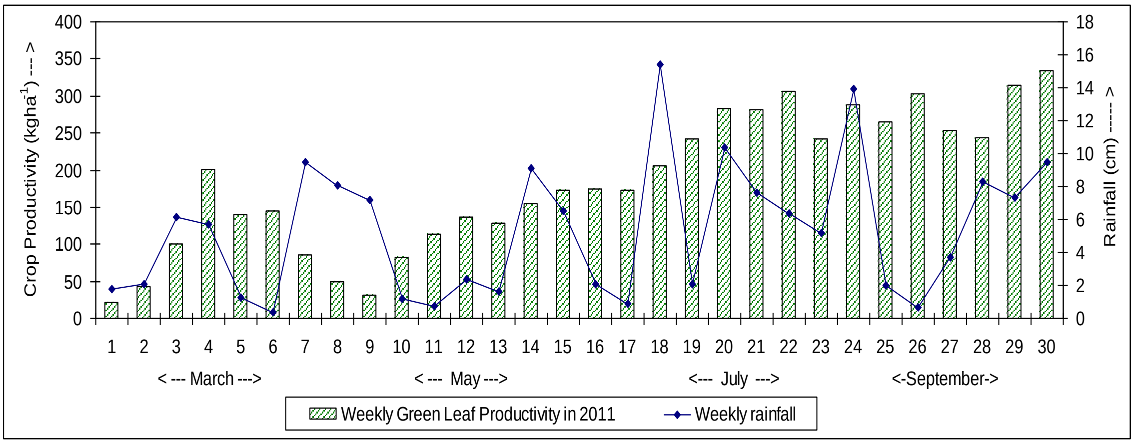


Fig. 135 : Rainfall distribution at Maud T.E. in 2011 (during March to December) and its interrelation with green leaf production.

Rainfall distribution and crop productivity during 2009 to 2011 is represented in figure 133, 134 and 135. It is well established that balanced distribution of rainfall has a strong relationship with crop productivity, however rain free period is also necessary both for higher photosynthetic acitivity as well as better management efficiency.

Pic. 88 : Weed cleaning operation at Maud T.E, Assam.

Pic. 89 : Spraying activity at Maud T.E. under FAO-CFC-TBI Project.

Pic. 90 : Green leaf plucking from different treatment plots at Maud T.E.

Performance of Inhana Rational Farming under large scale adoption at Maud T.E., Assam.

Inhana Rational Farming (IRF) package was adopted and practiced in the entire area (excluding the micro experimental area of 20 ha) of Maud T.E. i.e. 135 ha area, during 2009 to 2011. Same IRF plant management programme was taken up during all the three years, but for soil management different types of organic soil inputs were used during each year to study their relative effectivity in terms of crop response *vis-a –vis* application dose and economics. In the first year, on-farm produced Novcom compost (Average N content- 2.0% and moisture- 60%) was applied @ 3 ton/ha after mixing with 80 kg rock phosphate and 40 kg elemental- S. In the year 2010, outsourced press mud compost (N content- 2.5% and moisture-45%) was applied @ 9 ton/ha, where as in the year 2011, 3 ton castor de-oil cake (N content- 4.0 % and moisture-4.0%) and 1 ton of on-farm produced Novcom compost was applied.

Assessment of crop performance (of mature tea i.e. excluding young tea up to 5 years and HRP sections) during these three years indicated crop yield of 1440, 1363 and 2001 kg/ha in 2009, 2010 and 2011 respectively (table 59) under Inhana Rational Farming. In 2009 crop yield was 17.0 percent higher as compared to that obtained in 2008 under conventional organic practice. In 2010 however; due to huge helopeltis infestation (as observed in the entire crop producing belt), the crop declined recording 5.3 percent lower value as compared to 2009. However, in 2011 yield reflected an increasing trend recording approximately 39 percent higher crop as obtained in 2009. Yield obtained during 2009 and 2011 is of special significance considering that post organic conversion in 1999, crop productivity at Maud T.E. was mostly going downhill.

Assessment of crop performance *vis-a-vis* total cost of inputs indicated that application of off-farm soil inputs (press mud compost and Castor DOC) or quantitative increase in their dosage (in terms of press mud) only jacked up the cost but could not provide similar incremental benefit on crop productivity. In case off-farm soil input is concentrated organic manure, it has to be necessarily added with quality compost (as in this case Castor DOC + Novcom compost) to minimize its harmful effect and increase its nutrient utilization efficiency as well. At the same time, effective plant management package must be added to off– farm soil inputs for lowering the risk, avoiding losses and increasing the revenue by enhancing plant physiological efficiency.

Table 59 : Year wise crop performance *vis-à-vis* cost of production in general garden area (135ha) of Maud T.E. under IRF package, during FAO-CFC-TBI Project.

Components	2009	2010	2011
Made Tea Yield (kg/ha.) # *(Cycle Yield of Mature Tea 2004-2008 1445 Kg/ha)*	1440	1363	2001
Crop Productivity over 2009	+ 17 % (over 2008)	-5.3 %	+ 39 %
Type of Soil Input applied	Novcom compost *(On-Farm)*	Press mud compost *(Outsourced)*	Castor DOC + 1 ton Novcom compost
N applied/ ha	23 kg	100 kg	130 kg
Cost of Soil Inputs (Rs./ha)	3594	27000	19874
Increase in Cost under Soil Input over Year 2009	-	651%	453%
RFT Plant Management Cost (Inhana Solns. + Pest Management)	4500 2500+2000	5700 2500+3200	4500 2500+2000
Overall Increase in Cost over 2009	-	426%	219%

Made tea yield of mature tea i.e. excluding young tea (0 to 5 years) and HRP sections.

Evaluation of Crop Performance in Maud T.E. *vis-a-vis* Panitola Circle.

Post adoption of IRF, crop performance in Maud T.E. was compared with yield obtained in the same tea growing zone i.e. Panitola circle. Interestingly all other gardens in Panitola circle are under conventional chemical practice and any comparison between Maud T.E. and rest of the gardens in Panitola circle was actually a comparative study between organic and chemical gardens.

Year wise percent change (over 2008) in made tea productivity at Maud T.E. *vis-à-vis* rest gardens of Panitola Circle indicated better crop response in Maud T.E. as compared to the other gardens (fig. 136). Especially in 2010 under huge helopeltis infestation and unfavourable weather conditions in terms of intensive rainfall, less sunshine hours etc., higher yield (although very small hike) over 2008, indicated better pest control and better crop performance in Maud T.E., even under stressed conditions.

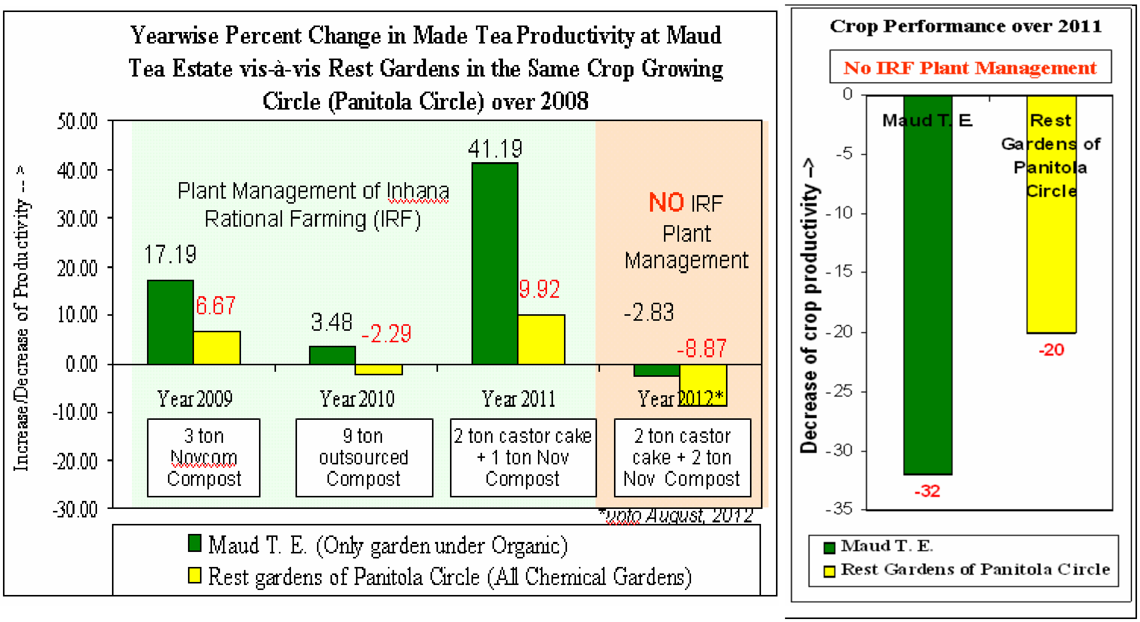


Fig. 136: Year wise change (% over 2008) in made tea yield at Maud T.E. *vis-à-vis* other Gardens in the same crop growing zone i.e. Panitola Circle.

Progress Towards Organic – Reducing Dependability on External Inputs

A true organic farming practice should minimize dependability on external inputs following overall development of surrounding ecology, which restores the natural pest and predator relationship. Also restoration of self-nourishment and self- protection quality of plant system under organic plant management schedule plays a complimentary role in reducing the usage of off-farm inputs. Post adoption of Inhana Rational Farming in the general garden area (135 ha) of Maud T.E. in 2009, total spraying rounds gradually reduced by 27 and 43 percent (fig. 137) in 2010 and 2011 respectively (as compared to 2009).

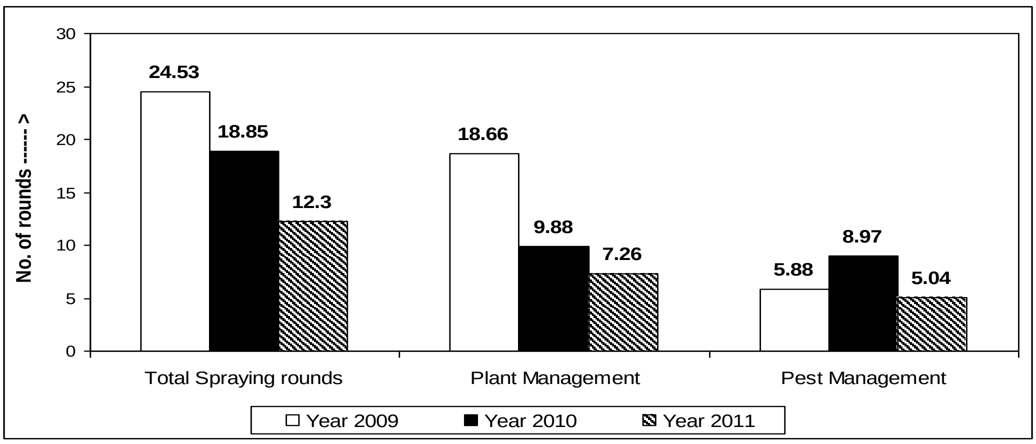


Fig. 137: Reduction in the usage of External Inputs under Inhana Rational Farming (IRF) at Maud T.E. under FAO-CFC-TBI Project.

Spraying for Pest management increased in 2010, primarily due to severe helopeltis infestation in the entire belt. However spraying rounds for plant management (using various potentised and energized solutions under IRF for activation of plant physiology) reduced significantly both in 2010 and 2011 (as compared to 2009). The results indicated that activation of plant physiology and energization of soil system under IRF package of practice complemented each other towards sustainable organic tea cultivation.

Impact of Plant Management under IRF package of practice towards Activation of Plant Physiology *vis-a-vis* Higher Crop Performance.

Maud T.E. and another sister organic garden (in the same agro-climatic zone of Assam) of the same organization, received identical organic soil inputs and almost similar pest management in 2009, 2010 and 2011. The only difference is that both gardens received total IRF package (IRF Plant Management Package + Novcom compost) in 2009 only. Thereafter in 2010 and 2011 only Maud T.E. received IRF Plant Management Package, while the same was discontinued in the sister organic garden from 2010 onwards.

Table 60: Impact of Inhana Rational Farming (IRF) plant management package towards crop response and economics.

Garden	2009		2010 & 2011	
	Total IRF Package Implemented in Both Gardens		Similar Soil & Pest Mgt. in both Gardens but No IRF Plant Package in Sister Organic Garden	
	Crop gain over 2008	Revenue Generated	Crop Gain/ loss w.r.t. 2009	Revenue Generated/ Loss
Maud T.E.	27,093 kg	(+) Rs. 55.07 lakh	(+) 9,424 kg	(+) Rs. 18.85 lakh
Sister Organic Garden	53,912 kg	(+) Rs. 107.82 lakh	(-) 22,352 kg	(-) Rs. 44.70 lakh

Note : *Revenue was calculated taking made tea price as Rs. 200/ kg. Net Impact of IRF Plant Management Package* on *crop performance would have been more pronounced, if there had not been any considerable loss in crop in 2010, in the entire zone due to environmental stress and unprecedented helopeltis Infestation.*


Pic. 91 : Pluckers returning to factory site for weighing of green leaf.


Pic. 92 : Green leaf in weathering turf as part of tea manufacturing process.


Pic. 93 : Steps of operation involved in tea manufacturing.

In 2009, both the gardens showed significantly higher crop performance under total IRF package as compared to 2008, when the gardens were under conventional organic practice (table 60). However, in 2010 and 2011, Maud T.E. (which received IRF plant management package) showed net crop gain of 9424 kg, while the sister organic garden which received identical soil input but discontinued IRF plant management; recorded a net crop loss of 22,352 kg (over 2009). In terms of economics while Maud T.E. gained revenue of Rs. 18.85 lakh (approx.), the sister organic garden suffered a loss of Rs. 44.70 lakh (approx.), during these two years.

Soil quality development under large scale adoption of Inhana Rational Farming (IRF) Package of Practice.

Soil samples were collected from Maud T.E. (from 135 ha at 5 ha interval) before initiation of experiment in 2009 and then every year before compost application. The soils were analyzed for different physicochemical, fertility and microbial parameters. The change in analytical values and their interrelationships were evaluated through thematic mapping in order to identify the problem and potentials of the tea estate.

Table 61: Impact of organic management on overall soil quality of Maud T.E. during 2009 to 2012 under FAO– CFC– TBI Project.

Soil Quality Parameter (0 to 50 cm)	Variation in Soil Quality under organic soil management			
	Year 2009	Year 2010	Year 2011	Year 2012
Soil physicochemical and fertility parameters				
Soil pH (water)	4.66	4.40	4.82	4.63
Electrical Conductivity (dSm^{-1})	0.033	0.036	0.039	0.051
Organic Carbon (%)	0.89	0.94	1.00	1.02
Available Nitrogen ($kgha^{-1}$)	369.24	394.04	360.34	405.10
Available Phosphate ($kgha^{-1}$)	39.41	40.33	30.73	65.71
Available Potash ($kgha^{-1}$)	145.82	212.51	127.63	199.49
Available Sulphate ($kgha^{-1}$)	69.99	80.11	59.34	64.72
Soil Microbial population (c.f.u. per gm moist soil)				
Total Bacterial Population	42.0×10^5	60.0×10^5	74.3×10^6	150.6×10^6
Total Fungal Population	53.6×10^4	109.0×10^4	14.9×10^4	28.8×10^4
Total Actinomycetes Population	14.8×10^4	43.1×10^4	13.7×10^4	32.0×10^4

Thematic maps were prepared not only to enable successful achievement of the Project objectivity but most importantly for scientific, easier and precision management of the Model Farm. Soil Quality parameters *viz.* pH, electrical conductivity, organic carbon, available NPKS, and microbial population in terms of total bacteria, fungi and actinomycetes were analyzed (for both top and sub soil samples) each year before compost application.

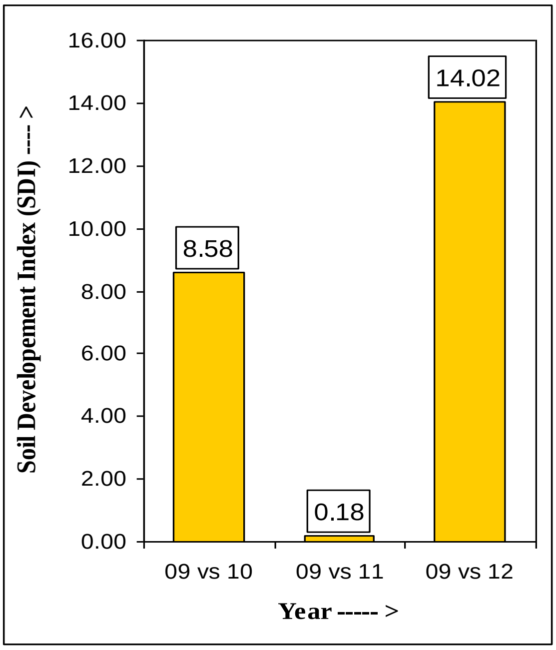


Fig. 138: Soil Development Index (SDI) of general garden area of Maud T.E. under IRF Plant Management with application of different types of organic soil inputs, during FAO-CFC-TBI Project.

Average analytical value of total 34 sets (both top and sub) of soil samples are given in table 61. Soil pH fluctuated year wise, however; the value did not show major variations with respect to the data obtained in 2009.

The results indicated that an effective organic soil management programme can serve to maintain soil pH, which is a consistent problem under chemical farming practice. Organic carbon percent increased by about 14.6 percent from the initial value. Soil fertility in terms of available N, P and K showed an increasing trend, however; with few exceptions. Value of available- N increased from 369 $kgha^{-1}$ in 2009 to 405 $kgha^{-1}$ in 2012, recording approx. 9.7 percent increase from initial value. Similarly available phosphate and potash also showed an increasing trend registering about 66.7 and 36.8 percent increase from initial value. Soil microbial population also increased post application of different organic soil inputs. Especially significant rise was recorded in terms of soil bacteria indicating improvement of soil health.

Soil Development Index (SDI) of rest garden area at Maud T.E. is presented in figure 138. The figure indicated that SDI value of Maud T.E. increased with progress in the period under Inhana Rational Farming. Year wise break up showed decrease in SDI value in 2010, which might be due to prolonged water logged situation in most of the sections of the garden due to intensive rainfall.

Made tea quality development under large scale adoption of Inhana Rational Farming (IRF).

In the present scenario an organic approach seems the only true pathway to restate the natural food quality. It is well understood that only an agricultural practice that shuns chemical pesticides can trigger the plants' natural defense mechanism leading to higher production of phytochemicals i.e. antioxidants. Analytical study reveals that organically grown crops contain about 1/3rd higher antioxidants and/or phenolic content than comparable conventional produce (Anonymous, 2005). Scientific studies evidences up to 30 percent higher antioxidant level in organic food as compared to conventional food grown under the same conditions (Felsot *et al*., 2003). But all these studies were based on the food grown just in the absence of fertilizers, pesticides and weedicides; there was no application of any comprehensive organic package.

In the present study an effort was made to evaluate the quality of organic tea grown under IRF in Maud T.E. *vis-à-vis* conventionally (under chemical farming) grown tea samples of some good Assam gardens to assess the impact of organic farming practice towards made tea quality. Table 62 represents quality of CTC black tea under conventional (chemical) and organic farming practice (IRF).

Table 62: Comparative evaluation of CTC back tea quality under conventional (chemical) and organic farming practice (IRF) in Assam.

Quality Parameters	Assam CTC Black Tea					
	Conventional Tea			Organic Tea (under IRF)		
	Range value	Mean	Std. Error	Range value	Mean	Std. Error
pH (1:100)	4.84 -5.09	4.94	± 0.03	4.59 – 5.23	4.87	± 0.02
EC[1] ($dS.m^{-1}$) 1:100	0.42 – 0.56	0.50	± 0.02	0.44 – 0.55	0.51	± 0.01
Total soluble salts (mg/l)	268.80–358.40	320.50	± 0.15	265.67– 351.10	326.40	± 0.23
Total dissolved solids (%) dry basis	34.78 – 43.30	38.38	± 0.83	30.64 – 42.26	38.47	± 1.73
Total Polyphenol content (mg/g)	86.40–127.00	92.16	± 3.94	94.56 – 131.42	106.58	± 4.94
Total Flavanoid content (mg/g)	72.58– 106.68	77.91	± 3.31	79.70 – 1	110.39	± 3.34

[1]EC : Electrical conductivity

Pic. 94 : Sorting of CTC tea under different grades.

Pic. 95 : Tea testing being done at Maud Tea Estate, Assam.

Pic. 96 : Appearance and colour of tea liquor with and without milk addition.

In all the cases mean pH value was lower (4.87) in case of organic tea samples as compared to conventional ones (4.94), which might indicate higher presence of free amino acids and phenolic compounds in the former (Bera *et al.*, 2013). Electrical Conductivity (EC) and Total Soluble Salts (TSS) in made tea samples reflect the nutritional and mineral management of tea plants. Under ideal conditions high TSS content is always accompanied by high Total Dissolved Solids (TDS) percent, higher polyphenol content and the corresponding high flavanoids. EC (0.50 and 0.51 dSm^{-1}), TSS (320.50 and 326.40 mg/l) and TDS (38.38 and 38.47 percent) values of conventional and organic tea samples indicated slightly higher values (on an average) in case of organic (under IRF) tea samples, for all the parameters under consideration.

Total polyphenol and flavanoid content in made tea are of major interest, considering that they reflect its antioxidant/ health giving potential. Total polyphenol content in conventional and organic (under IRF) tea samples varied from 86.4 to 127.0 mg/g and 94.56 to 131.42 mg/g respectively indicated that higher polyphenol content in case of organic tea samples as compared to its conventional counter parts.

Study of the month wise variation in total polyphenol content indicated its highest level during the period May to August (average varied from 108.32 to 120.42 mg/g), which started decreasing there after (Fig. 139). This is in tune with the quality graph of Assam tea production as evidenced by extrinsic quality in terms of liquor, briskness, aroma, etc.

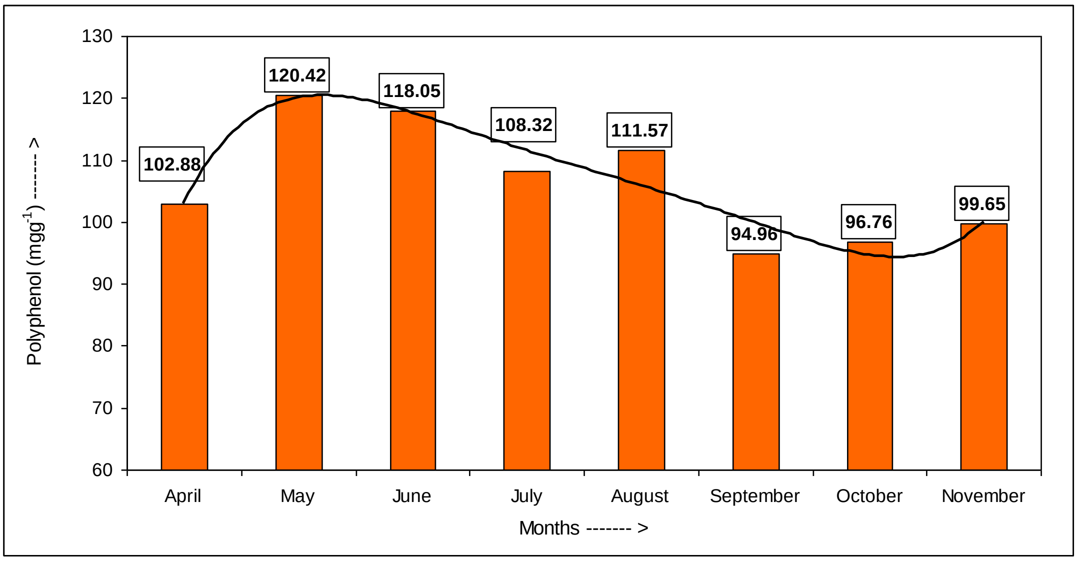


Fig. 139 : Month wise variation in total polyphenol content of made tea from Maud T.E. (Assam) as studied under FAO-CFC-TBI Project.

To evaluate the impact of long term organic practice on tea quality, Bera *et al.* (2013) analyzed CTC black tea samples from West Jalinga and Belseri tea estates, which have been practicing IRF for the past 10 years, from Maud T.E. where IRF was adopted for a period of 3 years as well as conventional branded Assam teas (Fig. 140). The study indicated an increase in total polyphenol and flavanoid content with increase in period under IRF protocol, which might be due to the activation of plant physiology under long term application of comprehensive soil and plant management programme.

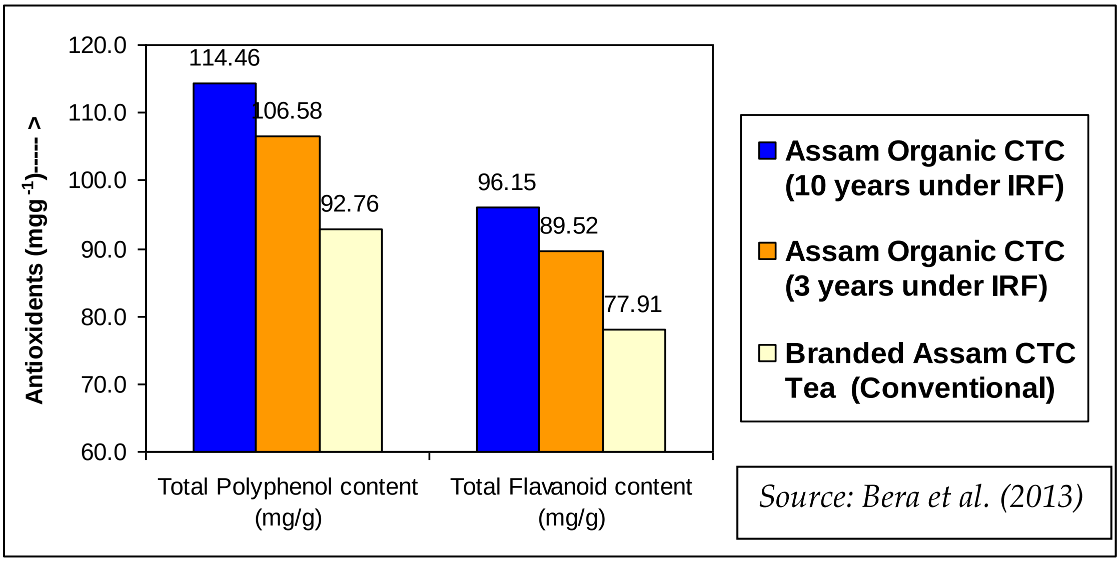


Fig. 140: Variation in antioxidant potential of Assam CTC black tea from gardens practicing IRF for 10 and 3 years respectively *vis-à-vis* Conventional Branded Samples.

The findings indicated that only a comprehensive organic package of practice can initiate an organic culture in soil, and the surrounding farm/ plantation ecology with positive influence towards the depressed plant physiology. Improvement in soil quality leading to better nutrient mineralization as well as suppression of soil borne plant pathogens along with reactivation of plant physiology (through specific plant management protocol) shall ensure healthy and productive plants due to effective absorption and assimilation of nutrients and lesser disease/ pest attack. While Soil Development Index (SDI) can serve as marker for effectiveness of the soil management programme the potential of comprehensive organic package shall be reflective in sustained crop performance and finally promotion of food quality (i.e., both extrinsic and intrinsic), which forms the ultimate objective of organic agricultural practice.

Development of Soil Resource Inventory for Effective Organic Management of Maud Tea Estate

Brief Summary

Soil resource inventory of Maud T.E. was developed through preparation of the various thematic maps based on the analysis report of soil samples collected before initiation of project and post practice of Inhana Rational Farming (IRF) for a period of three years.

Soil of Maud T.E. was moderate to strongly acidic in reaction (pH 4.31 – 5.50), however; minimal variation of soil pH was noted post three years of organic soil management under IRF. This is of special significance considering that in chemical gardens yearly application of lime becomes necessary for maintenance of soil pH. Evaluation of soil organic carbon stock at Maud T.E. before initiation of project revealed a status of 4500–6500 kgha^{-1} in major portion of the garden. Adoption of organic soil management under IRF led to notable reduction in the low (<than 5500 kgha^{-1}) carbon stock area and enabled uplifted status of 6500–7500 kgha^{-1} in significant portion of the plantation.

Nitrogen a critical nutrient for tea production varied from moderately low to moderate status and was found to respond positively under organic soil management. However, the most remarkable finding was increase in area representing moderately high to very high phosphate status, which confirmed the positive impact of compost application containing huge self- generated microbial pool; towards enhanced availability of phosphate in soil. Organic soil management under IRF also uplifted the potash content of a significant area of the garden from low to moderate status. In terms of available- SO_4 major portion of the garden (55.51 % of TGA) represented low to very low status which needs to be brought under the radar of priority soil management

Microbial load varied within 2000 to 4000 kgha^{-1} in major area of the garden (61.97 % of TGA), however; organic soil management under IRF uplifted the status to >4000 kgha^{-1} in significant portion of the garden.

Development of Soil Resource Inventory for Effective Organic Management of Maud Tea Estate

Introduction

Soil resource mapping and development of thematic maps is the most useful tool for identification of potential and problematic areas of any plantation in order to enable the formulation of an effective and customized soil management programme. This can also serve as the guiding material for the garden authority in terms of taking up decisions regarding yearly soil management protocol. This is of significance especially in case of organic soil management, where judicious application of organic soil inputs has a direct bearing on the related economics. This is because plantations generally depend on off-farm soil inputs due to general scarcity of resources for on-farm compost production in the required quantity.

Top (0 to 25 cm) and sub (25 to 50 cm) soil samples were collected (at 5 ha interval) from Maud T.E. (excluding the micro research area) in 2009 and later on every year before compost application. The samples were analyzed for different physicochemical, fertility and microbial parameters. Problem and potential areas of the garden as well as variation in soil quality (in terms of Fertility Index 'FI' and variation of Soil Organic Carbon Stock 'SOCS') post adoption of Inhana Rational Farming (IRF) for a period of three years were evaluated by developing soil thematic maps. Development of soil resource maps enabled scientific, easier and precision management of hundred hectare Model Farm Maud T.E.

Objective

1. Identification of problem and potential areas.
2. Selection of priority zone for taking up management.
3. Better utilization of existing on- farm resources.
4. Management policy development and speedy decision making.

Interpretation of the soil resource maps and impact of Inhana Rational Farming (IRF) on Soil Quality Development at Maud T.E., Assam.

It is important to manage the pH of soil since it can affect plant's ability to take up nutrients and soil microbial activity that affects the processes needed for plant nutrition (VanTine, 2003). Recommended soil pH for tea cultivation is 5.0-5.6 (Willson & Clifford 1992) below which tea plant cannot maximize yield production as acidification can result in plant root damage and reduce plant productivity (Kauppi *et. al.*, 1986). Long term tea cultivation has often led to serious soil acidification (77% of 70 tea fields having pH below 4.0) as a consequence of heavy chemical nitrogen (N) application (Oh *et. al.*, 2006). Study also shows that continuous use of chemical fertilizer without addition of lime reduces soil pH to a level that is unsuitable for economic production of crops (Tisdale & Nelson 1975). On the other hand, maintenance of soil pH with application of compost was recorded by other workers dealing with organic soil inputs (Rahaman, 2009; Minh 2010 and Sarwar *et al*., 2008).

Before initiation of organic soil management under IRF, major portion of the garden was dominated by moderately (4.61 to 5.00) acidic (65.28 % of TGA) followed by strong to moderately (pH: 4.31 to 4.60) acidic (34.24 % of TGA) soil (fig. 141 and 142). Since slight to moderately acidic pH (4.61 – 5.50) is most preferable for tea plants for better nutrient availability and rhizosphere environment, hence it should be a determinant criterion towards improvement of soil-plant relationship. Temporal variation of soil pH was minimal post three years of organic soil management (table 63A), which is of special significance considering that in chemical gardens yearly application of lime becomes necessary for maintenance of soil pH.

Organic carbon is a very critical factor in organically managed tea gardens not only for N availability but also for it's influence on the soil microbial status and soil physical character. Before adoption of IRF, majority of the garden area (77.74) was moderately low (0.61 to 1.00 %) in organic carbon while only 16.34 % of the soils showed moderate (1.00 to 1.49 %) content (fig. 143 and 144). Very low organic carbon status (< 0.60 %) is observed in Sec. 1(P), and part of Sec. 11 covering 6.12 % of TGA. However adoption of organic soil management programme under IRF over a period of three years enabled remarkable upliftment of organic carbon to moderate content in about 75 percent of TGA.

Temporal variation of soil pH under Inhana Rational Farming (IRF) package at Maud T.E. from 2009 to 2012 under FAO-CFC-TBI Project.

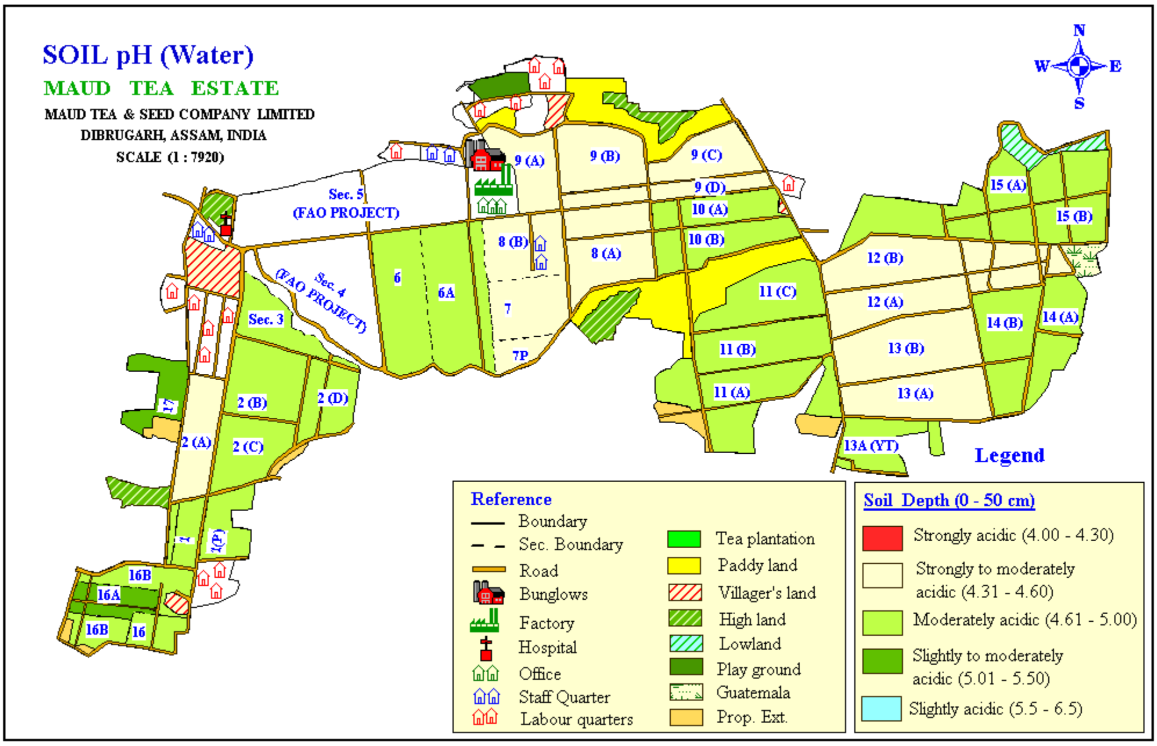


Fig. 141: Spatial distribution of soil pH before initiation of project in 2009.

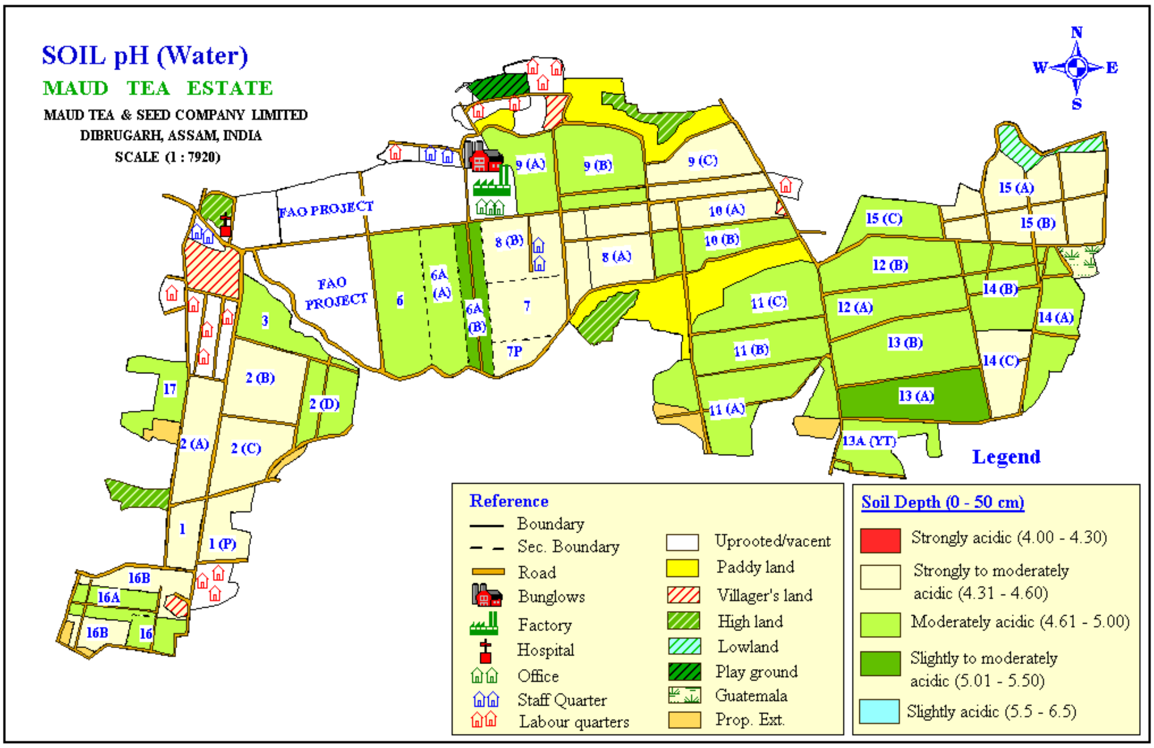


Fig. 142: Spatial distribution of soil pH post completion of experiment in 2012.

Temporal variation of soil organic carbon under Inhana Rational Farming (IRF) package at Maud T.E. from 2009 to 2012 under FAO-CFC-TBI Project.

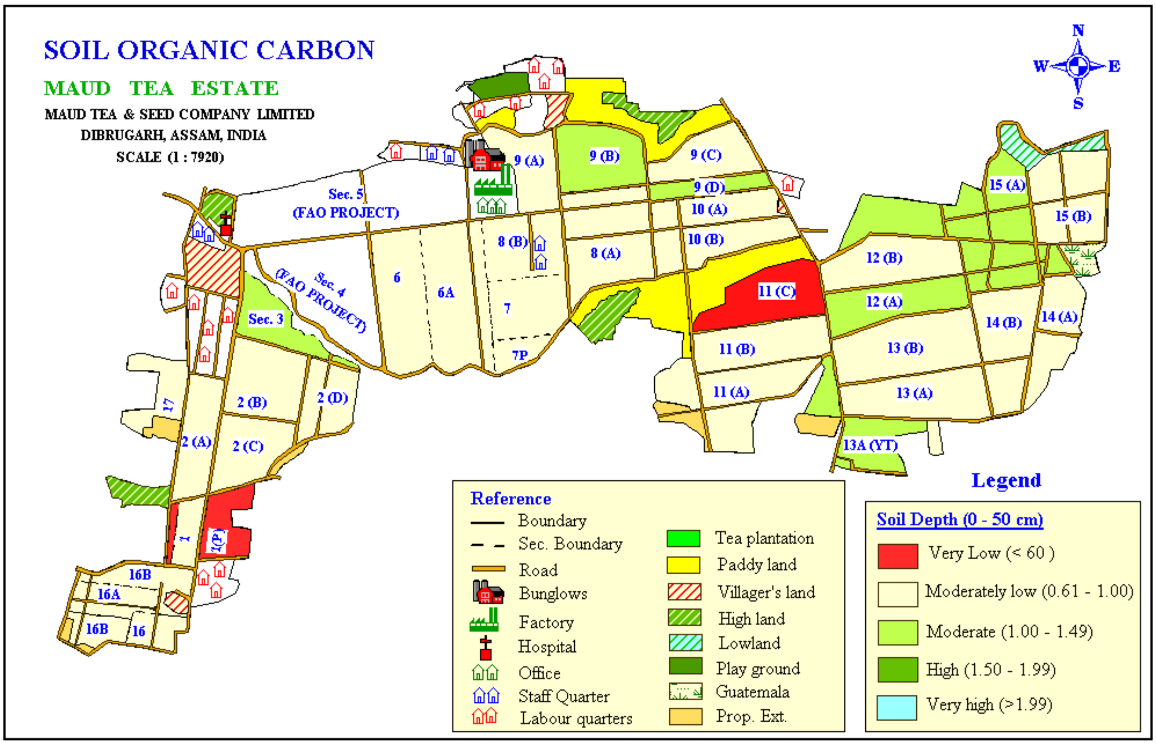


Fig. 143: Spatial distribution of soil Org. C before initiation of project in 2009.

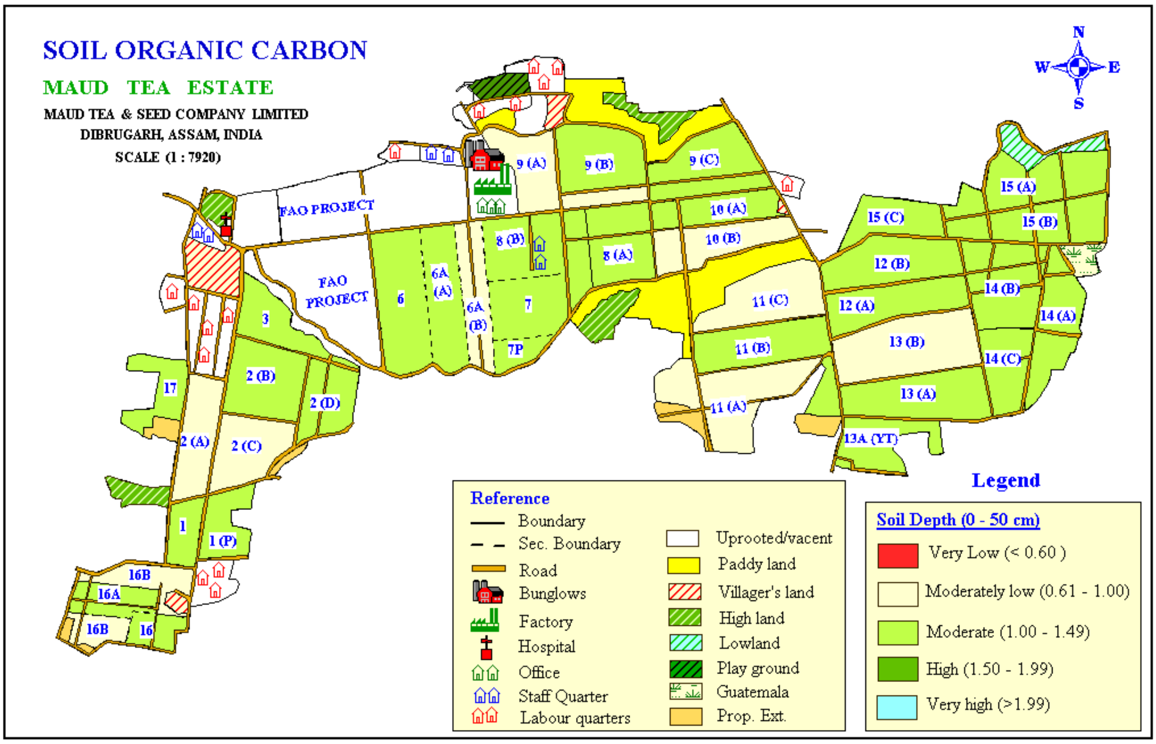


Fig 144: Spatial distribution of soil Org. C post completion of experiment in 2012.

Table 63A: Classification of various soil quality parameters and their representative share of TGA as depicted in the thematic maps.

Classification	Year 2009		Year 2012	
	Area (ha)	% of TGA*	Area (ha)	% of TGA*
Soil pH (H_20)				
Strongly Acidic (4.00 – 4.30)	-	-	-	-
Strongly to Moderately Acidic (4.31 – 4.60)	46.48	34.24	51.21	37.73
Moderately Acidic (4.61 – 5.00)	87.24	64.28	75.95	55.96
Slightly to Moderately Acidic (5.01 – 5.50)	2.00	1.48	8.56	6.31
Slightly acidic (5.51 – 6.50)	-	-	-	-
Soil Organic Carbon (%)				
Very Low (< 0.60)	8.30	6.12	-	-
Moderately Low (0.61 – 1.00)	105.24	77.54	33.93	25.00
Moderate (1.01 – 1.49)	22.18	16.34	101.79	75.00
High (1.50 – 1.99)	-	-	-	-
Very High (> 2.00)	-	-	-	-
Soil Available Nitrogen ($kgha^{-1}$)				
Low (< 280 $kgha^{-1}$)	8.30	6.12	-	-
Moderately Low (280 – 415 $kgha^{-1}$)	82.71	60.94	89.30	65.79
Moderate (415 – 550 $kgha^{-1}$)	44.71	32.94	46.42	34.21
High (550 – 685 $kgha^{-1}$)	-	-	-	-
Very High (> 685 $kgha^{-1}$)	-	-	-	-
Soil Available Phosphate ($kgha^{-1}$)				
Very Low (< 22.5 $kgha^{-1}$)	4.12	3.04	-	-
Low (22.5 – 45.0 $kgha^{-1}$)	66.38	48.91	45.79	33.74
Moderate (45.0 – 67.5 $kgha^{-1}$)	60.36	44.48	39.02	28.75
Moderately High (67.5 to 90.0 $kgha^{-1}$)	4.85	3.57	14.34	10.56
High (90.0 – 112.5 $kgha^{-1}$)	-	-	23.81	17.54
Very High (> 112.5 $kgha^{-1}$)	-	-	12.76	9.40
Soil Available Potash ($kgha^{-1}$)				
Low (< 145 $kgha^{-1}$)	72.13	53.15	2.39	1.76
Moderately Low (145 - 242 $kgha^{-1}$)	63.59	46.85	112.51	82.90
Moderate (242 - 339 $kgha^{-1}$)	-	-	20.82	15.34
High (339 – 436 $kgha^{-1}$)	-	-	-	-
Very High (> 436 $kgha^{-1}$)	-	-	-	-

*TGA : Total Geographical Area.

Temporal variation of soil available nitrogen under Inhana Rational Farming (IRF) package at Maud T.E. from 2009 to 2012 under FAO-CFC-TBI Project.

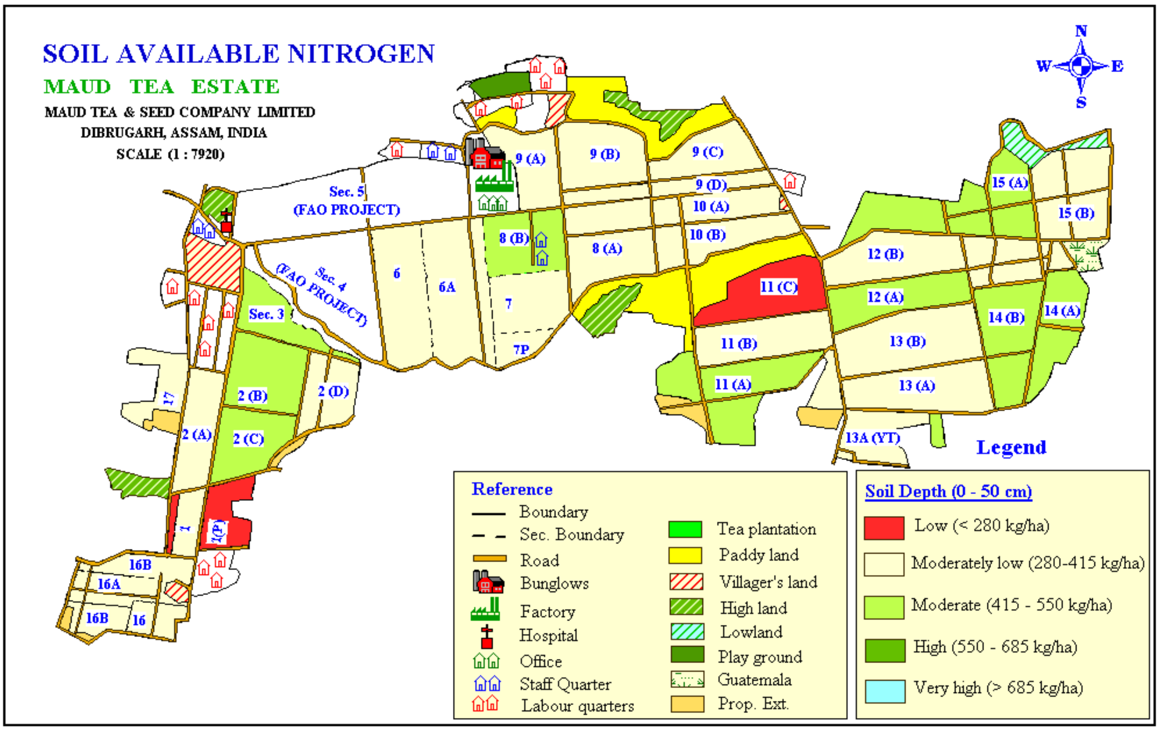


Fig. 145: Spatial distribution of soil Av.- N before initiation of project in 2009.

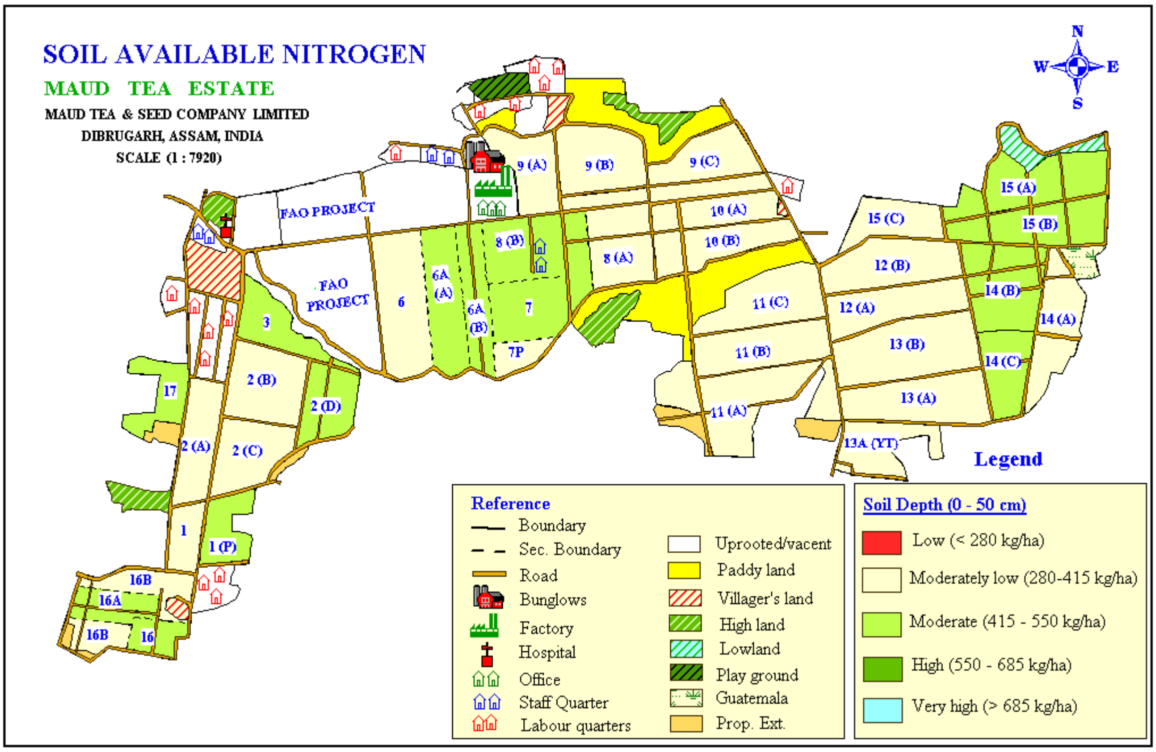


Fig. 146: Spatial distribution of soil Av.- N post completion of experiment in 2012.

Tea being a leaf crop, in the flush shoot nitrogen content is highest followed by potassium (K), calcium (Ca), phosphorus (P), sulfur (S), magnesium (Mg) and zinc (Zn). Nitrogen (N) is an important constituent of plants parts and plays a vital role in the physiology of the tea plant. It is estimated that harvestable crop contains 3.5-5% N on dry matter basis (Verma, 1997). Although applications of N can increase tea yields, it is recognized that the quality of the manufactured product is suppressed by large N rates (Cloughly *et al*., 1983).

Soil available nitrogen was found to be moderately low (280 – 415 $kgha^{-1}$) to moderate (415 to 550 $kgha^{-1}$) in status covering 60.94 % and 32.94 % of TGA respectively (fig. 145 and 146), which might not be a concern for chemical garden but is definitely vulnerable for yield sustainability under organic management. Low N status in section 1(P) and 11(part) covering about 6.12 % of TGA is in accordance to the very low soil organic carbon obtained in these areas, thereby substantiating the interrelationship between organic carbon and N availability in soils. Raising the content of soil organic carbon should definitely increase the availability of N; however, application of good quality, mature compost containing high population of naturally generated microbes; is of prime requisition. This was exhibited in case of Maud tea estate where after a period of three years, low N status in section 11 (part) and 1(P) were uplifted to moderately low and moderate status respectively. Finally area under moderately low and moderate soil available-N increased to 65.39 and 34.21 % of TGA respectively.

Phosphorus is required in lesser amount if compared with the necessity of certain high energy phosphate bonds involved in the respiratory photosynthetic process. These bonds transfer energy in some of the plants metabolic processes without which the plant cannot survive. However, availability of phosphate in acid tea soil is always under scanner as ionic forms of phosphorus ($H_2PO_4^-$) readily react with oxides (hydroxide), iron and aluminium which are abundant in acid soil, to form insoluble compounds that is hard to extract from soil (Tisdale & Nelson 1975, Wilson & Clifford 1992). Major portion of the garden covering 48.91 % of TGA showed low content of available-P_2O_5 (22.5 to 45.0 $kgha^{-1}$) followed by soils with moderate (45.0 to 67.5 $kgha^{-1}$) status (44.48 % of TGA). Before adoption of IRF package in 2009, moderately high content of available-P_2O_5 was observed only in part of section 15. Since P is involved in energy transfer reactions, it is responsible for effective plant metabolism. It also influences root growth and relative absorption of N by plants, hence its low content especially in organically managed tea soils shall invariably affect plant efficiency.

Temporal variation of soil available- P_2O_5 under Inhana Rational Farming (IRF) package at Maud T.E. from 2009 to 2012 under FAO-CFC-TBI Project.

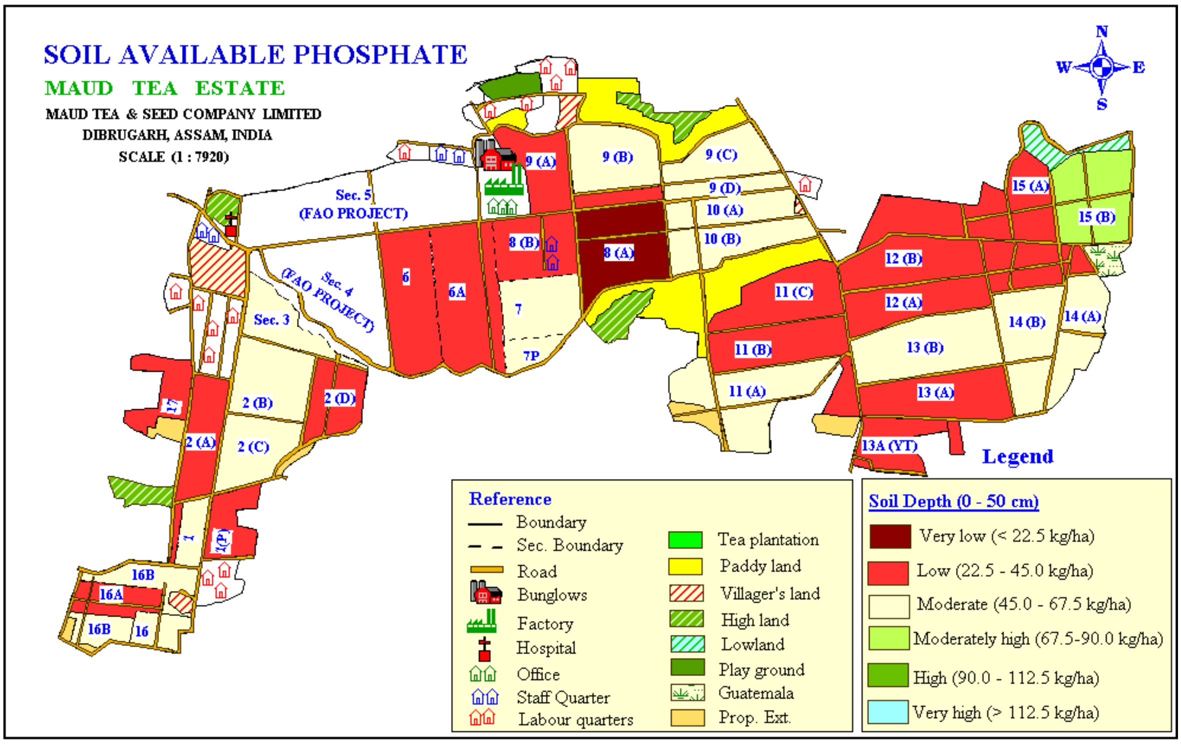


Fig. 147: Spatial distribution of soil Av.- P_2O_5 before initiation of project in 2009.

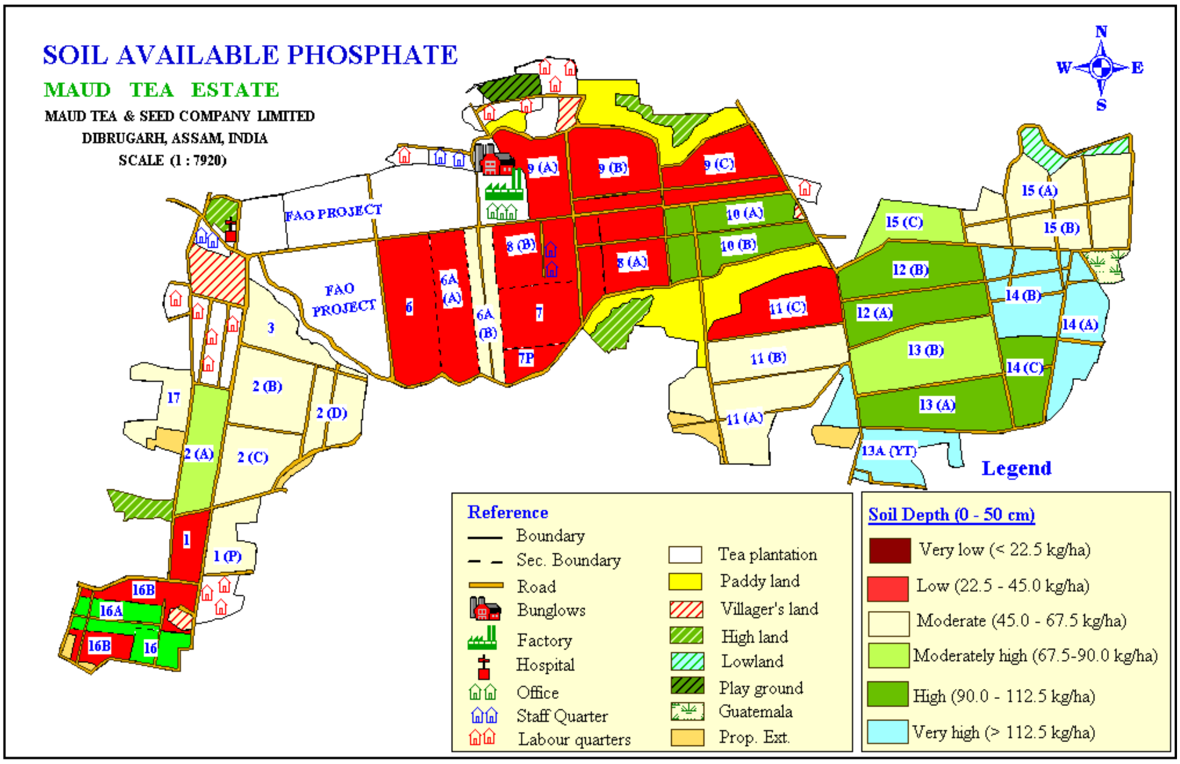


Fig. 148: Spatial distribution of soil Av.- P_2O_5 post completion of experiment in 2012.

Table 64B: Classification of various soil quality parameters and their representative share of TGA as depicted in the thematic maps.

Classification	Year 2009 Area (ha)	Year 2009 % of TGA*	Year 2012 Area (ha)	Year 2012 % of TGA*
Soil Available Sulphate ($kgha^{-1}$)				
Very Low (< 40 $kgha^{-1}$)	2.00	1.47	30.63	22.57
Low (40 – 80 $kgha^{-1}$)	73.34	54.04	99.26	73.14
Moderate (80 – 100 $kgha^{-1}$)	32.29	23.79	5.82	4.29
Moderately high (100 – 120 $kgha^{-1}$)	11.98	8.83	-	-
High (120 – 140 $kgha^{-1}$)	12.72	9.37	-	-
Very High (> 140 $kgha^{-1}$)	3.40	2.51	-	-
Soil Organic Carbon Stock ($kgha^{-1}$)				
< 3500 $kgha^{-1}$	-	-	-	-
3500 – 4500 $kgha^{-1}$	18.16	13.38	-	-
4500 – 5500 $kgha^{-1}$	44.53	32.81	14.61	10.76
5500 – 6500 $kgha^{-1}$	50.69	37.35	90.97	67.03
6500 – 7500 $kgha^{-1}$	22.34	16.46	30.14	22.21
> 7500 $kgha^{-1}$	-	-	-	-
Soil Fertility Index				
Very Low (< 72)	-	-	-	-
Low (72 – 110)	9.01	6.64	-	-
Moderately Low (111 – 148)	71.44	52.64	30.71	22.62
Moderate (149 – 186)	55.27	40.72	93.03	68.55
Moderately High (187 – 225)	-	-	7.92	5.84
High (226 – 263)	-	-	4.06	2.99
Very High (> 263)	-	-	-	-
Soil Microbial Load ($kgha^{-1}$)				
< 1000 $kgha^{-1}$	20.62	15.19	-	-
1000 – 1500 $kgha^{-1}$	3.92	2.89	1.65	1.22
1500 – 2000 $kgha^{-1}$	24.07	17.73	4.33	3.19
2000 – 2500 $kgha^{-1}$	27.42	20.21	33.23	24.48
2500 – 3000 $kgha^{-1}$	37.00	27.26	20.20	14.88
3000 – 3500 $kgha^{-1}$	10.78	7.94	40.98	30.20
3500 – 4000 $kgha^{-1}$	8.91	6.56	6.50	4.79
> 4000 $kgha^{-1}$	3.00	2.21	28.84	21.25

*TGA : Total Geographical Area.

To address the problem there was regular application of rock phosphate along with good quality/ mature Novcom compost containing high population of naturally generated microbes in order to favourably influence the proliferation of PSB status in soils. The impact of management done was clearly exhibited in the soil analysis results, according to which area representing moderately high (67.5 to 90.0 $kgha^{-1}$) to very high (> 112.5 $kgha^{-1}$) phosphate status increased to 37.5 % TGA in 2012 (fig. 147 and 148), which was merely 3.57 of TGA in 2009. The results confirmed that application of mature and well decomposed organic manure with enriched self- generated microbial pool positively influences soil reaction leading to enhanced availability of soil phosphate.

Next to nitrogen, potassium (K) is another essential nutrient and is taken up by plants in quite large quantities similar to or more than nitrogen. It has been reported that potassium and magnesium are required in large quantities, and they are both involved in almost all biological reactions in crop plants (Sedaghathoor *et al*., 2009). Although K is not a constituent of any organic molecule or plant structure, it is involved in numerous biochemical and physiological processes and plays a pivotal role towards plant growth, yield, quality and stress (Cakmak, 2005). Potassium as one of the major nutrient in plant shoot has strong influences on the quality of marketable tea (Venkatesan *et al*., 2006). Also, quality components of black tea were shown to be improved with increased K application in Chinese cultivation practices (Ruan and Hardter, 2001).

Soil available potash is a major constraint in Maud T.E varying from low (< 145.0 $kgha^{-1}$) to moderately low (145.0 to 242.0 $kgha^{-1}$) with moderate (242.0 to 339.0 $kgha^{-1}$) status only in part of section 14 (fig. 149 and 150). Potash is an important element for overall tea growth but most importantly is critical for young tea development. Hence, low potash status especially in young tea sections *viz.* 13A, 1P, 2 calls for special management practices. However, potash management is a Herculean task in organically managed soils since most of the available soil inputs are low in potash. Organic soil management under IRF positively influenced the available potash content in soil as indicated by the reduction in low potash area from 28.26 to 2.39 % of TGA, area with moderately low status covered 82.90 % of TGA while 15.34 % of TGA came up with moderate potash status. The behaviour of potassium in soil is influenced primarily by soil cation exchange capacity and mineral weathering, rather than microbiological processes. As CEC of these soils increased during the experiments, the potash status also increased.

Temporal variation of soil Av.- K_2O under Inhana Rational Farming (IRF) package at Maud T.E. Estate from 2009 to 2012 under FAO-CFC-TBI Project.

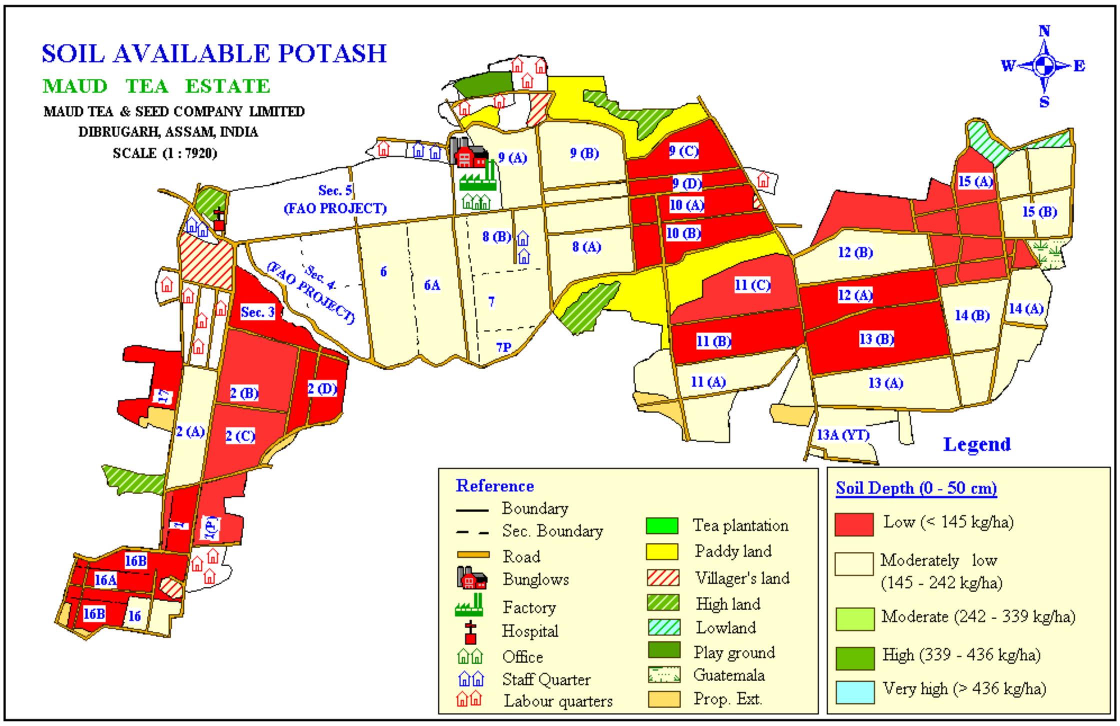


Fig. 149: Spatial distribution of soil Av.- K_2O before initiation of project in 2009.

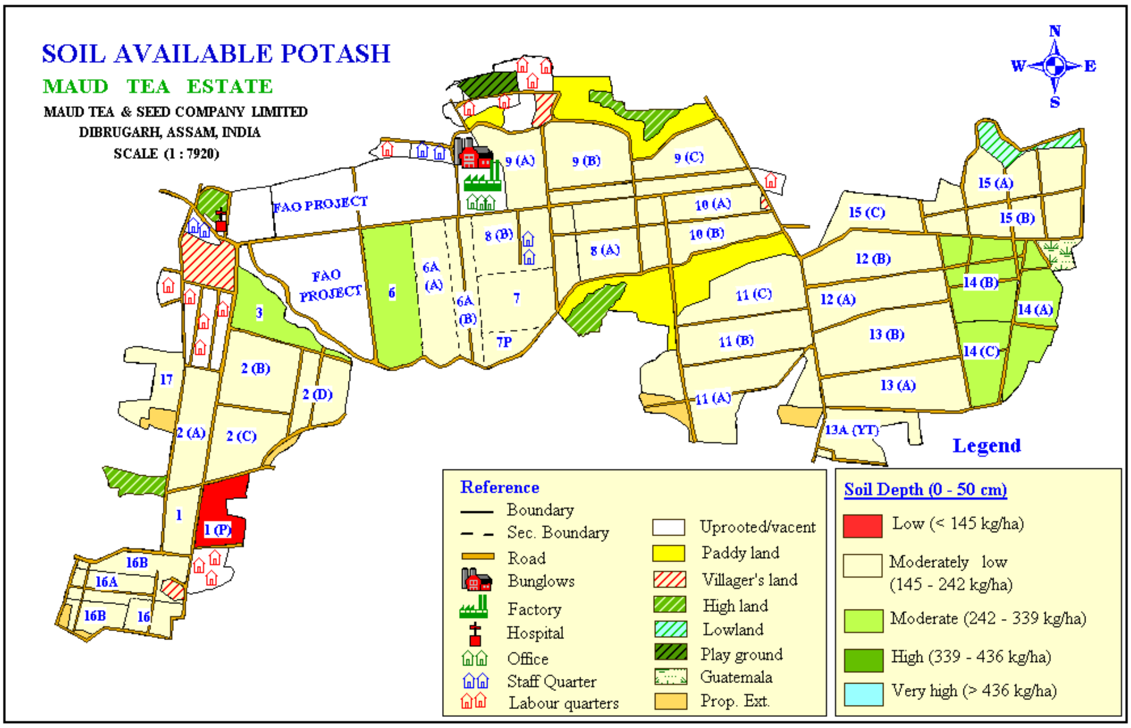


Fig. 150: Spatial distribution of Av. K_2O post completion of experiment in 2012.

Temporal variation of soil available- SO_4 under Inhana Rational Farming (IRF) package at Maud T.E. from 2009 to 2012 under FAO-CFC-TBI Project.

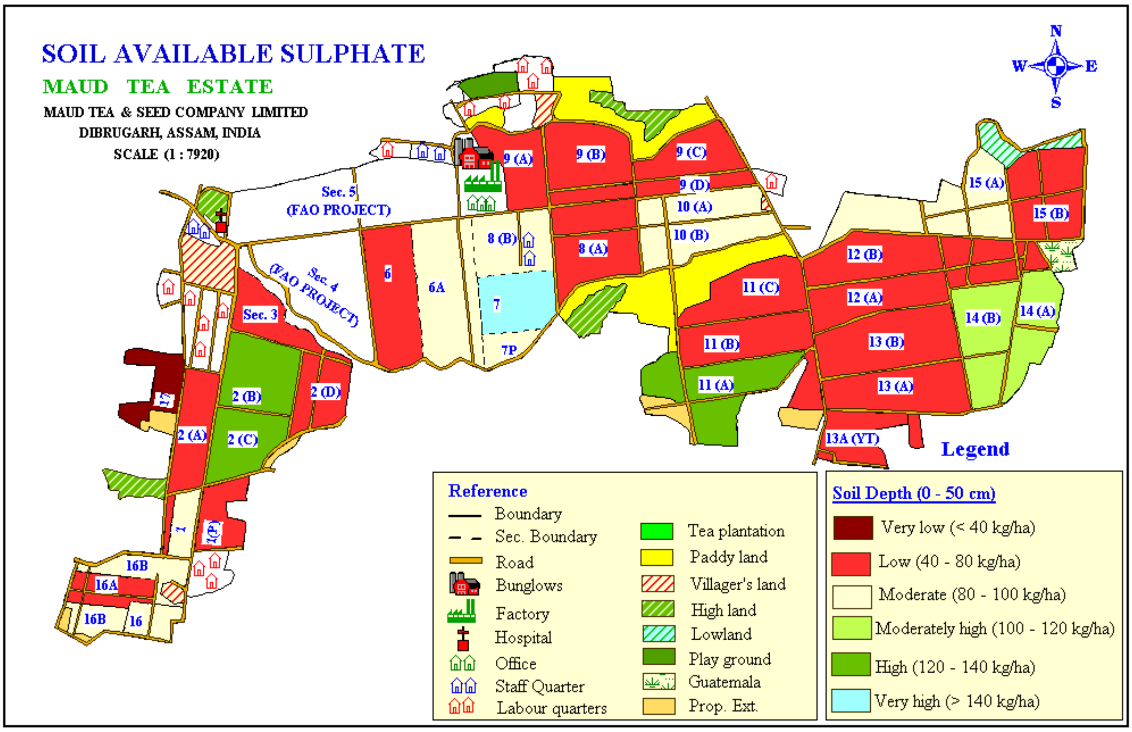


Fig. 151: Spatial distribution of soil Av. SO_4 before initiation of project in 2009.

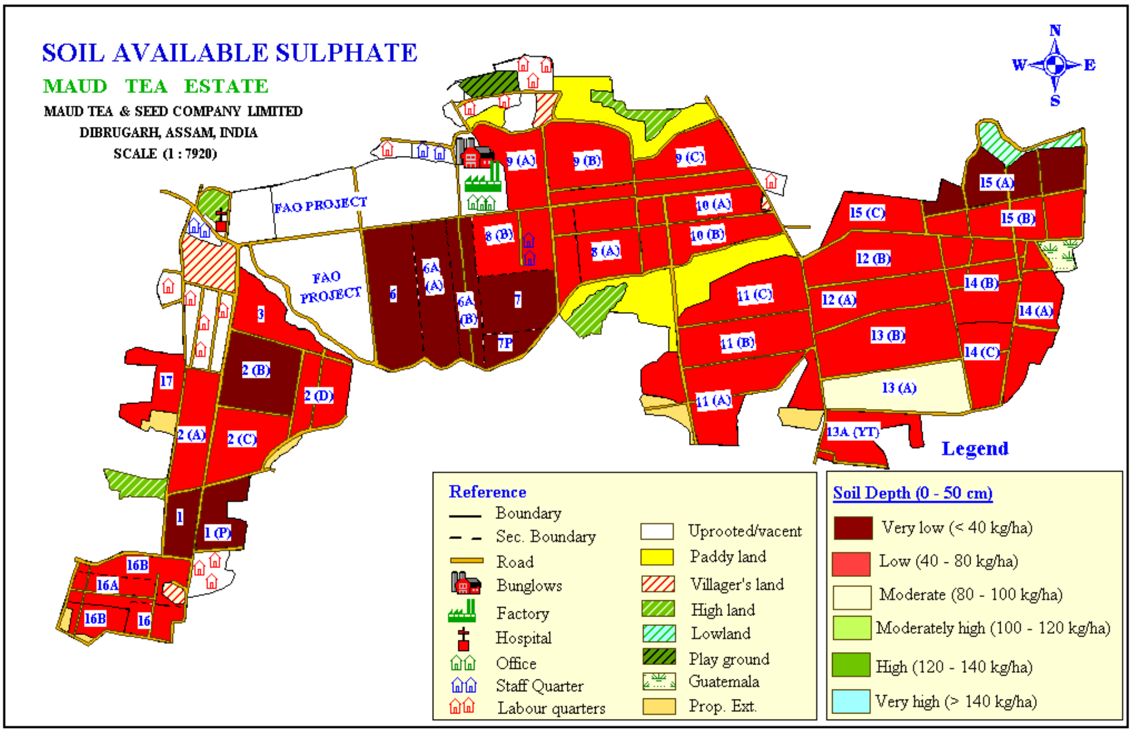


Fig. 152: Spatial distribution of Av. SO_4 post completion of experiment in 2012.

Sulfur requirement for tea is very high at 16 to 26 kg/ ha/ year. The sulfur content of fresh green tea leaves should be maintained at 8% to 2% on dry matter basis to achieve maximum yield of fresh leaves which can be processed into high quality tea products. Young leaves are hardest hit by unhealthy looking pale yellow color, and general yellowing of the inter-veinal areas. New shoots are smaller and internodes (distance between leaves) shorter due to a slow down in growth that is followed by general shoot necrosis if sulfur deficiency persists (Mabbett, 2005). Most importantly tea quality *viz.* color, brightness, strength, body, taste and flavor of the tea liquor are adversely affected by sulfur-deficiency. Distribution of soil available-S generally shows great variance from very low to very high status. As the release of available sulphate from its organic state is mainly dependant on microbiological processes, its supply in soil fluctuates with season and some time daily changes in environmental conditions. This fluctuation causes some difficulties in predicting and measuring the amount of sulphur available to plants.

Major portion of the garden (55.51 % of TGA) represented low to very low content of available- SO_4 which need to be brought under the radar of priority soil management (fig. 151 and 152). The study indicated moderately low to low available- SO_4 status in strongly to moderately acidic soils (except section 8) indicating the negative influence of low pH towards sulphate availability in soil. Since S plays the major role in synthesis of vitamins as well as in general metabolism, regular application of Elemental-S was done after mixing with compost. However, more effective and strict soil management regimen needs to be taken up towards upliftment of the garden SO_4 status.

Global soil carbon stocks of agricultural land have decreased historically and continue to decline (Lal, 2004). Thus, improved agronomic practices that could lead to reduced carbon losses or even increased soil carbon storage are highly desired (Gattingera *et al.*, 2012). Application of organic fertilizer such as compost or waste products from livestock husbandry in the form of manure (Diacono and Montemurro, 2010) allocates more carbon below- ground. Hence, adoption of organic agriculture leads to a reduction in soil carbon losses or even contributes towards higher soil carbon concentrations and net carbon sequestration over time (Niggli *et al.*, 2009). Introducing organic farming is considered an interesting and sustainable option for greenhouse gas (GHG) mitigation in agriculture. In contrast to the adoption of single GHG mitigation practices organic farming as a system approach provides many other co-benefits, such as adaptation to climate change, biodiversity and soil conservation (Gattingera *et al.*, 2012). Soil bulk densities were found to be lower for the organic practice (Gattingera *et al.*, 2012), thus the observed increase in SOC stocks in organically managed soils resulted from SOC enrichment and not from soil compaction.

Temporal variation of soil organic carbon stock under Inhana Rational Farming (IRF) at Maud T. E. from 2009 to 2012 under FAO-CFC-TBI Project.

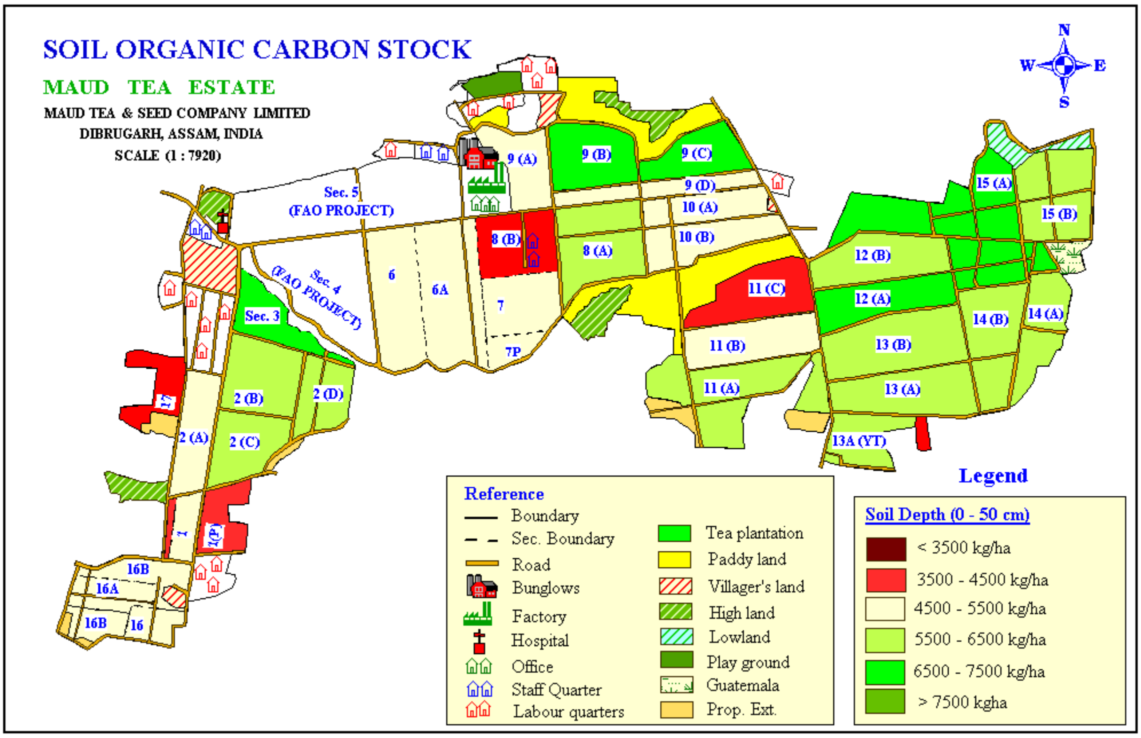


Fig. 153: Spatial distribution of soil Org. C stock before project initiation in 2009.

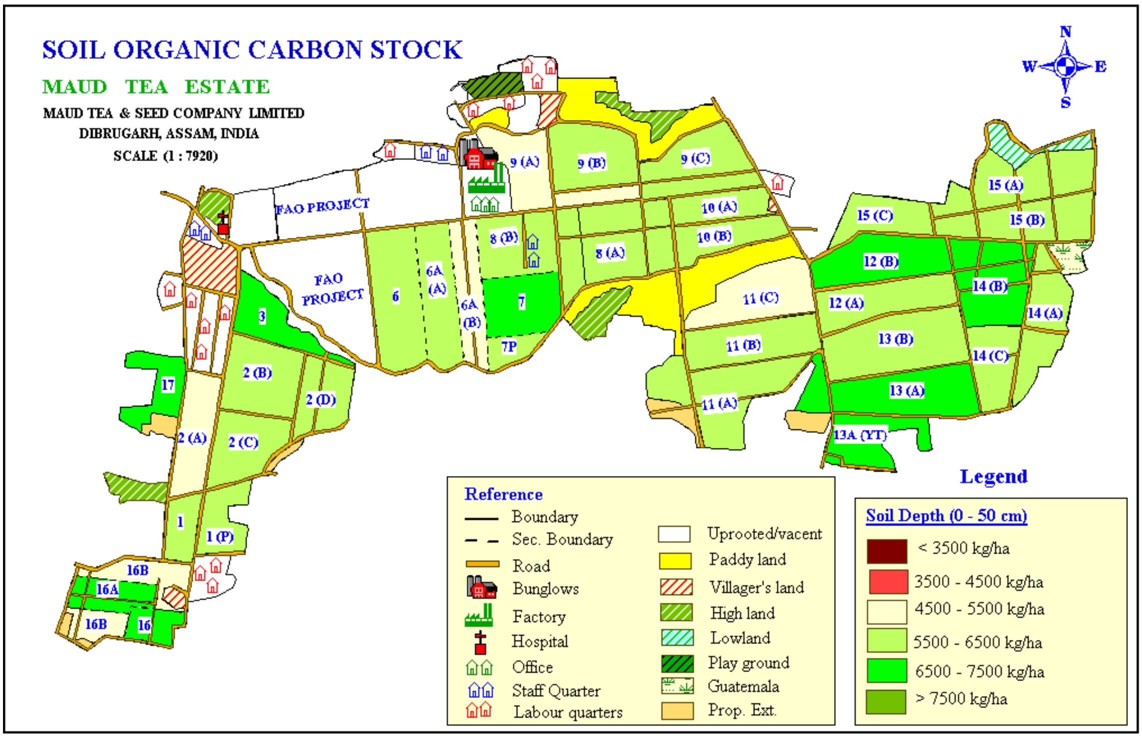


Fig. 154: Spatial distribution of soil Org. C stock post experiment in 2012.

Evaluation of soil organic carbon stock at Maud T.E. before initiation of project revealed a status of 4500–5500 kgha^{-1} and 5500–6500 kgha^{-1} in major portion of the garden i.e. covering 32.81 % and 37.35 % of TGA respectively. Only a small portion of the total area (16.46 % of TGA) had comparatively higher organic carbon stock of 6500–7500 kgha^{-1} (table 63B). However, organic soil management under IRF for a period of three years improved the soil organic carbon stock of the garden to a considerable extent. Most significant outcome was reduction in the low (<than 5500 kgha^{-1}) stock area from 46.19 % to 10.76 % of TGA. Moreover, assessment of the spatial distribution in 2012 indicated relatively high organic carbon stock (5500–6500 kgha^{-1}) in major portion of the area (67.03 % of TGA) as well as a status of 6500–7500 kgha^{-1} in 22.21 % of TGA (fig. 153 and 154). However, upliftment in soil organic carbon stocks might not only be due to net carbon gain following adoption of a new management practice but also due to reduced carbon loss if compared with previous conventional organic practice.

Quantification of soil fertility using fertility index [formulated using the value of available macro nutrients i.e. N, P, K and S (Annexure)] revealed low (72 – 110) to moderately low (111 – 148) status in 59.28 % of TGA while moderate (149 – 186) fertility in about 40.72 % of TGA, before adoption of IRF. Moderately high to high fertility index is an important component especially for organically managed tea soils not only for achieving the desired yield potential but most importantly to sustain it in the long run, without any soil deterioration. However, post three years organic soil management under IRF there was notable impact on the soil nutrient mineralization potential, which was reflected by the fertility index (fig. 155 and 156) of soil. Henceforth, the index upgraded towards high (226-263) to moderately high (187 – 225) value in about 8.83 % of TGA and moderate status in approx. 68.55 % of TGA.

The living population inhabiting soil includes macrofauna, mesofauna, microfauna and microflora. 80–90% of the processes in soil are mediated by microbes (Nannipieri and Badalucco, 2003). Microbial load is defined as total number of bacteria, fungi and actinomycetes in a given quantity of soil. Manure used in organic farming treatment enhanced the bacteria and fungal population greater than conventional farming (Ying-Po and Ching, 1995). Especially soil fungal population is favoured largely by organic farming systems (Drinkwater *et al*., 1995; Girvan *et al*., 2004). Total microbial load was well matched with soil nutrients and organic carbon that is microbial load was highest at the soil surface where organics and nutrients were highest. (Krishna *et al*., 2012).

Temporal variation of soil fertility index under Inhana Rational Farming (IRF) package at Maud T.E. from 2009 to 2012 under FAO-CFC-TBI Project.

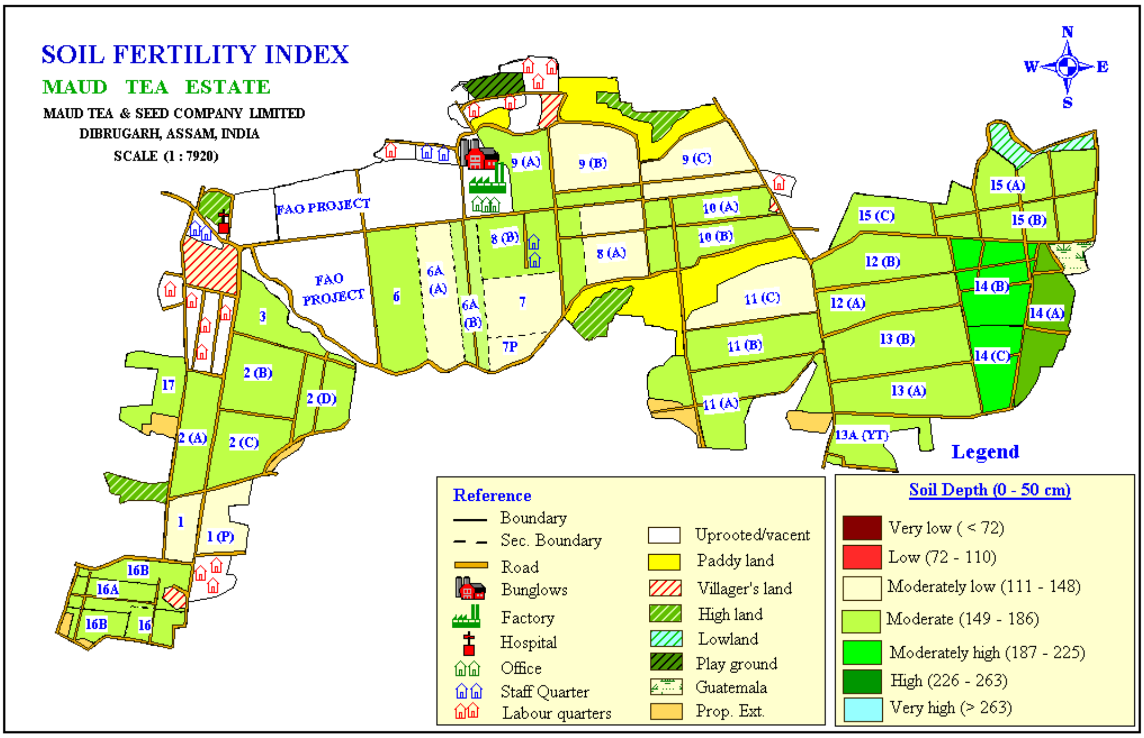


Fig. 155: Spatial distribution of soil fertility index before project initiation in 2009.

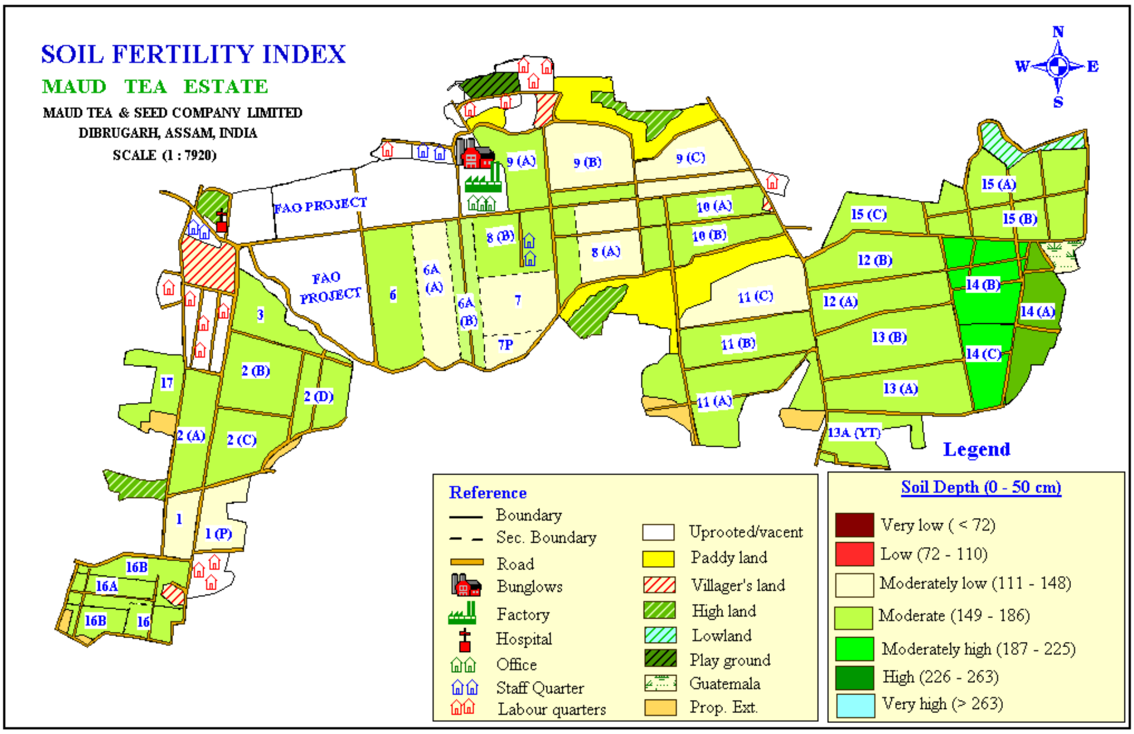


Fig. 156: Spatial distribution of soil fertility index post experiment in 2012.

Temporal variation of soil microbial load under Inhana Rational Farming (IRF) package at Maud T.E. from 2009 to 2012 under FAO-CFC-TBI Project.

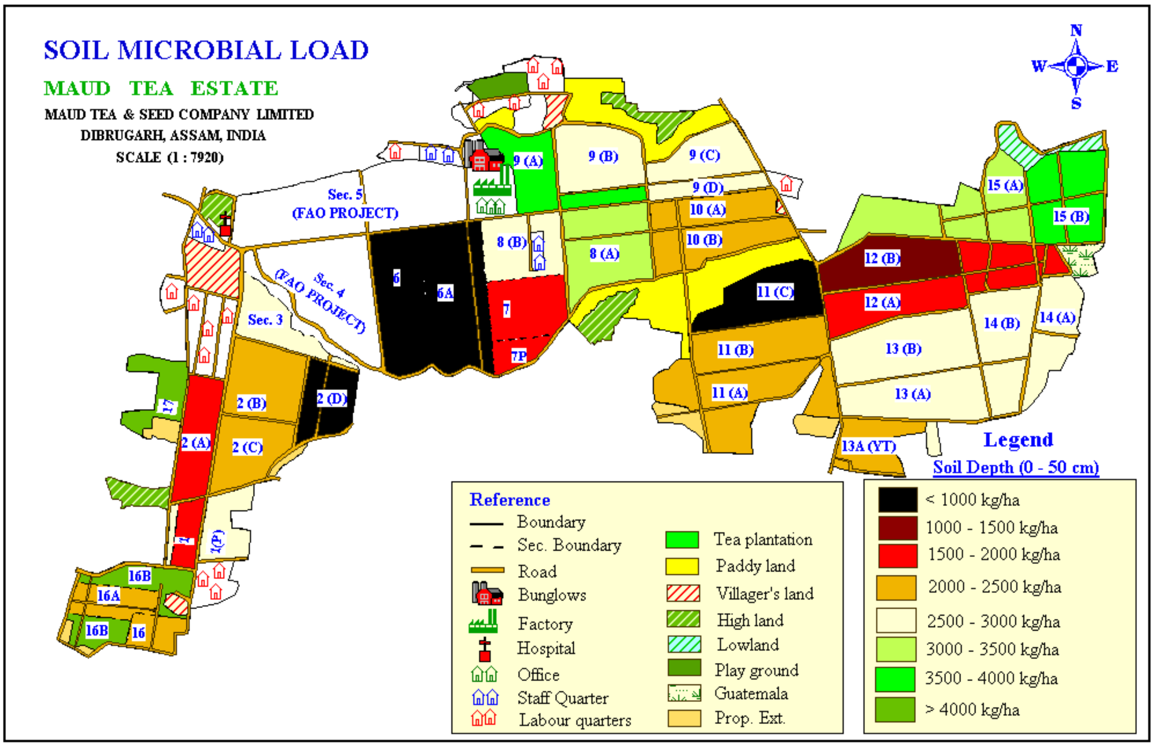


Fig. 157: Spatial distribution of soil microbial load before project initiation in 2009.

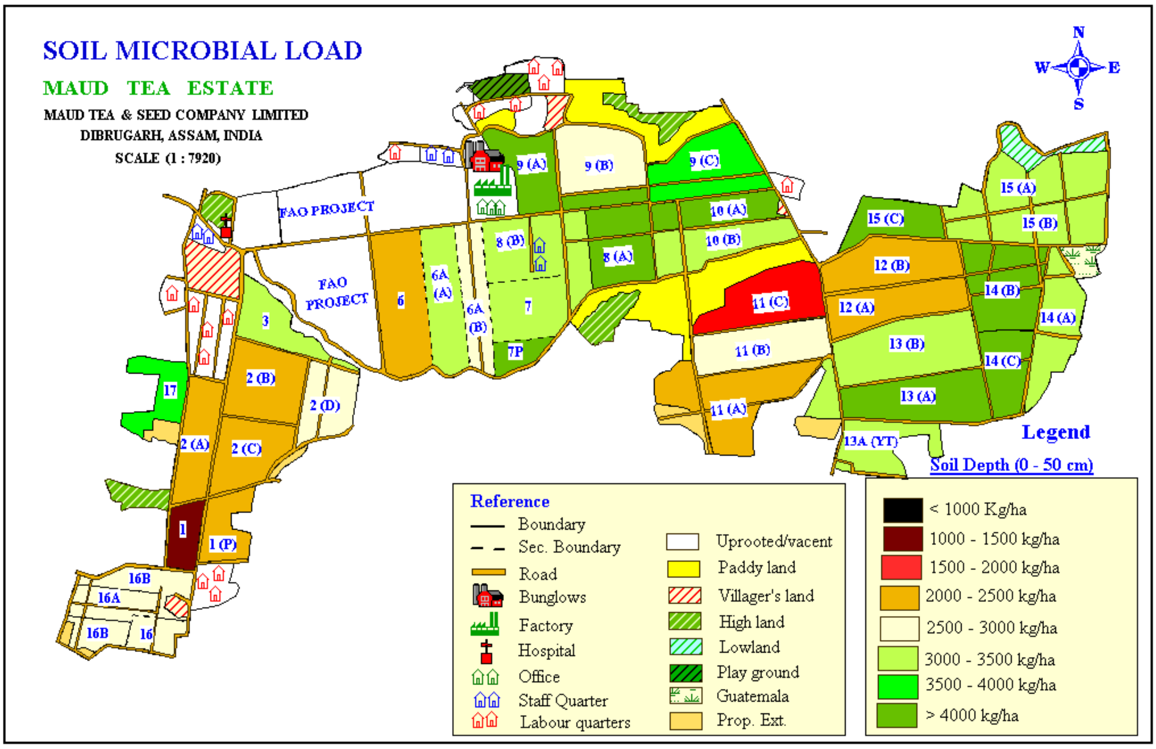
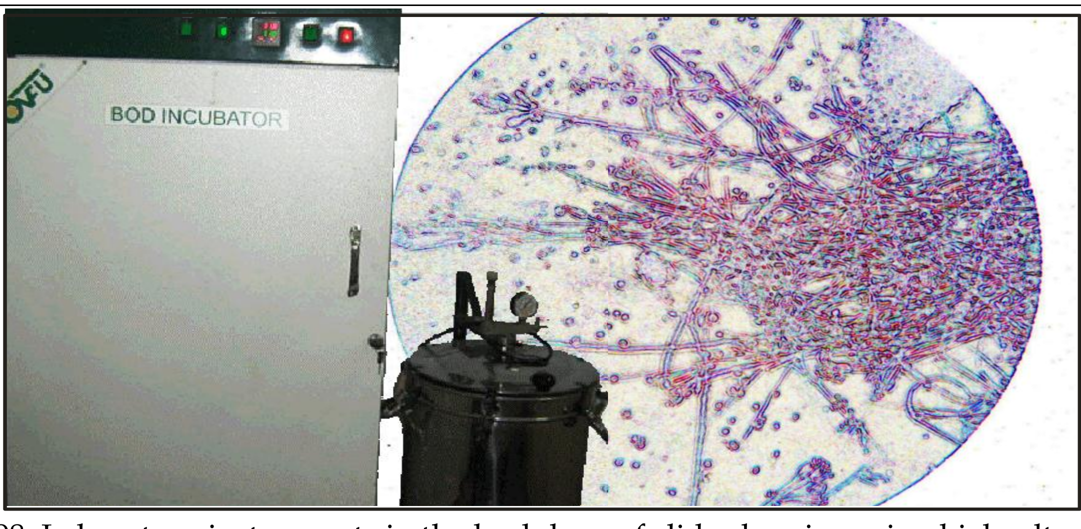


Fig. 158: Spatial distribution of soil microbial load post experiment in 2012.

Total microbial load (i.e., bacteria, fungi and actinomycetes) should be above $1x10^8$/gm of soil (Yadav, 2011). Soil Microbial load was calculated as total biomass of bacteria, fungi and actinomycetes in kgha^{-1} based on the average weight of bacteria, fungi and actinomycetes (Anonymous, 2012).

Microbial load in terms of total wet biomass of bacteria, fungi and actinomycetes varied within 2000 to 4000 kgha^{-1} in major area of the garden (61.97 % of TGA). At the same time a considerable area (35.81 % of TGA) showed microbial status below 2000 kgha^{-1} (fig. 157 and 158). One of the prime objectivity of organic soil management under IRF was to increase microbial load to ensure better soil-plant-nutrient dynamics. The impact of organic soil management under IRF was clearly demonstrated by the value obtained in 2012, which indicated microbial load >4000 kgha^{-1} in about 21.25 % of TGA. At the same time area under microbial load below 2000 kgha^{-1} reduced by 87.6 % with the three years time frame, thereby reflecting the adoption of an effective soil management programme at Maud T.E.

Pic. 97: In-house laboratory of Inhana Biosciences, Kolkata.



Pic. 98: Laboratory instruments in the backdrop of slide showing microbial culture.

Research and Publication

Research Programme undertaken

Ph.D Programme

Two Ph.D programes related to FAO-CFC-TBI project 'Development Production and Trade of Organic Tea' was registered in Calcutta University.

Ph.D Thesis I

Research Scholar : Mr. S. K. Bera

Title : Effect of different methods and organic Packages of Practice for management of organic tea plantation with special emphasis on organic soil input quality.

Ph.D Thesis II

Research Scholar : Mr. A. K. Das

Title : Evaluation of the effect of different organic methods and Packages of Practice towards development of tea nursery, new plantation and organic conversion.

MSc. Project Programme

4 MSc Project Programme related to FAO-CFC-TBI project 'Development Production and Trade of Organic Tea' was taken in *Institute of Agricultural Science, Calcutta University, in Partial Fulfillment of the Requirements for the Degree of Master of Science (Agriculture) in Agricultural Chemistry and Soil Science during 2009-10 to 2011-12.*

MSc Thesis I (2009-2010)

MSc Student : Mr. S. Banerjee

Title : Assessment of Novcom composting Method – an effective bio-degradation process and its impact on the soils under various management practices.

MSc Thesis II (2010-2011)

MSc Student : Mr. R. Molla

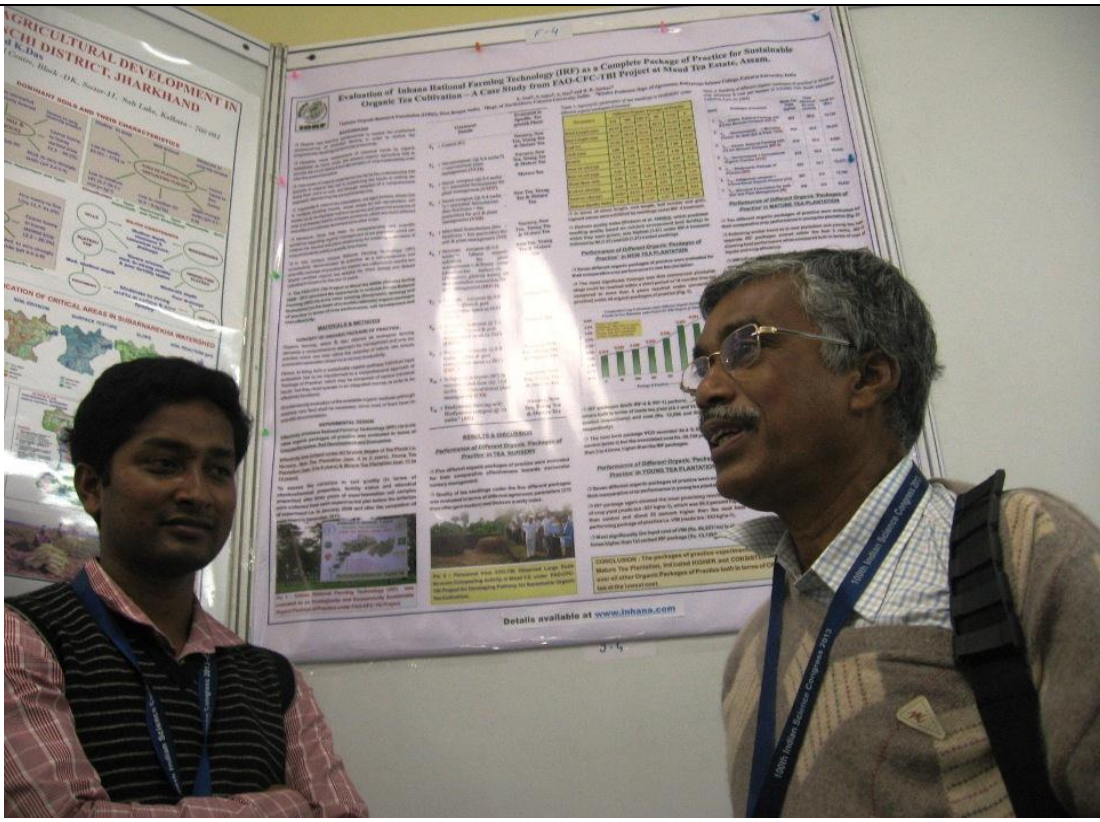
Title : Comparative evaluation of the quality of different forms of compost and their impact on soil N dynamics in acid tea soils.

MSc Thesis III (2011-2012)

MSc Student : Mr. M. Khan

Title : Development of a soil quality index to evaluate the impact of different organic soil inputs on soil quality development in acid tea soils.

Pic 99 : Dr. Antara Seal. Technical Manager of Inhana Biosciences presented the findings of the FAO-CFC-TBI Project at Maud T.E. in National Seminar on Organic Tea held at Tocklai Experimental Station, Jorhat.



Pic 100 : Discussion with Prof. A.K. Dolui about findings of the FAO-CFC-TBI Project at Maud T.E. as exhibited during Poster session of 100th Indian Science Congress held at Kolkata

MSc Thesis III (2012-2013)

MSc Student : Mr. P. Goura

Title : Evaluation of different on-farm produced compost quality and their post soil application effectivity in terms of Soil Development and Crop Response.

Research Articles Published in International /National Journal and National/ International Conference.

1. Seal A., Bera R., Chatterjee A. K. and Dolui A. K. (2012). **E**valuation of a new composting method in terms of its biodegradation pathway and assessment of the compost quality, maturity and stability (2011). *Archives of Agronomy and Soil Science, Germany*., vol. 58, no. 9, pp. 995-1012.

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Annexure

Details of Package of Practices Experiment in Mature Tea (Sec.4)

Treatment details

T1) VCO : Vermicompost + Conventional Plant Management

Soil Management :

Application of Vermicompost at the rate 9.4 ton/ ha.

To supply 60 kg N that is required for 1500 kg crop target, considering 1.74 % N and 54.3 % moisture in compost- as per analytical data.

Plant Management :

Sl. No.	Herbal concoctions	Pest/ Disease control & Rate of Application	No. of rounds given
1	Polygunam hydropiper (PHC)	Red spider and other Mites (25 ltr./ha)	8
2	Piro onio/ Bitter Fern (POC)	For Thrips, Green Fly, Helopeltis and other minor insects (25 ltr./ha)	Not available on-farm
3	Ind-Safari (ISC) [fish waste & cow urine concoction]	All Insect Pests and Caterpillars (2.5 kg/ha)	1
4	Garlic & Red Chilly (GCC)	All types of insects (5 kg/ha)	5
5	Vitex negundo (nigandhi) [VNC]	Helopeltis and All Insects (25 ltr./ha)	2
6	Copper Fungicide	Blister Blight (-)	-
7	Equizitam (Horse Tail) Or Rice Husk (ERHC)	Blister Blight, Black Rot, any other fungal disease (5 ltr./ ha)	Not available on-farm
8	Clerodendron infortunatum concoction (CIC).	Insecticidal and fungicidal properties. Ideal for Blister Blight and Insects (250 ltr./ ha)	8
9	Artimisia vulgaris (titapatti) [AVC]	Mainly works as repellent and does not have much knock down effect (20 kg/ ha)	Applied with all others except, ISC
10	Neem Seed Concoction (NSC).	All Insect Pests (12.5 ltr./ ha)	Not available on-farm

On an average 24 rounds of spraying was done yearly. All the sprays were for pest/ disease control. ***Application was done as per Protocol of the Advisor of Conventional Organic Management.***

<u>T2) VMIP : Vemicompost + Microbial Formulations for Plant Management</u>

<u>Soil Management</u> :
Application of Vermicompost at the rate 9.4 ton/ ha.

To supply 60 kg N that is required for 1500 kg crop target, considering 1.74 % N and 54.3 % moisture in compost- as per analytical data.

<u>Plant Management</u> :

Sl.No	Microbial Inoculants (Growth Promoters & pest/ disease management)		Growth Promoter & Pest/disease control
1.	*Verticillium chlamydosporium*	:	For Aphids control
2.	*Paeciilomyces fumosoroseus*	:	For Red Spider Mite (RSM control)
3.	*Beauveria bassiana*	:	Control wide spectrum of insects.
4.	*Combination of Bacillus, Pseudomonas, Azotobacter and Azospirillum*	:	Growth promoter Application : March-April, April-May, July-August and August-September.
5.	*Trichoderma viride*	:	For Poria control
6.	*Metarhizium anisopliae*	:	Termite Control

Verticillium lecani, Paeciilomyces fumosoroseus & Beauveria bassiana was either given singly or in combination depending upon the Protocol suggested for single or mixed infection. Total 17 rounds were given, which included pest management and growth promotion.

The Protocol has been taken from the Group, which has developed the above Microbial Formulations.

Note : Growth Promoter is applied @ 250ml/ha & rest of the solutions were applied @ 500 ml/ha

<u>T3) VMI : Vermicompost + Microbial Formulations for Soil & Plant Management</u>

<u>Soil Management</u> :
1) Application of Vermicompost at the rate 9.4 ton/ ha.

To supply 60 kg N that is required for 1500 kg crop target, considering 1.74 % N and 54.3 % moisture in compost- as per analytical data.

2) Application of Bio-fertilizer: 1125 kg of City compost organic fertilizer induced with N fixing bacteria & PSB and 37.5 kg Bio-NPK (combination of *Bacillus, Pseudomonas, Azotobacter and Azospirillum*)/ ha. – as per recommendation.

Plant Management : **Same as VMIP**

T4) MI : Microbial Formulations* [Biofertilizers & Biopesticides/ Bio growth Promoter]

Soil Management :

Application of Bio-fertilizer: 1125 kg of City compost organic fertilizer induced with N fixing bacteria & PSB and 37.5 kg Bio-NPK (combination of *Bacillus, Pseudomonas, Azotobacter and Azospirillum*)/ ha. – as per recommendation.

Plant management : **Same as VMIP**

T5) IRF- 1 : Inhana Rational Farming* 1 (IRF 1)

Soil Management :

Application of Novcom Compost @ 2.6 ton/ ha with 2.19 % N and 56.73 % moisture

Basis : Recommendation of 3 ton/ ha Novcom compost (with 2.0% N and 60% moisture) in 1200 ha Organic Tea Plantation in Assam, which is under Inhana Rational Farming Technology, for last 11 years.

Plant Management :

Sl. No.	Plant management (for plant physiological development)	Sl. No.	Plant management (for pest/ disease management)
1.	IB 1 (Samridhi)	1.	IB 13 (Sp. Immunosil1)
2.	IB 2 (Immunosil)	2.	IB 14 (Sp. PP5)
3.	IB 3 (OrganiK)	3.	IB 15 (CDS - F)
4.	IB 4 (OrganiN)	4.	IB 16 (CDS – G)
5.	IB 5 (Solution I)	5.	IB 17 (KPS)
6.	IB 6 (Solution II)	6.	IB 18 (Sp. Immunosil 2)
7.	IB 7 (Solution PP5)	7.	IB 19 (Jay Vijay)
8.	IB 8 (Atermit)	8.	IB 20 (Sp. Jay Vijay)
9.	IB 9 (ZXN)		
10.	IB 10 (Special Solution I)		
11.	IB 11 (Special Solution II)		
12.	IB 12 (Special Solution III)		

On an average 13 rounds of spraying for plant physiology development and 10 rounds for pest management was done yearly as per the protocol of Technology Developer.

* Details of solutions and their working mechanism in Page viii to xiii.

T6) IRF- 2 : Inhana Rational Farming 2

Soil Management :
Application of Novcom Compost @ 8.0 ton/ ha

To supply 60 kg N that is required for 1500 kg crop target, considering 2.19 % N and 56.73 % moisture in compost- as per analytical data

Plant Management : **Same as IRF 1**

T7) IRF- 3 : Inhana Rational Farming 3

Soil Management :
Application of Novcom Compost @ 4.0 ton/ ha. (50% higher dose than Inhana recommendation i.e. 3 ton/ ha).
Plant Management : **Same as IRF 1**

T8) IRF- 4 : Inhana Rational Farming 4

Soil Management :
Application of Novcom Compost @ 5.1 ton/ ha. (100% higher dose than Inhana recommendation i.e. 3 ton/ ha).
Plant Management : : **Same as IRF 1**

T9) BD : Biodynamic Farming (BD)

Soil Application :

B.D. Products	For use	Method for use
BD 500 – (Cow Horn Manure)	Root development & soil structure.	Apply 75 gm BD 500/ ha, every 4 times in a year i.e. late afternoon/ evening – descending moon.
BD 501 – (Cow Horn Silica)	Enhances photosynthetic process, making the plant vigorous & resistant towards air borne fungal diseases.	Apply 2.5 gm BD 501/ ha, every 4 times in a year i.e. early morning 6-8 a.m. at sunrise.

B.D. Products	For use	Method for use
BDP 502-507 (Compost, CPP, Liquid manure inoculums)- **Biodynamic Compost**	Effective soil conditioner and an immediate source of nutrient.	Apply 10 ton B.D. Compost/ ha at late afternoon/ evening– descending moon Date. *As per analytical data B.D compost contained 1.78 % N and 48.54 % moisture*
BDP 502-507 (Compost, CPP, Liquid manure inoculums)- **Cow Pat Pit (CPP)**	Strong soil conditioner provides resistance powers.	Apply 2.5 kg CPP per ha, every 3 months as per BD calendar Date.
<u>Plant Application</u> :		
Urja (for herbal Insect, pest, tonic inoculums)	Pest repellent & Herbal insecticide.	@ 500 g /ha + 10 kg leaves (each) of three types of medicinal plant as per the following list. Dried leaves of Urtica dioca, or Nettle, Leaves of Neem, Ipomoea, Nerium, Datura, Custard apple, Papaya, Calotropis, etc.

On an average 12 rounds of spraying for plant development and 8 rounds for pest management was done yearly.

The above Protocol is from a Biodynamic Expert

<u>T10) Conventional Organic Practice (CO)</u>

<u>Soil Management</u> :

Application of Indigenous (FYM) compost (*1.68 % N and 46.46 % moisture*) @ 13.5 ton/ ha.

As per recommendation based on N harvested for 1500 kg yield, N loss due to pruning and compost efficiency.

<u>Plant Management</u> : **Same as VCO**

The recommendation is from the Advisor of Conventional Organic Management.

<u>T11) C : Control</u>

Details of Soil Input Experiment in Mature Tea (Sec. 6A)

Treatment details

T1) Control

T2) VC : VERMICOMPOST

Application Rate : 9.4 ton/ ha

To supply 60 kg N that is required for 1500 kg crop target, considering 1.74 % N and 54.3 % moisture in compost- as per analytical data.

T3) VCBF : VERMI COMPOST + BIO-FERTILIZER

Application Rate :

- Vermicompost : @ 9.4 ton/ ha
  To supply 60 kg N that is required for 1500 kg crop target, considering 1.74 % N and 54.3 % moisture in compost- as per analytical data.
- Biofertilizer : 1125 kg of City compost organic fertilizer induced with N fixing bacteria & PSB and 37.5 kg Bio-NPK (combination of *Bacillus, Pseudomonas, Azotobacter and Azospirillum*)/ ha. – as per expert recommendation.

T4) NOV- 1 : NOVCOM COMPOST

Application Rate : 8.0 ton/ ha.

To supply 60 kg N that is required for 1500 kg crop target, considering 2.19 % N and 56.73 % moisture in compost- as per analytical data

T5) NOV- 2 : NOVCOM COMPOST– Inhana Recommended Rate

Application Rate : 2.6 ton/ ha.

Basis : Recommendation of 3 ton/ ha Novcom compost (with 2.0% N and 60% moisture) in 1200 ha Organic Tea Plantation in Assam, which is under Inhana Rational Farming Technology, for last 10 years.

T6) NOV- 3 : NOVCOM COMPOST–100% higher than NOV- 2

Application Rate : 5.1 ton/ ha.

T7) BF : BIO-FERTILIZER

Application Rate : 1125 kg of City compost organic fertilizer induced with N fixing bacteria & PSB and 37.5 kg Bio-NPK (combination of *Bacillus, Pseudomonas, Azotobacter and Azospirillum*)/ ha. – as per expert recommendation.

T8) BDS : BIODYNAMIC SOIL INPUT (with 1.78 % N and 48.54 % moisture)

Application Rate : 10 ton/ha

Dose : As per expert recommendation

T9) IC- 1 : INDIGENOUS COMPOST

Application Rate : 8.3 ton/ ha.

To supply 60 kg N that is required for 1500 kg crop target, considering 1.68 % N and 46.46 % moisture in compost- as per analytical data.

T10) IC- 2 : INDIGENOUS COMPOST (1.68 % N and 46.46 % moisture)

Application rate : 13.5 ton/ ha.

As per recommendation based on N harvested for 1500 kg yield, N loss due to pruning and compost efficiency.

T11) OC : OIL CAKE (OC)

Application Rate : 1.7 ton/ ha.

To supply 60 kg N that is required for 1500 kg crop target, considering 4.54 % N and 3.08 % moisture in compost- as per analytical data.

Details of Package of Practices Experiment in Young Tea and New Tea Plantation

T1) C : Control

T2) VCO : Vermicompost + Conventional Plant Management

Treatment is same as done for mature tea experiment in Sec.4.

T3) VMI : Vermicompost + Microbial Formulations for Soil & Plant Management

Treatment is same as done for mature tea experiment in Sec.4.

T4) IRF- 1 : Inhana Rational Farming 1

Treatment is same as done for mature tea experiment in Sec.4.

T5) IRF- 2 : Inhana Rational Farming 2

Treatment is same as done for mature tea experiment in Sec.4.

T6) MI : Microbial Formulations [Biofertilizers & Biopesticides/ Bio growth Promoter]

Treatment is same as done for mature tea experiment in Sec.4.

T7) BD : Biodynamic Farming

Treatment is same as done for mature tea experiment in Sec.4.

T8) CO : Conventional Organic Practice

Treatment is same as done for mature tea experiment in Sec.4.

DETAILS OF SOLUTIONS USED UNDER INHANA RATIONAL FARMING

Sl. No.	PLANT MANAGEMENT (for plant physiological development)	Sl. No.	PLANT MANAGEMENT (for pest/ disease management)	Sl. No.	NURSERY MANAGEMENT
1.	IB 1 (SAMRIDHI)	1.	IB 13 (SP. IMM. 1)	1.	IB 21 (NS 1)
2.	IB 2 (IMMUNOSIL)	2.	IB 14 (SP. PP5)	2.	IB 22 (NS II)
3.	IB 3 (ORGANIK)	3.	IB 15 (CDS -F)	3.	IB 23 (NS III)
4.	IB 4 (ORGANIN)	4.	IB 16 (CDS – G)	4.	IB 24 (SP. SOLN.)
5.	IB 5 (SOLUTION I)	5.	IB 17 (KPS)	**Sl. No.**	**YOUNG TEA MANAGEMENT**
6.	IB 6 (SOLUTION II)	6.	IB 18 (SP. IMM.2)	1.	IB 25 (YT I)
7.	IB 7 (SOLUTION PP5)	7.	IB 19 (JAY VIJAY)	2.	IB 26 (YT 2)
8.	IB 8 (ATERMIT)	8.	IB 20 (SP. JAY VIJAY)	3.	IB 27 (YT 3)
9.	IB 9 (ZXN)	**Sl. No.**	**SOIL MANAGEMENT**	**Sl. No.**	**Shade tree & green crop mgt.**
10.	IB 10 (SP. SOLUTION II)	1.	IB 31 (NOVCOM)	1.	IB 28 (SOL. GT)
11.	IB 11 (SP. SOLUTION II)	2.	IB 32 [NOVCOM (SP.)]	2.	IB 29 (SOL. GC)
12.	IB 12 (SP. SOLUTION III)	3.	IB 33 [NOVCOM (CD)]	3.	IB 30 (SOL. BM)

COMPOSITION OF SOLUTIONS UNDER INHANA RATIONAL FARMING TECHNOLOGY

SL. NO.	SOLUTION CODE	NAME OF THE SOLUTION	BIOLOGICALLY ACTIVATED & POTENTISED EXTRACT OF
1.	**IB 1**	**SAMRIDHI**	• Hyoscyamus niger • Ficus benghalensis • Dendrocalamus strictus Nees.
2.	**IB 2**	**IMMUNOSIL**	• Ocimum sanctum • Calotropic procera R. • Cynodon dactylon
3.	**IB 3**	**ORGANIK**	• Adhatoda vasica Nees • Zingiber officinale Roscoe • Embellia ribs.
4.	**IB 4**	**ORGANIN**	• Calotropis Procera R. • Dendrocalamus strictus Nees • Bombax malabaricum D. C.
5.	**IB 5**	**SOLUTION I**	• Cynodon dactylon • Calotropic gigantean.
6.	**IB 6**	**SOLUTION II**	• Hyoscyamus niger • Solanum Verbascifolium
7.	**IB 7**	**PP5**	o Ocimum sanctum
8.	**IB 8**	**ATERMIT**	• Solanum verbascifolium • Prosopis spicigera • Ocimum bascilicum.
9.	**IB 9**	**ZXN**	o Albizzia maranguihses o Biscifia javanica o Erythrina Variegate Linn.
10.	**IB 10**	**SPECIAL SOLUTION I**	• Costus specicus sm. • Typhora indica mer.
11.	**IB 11**	**SPECIAL SOLUTION II**	• Solanum xanthocarpum schard • Aristolochia indica Linn.
12.	**IB 12**	**SPECIAL SOLUTION III**	• Sida Cordifolia Linn. • Barberis asiatica Roxb. Ex. De.

SL. NO.	SOLUTION CODE	NAME OF THE SOLUTION	BIOLOGICALLY ACTIVATED & POTENTISED EXTRACT OF
13.	**IB 13**	**SPECIAL IMMUNOSIL 1**	• Ficus racemosa Linn. • Calotropuc procera R.
14.	**IB 14**	**SPECIAL PP5**	• Ocimum sanctum • Costus specicus sm.
15.	**IB 15**	**CDS - F**	• Veronica cineria Less. • Solanum verbascifolium (Root &stem)
16.	**IB 16**	**CDS - G**	• Veronica cineria Less. • Solanum verbascifolium (Root)
17.	**IB 17**	**KPS**	• Prosopis spicigera • Costus specisus sm.
18.	**IB 18**	**SPECIAL IMMUNOSIL 2**	• Barberis asiatica Roxb. Ex. De. • Ficus racemosa Linn. • Ocimum sanctum • Cynodon dactylon
19.	**IB 19**	**JAYVIJAY**	• Bombax malabaricum D.C. • Calotropic procera R • Ocimum bascilicum.
20.	**IB 20**	**SPECIAL JAYVIJAY**	• Bombax malabaricum D.C. • Calotropic procera R • Ocimum bascilicum. • Biscifia javanica
21.	**IB 31**	**NOVCOM**	• Cynodon dactylon • Ocimum bascilicum • Sida cordifolia Linn.
22.	**IB 32**	**NOVCOM (SPL.)**	• Sida cordifolia Linn. • Cynodon dactylon • Solanum xanthocarpum schard • Aristolochia indica Linn.
23.	**IB 33**	**NOVCOM (CD)**	• Sida cordifolia Linn. • Ocimum bascilicum • Ficus hispida Linn.

SL. NO.	SOLUTION CODE	NAME OF THE SOLUTION	BIOLOGICALLY ACTIVATED & POTENTISED EXTRACT OF
24.	**IB 21**	**NS I**	• Ficus hispida Linn.
25.	**IB 22**	**NS II**	• Erythrina Variegate Linn.
26.	**IB 23**	**NS III**	• Alstonia schlaris R.
27.	**IB 24**	**SP. SOLUTION**	• Fumaria indica pngsley • Tylophora indica mer.
28.	**IB 25**	**YT 1**	• Aristolochia indica Linn. • Ficus racemosa Linn.
29.	**IB 26**	**YT 2**	• Ficus racemosa Linn. • Sida cordifolia Linn.
30.	**IB 27**	**YT 3**	• Sida cordifolia Linn. • Cocculas hirsutus
31.	**IB 28**	**SOL. GT**	• Caeslpinia erista Linn. • Ficus racemosa Linn.
32.	**IB 29**	**SOL. GC**	• Arbus prectorius Linn. • Veronica cineria Less.
33.	**IB 30**	**SOL. BM**	• Cocculas hirsutus Diels.

Guiding Philosophy of EEA Principle behind Development of Various Inhana Solutions.

Inhana solutions are developed under the Element Energy Activation Principle. Radiant solar energy is stored in plants and the binded stored energy components are extracted from energy rich plant part by a specific extraction procedure and subsequently potentised in the order of 10^3 to 10^4, so that the activated energy forms release the energy components when sprayed in the plant system (matter). Now according to the requirement different extracted energy components are combined in desired proportion to make different solutions which regulate sequential physiological activities to attend the root cause. So a numerous number of solutions can be prepared as per requirement guided by this Element Energy Activation Principle.

Process Flowchart of Inhana Solutions under E.E.A Principle

Selection of specific plants (Specific days and specific time)

Alcoholic extraction (Specific plant parts in specific time and procedure)

Energisation (Isolation of Energy Components)

Potentization (Release of Bound Energy in order of 10^3 to 10^4 times)

Combination of the activated, potentised and energized extract

Process Flowchart of Inhana Solutions under E.E.A Principle

Selection of specific plants (Specific days and time)

Radiant energy from the Basic Life force (Solar Energy) is stored in plants. As the specific energies are stored in specific parts of the different plants, selection of the plants or more precisely selection of specific plant parts are most important. Not only that, specific days and time are also important as the energy storage potentials of the plants varies with various star occurrence. So the astronomical parameters are important to extract maximum stored energy.

Alcoholic Extraction (Specific plant parts in specific time and procedure)

Specific plant parts *viz.* roots, stem, leaf, root hair, leaf vein etc. are taken for extraction as early as possible from the collection time, before the living parts become inert and stored radiant energy is dissipated. Since the energy components are extremely subtle and abstract in nature and simultaneously they need a medium (matter) and after / during extraction they should be transferred to a medium which is less gross and the same time has higher surface tension. Alcohol is used for the extraction process because it has the potential to isolate the bound energy in gross form and stored within it.

Energization (Isolation of Energy Components)

Energization is the process through which energy components are isolated from its gross form and stabilize in alcoholic medium. Both extraction and energization process operates simultaneously as the extracted gross components should be immediately transferred to a medium from which these can be liberated easily. The total energization procedure continues for several days up to 21 days to extract maximum stored energy to this medium. Still only a part of the stored energy can be isolated from its plant source.

Potentization (Release of Bound Energy in order of 10^3 to 10^4 times)

Potentization is the process through which the extracted bind energy is activated to perform in desired order when applied in plants. In this process specific energy is transformed to its nearly original source or more specifically as it was transformed to differential energy from Basic Life Force. This form is Lifetrons, which are much subtler than electron, proton or atom. The bind energy manifests when it is separated from the binding agents. In this process the medium used is pure filtered water free from heavy particles. The potentization is done in the order of 10^3 to 10^4 times according to the specific energy components and the objectives of the specific role. Potentized energy components are actually in the binding form but are separated from other differential energy and posses a huge liberating potential than its previous stage.

Hence when they are applied on the plant system they enters primarily through the stomatal opening and they are being accepted by the plant system because of this primary (Subtler) form. Thereafter they can reach to the desired sight more quickly as no transformation of that energy form is required.

Combination of the Potentised and Energized extracts

Combination of this potentised and energized extract are done according to the specific objectivity of the solutions. As all solutions have regulatory role and no inhibitory action, these are applied to regulate specific plant functions in desired and successive order. These solutions try to solve any problem leading to the root cause of the problem. For example Immunosil has been developed for disease management of crop.

For effective disease management, both structural and biochemical defense of plant is a must. Simultaneously, any cidal approach to fungal pathogens is not only ineffective, this is unscientific and unethical. Modern research reveals that silica can provide structural defense against fungal pathogens. But most of the plants can not uptake the silica from the soil to the desired level that is required to elevate their structural defense. Two physiological processes are involved in the silica absorption – anaerobic glycolysis and aerobic respiration. Immunosil gives specific energy components which hastens the intensity and quality of these processes. Root systems need to be energized hence 'Apana Prana' is provided; then silica should be translocated where water element is involved, so 'Udana Prana" is provided and so on. So according to the sequential regulatory plant functions and their required intensity specific energy components are combined in different proportions to develop individual solution.

Details of Different On-farm Composting Programme taken up at Maud T.E.

Method of Vermi compost production at Maud T.E.

Raw materials used : Common garden weeds *viz. Mikania micrantha*, *Ageratum houstonianum*, *Axonopus compressus, Digitaria setigera Roth* etc. and cow dung at 60 : 40 ratio was used for making compost.
Earth worm : 4000 – 4500 earth worms (*Esenia foetida*) were required for each layer comprising about 600 to 650 kg of raw materials.

Vermi shed and Vermi compost pit : A plastic shed with bamboo structure was made for protecting the vermi pit from direct sunlight as well as rainfall. A vermi compost pit was prepared measuring 15 ft. in length, 4 ft. in breadth and 4 ft. in height. Base of the pit was soled with bricks followed by a sand layer. At the top of sand bed, thick cow dung slurry was sprayed.

Preparation of Vermi Compost :
At a selected upland chopped green matter and cow dung was stacked in a heap measuring 10 ft. in length, 6 ft. in breadth and 4 ft. in height. Proper watering was done, so that decomposition was initiated. This was kept for about 20 to 25 days and frequent watering was done till the materials were semi decomposed and temperature of the heap came down. Then the materials were ready for using in the vermi pit. The semi decomposed raw materials were transferred into the vermi pit and vermi was added layer wise in the specific quantity. Watering on regular basis was done to keep the vermi pit moist. The vermi compost was ready in 40 to 50 days time.

Method of Biodynamic compost production at Maud T.E.

Raw materials used : Common garden weeds *viz. Mikania micrantha*, *Ageratum houstonianum*, *Axonopus compressus, Digitaria setigera Roth* etc. and cow dung at 60 : 40 ratio was used for making compost.

Preparation of Biodynamic Compost :
At first 2 kg Cow Pat Pit (CPP) was mixed with some water and kept for 4-6 hours. After that at least 30 ltr. of water was added to it and stirred well. A plane land facing east- west direction was chosen for better effectivity. After cleaning the land, the soil was moistened by spraying water on the surface. A

15 ft. long bamboo strip was placed in the middle of the land with the help of two bricks. Two 2 ft. long bamboo strips (lying across) were placed at every 2ft. interval on the main strip. Dry grasses were spread over the bamboo structure (up to 6 inches height) and watered to make it wet. A layer of cow dung (about 3 inches thick) was made next and water was sprayed on it. 2 ltr. CPP mixture was sprayed on the layer. The processes of layering with grasses and cow dung were repeated until the height was raised up to 2 ft. Then a layer of fresh green matter was made over it (about 4 inches height) and 15 kg CaO was broadcasted on top of the layer. The process of layering with grass and cowdung was again repeated until the height of the heap reached to about 4 ft. The top layer of the heap was made of cow dung. 3 holes were made on the heap and some CPP mixture was poured in those holes. After that CPP mixture was used to moisten the heap. Concentrated cow dung slurry was prepared by mixing a certain amount of soil with cow dung and the entire heap was plastered by it.

<u>Method for preparation of CPP</u> :
A structure 1.5 ft. in length x 1.5 ft. in breadth x 1 ft. in height was made using bricks and the inner wall was pasted with fresh cow dung. The bottom of the structure was not lined with bricks. The pit is filled with fresh firm cow dung, eggshells and basalt dust was inserted into the dung (for 20kg of manure 65gms crushed eggshells and 166gm basalt dust was used) and spaded for an hour, next jaggery solution (100gm jaggery and one liter water) was sprinkled over it. After gently patting the cow dung six holes, 2 inches deep were made in it, followed by incorporation of Biodynamic preparations (1gm each of 503-506 and 1ml of 507). Fresh jute sack was placed over the pit to maintain moisture and to avoid excessive drying. The mixture was aerated once during a month with a garden fork. CPP gets ready in 60 days.

Method of Indigenous compost production at Maud T.E.

<u>Raw materials used</u> : Common garden weeds *viz. Mikania micrantha*, *Ageratum houstonianum*, *Axonopus compressus, Digitaria setigera Roth* etc. and cow dung at 60 : 40 ratio was used for making compost. 800 kg of Cow Dung and 1700 kg of Green Matter was used for producing 1 ton of compost.

<u>Preparation of Indigenous compost</u>:
At a selected upland and flat area chopped green matter was spread to make a base layer measuring 15 ft. in length and 4 ft. wide. Green matter was chopped

down to 1/2" Size and placed evenly till 1 ft. followed by a layer of cow dung. The process was repeated till the heap reached a height of about 5 ft. The heap was covered with clay mud. The heap was demolished and upturned once the height reduced below 4 ft. and reconstructed to a height of about 5 ft. Compost was ready in 3 months time.

Method of Novcom compost production at Maud T.E.

Raw materials used : Common garden weeds *viz. Mikania micrantha*, *Ageratum houstonianum*, *Axonopus compressus, Digitaria setigera Roth* etc. and cow dung at 80 : 20 ratio was used for making compost.

Novcom solution : Biologically activated and potentized extract of Doob grass (*Cynodon dactylon*), Bel (*Sida cordifolia L*) and common Basil (*Ocimum bascilicum*).

Total requirement of Novcom solution : Total 250 ml Novcom solution is required for 1 ton of raw materials (100 ml on day 1 followed by 75 ml each, on day 7 and day 14).

Preparation of Novcom compost :

Day 1 : At a selected upland and flat area chopped green matter was spread to make a base layer measuring 10 ft. in length, 5 ft. in breadth and 1 ft. in thickness. This layer was sprinkled thoroughly with diluted Novcom solution (5 ml/ ltr. of water) and over this layer, a layer of cow dung (3 inches in thickness) was made followed by a second layer of chopped green material, once again 1 ft. in thickness. The green matter layer was once again sprinkled with diluted Novcom solution (5 ml/ ltr. of water) and the process was continued till the total height reached to about 6 ft. After construction of each layer of green matter it was compressed downward from the top and inward from the sides for compactness.

Day 7 : On the 7th day compost heap was demolished and churned properly. The material was next laid layer wise and after making each layer diluted Novcom solution (5 ml/ ltr.) was sprinkled thoroughly as done on 1st day. After seven days the volume of the composting material decreased due to progress in decomposition process. Hence, to once again maintain the heap height to about 6 ft.; the length and breadth of the heap was maintained at 6 ft. x 6 ft. respectively. The heap was once again made compact as described earlier.

Day 14 : The same process was repeated as on day 7 and to maintain heap height to about 6 ft., the length and breadth of the heap was further reduced to 6 ft. x 4 ft. respectively.

Day 21 : The composting process was complete and compost was ready for use.

Details of different Indices Used for Interpretation of the Field data

1. SOIL FERTILITY INDEX

In chemical management, soil is viewed and analyzed compartmentally and recommendation/ treatment is given looking at a single objectivity. Such as if N is deficient / required / limiting factor, urea or other N-fertilizer is applied. The same theory also applied in case of other macro nutrients.

However, organic soil management should be viewed in a composite manner and it's recommendation should be judged in a whole and not in a compartmental basis. That's why the concept of Soil fertility Index is developed to assess the overall status of major nutrients towards in any tea soils.

Basis of Calculation

1. Values of Available N, P_2O_5, K_2O and SO_4 in the soil are taken.
2. 1st these values are fitted in a 0 to 100 scale
3. Then the values of NPKS are multiplied by a weighted factor (5 : 1 : 2.58 : 0.5). This weighted factor (5 : 1 : 2.5 : 0.5) is actually the ratio of NPKS requirement in tea productivity.
4. Average of these weighted value of NPKS is considered as Fertility Index

2. SOIL DEVELOPMENT INDEX (SDI)

Soil development index (SDI) is a concept to express the overall soil rejuvenation by quantifying the extent of development of different soil quality indices for easy understanding of the end-users. SDI must reflect the extent of soil management undertaken and at the same time correlate with crop response. Specially in case of tea plantations, where there may be significant heterogeneity in the soil character of individual sections, assessment of SDI can help in the identification of priority areas, which if attended effectively might significantly influence the productivity of entire garden. The analytical values of the soil quality parameters before initiation of experiment in 2009 and after three consecutive years of compost application (i.e. in 2011) were used as per the following formula to calculate soil development index under different treatments.

$$\text{Soil Development Index (SDI)} = \frac{a}{n^2}\left\{\sum_{n=1}^{n} \frac{100(X_1 - C_1)}{C_1} + \frac{100(X_2 - C_2)}{C_2} + \cdots + \frac{100(X_n - C_n)}{C_n}\right\}$$

Where X = Soil Quality parameters after Experimentation; C = Value of individual Soil Quality Parameter before Experimentation ; a = no. of Soil Quality Parameters showing increased over initial value.

3. PLANT DEVELOPMENT INDEX (PDI)

Different agronomic parameters *viz.* plant height, girth, number of leaves etc., that indicators of bush health, thereby regulating the bush yield potential also reflect the effect of management undertaken. However, to quantify the extent of plant development by a single value, plant development index was formulated utilizing such easily measurable agronomic parameters. Four parameters *viz.* plant height, number of leaves, number of branches and plant girth were considered and cumulative impact of these parameters were measured through Plant Development Index (PDI).

Plant Development Index (PDI)

$$= \frac{1}{n}\left\{\sum_{n=1}^{n} \frac{100(X_1 - C_1)}{C_1} + \frac{100(X_2 - C_2)}{C_2} + \cdots + \frac{100(X_n - C_n)}{C_n}\right\}$$

Where X = Agronomic Parameter; C = Control

4. PLANT STRENGTH *(Maskina et al., 1984)*

Growth response of the tea seedlings can be studied in terms of plant strength (Ponmurugan and Baby, 2007). Plant strength was calculated on the basis of total dry weight and height of the plant; as described by Maskina *et al.* (1984).

Plant strength was determined as dry matter per unit height

$$\text{Plant Strength} = \frac{\text{(dry matter of the plant (mg)}}{\text{height of the plant (cm)}}$$

5. DICKSON QUALITY INDEX *(Dickson et al., 1960)*

The quality index was devised by evaluating how well a number of possible combinations of morphological parameters predicted field performance of seedlings and selecting the best combination (Dickson *et al*. 1960[a]). In a subsequent test, this index was able to predict quality based on the nutrient environment (soil fertility) in which the seedlings were grown (Dickson *et al*. 1960[b]). The index was successfully used by Roller (1976) to differentiate between plantable and non-plantable containerized seedlings. The index may reflect the out-planting success of various stock-types (Ritchie 1984).

$$\textbf{Dickson Quality Index} = \frac{\text{Total Seedling Dry wt(g)}}{\dfrac{\text{Height (cm)}}{\text{Diameter (mm)}} + \dfrac{\text{Shoot wt (g)}}{\text{Root wt (g)}}}$$

6. SPEED OF GERMINATION *(Bartlett, 1973)*

Speed of germination was calculated from Bartlett's Rate Index (Bartlett, 1973), which was worked out from the daily germination counts and determined as follows.

$$\text{BRI} = \frac{P_1 + (P_1 + P_2) + (P_1 + P_2 + P_3) + \text{-------} + (P_1 + P_2 + P_3 + \text{-----} + Pn)}{N\,(P_1 + P_2 + P_3 + \text{-------} + Pn)}$$

P1 + P2 + P3 -----and Pn are the germination per cent at 1st, 2nd, 3rd and nth day, respectively.

'N' is the total number of days taken for germination.

7. SEEDLING VIGOUR INDEX *(Abdul Baki and Anderson, 1973)*

Vigour index was computed by adopting the following formula as suggested by Abdul Baki and Anderson (1973) and expressed in number.

SVI=Germination (%) X Seedling length (cm)

8. GERMINATION INDEX *(Yang et al., 2005).*

Germination index (G.I.) is computed by using the following formula :

$$\textbf{G.I.} = \sum (n/d)$$

i.e. summation of mean number of germinated seeds per day for t days,

where, n = number of seedlings emerging on day 'd'
d = day after planting

The seed lot having greater germination index is considered to be more vigorous.

9. GERMINATION PERCENT (GP) ***(Yang et al., 2005).***

Germination percent (GP) = (number of germinated seeds/total number of seeds) × 100

10. EMERGENCE PERCENT (EP) ***(Yang et al., 2005)***

Emergence percent (EP) = (number of emerged seedlings/total number of seeds) × 100

11. EMERGENCE INDEX (EI) ***(Yang et al., 2005)***

Emergence index (EI) = $\sum (G_t/D_t)$, summation of mean number of emerged seedlings per day for t days.

12. SOIL ORGANIC CARBON STOCK (***Veldkamp, 1994)***

Adoption of organic agriculture leads to a reduction in soil carbon losses or even to higher soil carbon concentrations and net carbon sequestration over time (Niggli *et al.*, 2009). Soil bulk densities were found to be lower for the organic practice (Gattingera *et al.*, 2012), thus the observed increase in SOC stocks in organically managed soils resulted from SOC enrichment and not from soil compaction.

Soil Organic carbon stock (kg ha^{-1}) was calculated using the following equation (Veldkamp 1994):

$$\mathbf{SOC = 10^4 \times Cs \times h \times q,}$$

where Cs is soil organic carbon content (%), h is the thickness of soil layer (m), and q is soil bulk density (g cm^{-3}).

13. SOIL MICROBIAL LOAD

Microbial load is defined as total number of bacteria, fungi and actinomycetes in a given quantity of soil. Total microbial load is well matched with soil nutrients and organic carbon meaning that its is highest at the soil surface where organics and nutrients were highest. (Krishna *et al*., 2012).

Total microbial load (bacteria, fungi and actinomycetes) should be above 1x 10^8/ gm of soil (Yadav, 2011) and was calculated as total biomass of bacteria, fungi and actinomycetes in $kgha^{-1}$ based on the average weight of bacteria, fungi and actinomycetes (Anonymous, 2012).

Table 1. Microbial groups with representative size, numbers, and biomass found in soil.

Microbial Group	Example	Size (µm)	Numbers no. g-l of soil	Biomass wet mass kg ha-l of soil
Viruses	Tobacco Mosaic	0.02 x 0.3	10^{10} - 10^{11}	
Bacteria	*Psuedomonas*	0.5 x 1.5	10^8 - 10^9	300 - 3000
Actinomycetes	*Streptomyces*	0.5 - 2.0 ‡	10^7 - 10^8	300 - 3000
Fungi	*Mucor*	8.0 ‡	10^5 - 10^6	500 - 5000
Algae	*Chlorella*	5 x 13	10^3 - 10^6	10 - 1500
Protozoa	*Euglena*	15 x 50	10^3 - 10^5	5 - 200
Nematodes	*Pratylenchus*	1,000 §	10^1 - 10^2	1 - 100
Earthworms	*Lumbricus*	100,000 §		10 - 1000
‡ diamter of hyphae	§ length			

Reference:
http://www4.ncsu.edu/~lagillen/SSC%20532/Chapter%2010/Chapter%2010.html

Anonymous (2012). Soil Microbiology SSC 532. Department of Soil Science, College of Agriculture and Life Science, NC State University. Available in http://www4. ncsu.edu/ ~lagillen / SSC%20532/ Chapter %2010/Chapter%2010.html

14. AGRONOMIC EFFICIENCY (AE_{CN})

Agronomic efficiency of added compost-N is a useful measure of nutrient use efficiency as it provides an index that quantifies total economic output relative to the utilization of the system resources.

$$\text{Agronomic Efficiency of Added Compost N } (AE_{CN}) = \frac{Y_{Treatment} - Y_{Control}}{N_{Applied}} \quad (\textit{kg green leaf kg N Applied}^{-1})$$

(Ref. : Novoa & Loomis, 1981)

Where, $Y_{Treatment}$: Yield under compost application; $Y_{Control}$: Yield under control; $N_{Applied}$: Amount of N given in the form of compost.

15. PARTIAL FACTOR PRODUCTIVITY (PEP_{CN})

The advantage of PEP_{CN} is that it quantifies total economic output from any particular factor/nutrient, relative to its utilization from all resources in the system, including indigenous soil nutrients and nutrients from applied inputs (Cassman *et al*.,1996).

$$\text{Partial Factor Productivity of Applied Compost N } (PFP_{CN}) = \frac{Y_{Treatment}}{N_{Applied}}$$ (*kg made tea kg N Uptake*$^{-1}$)

(Ref. : Yadav, 2003)

Where, $Y_{Treatment}$: Yield under compost application; $N_{Applied}$: Amount of N given in the form of compost.

16. PHYSIOLOGICAL EFFICIENCY OF COMPOST N (PE_{CN})

Physiological efficiency of compost- N is also called internal efficiency and is commonly used to test the comparative efficiencies of crops/ cultivars and management treatments (Aynehband *et al*., 2012).

$$\text{The Physiological Efficiency of Compost N } (PE_{CN}) = \frac{Y_{Treatment} - Y_{Control}}{NU_{Treatment} - NU_{Control}}$$ (*kg made tea kg N Uptake*$^{-1}$)

(Isfan, 1990)

Where, $Y_{Treatment}$: Yield under compost application; $Y_{Control}$: Yield under control; $NU_{Treatment}$: nitrogen uptake (in harvested part) under compost application; $NU_{Control}$: Nitrogen uptake under control.

17. CROP RECOVERY EFFICIENCY OF APPLIED COMPOST N (RE_{CN})

Recovery efficiency is defined as the amount of nutrient in the crop as a ratio of the amount applied or available. Its calculation varies widely depending on the system being considered: the soil-plant system, the whole plant, the above-ground portion of the plant, or the harvested portion of the plant may be considered as the vessel of recovery.

$$\text{Crop Recovery Efficiency of Applied Compost N } (RE_{CN}) = \frac{NU_{Treatment} - NU_{Control}}{N_{Applied}} \times 100$$ (*kg made tea kg N Uptake*$^{-1}$)

(Ref. : Dilz, 1988)

Where, $NU_{Treatment}$: nitrogen uptake (in harvested part) under compost application; $NU_{Control}$: Nitrogen uptake under control; $N_{Applied}$: Amount of N given in the form of compost.

18. RELATIVE AGRONOMIC EFFECTIVENESS (RAE)

Information on relative agronomic effectiveness (RAE) of tea plantation under various available organic soil inputs could assist in selection of proper input thereby leading to economic crop production.

$$\text{Relative Agronomic Effectiveness (RAE)} = \frac{Y_{\text{Treatment 1}} - Y_{\text{Control}}}{Y_{\text{Treatment 2}} - Y_{\text{Control}}} \times 100 \quad (\textit{Percent})$$

(Ref. : Law-Ogbomo et al, 2011)

Where, $Y_{\text{Treatment}}$: Yield under compost application; Y_{Control} : Yield under control.

Methods of Analysis of Soil and Compost Samples

Processing of samples in the laboratory

The soil samples were divided into two parts. One part was kept in the refrigerator at 4^0C for doing microbial analysis. The other part was air dried, ground in a wooden mortar and pestle and passed through 2 mm sieve. The sieved samples were stored separately in clean plastic containers.

Similarly compost samples were first divided into two parts. One part was preserved for microbial analysis as done for soil samples. The other part as air dried, cut into smaller pieces with the help of a grinder and then stored separately in clean plastic containers.

Analysis of Soil Samples

1. SOIL TEXTURE

Particle size fractions of soils, namely sand, silt and clay was carried out following International Pipette method (Black, 1965).

2. BULK DENSITY, PORE SPACE AND VOLUME EXPANSION

Bulk density, pore space and volume expansion of soils were determined by the Keen-Rackzowski Box as per the methodology described by Baruah & Barthakur (1999).

3. pH

pH of the soil was determined using soil : water suspension in the ratio 1 : 2.5 (Jackson, 1973) using glass electrode pH meter.

4. ELECTRICAL CONDUCTIVITY (EC)

Electrical conductivity of the soil suspension (1 : 5) was measured (Jackson, 1973) at room temperature by using a direct reading conductivity meter.

5. CATION EXCHANGE CAPACITY (CEC)

The CEC of soils was determined by leaching the soils with HCl followed by filtration and dissolving the filtrate in Barium Acetate solution. The liberated H^+ was titrated with NaOH, using phenolphthalein indicator.

6. ORGANIC CARBON

Organic carbon content in the soil was estimated by oxidizing the soil with a mixture of 1N potassium dichromate ($K_2Cr_2O_7$) and concentrated sulphuric acid (H_2SO_4) and back titrating the excess $K_2Cr_2O_7$ with standard ferrous ammonium sulphate solution, following the methodology of Walkley and Black (1934) as outlined by Jackson (1973).

7. AVAILABLE (MINERALIZABLE) NITROGEN

Available nitrogen content in soils was determined by distilling 20 g soil with alkaline $KMNO_4$ solution and determining the NH_3 liberated by titration with 0.02N H_2SO_4 following the method of Subbiah and Asija (1956).

8. BRAY'S 1 EXTRACTABLE AVAILABLE PHOSPHORUS (P)

Available P_2O_5 content in soils was determined by treating soil with Bray's 1 extractant and estimated using a spectrophotometer at a wavelength of 660 nm, following the method as described by Jackson (1973).

9. AVAILABLE POTASSIUM

Available potassium content in soils was determined by shaking 5 g soil with 25 ml neutral N ammonium acetate adjusted to pH 7.0 for 5 minutes. Potassium in the extract was determined by flame photometer following the method of Hanway and Heidal (1952).

10. CALCIUM CHLORIDE EXTRACTABLE AVAILABLE SULPHUR (S)

Extractable sulphur content of the soils was determined by shaking 5.0 g soil with 25 ml 0.15 % $CaCl_2$ solution. Sulphate in the extracts was estimated turbidimetrically using a spectrophotometer at a wavelength of 340 nm following the methodology of Williams & Steinbergs (1959).

11. TOTAL BACTERIA, FUNGI, ACTINOMYCETES AND PHOSPHATE SOLUBILIZING BACTERIA (PSB) COUNT

Estimation of bacteria, fungi and actinomycetes was done as per plate counting method using Thornton's media, Martin's media and Jensen's media respectively according to the procedure outlined by Black (1965). Total phosphate solubilizing bacteria (PSB) count was also done as per plate counting method using Pikovskays's media according to procedure outlined by Black (1965).

12. TOTAL AMMONIFIERS AND TOTAL NITRIFIERS POPULATION

Estimation of total ammonifiers and total nitrifiers population was done using Remy's solution and Stefenson's media respectively and the population was counted as per MPN method (Black, 1965).

Analysis of Compost Samples

1. MOISTURE (AIR DRY)

10g moist compost was kept at room temperature for 96 hours and the final weight was recorded. Moisture percent was calculated from the difference in weight (Black, 1965).

2. BULK DENSITY, POROSITY AND WATER HOLDING CAPACITY

Bulk density, porosity and water holding capacity were done as per the methology described by Trautmann and Krasny (1997).

3. pH

pH of the compost was determined using soil : water suspension in the ratio 1 : 5 (Black, 1965) with a glass electrode pH meter.

4. ELECTRICAL CONDUCTIVITY (EC)

Electrical conductivity of the compost suspension (1 : 5) was measured (Black, 1965) at room temperature using a direct reading conductivity meter.

5. ORGANIC CARBON, TOTAL ASH CONTENT AND VOLATILE SOLIDS

Organic carbon was measured using gravimetric method as per Trautmann and Krasny (1997). Total ash content and volatile solids were also estimated as per the method described by Trautmann and Krasny (1997).

6. TOTAL NITROGEN

Total nitrogen was done as per acid digestion method taking 0.5g air dry compost sample (Black 1965)

7. TOTAL P AND K

Total P and K were estimated using tri acid digestion method. Finally Total P was estimated using a spectrophotometer at wave length of 470 nm. Total K was estimated directly using flame photometer (Black, 1965).

8. CATION EXCHANGE CAPACITY (CEC)

Cation exchange capacity of compost was measured as per the procedure described by Harada and Inoko (1980).

9. COMPOST MINERALIZATION INDEX (CMI)

Compost mineralization index was calculated as the ratio of ash content and total oxidizable carbon as described by Rekha *et al.* (2005).

10. SORPTION CAPACITY INDEX

Sorption capacity index was calculated as the ratio of cation exchange capacity and total oxidizable carbon as described by Rekha *et al.* (2005).

11. CO_2 EVOLUTION RATE

CO_2 evolution rate (mgCO_2-C/g OM/day) was determined using alkaline NaOH trap as per the procedure described by Trautmann and Krasny (1997).

12. WATER SOLUBLE CARBON

Water soluble carbon was determined using 10 gm of air dry compost sample following the procedure of Vance *et al.* (1987).

13. WATER SOLUBLE ORGANIC AND INORGANIC NITROGEN

Water soluble organic and inorganic nitrogen was determined by the procedure of Chanyasak and Kubota (1981).

14. HUMIFICATION RATIO

Humification ratio was calculated as (extractable carbon/ total organic carbon) x 100, as described by Rekha *et al.* (2005).

15. TOTAL BACTERIAL, FUNGI, ACTINOMYCETES AND PHOSPHATE SOLUBILIZING BACTERIA (PSB) COUNT

Estimation of bacteria, fungi and actinomycetes was done as per plate counting method using Thornton's media, Martin's media and Jensen's media respectively according to procedure outlined by Black (1965). Total phosphate solubilizing bacteria (PSB) count was also done as per plate counting method according to procedure outlined by Black (1965).

16. NH_4^+ - NITROGEN AND NO_3^- - NITROGEN

Determination of NH_4^+ - Nitrogen and NO_3^- - Nitrogen was done according to the method of Chanyasak and Kubota (1981).

17. GERMINATION INDEX (PHYTOTOXOCITY BIOASSAY)

Germination index (Phytotoxicity bioassay) was done as per the methodology of Zucconi *et al.* (1981). Germination tests were performed with garden cress (*Lepidium sativum* L.). Garden cress seeds were used because of their rapid germination and sensitivity to phytotoxic compounds.

The germination index, inversely related to the presence of phytotoxic substances in compost, was calculated as the percentage of seeds germinated multiplied by the average length of roots (in mm) expressed as percentage over control using distilled water (Hirai *et al.* 1983).

ECONOMICS OF DIFFERENT ON-FARM COMPOSTING

Table 1 : Cost components and Total Cost of Novcom Composting Method studied at Maud T. E., Assam under FAO – CFC – TBI Project on Finding out Pathway for Sustainable Organic Tea Cultivation.

Parameters	Value
Basic Information	
Size of Heap	360 cft. (10 ft x 6 ft x 6ft)
Total Raw Material used/heap	4500 kg
Duration of biodegradation (composting)	21 - 30 days
Weight of Final Compost	2925 – 3375 kg (Mean 3128 kg)
Recovery (percent)	65 - 75 % (mean 69.5 %)
Total Mandays required/heap	13.2
Various Cost Components of Novcom Compost	
Cost of 3500 kg Green matter (@ Rs. 0.23/kg)	Rs. 805/-
Cost of 1000 kg cowdung (@ Rs. 0.40 /kg)	Rs. 400/-
Cost of total 13.2 Mandays (@ Rs. 71.5/-) (5 mandays for chopping of green matter, 4 man days for 1st day heap construction, 2 mandays each for 1st and 2nd turning, 0.2 mandays for watering and monitoring)	Rs. 944/-
Cost of Novcom solution (@ Rs. 600/ltr.)	Rs. 525/-
Total Cost	Rs. 2674/-
Cost of 1 kg Final Compost (*with chopping*)	Rs. (0.79 – 0.92)/- **(Mean Rs. 0.86/-)**
Cost of 1 kg Final Compost (*without chopping*)	Rs. (0.69 – 0.79)/- **(Mean Rs. 0.74/-)**

****Based on market rate as on 1st April, 2011***

Table 2 : Cost components and Total Cost of Biodynamic Composting Method studied at Maud T. E., Assam under FAO – CFC – TBI Project on Finding out Pathway for Sustainable Organic Tea Cultivation.

Parameters	Value
Basic Information	
Size of Heap	240 cft. (15 ft x 4 ft x 4 ft)
Total Raw Material used/heap	2200 kg
Duration of biodegradation (composting)	80 - 90 days
Weight of Final Compost	1188 - 1408 kg (Mean 1342 kg)
Recovery (percent)	54 – 64 % (Mean 61 %)
Total Mandays required/heap	4.2
Various Cost Components of Biodynamic Compost	
Cost of 1500 kg Green matter (@ Rs. 0.23/kg)	Rs. 345/-
Cost of 700 kg cowdung (@ Rs. 0.40 /kg)	Rs. 280/-
Cost of total 4.2 Mandays (@ Rs. 71.5/-) (3 man days for 1st day heap construction, 1 mandays for covering the heap with mud and 0.2 mandays for watering and monitoring)	Rs. 300/-
Cost of Biodynamic solutions (BD 502 to 507) (@ Rs. 150/set)	Rs. 150/-
Cost of Lime (@ Rs 16/kg)	Rs. 80/-
Cost of Bamboo (@ Rs 29/-)	Rs. 87/-
Total Cost	**Rs. 1242/-**
Cost of 1 kg Final Compost	Rs. (0.88 – 1.05)/- **Mean 0.92/-**

Based on market rate as on 1st April, 2011

Table 3 : Cost components and Total Cost of Indigenous (FYM) Composting Method studied at Maud T. E., Assam under FAO – CFC – TBI Project on Finding out Pathway for Sustainable Organic Tea Cultivation.

Parameters	Value
Basic Information	
Size of Heap	300 cft. (15 ft x 4 ft x 5ft)
Total Raw Material used/heap	2700 kg
Duration of biodegradation (composting)	80 - 90 days
Weight of Final Compost	1430 – 1594 kg **(Mean 1536 kg)**
Recovery (percent)	53 - 59 % **(Mean 57 %)**
Total Mandays required/heap	6.2
Cost Component of Indigenous (FYM) Compost	
Cost of 2000 kg Green matter (@ Rs. 0.23/kg)	Rs. 460/-
Cost of 700 kg cowdung (@ Rs. 0.40 /kg)	Rs. 280/-
Cost of total 6.2 Mandays (@ Rs. 71.5/-) (3 man days for 1st day heap construction, 1 mandays for covering the heap with mud, 2 mandays for 1 turning and 0.2 mandays for watering and monitoring)	Rs. 433/-
Total Cost	**Rs. 1183/-**
Cost of 1 kg Final Compost	Rs. (0.74 – 0.82)/- **(Mean Rs. 0.77/-)**

**Based on market rate as on 1st April, 2011*

ECONOMICS OF DIFFERENT ORGANIC PACKAGE OF PRACTICE

Table 4 : Cost components and Total Cost of Inhana Rational Farming 2 (IRF- 2) package studied at Maud T. E., Assam under FAO – CFC – TBI Project.

Target Yield	: 1500 kg/ha (UP)	Crop Efficiency	: 113.34 % (Avg.)
Period of Study	: 3 years (2009-2011)	(Over Target yield)	
Pruning	: UP- Corrected LP- UP	Rank	: 1st (Out of 10)

Sl No.	Inhana Rational Farming Package (IRF 2) Inputs	Application	Total Cost/ha
Soil Management			
1.	Novcom Compost	Average 8.0 ton/ha @ Rs. 860 /ton (Based on actual N value on dry wt.)**	Rs. 6880/-
2.	Rock Phosphate (RP)	80 kg RP/ha mixed with Novcom compost	Rs. 360/-
3.	Elemental Sulphur (E-S)	40 kg /ha E-S mixed with Novcom compost	Rs 556/-
4.	Cowdung slurry (CDS)	200 ltr CDS /ha for ground application	Rs 98/-
Plant Management			
5.	Various Inhana Solutions for activation of plant physiology.	About 12 rounds average/year @ 500 to 1000 ml solution (each) /ha /round	Rs 2,500/-
7.	Micronized sulphur (MS) and Jay Vijay (JV) concoction	On an average 600 ml MS and 500 ml of JV was used for pest mgt, average 2 round in a year	Rs. 202/-
6	Neem oil (NO), Karanj Oil (KO) and Jay Vijay (JV) concoction	On an average 4 ltr of NO, 2 ltr. of KO and 500 ml of JV was used for pest mgt, average 8 round in a year	Rs 3200/-
Total Inhana Rational Farming (IRF 2) Package cost per ha			**Rs 13,796/-**

**** Based on 9.4 ton/ha (*considering standard value f 2 % N & 60 % moisture*) the package cost would be Rs.15,000/- i.e. 17.50 % efficiency in the cost.**

Table 4 : Cost components and Total Cost of Inhana Rational Farming 4 (IRF- 4) Package studied at Maud T. E., Assam under FAO – CFC – TBI Project.

Target Yield	: 1500 kg/ha (UP)	Crop Efficiency (Over Target yield)	: 110.05 % (Avg.)
Period of Study	: 3 years (2009-2011)		
Pruning	: UP- Corrected LP- UP	Rank	: 2nd (Out of 10)

Sl No.	Inhana Rational Farming Package (IRF 4) Inputs	Application	Total Cost/ha
Soil Management			
1.	Novcom Compost	Average 5.1 ton/ha @ Rs. 860 /ton (Based on actual N value on dry wt)**	Rs. 4386/-
2.	Rock Phosphate (RP)	80 kg RP/ha mixed with Novcom compost	Rs. 360/-
3.	Elemental Sulphur (E-S)	40 kg /ha E-S mixed with Novcom compost	Rs 556/-
4.	Cowdung slurry (CDS)	200 ltr CDS /ha for ground application	Rs 98/-
Plant Management			
5.	Various Inhana Solutions for activation of plant physiology.	About 12 rounds average/year @ 500 to 1000 ml solution (each) /ha /round	Rs 2,500/-
6.	Micronized sulphur (MS) and Jay Vijay (JV) concoction	On an average 600 ml MS and 500 ml of JV was used for pest mgt, average 2 round in a year	Rs. 202/-
7.	Neem oil (NO), Karanj Oil (KO) and Jay Vijay (JV) concoction	On an average 4 ltr of NO, 2 ltr. of KO and 500 ml of JV was used for pest mgt, average 8 round in a year	Rs 3200/-
Total Inhana Rational Farming (IRF 4) Package cost per ha			**Rs 11,302/-**

**** Based on 6.0 ton/ha (*considering standard value of* 2 % *N & 60 % moisture*) the package cost would be Rs.12,076/- i.e. 17.60 % efficiency in the cost.**

Table 6 : Cost components and Total Cost of VMI Package studied at Maud T. E., Assam under FAO – CFC – TBI Project.

Target Yield	: 1500 kg/ha (UP)	Crop Efficiency (Over Target yield)	: 103.53 % (Avg.)
Period of Study	: 3 years (2009-2011)		
Pruning	: UP- Corrected LP- UP	Rank	: 3rd (Out of 10)

Sl No.	VMI Inputs	Application	Total Cost/ha
Soil Management			
1.	Vermi Compost	Average 9.4 ton compost /ha @ Rs. 4000/ton	Rs 37, 600/-
2.	City compost Bio-NPK i.e. combination of Bacillus, Pseudomonas, Azotobacter and Azospirillum per ha; plant mgt. using diff. microbial inoculants.	City compost @1125 kg and 37.5 kg Bio-NPK in 3 split doses	Rs 19,425/-
Plant Management			
3.	Bio-NPK (combination of *Bacillus*, Pseudomonas, Azotobacter and Azospirillum	250 ml per ha and 4 times in a year	Rs 475/-
4.	Combination of *Verticiliium chlamydosporium*, *Beauveria bassiana* and *Paeciilomyces fumosoroseus*	500 ml per ha (each) and 5 times in a year	Rs 5438/-
5.	Combination of *Verticiliium chlamydosporium* and *Beauveria bassiana*	500 ml per ha (each) and 2 times in a year	Rs 1450/-
6.	Combination of *Verticiliium chlamydosporium*, and *Paeciilomyces fumosoroseus*	500 ml per ha (each) and 2 times in a year	Rs 1450/-
7.	*Trichoderma viride*	250 ml per ha once in pruned & skipped year	Rs 56/-*
8.	*Paeciilomyces fumosoroseus, Verticiliium chlamydosporium and Metarhizium anisoliae per ha.*	500 ml per ha once in pruned & skipped year	Rs. 363/-*
Total VMI input cost per ha			**Rs. 66,257/-**

Note : *Paeciilomyces fumosoroseus, Verticiliium chlamydosporium, Metarhizium anisoliae &Trichoderma viride spray (1 round each) was only recommended in pruned & skipped year.*

* Total cost incurred in one year is divided in 3 years to derive average cost.

Table 7 : Cost components and Total Cost of Inhana Rational Farming 3 (IRF-3) Package studied at Maud T. E., Assam under FAO–CFC–TBI Project.

Target Yield : 1500 kg/ha (UP)	Crop Efficiency : 100.85 % (Avg.) (Over Target yield)
Period of Study : 3 years (2009-2011)	
Pruning : UP- Corrected LP- UP	Rank : 4th (Out of 10)

Sl No.	Inhana Rational Farming Package (IRF 3) Inputs	Application	Total Cost/ha
Soil Management			
1.	Novcom Compost	Average 4.0 ton/ha @ Rs. 860 /ton (Based on actual N value on dry wt.)**	Rs. 3440/-
2.	Rock Phosphate (RP)	80 kg RP/ha mixed with Novcom compost	Rs. 360/-
3.	Elemental Sulphur (E-S)	40 kg /ha E-S mixed with Novcom compost	Rs 556/-
4.	Cowdung slurry (CDS)	200 ltr CDS /ha for ground application	Rs 98/-
Plant Management			
5.	Various Inhana Solutions for activation of plant physiology.	About 12 rounds average/year @ 500 to 1000 ml solution (each) /ha /round	Rs 2,500/-
6.	Micronized sulphur (MS) and Jay Vijay (JV) concoction.	On an average 600 ml MS and 500 ml of JV was used for pest mgt, average 2 round in a year	Rs. 202/-
7.	Neem oil (NO), Karanj Oil (KO) and Jay Vijay (JV) concoction.	On an average 4 ltr of NO, 2 ltr. of KO and 500 ml of JV was used for pest mgt, average 8 round in a year	Rs 3200/-
Total Inhana Rational Farming (IRF 3) Package cost per ha			**Rs 10,356/-**

**** Based on 4.5 ton/ha (*considering standard value of 2 % N & 60 % moisture*) the package cost would be Rs.10,786/- i.e. 12.50 % efficiency in the cost.**

Table 8 : Cost components and Total Cost of Inhana Rational Farming 1 (IRF-1) Package studied at Maud T. E., Assam under FAO – CFC – TBI Project.

Target Yield : 1500 kg/ha (UP)	Crop Efficiency : 99.23 % (Avg.) (Over Target yield)
Period of Study : 3 years (2009-2011)	
Pruning : UP- Corrected LP- UP	Rank : 5th (Out of 10)

Sl No.	Inhana Rational Farming Package (IRF 1) Inputs	Application	Total Cost/ha
Soil Management			
1.	Novcom Compost	Average 2.6 ton/ha @ Rs. 860 /ton (Based on actual N value on dry wt.)**	Rs. 2236/-
2.	Rock Phosphate (RP)	80 kg RP/ha mixed with Novcom compost	Rs. 360/-
3.	Elemental Sulphur (E-S)	40 kg /ha E-S mixed with Novcom compost	Rs 556/-
4.	Cowdung slurry (CDS)	200 ltr CDS /ha for ground application	Rs 98/-
Plant Management			
5.	Various Inhana Solutions for activation of plant physiology.	About 12 rounds average/year @ 500 to 1000 ml solution (each) /ha /round	Rs 2,500/-
6.	Micronized sulphur (MS) and Jay Vijay (JV) concoction	On an average 600 ml MS and 500 ml of JV was used for pest mgt, average 2 round in a year	Rs. 202/-
7.	Neem oil (NO), Karanj Oil (KO) and Jay Vijay (JV) concoction	On an average 4 ltr of NO, 2 ltr. of KO and 500 ml of JV was used for pest mgt, average 8 round in a year	Rs. 3200/-
Total Inhana Rational Farming (IRF 1) Package cost per ha			**Rs. 9,152/-**

**** Based on 3 ton/ha (*considering standard value of* 2 % *N & 60 % moisture*) the package cost would have been Rs. 9,496/- i.e. 15.38 % efficiency in the cost is achieved.**

Table 9 : Cost components and Total Cost of VMIP Package studied at Maud T. E., Assam under FAO – CFC – TBI Project.

Target Yield : 1500 kg/ha (UP)

Period of Study : 3 years (2009-2011)

Pruning : UP- Corrected LP- UP

Crop Efficiency : 98.88 % (Avg.) (Over Target yield)

Rank : 6th (Out of 10)

Sl No.	VMIP Inputs	Application	Total Cost/ha
Soil Management			
1.	Vermi Compost	Average 9.4 ton compost /ha @ Rs. 4000/ton	Rs 37, 600/-
Plant Management			
	Bio-NPK (combination of *Bacillus*, Pseudomonas, Azotobacter and Azospirillum	250 ml per ha and 4 times in a year	Rs 475/-
3.	Combination of *Verticiliium chlamydosporium*, *Beauveria bassiana* and *Paeciilomyces fumosoroseus*	500 ml per ha (each) and 5 times in a year	Rs 5437.5/-
4.	Combination of *Verticiliium chlamydosporium* and *Beauveria bassiana*	500 ml per ha (each) and 2 times in a year	Rs 1450/-
5.	Combination of *Verticiliium chlamydosporium*, and *Paeciilomyces fumosoroseus*	500 ml per ha (each) and 2 times in a year	Rs 1450/-
6.	*Trichoderma viride*	250 ml per ha once in pruned & skipped year	Rs 56/-*
7.	*Paeciilomyces fumosoroseus, Verticiliium chlamydosporium and Metarhizium anisoliae per ha.*	500 ml per ha once in pruned & skipped year	Rs. 363/-*
Total VMIP input cost per ha			**Rs. 46,832/-**

Note : *Paeciilomyces fumosoroseus, Verticiliium chlamydosporium, Metarhizium anisoliae and Trichoderma viride spray (1 round each) was only recommended in pruned & skipped year.*

* Total cost incurred in one year is divided in 3 years to derive average cost.

Table 10 : Cost components and Total Cost of VCO Package studied at Maud T. E., Assam under FAO – CFC – TBI Project.

Target Yield : 1500 kg/ha (UP)	Crop Efficiency : 92.83 % (Avg.) (Over Target yield)
Period of Study : 3 years (2009-2011)	
Pruning : UP- Corrected LP- UP	Rank : 7th (Out of 10)

Sl No.	VCO Inputs	Application	Total Cost/ha
Soil Management			
1.	Vermi Compost	Average 9.4 ton compost/ha @ Rs. 4000/ton	Rs 37, 600/-
Plant Management			
2.	Polygunam hydropiper (PHC) and Artimisia vulgaris (AVC) concoction	@ 25 ltr. concoction of PHC and 20 ltr. concoction of AVC in 500 ltr. water/ ha 8 times in a year	Rs 176/-
3.	Clerodendron infortunatum (CIC) and Artimisia vulgaris (AVC) concoction	@ 250 ltr. concoction of CIC and 20 ltr. concoction of AVC in 500 ltr. water/ ha, 10 times in a year	Rs 1350/-
4.	Garlic and red chilli(GCC) and Artimisia vulgaris (AVC) concoction.	@ 5 ltr. Concoction of GCC and 20 ltr. concoction of AVC in 500 ltr. water/ ha, 5 times in a year	Rs 1078/-
5.	Vitex negundo (VNC) and Artimisia vulgaris (AVC) concoction.	@ 25 ltr. concoction of VNC and 20 ltr. concoction of AVC in 500 ltr. water/ ha 2 times in a year	Rs 77/-
6.	Ind-Safari (ISC) and Artimisia vulgaris (AVC) concoction	@ 2.5 ltr. Concoction of GCC and 20 ltr. concoction of AVC in 500 ltr. water/ ha, once in a year	Rs 30/-
Total VCO input cost per ha as per recommendation			**Rs 40, 311/-**

On an average 24 rounds of spraying/year (26 round per year was recommended) was done in 3 years, so the **actual input cost of Indigenous Package (CO) was 40,184/-**

Table 11 : Cost components and Total Cost of Indigenous (CO) Package studied at Maud T. E., Assam under FAO – CFC – TBI Project.

Target Yield : 1500 kg/ha (UP)	Crop Efficiency : 89.16 % (Avg.) (Over Target yield)
Period of Study : 3 years (2009-2011)	
Pruning : UP- Corrected LP- UP	Rank : 8th (Out of 10)

Sl No.	Indigenous (CO) Inputs	Application	Total Cost/ha
Soil Management			
1.	Indigenous (FYM) Compost	Average 13.5 ton compost/ha @ Rs. 770 /ton	Rs 10, 395/-
Plant Management			
2.	Polygunam hydropiper (PHC) and Artimisia vulgaris (AVC) concoction	@ 25 ltr. concoction of PHC and 20 ltr. concoction of AVC in 500 ltr. water/ ha 8 times in a year	Rs 176/-
3.	Clerodendron infortunatum (CIC) and Artimisia vulgaris (AVC) concoction	@ 250 ltr. concoction of CIC and 20 ltr. concoction of AVC in 500 ltr. water/ ha, 10 times in a year	Rs 1350/-
4.	Garlic and red chilli(GCC) and Artimisia vulgaris (AVC) concoction.	@ 5 ltr. Concoction of GCC and 20 ltr. concoction of AVC in 500 ltr. water/ ha, 5 times in a year	Rs 1078/-
5.	Vitex negundo (VNC) and Artimisia vulgaris (AVC) concoction.	@ 25 ltr. concoction of VNC and 20 ltr. concoction of AVC in 500 ltr. water/ ha 2 times in a year	Rs 77/-
6.	Ind-Safari (ISC) and Artimisia vulgaris (AVC) concoction	@ 2.5 ltr. Concoction of GCC and 20 ltr. concoction of AVC in 500 ltr. water/ ha, once in a year	Rs 30/-
Total Indigenous (CO) input cost per ha as per recommendation			**Rs 13, 106/-**

On an average 24 rounds of spraying/year (26 round per year was recommended) was done in 3 years, so the **actual input cost of Indigenous Package (CO) was Rs. 12,954/-**

Table 12 : Cost components and Total Cost of Biodynamic (BD) Package studied at Maud T. E., Assam under FAO – CFC – TBI Project.

Target Yield : 1500 kg/ha (UP)	Crop Efficiency : 87.36 % (Avg.) (Over Target yield)
Period of Study : 3 years (2009-2011)	
Pruning cycle : UP- Corrected LP- UP	Rank : 9th (Out of 10)

Sl No.	**Biodynamic Inputs**	**Application**	**Total Cost/ha**
Soil Management			
1.	Biodynamic Compost (BD 502 – 507)	10 ton /ha@ Rs. 920 /ton	Rs 9,200/-
2.	Cow Pat Pit (CPP) (BD 502 – 507)	2.5 kg CPP per ha, every 3 months as per BD calendar Date	Rs. 138/-
3.	Cow Horn Manure (BD 500)	75 gm BD 500/ ha, every 4 times in a year i.e. late afternoon/ evening – descending moon	Rs. 1500/-
Plant Management			
4.	Cow Horn Silica (BD 501)	2.5 gm BD 501/ ha, every 4 times in a year i.e. early morning 6-8 a.m. at sunrise.	Rs. 1500/-
5.	Urja	Urja @ 500 g /ha + 10 kg leaves (each) of Neem, Datura and Papaya. Recommended as pest repellent to be given after the pest occurrence. (*Average- 8 rounds/year based on 3 years actual application*)**	Rs. 2576/-
Total Biodynamic Package (BD) cost per ha			**Rs 14, 914/-**

** This cost may vary according to the pest intensity/occurrence of individual garden.

Table 13 : Cost components and Total Cost of Microbial Formulation for both Soil and Plant (MI) Package studied at Maud T. E., Assam under FAO – CFC – TBI Project.

Target Yield	: 1500 kg/ha (UP)	Crop Efficiency (Over Target yield)	: 86.23 % (Avg.)
Period of Study	: 3 years (2009-2011)		
Pruning	: UP- Corrected LP- UP	Rank	: 10th (Out of 10)

Sl No.	Microbial Formulation Inputs	Application	Total Cost/ha
Soil Management			
1.	City compost and Bio-NPK i.e. combination of *Bacillus, Pseudomonas, Azotobacter* and *Azospirillum* per ha.	City compost @1125 kg and 37.5 kg Bio-NPK in 3 split doses	Rs 19,425/-
Plant Management			
2.	Bio-NPK (combination of *Bacillus*, Pseudomonas, Azotobacter and Azospirillum	250 ml per ha and 4 times in a year	Rs 475/-
3.	Combination of *Verticiliium chlamydosporium, Beauveria bassiana* and *Paeciilomyces fumosoroseus*	500 ml per ha (each) and 5 times in a year	Rs 5438/-
4.	Combination of *Verticiliium chlamydosporium* and *Beauveria bassiana*	500 ml per ha (each) and 2 times in a year	Rs 1450/-
5.	Combination of *Verticiliium chlamydosporium*, and *Paeciilomyces fumosoroseus*	500 ml per ha (each) and 2 times in a year	Rs 1450/-
6.	*Trichoderma viride*	250 ml per ha once in pruned & skiffed year	Rs 56/-*
7.	*Paeciilomyces fumosoroseus, Verticiliium chlamydosporium and Metarhizium anisoliae per ha.*	500 ml per ha once in pruned & skiffed year	Rs. 363/-*
Total Microbial Formulation for both Soil & Plant (MI)Package Cost / ha			**Rs. 28,657/-**

Note : *Paeciilomyces fumosoroseus, Verticiliium chlamydosporium, Metarhizium anisoliae and Trichoderma viride spray (1 round each) was only recommended in pruned & skiffed year.*

* Total cost incurred in one year is divided in 3 years to derive average cost.