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Adoption of Inhana Rational Farming (IRF) Technology as an Organic Package of Practice towards Improvement of Nutrient Use Efficiency of Camellia Sinensis through Energization of Plant Physiological Functioning

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Abstract:
The effectivity of Inhana Rational Farming (IRF) Technology towards energization of plant physiological functioning was evaluated in comparison to other organic packages of practice under FAO-CFC-TBI Project at Maud Tea Estate, Dibrugarh, Assam, India during 2008 to 2013. The study area lies in 27.26^0 N latitude and 95.12^0E longitude covering a total area of 154.58 ha area with level to nearly level landscape. The experiment was laid down as per randomized block design (RBD) with 8 treatments replicated 3 times. The treatments included available two organic methods viz. Biodynamic Farming (BD) and Inhana Rational Farming (IRF) (developed by Dr. P. Das Biswas, Founder, Inhana Biosciences, Kolkata) as well as organic inputs viz. vermicompost, bio-fertilizers, bio-pesticides, herbal formulations which are used in organic tea gardens in India on large scale. The organic inputs selected for evaluation were combined to form different 'Packages of Practice' based on scientific rationale. The different packages were : Biodynamic (BD) with Biodynamic compost, Conventional Organic Practice with Indigenous compost @ 13.5 ton/ha (CO), Inhana Rational Farming Technology with 8 ton Novcom Compost (IRF-2), Inhana Rational Farming Technology with 5.1 ton Novcom Compost (IRF-4), Vermicompost @ 9.4 ton/ha + Conventional Organic Practice (VCO), Vermicompost @ 9.4 ton/ha + Microbial Formulations for both soil and plant management (VMI), Vermicompost @ 9.4 ton/ha + Microbial Formulations for only plant management i.e. Bio-pesticides+ Bio-growth promoter (VMIP).
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. But the most significant finding was that there was a considerable enhancement of nutrient use efficiency under the treatment plots which received total package of practice(ie. both plant and soil management) in comparison to the plots which received only the soil management part of the same package of practice (12.35 to 93.77 % increase). The results indicated towards a definitive role of organic plant management w.r.t. enhancement of the plant physiological functioning. While the agronomic efficiency was found highest in both soil management as well as complete package under IRF technology but also the percent change in agronomic efficiency (total package vs. only soil management part of the same package) was highest in case of IRF package of practice. This indicated positive impact of IRF plant management programme towards plant physiological functioning leading to higher crop response.

Keywords: *Organic Farming, Agronomic efficiency, FAO project, Rational Farming Technology, Plant physiology*

1. Introduction

Plant nutrition and fertilization have become synonymous in commercial agriculture but in most intensive agricultural production systems, over 50% and up to 75% of the N applied to the field is not used by the plant and is lost by leaching into the soil (Raun *et al*, 1999, Hodge *et al*, 2000 and Asghari *et al*, 2011). Nutrient Use Efficiency (NUE) in plants is complex and depends on nitrogen availability in the soil and on how plants use nitrogen throughout their life span. Some microorganisms are able to improve soil fertility by metabolizing N that is not absorbed by plants (Hirel *et al*, 2011). Increasing NUE and limiting nitrogen fertilizer use are both important and can serve to preserve the environment and improve a sustainable and productive agriculture (Daubresse *et al*, 2010), for which improving NUE is essential. Compost application has been shown to increase soil fertility and stimulate microbial activity (Glaster et al, 2002) but additionally their auxin-like activity positively impacts plant physiology by influencing nutrient uptake and root architecture (Canellas *et al*, 2008 and Trevisan *et al*, 2010). This is of remarkable importance for plant development, once it may affect not only plant nutritional aspects, but also plant response to environment challenges. The reactions of plants to endogenous and environmental signals are related to the presence of molecules used as chemical messengers (Swarup et al. 2002). Plant hormones such as auxin, gibberellin, and abscisic acid are able to regulate the activity of the proton pumps eliciting key physiological responses (Marré and Ballarin-Denti 1985). In these respect sustainable agricultural practices has been found to minimize the detrimental impact of the overuse of N on the environment (Hirel et al, 2011). Barik et al (2014) found an increase in nutrient use efficiency when organic soil management was taken up in combination with organic plant management i.e. under comprehensive organic package of practice.

Inhana Rational Farming Technology developed by Dr. P. Das Biswas, Founder Director of Inhana Biosciences and a noted scientist who was pioneering in introduction of Scientific Organic Farming in India from the last decade; is an unique Organic Package of Practice which blends ancient wisdom with scientific knowledge, ensuring an effective road map for successful and large scale organic agriculture (Barik *et al*, 2014). Rational Farming Technology is an organic package of practice, which works towards (i) energization of soil system i.e., enabling the soil to function naturally and in the most effective way as an effective growth medium for plants and (ii) energization of plant system i.e., activation of plant physiology enabling better uptake, utilization and assimilation of nutrients as well as enhancement of structural and biochemical defenses or plants host defense mechanism. The present study was aimed to evaluate, whether the two way approach of Inhana Rational Farming Technology can enhance crop productivity through improvement of nutrient use efficiency thereby indicating towards activation of plant physiological functioning.

2. Materials and Methods

2.1 Study area

The study was under FAO-CFC-TBI project entitled 'Development, Production and Trade of Organic Tea', which was conducted at Maud tea estate (Assam) from 2008-09 to 2012-13. Analytical work was done at Inhana Biosciences laboratory, Kolkata. Young mature tea plantation (25+ years) was taken for the study and the treatments were placed as per randomized block design with three replications and individual plot size of 0.20 ha. Field experiment was laid out in such a manner that one plot received complete package of practice (both soil, plant and pest management) and another plot received only soil management part of that practice.

Effect of Organic Plant Management Practice → [**Crop performance in the plot receiving complete package of practice** – **Crop performance in the plot receiving only soil management practice**]

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. 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.

2.2 Treatment Details

Experimental Plot 1			Experimental Plot 2		
Package of Practice			**Only Soil Input**		
T_1	**:**	**Control (C).**	**T_1**	**:**	**Control (C).**
T_2	:	Vermicompost @ 9.4 ton/ ha + Herbal concoctions for pest and disease management (VCO).	T_2	:	Vermicompost @ 9.4 ton/ ha
T_3	:	Vermicompost @ 9.4 ton/ ha + Bio-growth promoter + Bio-pesticides (VMIP).	T_3	:	Vermicompost @ 9.4 ton/ ha
T_4	:	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	:	Vermicompost @ 9.4 ton/ ha + Bio-fertilizer (1.125 ton City compost + 37.5 kg Bio-NPK)
T_5	:	Novcom compost @ 8.0 ton/ha + 40 kg Elemental-S + 80 kg Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-2).	T_5	:	Novcom compost @ 8.0 ton/ha + 40 kg Elemental-S + 80 kg Rock Phosphate
T_6	:	Novcom compost @ 5.1 ton/ha + Elemental-S + Rock Phosphate + IRF plant management package + Neem & Karanj oil concoction for pest management (IRF-4).	T_6	:	Novcom compost @ 8.0 ton/ha + 40 kg Elemental-S + 80 kg Rock Phosphate
T_7	:	Biodynamic compost @ 10 ton/ ha + Cow Pat Pit + Cow horn manure + Biodynamic package for plant management (BD).	T_7	:	Biodynamic compost @ 10 ton/ ha
T_8	:	Indigenous compost/ Farm Yard Manure (FYM) @ 13.5 ton/ ha + Herbal concoctions for pest and disease management (CO).	T_8	:	Indigenous compost/ Farm Yard Manure (FYM) @ 13.5 ton/ ha

2.3. Preparation of different compost

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 compost or Farm Yard Manure (FYM), Biodynamic compost and Novcom compost; as per their standard processes (described below) at Maud tea estate in Dibrugarh, Assam (India). Vermicompost was produced within a period of 75 days, the biodegradation period for Indigenous and Biodynamic compost was 90 days while that for Novcom compost was 21 days. Details of the compost preparation were given by Bera *et al* (2013).

Pic. 1 : Large scale Novcom composting programme at Maud Tea Estate, Assam under FAO-CFC-TBI Project during 2008 – 2013.

2.4. Analysis of Compost Sample

Compost samples (15 samples from each type) were drawn from all the compost heaps during the period 2008-2012. Total N, P and K content in compost was determined by acid digestion method (Jackson, 1973).

2.5. Details of different Organic Package of Practice

2.5.1. Vermicompost for soil management and conventional plant Management (VCO)

2.5.1.1. 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)*

2.5.1 2. Plant Management

Sl. No.	Herbal concoctions	Pest/ Disease control & Rate of Application
1	Polygunam hydropiper (PHC)	Red spider and other Mites (25 ltr./ha)
2	Piro onio/ Bitter Fern (POC)	For Thrips, Green Fly, Helopeltis and other minor insects (25 ltr./ha)
3	Ind-Safari (ISC) [fish waste & cow urine concoction]	All Insect Pests and Caterpillars (2.5 kg/ha)
4	Garlic & Red Chilly (GCC)	All types of insects (5 kg/ha)
5	Vitex negundo (nigandhi) [VNC]	Helopeltis and All Insects (25 ltr./ha)
6	Copper Fungicide	Blister Blight (500 ml/ha)
7	Equizitam (Horse Tail) Or Rice Husk (ERHC)	Blister Blight, Black Rot, any other fungal disease (5 ltr./ ha)
8	Clerodendron infortunatum concoction (CIC).	Insecticidal and fungicidal properties. Ideal for Blister Blight and Insects (250 ltr./ ha)
9	Artimisia vulgaris (titapatti) [AVC]	Mainly works as repellent and does not have much knock down effect (20 kg/ ha)
10	Neem Seed Concoction (NSC).	All Insect Pests (12.5 ltr./ ha)

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.

2.5.2. Vemicompost for soil management and Microbial Formulations for plant management (VMIP)

2.5.2.1 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.)

2.5.2.2. Plant Management

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.

Note : The Protocol has been taken from the Group, which has developed the above Microbial Formulations; Growth Promoter is applied @ 250ml/ha & rest of the solutions were applied @ 500 ml/ha

2.5.3. Vermicompost for soil management and Microbial formulation for Soil and Plant Management (VMI)

2.5.3.1. 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) with* 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.

2.5.3.2. Plant Management
Same as VMIP

2.5.4. *Inhana Rational Farming*
Inhana Rational Farming (IRF) Technology developed by Dr. P. Das Biswas, associated with organic research for the last 15 years; has a WHOLISTIC approach so that all components of the ecosystem are taken in an integrated manner i.e. soil system, plant system and their interrelated and integrated relationships with the environment as a whole. It provides the right environment for all the components, be it plant or soil, which ultimately leads to ecological improvement thereby ensuring economic sustainability. Inhana Rational Farming Technology is till now probably the only package of practice which provides complete solutions for organic farming from seed showing to harvesting in an effective and Economic way (Barik *et al*, 2014).

2.5.4.1. **Objectivities of Rational Farming Technology**

- **Energization of the Soil System i.e., enabling the soil to function naturally and in the most effective way as an effective growth medium for plants.**

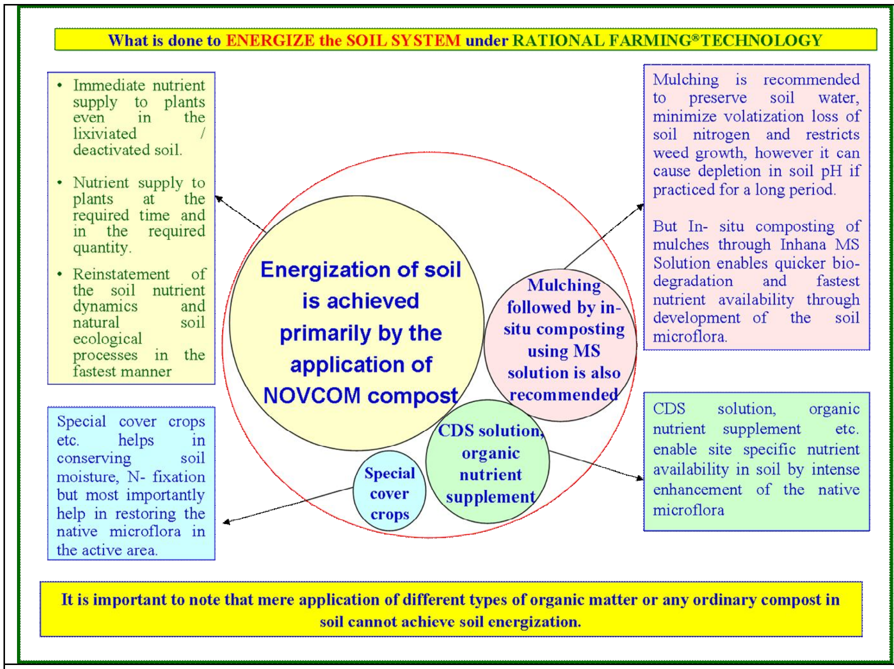


Fig. 1 : Flow diagram of Energization of Soil System under Inhana Rational Farming Technology (IRF).

- **Energization of the Plant System i.e., the plants become efficient in optimum extraction, utilization and assimilation of nutrients as well as enhancement of the biochemical and structural defense of the plant system through the activation of the plants host defense mechanism.**

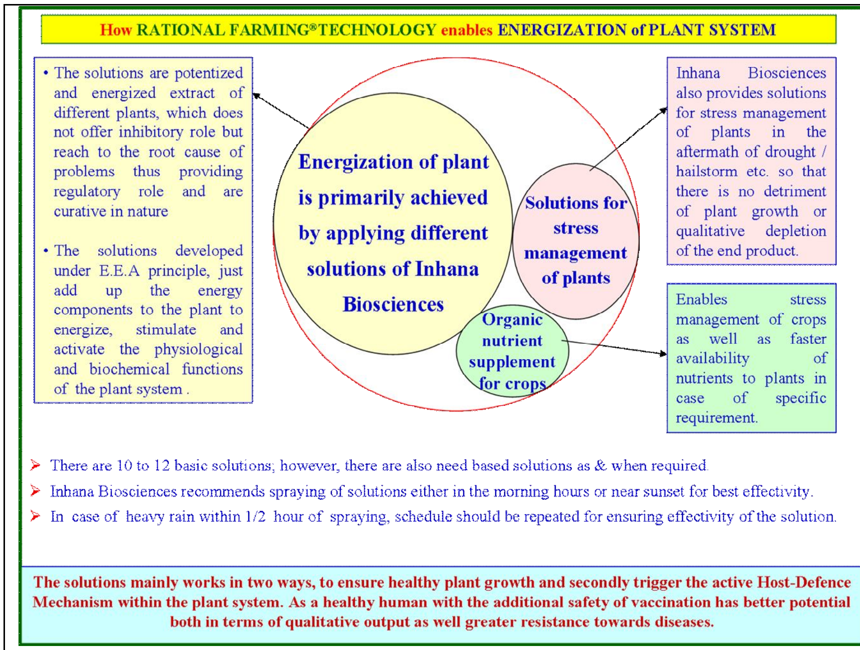


Fig. 2 : Flow diagram of Energization of Plant System under Inhana Rational Farming Technology (IRF).

2.5.4.2. Element- Energy Activation (E.E.A.)® Principle in Plant System

A brief details: All living bodies are like machines and the vital driving force or enemy behind them is "Chaitanya Shakti" or Basic Life Force. Solar energy is the manifestation of "Chaitanya Shakti". Except at birth and at death, two major processes (Nourishment & Self protection) are going on in every living body.

2.5.4.2.1. Self-Nourishment

Five basic elements (Panchamahabhutas) Soil, Air, Water, Fire and Space take care of nourishment till time we Humans do not interfere with these qualities, it performs without any problem. The individual element responsible or role of Panchamahabhutas for specific mechanism of nourishment is as follows.

- Earth : Nutrition and structure formation.
- Water: Transportation of nutrients for transpiration.
- Fire : Metabolism, Ripening of fruits, Photosynthesis.
- Air : Respiration
- Space: Making space available for any bio-chemical reaction .

2.5.4.2.2. The Self-Defense

The self-defense mechanism is said to be controlled by five different Life Forces or Prana-Shaktis. These are originated from the basic life-force ie, Solar energy. The life forces or Prana-Shaktis are actually vehicles of these basic elements and movement of nutrients is impossible without them. Their role in the plant system are as follow.

- Apana Prana : Controls the function of roots extraction of nutrients.
- Samana Prana : Controls transpiration.
- Udana Prana : Controls Photosynthesis and secretion of enzymes, hormones.
- Prana Prana : Controls respiration and eases movement of respiratory products.
- Vyana Prana : Makes space available for all functions.

2.5.4.2.3. Self Protection

If there is any imbalance in sub functions like structure, Formation, Circulation, Metabolism etc as well as nourishment then the whole system tries to protect itself. This self-defense mechanism is controlled by five different Life Forces or Prana Shaktis.
All these process, functions and sub-functions are interdependent and operate in an orchestral manner, in nature. Any imbalance leads to the disease or pest manifestation or lack of nourishment. According to EEA® Principle to overcome the disease or pest infestation, life forces are to be stimulated instead of encountering from outside leading to unfavourable repercussions.
Similarly, deactivated plant system can't uptake, assimilate or utilize the stored and applied nutrients in an effective manner. Addition of nutrients can't change the phenomenon for which life forces are to be added.

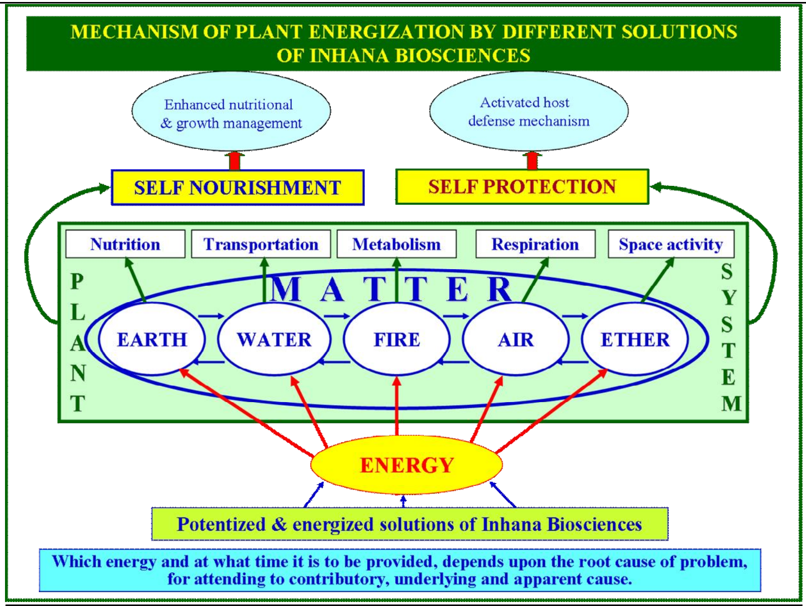


Fig. 3 : Flow diagram of Mechanism of Plant Energization under Inhana Rational Farming Technology.

2.5.4.3. Brief scientific details of the development of Inhana Solutions

- All Inhana Solutions are developed on the 'Element Energy Activation' (E.E.A.) Principle. Hence the auxiliary (solvent) and inert ingredients used are same for all the solutions.
- Inhana solutions are botanical extracts containing energy components in activated forms, so that they can perform in desired order when applied on the plant system (matter).
- Specific plant parts *viz.* roots, stem, leaf, root hair, leaf vein etc. are taken for extraction of the energy components, which are extremely subtle and abstract in nature and simultaneously need a medium (matter).
- Hence, during and after extraction they are transferred to a medium which is less gross and at the same time has higher surface tension and alcohol serves as this medium.
- The next step Energization is the process through which energy components are isolated from its gross form and stabilized in alcoholic medium. However, both extraction and energization process operates simultaneously as the extracted gross components should be immediately transferred to a medium
- This step is followed by Potentization, through which the extracted bind energy is activated for enhancement of their liberating potential, so that these energy components can perform in desired order when applied in plants. 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.

2.5.4.4. Details on processing of the plant extracts are as follows

- Solvents used for the extraction of the plant extracts: Standard quality Ethyl alcohol (C_2H_5OH), purity 99.8%.
- The mechanism of activation, energization and potentization of plant extracts is being attached for convenience. Except filtered water (free from heavy particles) no other ingredients are added during these processes.
- It is being confirmed that the inert ingredient added to the formulation is water (H_2O). No other inert ingredient like stabilizers, emulsifiers etc. are added to the formulation because the process does not allow such additions during preparation of the solutions or during their application on plants. Hence, the mixing of such components in any stage shall only decrease the potency of the solutions.

2.5.4.5. Guiding philosophy of EEA principle behind development of Inhana Solutions

All Inhana solutions are developed under the Element Energy Activation (E.E.A.) Principle. Radiant solar energy is stored in plants and these binding stored energy components are extracted from energy rich plant parts 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 on 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 the Element Energy Activation Principle.

2.5.4.6. 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.

2.5.4.7. Soil Management

In case of IRF 2 Novcom Compost was applied @ 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), where as in case of IRF, dose of Novcom compost was 5.1 ton/ ha.

2.5.4.8. Plant Management

On an average 12 rounds of spraying for plant physiology development which is same for both IRF-2 and IRF- 4 treatment module.

Plant management (for plant physiological development)			
Sl. No	**Solution Name**	**Biologically activated & potentised extract of**	**Role in Plant Physiological Development**
1.	IB 1 (Samridhi)	Hyoscyamus niger, Ficus benghalensis & Dendrocalamus strictus Nees.	**O**rganic growth promoter, activator and regulator 1. Energizes and stimulates the plants system for the best use of nutrients both applied and stored in the soil. 2. Regulates every stage of the Grand Growth Period influencing growth correlation.
2.	IB 2 (Immunosil)	Ocimum sanctum, Calotropic procera R. & Cynodon dactylon	**S**ilica induced immunity against fungal attack 1. Activates plants' host defense mechanism through silica management providing structural defense against fungal pathogens. 2. It also stimulates plants immune system by activating the biosynthesis of different phenolic compounds having fungi-toxic property.
3.	IB 3 (OrganiK)	Adhatoda vasica Nees, Zingiber officinale Roscoe & Embellia ribs.	**O**rganic solution for potash absorption and utilization 1. Increases the efficiency of potash uptake through energized root capacity, so that gradual reduction in application is ensured. 2. It activates suction pressure by influencing diffusion pressure deficit.
4.	IB 4 (OrganiN)	Calotropis Procera R., Dendrocalamus strictus Nees & Bombax malabaricum D. C.	**E**nsures biological absorption of atmospheric-N directly by plant. 1. Helps the plant to utilize the atmospheric nitrogen. It also balances the quantity of nitrogen in the plant system at the right time, thereby preventing deleterious effect on quality of the produce. 2. Ensures gradual reduction of chemical nitrogen application.
5.	IB 5 (Solution I)	Cynodon dactylon & Calotropic gigantean.	**E**nergizes the various biochemical process of plant resulting in harmonious grand growth period. 1. Regulates and stimulates the cellular oxidation process. 2. Energizes the phloemic function resulting in encouraged translocation of organic solutes. Stimulates the hydrolysis of starch to D-Glucose units by enhancing the enzymatic activity.
6.	IB 6 (Solution II)	Hyoscyamus niger & Solanum Verbascifolium	**E**nergizes and activates respiration and photosynthesis activity and plays complementary role of solution-I 1. Energizes respiration by activating the protoplasmic factors and the concentration of respiratory substrate. 2. Stimulates the rate of photosynthesis by quick translocation of carbohydrates.
7.	IB 7 (Solution PP5)	Ocimum sanctum	**S**timulates the root function, activates root growth/ penetration and energizes soil in the root zone thus improves soil-plant relationship. 1. Develops the CEC of soil. 2. Energizes the production of micro-flora and bio-flora around the root zone. 3. Improves the degree of base saturation to the desired level. 4. Enhances the Root Cation Exchange Capacity. 5. Stimulates the root growth and penetration by activating the Contact Exchange Capacity of the Root.
8.	IB 8 (Atermit)	Solanum verbascifolium, Prosopis spicigera & Ocimum bascilicum.	**O**rganic solution for termite management. 1. It has both controlled and contained action. It restricts the movement of termites. 2. Repels termite activity by influencing thermostatic environment of the soil.
9.	IB 9 (ZXN)	Albizzia maranguihses, Biscifia javanica & Erythrina Variegate Linn.	**E**nsures enhanced photosynthesis and balances respiration 1. It influences the action spectrum and absorption spectrum of plants. 2. It enhances or activates Xanthophills.
10.	IB 10 (Special Solution I)	Costus specicus sm. & Typhora indica mer.	**I**mproves plant transport by deliberating essential substances to the various internal mechanism.
11.	IB 11 (Special Solution II)	Solanum xanthocarpum schard & Aristolochia indica Linn.	**I**mproves the movement of solutions by providing systemic presence to give structural integrity.
12.	IB 12 (Special Solution III)	Sida Cordifolia Linn. & Barberis asiatica Roxb. Ex. De.	**I**mproves the plant's capacity for starch synthesis.

2.5.4.9. Pest Management

10 rounds for pest management was done yearly as per the protocol, which was same for both IRF-2 and IRF-4 treatment module.

Plant management (for pest/ disease management)			
Sl. No	**Solution Name**	**Biologically activated & potentised extract of**	**Role in Plant Physiological Development**
1.	IB 13 Sp. Immunosil1	Ficus racemosa Linn. & Calotropuc procera R.	**A**ctivates necrosis or hypersensitive defense system by disintegrating the hypha.
2.	IB 14 Sp. PP5	Ocimum sanctum & Costus specicus sm.	**I**mprove root health and activates apoplastic and symplastic mechanism.
3.	IB 15 CDS - F	Veronica cineria Less. & Solanum verbascifolium (Root &stem)	**I**mproves and fortifies the cow dung and cow urine concoction towards better toxicity removal and plant sanitization effect.
4.	IB 16 CDS – G	Veronica cineria Less. & Solanum verbascifolium (Root)	**I**mproves and fortifies cow dung and cow urine concoction for faster organic activity in the surface soil.
5.	IB 17 KPS	Prosopis spicigera & Costus specisus sm.	**A**ctivates karanj seed and cow urine concoction for anti-ovulatory effect on Helopeltis Theivora.
6.	IB 18 Sp. Immunosil 2	Barberis asiatica Roxb. Ex. De., Ficus racemosa Linn., Ocimum sanctum & Cynodon dactylon	**I**nfluences the cell wall swelling, thereby inhibits host penetration and infection by pathogens.
7.	IB 19 Jay Vijay	Bombax malabaricum D.C., Calotropic procera R & Ocimum bascilicum.	**O**rganic pest management 1. An organic pest repellant with anti-feedant action. 2. It activates the Plants Host Defense Mechanism. 3. It enhances Environmental Resistance and reduces the Biotic Potential.
8.	IB 20 Sp. Jay Vijay	Bombax malabaricum D.C., Calotropic procera R, Ocimum bascilicum. & Biscifia javanica	**A**ctivates plant system for enhanced secretion of phytoalexins particularly pisatin and orchinol.
Other concoction recommended for organic pest management			
9.	Micronized sulphur (MS) and Jay Vijay (JV) concoction		For Red Spider control
10.	Lime sulphur and Jay Vijay (JV) concoction		For Red Spider control
11.	Neem oil (NO), Karanj oil (KO) and Jay Vijay (JV) concoction		For control of different types of leaf sucking and chewing pests
12.	Neem oil (NO), cow urine and Jay Vijay (JV) concoction		For control of different types of leaf sucking and chewing pests

2.5.5. Biodynamic Farming (BD)

2.5.5.1. 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	Effective soil conditioner and an	Apply 10 ton B.D. Compost/ ha at late

(Compost, CPP, Liquid manure inoculums)- Biodynamic Compost	immediate source of nutrient.	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.

2.5.5.2. Plant Application

Urja (for herbal Insect, pest, tonic inoculums)	Pest repellent & Herbal insecticide.	@ 500 g /ha + 10 kg leaves (each) of three types of medicinal plant among 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.

2.5.6. Conventional Organic Practice (CO)

2.5.6.1. Soil Management

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).

2.5.6.2. Plant Management

Same as VCO

2.6. Analysis of Crop Yield and Economics

Crop yield in terms of green leaf was noted in every plucking round. Comparative crop performance was evaluated through relative agronomic effectiveness (RAE) as per the following formula

Relative Agronomic Effectiveness (RAE)	=	$\frac{Y_{Treatment\ 1} - Y_{Control}}{Y_{Treatment\ 2} - Y_{Control}}$	x	100	%	(Law-Ogbomo et al, 2011)

2.7. Analysis of Nutrient Use efficiency of Applied Compost

Nutrient Use efficiency of applied compost in terms of different agronomic indices viz. agronomic efficiency of applied compost N (AE_{CN}), partial factor productivity of applied compost N (PFP_{CN}), physiological efficiency of compost N (PE_{CN}), apperent recovery efficiency of applied compost N (RE_{CN}), Crop removal efficiency of applied compost N (CRE_{CN}) and crop response ratio of applied compost (CRR_C) as per following formula.

Agronomic Efficiency of Added Compost N (AE_{CN})	=	$\frac{Y_{Treatment} - Y_{Control}}{N_{Applied}}$			(kg green leaf kg N Applied^{-1})	(Novoa & Loomis, 1981)
Partial Factor Productivity of Applied Compost N (PFP_{CN})	=	$\frac{Y_{Treatment}}{N_{Applied}}$			(kg made tea kg N Uptake^{-1})	(Yadav, 2003)
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)
Apparent Recovery Efficiency of Applied Compost N (RE_{CN})	=	$\frac{NU_{Treatment} - NU_{Control}}{N_{Applied}}$	x	100	kg made tea kg N Uptake^{-1})	(Dilz, 1988)
		$NPK_{Applied}$				

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; $N_{Applied}$: Amount of N given in the form of compost

3. Result and Discussion

Nutrient use efficiency can be expressed in several ways. Mosier *et al.* (2004) described four agronomic indices commonly used to describe nutrient use efficiency: partial factor productivity (PFP, kg crop yield per kg nutrient applied); agronomic efficiency

(AE, kg crop yield increase per kg nutrient applied); apparent recovery efficiency (RE, kg nutrient taken up per kg nutrient applied); and physiological efficiency (PE, kg yield increase per kg nutrient taken up). Crop removal efficiency (removal of nutrient in harvested crop as % of nutrient applied) is also commonly used to explain nutrient efficiency (Roberts, 2008).

3.1. Agronomic efficiency of tea plants under Different Organic Soil Inputs.

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. Maximum AE_{CN} was observed in case of Novcom compost applied plots (19.13 kg green leaf kg N Applied^{-1}) followed by VCBF (13.92 kg green leaf kg N Applied^{-1}), oil cake (10.38 kg green leaf kg N Applied^{-1}) and vermi compost (9.90 Kg green leaf kg N Applied^{-1}) treatments respectively. Higher value in Novcom compost plots 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 Novcom compost treated plots might be due to 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.

Pic. 2 : Dr. P. Das Biswas, scientist and developer of IRF Organic Package of practice, presenting the findings of FAO-CFC-TBI Project at Maud Tea Estate before the delegation from IFOAM, TRA Scientists and Dr. T.C. Chaudhury, project co-coordinator from Tea Board of India.

Pic. 3 : Prof. A. Chatterjee, member of Advisory team presenting the findings in FAO-CFC-TBI Project meeting at Maud Tea Estate, Assam.

Pic. 4 : Professors from Calcutta and Viswa Bharati university in discussion regarding the project findings at Maud Tea Estate, Assam.

Pic. 5 : Inter plot vegetative barrier to restrict overlapping of treatment effect in the treatment plots under FAO-CFC-TBI project at Maud Tea Estate, Assam.

Treatment	Nutrient Use Efficiency				
	(AE_{CN})	**(PFP_{CN})**	**(PE_{CN})**	**(RE_{CN})**	**(RAE)**
Vermi Compost (VC)	9.90	17.85	32.28	7.16	51.73
Vermi compost + microbial formulation for soil management (VCBF)	13.92	17.72	33.27	9.77	78.07
Novcom Compost (NOV)	19.13	20.00	35.19	12.69	100.00
Biodynamic Compost (BD)	5.31	13.91	32.26	3.86	34.05
Indigenous Compost (FYM)	8.93	17.62	31.66	6.59	46.69

Table 1: Agronomic indices to determine nutrient use efficiency under different organic 'Packages of Practice'

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). Decline in partial productivity for N has been reported in cereal based system leading to higher investment in N to maintain higher yields. Decline in partial factor productivity for N may be attributed to nutrient imbalance, decline in indigenous soil-N supply, subsoil compaction, reduced root volume and increased incidence of pests and diseases (Karim and Ramasamy, 2000). Adoption of efficient N management practices is responsible for higher partial factor productivity (Yadav, 2003). Highest PEP_{CN} was obtained in case of Novcom compost applied plots (20.00 kg made tea kg N Uptake^{-1}) vermi compost applied plots (17.85 kg made tea kg N Uptake^{-1}). Higher PFP_{CN} under Novcom compost treatment might be to due to increased uptake and utilization of indigenous nutrients and by increasing the efficiency with which applied nutrients are taken up by the crop and utilized to produce crop (Cassman *et al.*, 2006).

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). PE_{CN} is highest in case of Novcom compost (35.19 kg made tea kg N uptake^{-1}) applied plots. This might be due to the high population of microflora within Novcom compost, which positively influenced the internal efficiency of compost- N post soil application. But the most important finding is that PE_{CN} in the oilcake (30.30 kg made tea kg N Uptake^{-1}) applied plots are lowest among all other treatments. The results indicate that concentrated organic manure like oilcake might be a very high source of N as compare to other organic inputs, but in order to obtain the relative PE_{CN} and thereby sustained crop production, the inherent microbial potential of the input becomes mandatory.

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. The inputs may or may not include: applied manures, mineralization of soil nutrients, atmospheric deposition, and contribution of soil micro-organisms, in addition to applied fertilizers. Recovery can be calculated for each single source or for the total of all sources (Bruulsema *et al*., 2004). Novcom compost treated plots once again showed highest RE_{CN} (12.69 kg made tea kg N Uptake^{-1}) followed by VCBF (9.77 kg made tea kg N Uptake^{-1}) applied plots. Low recovery value is primarily because (i) only harvested portion of the plant was considered and (ii) due to slow nutrient releasing potential of the compost-N as compared to inorganic/ chemical- N.

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. As highest crop production was obtained in case of Novcom compost treatment, taking its yield as reference (RAE : 100), the next best treatment (VMI) had the relative agronomic effectiveness of 78.07 percent followed by VC (51.73 percent). RAE in case of all other organic inputs is <50 percent. The results clearly indicate the relative effectiveness of Novcom compost over the rest other organic soil inputs.

3.2. 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).

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

Table 2: Agronomic indices to determine nutrient use efficiency in terms of compost N application under different organic packages of practice

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.

Pic. 6 : Dr. P. Das Biswas, inspect pruning activity at Maud T.E. under FAO-CFC-TBI Project.

Pic. 7 : New leaf initiation after pruning operation.

Pic. 8 : Light pruning (LP) in Soil Input experimental plots under FAO-CFC-TBI Project at Maud T.E.

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

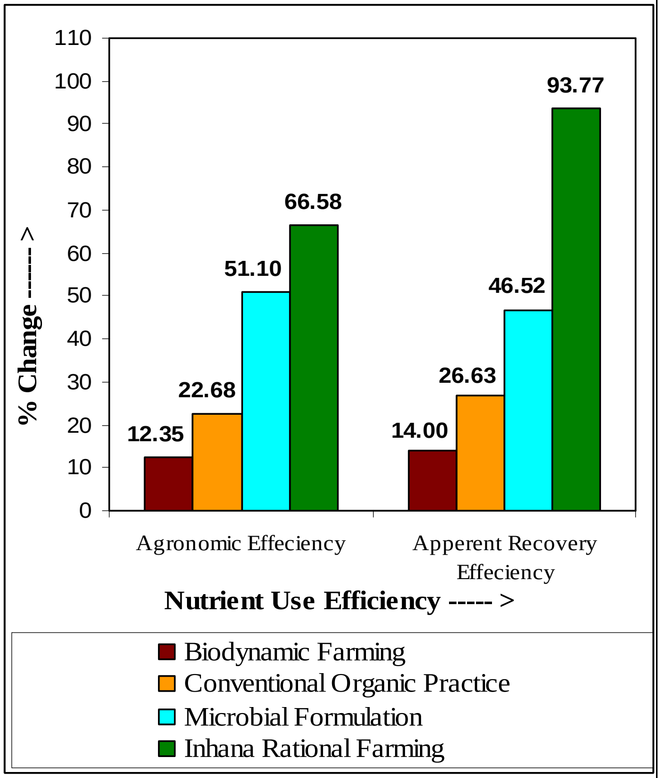
Improvement in compost use efficiency entails improvement of yield (Olsen and Sommers, 1982), especially increase in nitrogen use efficiency (NUE, as assessed through agronomic and relative agronomic efficiency), which plays an essential role in cutting down the production costs (Silspoor and Momayezi, 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 3 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.

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		

Table 3: Impact of plant management on agronomic efficiency of mature tea plants

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. 4) 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.



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

Fig. 4: 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.

4. Conclusion

Assessment of nutrient use efficiency under organic plant management indicated towards their efficient role w.r.t. enhancement of plant physiological functioning. Among the different organic packages evaluated, significant improvement was noticed in case of Inhana Rational Farming (IRF) Technology, which indicated its potential towards activation of plant functioning which is a perquisite for achieving sustainable crop performance within a defined time frame. The observation also supports the principle of energy management towards activation of plant physiology ultimately contributing towards crop performance.

Pic. 2 : Dr. P. Das Biswas, developer of Inhana Rational Farming (IRF) Technology (extreme left) discussing with Ms Joelle Kato, Programme Manager (IFOAM), and Dr. T.C. Chaudury, project co-coordinator of FAO-CFC-TBI Project.

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