

Improvement of Soil and Plant Health through Adoption of an Organic Package of Practice for Rice Cultivation in New Alluvial Soil of West Bengal

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of Organic farming is to achieve crop sustainability through restoration of soil dynamics, improvement of plant health through improvement of the soil - plant interactions, nourishment of the environmental resistance and reducing pest interferences. Lack of scientific guidelines and comprehensive organic package of practice (POP) has rendered the objective unachievable. The present study was initiated at Howrah Krishi Vigyan Kendra in 2015 and 2016 to evaluate the potential of Inhana Rational Farming (IRF) Technology, an organic POP, towards increasing crop productivity and restoration of soil quality under rice cultivation under different farming model viz. organic, integrated, non-pesticidal crop management as well as KVK.s recommendation with reduced fertilizer dosage. Treatments with organic plant management practices (IRF technology) showed 5% higher crop productivity (4774 kg/ha) in comparison to conventional farmers' practice (4537 kg/ha) for Swarna sub-1 rice variety. Where as in case of

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scented rice varieties like *Gobindobhog*, the organic practice showed highest crop performance (3194 kg/ha) among all the treatments, and achieved 17% higher yield than that obtained under conventional farmers' practice (2726 kg/ha). Also the non-pesticidal crop management, a new concept of synthetic pesticide free crop cultivation under IRF Technology showed higher crop performance (4991 kg/ha and 2978 kg/ha in *Swarna sub-1* and *Gobindobhog* rice varieties respectively) than conventional farmers practice. Organic plant management under IRF aimed at activation of plant physiology was found to have a positive impact towards agronomic development and yield performance as compared to conventional practice. Assessment of soil quality parameters indicated increasing trend of soil quality especially in terms of soil biological parameters for plots receiving Novcom compost.

Keywords: Farming models; organic agriculture; Inhana rational farming technology; soil quality; rice.

1. INTRODUCTION

Conventional agriculture which brought in the "Green Revolution" of the 1960s, has been considered as the solution to the global hunger problem. But the increase in crop came at the cost of environmental degradation and lowered food security over the long term [1]. At the same time, dumping of harmful agrochemicals has substantially contaminated our environment that resulted in residue, resistance and resurgence problem [2]. In this scenario, going back to organic agriculture is the most viable option for future crop sustainability as well as ecological sustenance. However, organic agriculture faces some major bottle necks both principally and in terms of practical applicability [3]. Long term study around the world showed significant yield gap in crop productivity between organic and conventional agriculture despite the progress in organic research [4]. Organic cultivation in India lacks proper guidelines; application of organic inputs based on the same input substitution theory of chemical farming makes organic agriculture costly, as well as a risky proposition [1]. In this background Inhana Rational Farming (IRF) Technology, a complete package of practice showed promising results in different agricultural crops under organic and integrated model based on on-farm resource availability and socio-economic framework [5]. The technology mainly focuses on the development of soil and plant health to restore the self-nourishment and self-protection behaviour of plant system [6]. The present study was done jointly by Howrah KVK and Inhana Organic Research Foundation (IORF), Kolkata where effectiveness of the different organic and integrated cultivation models were compared with the conventional farming practice in terms of crop sustainability and soil quality development.

2. MATERIALS AND METHODS

Study was initiated in the year 2015 at Howrah Krishi Vigyan Kendra (KVK) which is situated at Jagatballavpur village under Jagatballavpur Block of Howrah district (located at '22.6784°N, 88.1232°E), a new alluvial soil of West Bengal, India. It is situated in the hot, moist, sub-humid agro-ecological situation having annual rainfall between 1100 to 1500 mm of which 75-80% is received during June to September. The mean annual maximum and minimum temperature fluctuates from 40.2° to 10.8°C and relative humidity ranges between 66 to 85%. The study was undertaken with an objective to find out the evaluation of different packages of practice viz. T1: Control, T2: Organic farming (Inhana Rational Farming Technology, IRF), T3: Integrated farming practice, T4: Non-pesticidal crop management (IRF plant management) (NPCM), T5: Conventional Farming with recommended dose of fertilizer and T6: KVKs treatment (with reduced chemical dose) were studied in terms of crop response and soil quality development. Kharif Rice, variety: *Gobindobhog* and *Swarna Sub-1* were taken for the study and the treatments were placed under Randomized Block Design (RBD) with three replications and individual plot size of 18 sq. m (6 m x 3 m)..

2.1 Inhana Rational Farming (IRF) Technology

IRF Technology developed by Dr. P. Das Biswas (noted scientist and pioneer of Scientific Organic Farming in India); is an organic POP which blends ancient wisdom with modern scientific knowledge, in order to enable large scale organic agriculture [7]. The technology provides a nature receptive pathway for crop production that nurtures the interrelated and integrated relationships of the ecosystem components, in

order to ensure ecological sustainability for corollary economic sustenance [8]. IRF provides complete solutions for organic farming from seed sowing to crop harvest in an effective and economic manner with the objectivity of (i) Energization of Soil System *i.e.*, enabling the soil to function naturally and in the most effective way as a growth medium for plants and (ii) Energization of Plant System *i.e.*, enabling efficient extraction, utilization and assimilation of nutrients along with restoration of biochemical and structural defences of the plants against pest and disease [1]. IRF Technology utilizes various In-House solutions for soil and plant energization. Technology specific plants, which store the energy of these five basic elements as well as five basic life forces, are selected in accordance with parameters related to sunset, seasons and various factors. Botanical extracts of these plants are then potentized and energized following Element Energy Activation (E.E.A.) Principle. Each and every solution individually has one or more function but when applied as a complete package the solutions work in an integrated manner giving comprehensive results. However, IRF Technology also ensures need-based solutions for all problems as per crop species and agro-climatic variations [1]. Details about the technology in terms of working principles and solutions have been provided by workers who have utilized this technology for organic crop management [9,8,1,6,10].

2.2 Soil Management

Four different treatments *viz* (i) Control, (ii) Organic Package of Practice (T2), (iii) Integrated Package of Practice and (iv) Conventional Package of Practice (farmer's practice were taken to understand the effectivity of compost application. In the conventional treatment plots total NPK was applied as per recommended dose for the area (NPK: 120 : 60:60 kg/ha) in the form of urea, single super phosphate and muriate of potash. In the organic plots Novcom compost was applied @ 2 ton/bigha where as in the integrated treatment plot, Novcom compost @ 1 ton /ha and NPK @ 60:30:30 kg/ha (50% of recommended dose) were applied.

2.3 Rice Cultivation

Rice varieties *viz* *Swarna sub-1* and *Gobindobhog* were taken for the study and the treatments were placed under Randomized Block

Design (RBD) with three replications and individual plot size of 18 sq. m (3 m x 6 m). In the Conventional (CCM) and Non Chemical Pest Management (NCPM) treatment plots total NPK was applied as per recommended dose for the area (NPK : 120 : 60:60 kg/ha) in the form of urea, single super phosphate and muriate of potash. In the organic plots Novcom compost was applied @ 2 ton/bigha where as in the integrated treatment plots, Novcom compost @ 1 ton/ha and NPK @ 60:30:30 kg/ha (50% of recommended dose) were applied. Land was prepared by deep ploughing followed by laddering. Thirty days old seedlings were transplanted in the main field at the rate of three seedlings per hill. The main crop was fertilized according to the selected treatments. In the conventional experimental plots 25% of total N, 100 of total P₂O₅ and 50% of total K₂O were applied at the time of final land preparation. During 1st top dressing (15 days after transplanting) 50% of total N and 25% of K₂O were applied. During 2nd top dressing (45 days after transplanting) 25% of total N and 25% of total K₂O were applied. In the organic plots, Novcom compost was applied during land preparation where as in the integrated treatment plots mixture of Novcom compost and basal dose of NPK was applied. First and second top dressings were done in the same way of conventional treatment plots. Intercultural operations such as weeding and water management measures were done as and when required for ensuring and maintaining normal crop growth.

2.4 Rice Yield Methodology

Grain yield was determined from a 5 sq. m sampling area from each plot, adjusted to 14% moisture content and expressed as t/ha. Productivity per day was the grain yield over total growth duration. Above ground biomass was the total dry matter of straw, rachis and filled and unfilled grains. Harvest index was calculated as:

$$HI = 100 \times (\text{grain weight} / \text{above ground total biomass})$$

At maturity, 12 hills were harvested diagonally from a 5 sq. m area where grain yield was determined. Panicles were hand-threshed and the filled grains were separated from half-filled and empty one and oven-dried at 70°C to a constant weight for determining 1000-grain weight. Duncan's New Multiple Range Test was

done to evaluate the studied agronomic data base.

2.5 Analysis of Soil Samples

Soil (0 to 30 cm) samples were collected from twelve different treatment plots (three plots each from five different treatments) at Howrah Krishi Vigyan Kendra farm before initiation of experiment and post harvesting. The soil samples were divided into two parts. One part was kept in the refrigerator at 4°C 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. The pH and EC of the soil was determined using soil : water suspension using glass electrode [11]. Organic carbon content in the soil was estimated following the methodology of Walkley and Black [12] as outlined by Jackson [11]. Available nitrogen content in soils was determined following the method of Subbiah and Asija [13]. Available P₂O₅ content in soils was determined by extracting soil with Olsen reagent using a spectrophotometer as per the method described by Jackson [11]. Available potassium content in soils was determined by flame photometer following the method of Hanway and Heida I [14]. Extractable sulphur was estimated turbidimetrically using a spectrophotometer at a wavelength of 340 nm following the methodology of Williams and Steinbergs [15]. Microbial biomass carbon was measured using the dichromate oxidation method of Vance et al. [16]. Soil respiration was measured through chemical titration of trapped CO₂ as per the methodology of Haney et al. [17]. FDAH was determined as per the standard methodology by Haney et al. [17].

2.6 Analysis of Soil Quality

Pre and post experiment soil samples and compost samples were collected from the study area for doing the necessary soil and compost analysis. The soil samples were divided into two parts. One part was kept in the refrigerator at 4°C 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. Soil physicochemical and fertility parameters were analyzed as per standard procedure suggested by Jackson [11] while soil microbial study was done as per the methodology of Weaver [18].

3. RESULTS AND DISCUSSION

3.1 Crop Performance under Different Treatments

Grain Yield is most important parameter to study the effectivity of any management practice. Rice yield is determined by yield components and associated characters. Fageria et al. [19] and Fageria [20] reported that rice yield was highly correlated with shoot dry weight, panicle number and grain harvest index. Gravois and Helms [21] reported that optimum rice yield could not be attained without optimum panicle density of uniform maturity. Similarly, Ottis and Talbert [22] reported a high correlation ($R^2 > 0.85$) between yield and panicle density. The most important factor for the determination of spikelet number during reproductive growth stage is the amount of N absorbed, although photosynthesis is also contributed by the spikelet number [23]. Similarly, specific absorption rate of N per root dry weight during grain filling stage is the most important factor for achieving high rice productivity [24]. In case of *Swarna Sub 1* paddy variety (Table 1) crop yield was highest under NPCM Package of Practice (4991 kg/ha) closely followed by integrated package of practice (4835 kg/ha) and organic (4774 kg/ha). However in case of *Gobindobhog* paddy variety (Table 2) crop yield was highest under Organic Package of Practice (2512 kg/ha) followed by integrated crop management (2419 kg/ha) and NPCM Package of Practice (2294 kg/ha). Highest grain yield under integrated package of practice was primarily contributed by higher number of productive panicle/sq.m, higher filled grains/panicle and higher 1000 grain weight.

However in case of *Gobindobhog* paddy variety highest harvest index was found in case of NPCM treatment plots (HI : 56.5) closely followed by organic treatment plots (HI : 56.0). Higher HI indicated better physiological efficiency, which may due to application of IRF Plant Management package in integrated and organic treatment plots towards upliftment of plant physiology. Similar impact was noted under Inhana Plant Management package by several other workers in case of crops like paddy [8,1,6,9].

Affectivity index (%) was calculated as (Number of effective tillers hill⁻¹ / Number of total tillers hill⁻¹) x 100. Affectivity index indicate the transformation of tillers to productive panicle which has a direct relationship with grain yield performance. Though number of tillers/hill were

comparatively lower under organic package of practice but their conversion present to productive tillers were highest under this treatment closely followed by other treatments received IRF Plant Management Package. This indicated that organic plant management under Inhana Rational Farming (IRF) enhanced plant physiology which resulted in higher affectivity index (Fig. 1).

3.2 Soil Quality Development under Organic Soil Management

Assessment of soil quality in terms of soil fertility showed increase in the value of soil fertility components under organic and integrated treatment plots, which pointed towards the positive influence of compost application in soil (Table 3). Nitrogen is the most important

Table 1. Agronomic indices for rice (Var: Swarna sub-1) at Howrah Krishi Vigyan Kendra Farm, West Bengal, India

Treatments	No of tillers/hills	Productive panicle/sq.m	Field grains/panicle	1000 grain wt.(g)	Yield (kg/ha)	Straw Yield (kg/ha)	Harvest Index
Control (T ₁)	12.67 ^{NS}	191.67 ^{NS}	103.33 ^e	18.80 ^{NS}	3585 ^a	2847 ^b	55.74 ^{NS}
Organic Package of Practice (T ₂)	13.00 ^{NS}	201.67 ^{NS}	129.00 ^{bc}	19.14 ^{NS}	4774 ^b	2776 ^c	63.22 ^{NS}
Integrated Package of Practice (T ₃)	13.65 ^{NS}	209.67 ^{NS}	131.68 ^{ab}	19.12 ^{NS}	4835 ^{ab}	2962 ^{ab}	62.01 ^{NS}
Conventional Package of Practice (farmer's practice) (T ₄)	13.67 ^{NS}	206.67 ^{NS}	139.33 ^a	19.18 ^{NS}	4991 ^a	2956 ^{ab}	62.80 ^{NS}
T5: Conventional Farming with recommended dose of fertilizer	13.63 ^{NS}	204.33 ^{NS}	121.33 ^c	19.07 ^{NS}	4537 ^c	3079 ^a	59.57 ^{NS}
T6: KVKs treatment (with reduced chemical dose)	13.33 ^{NS}	202.34 ^{NS}	117.33 ^d	18.93 ^{NS}	4352 ^d	3044 ^a	58.75 ^{NS}

Note :The figures marked with different letters in the same column were significantly different at P < 0.05 under Duncan's New Multiple Range Test

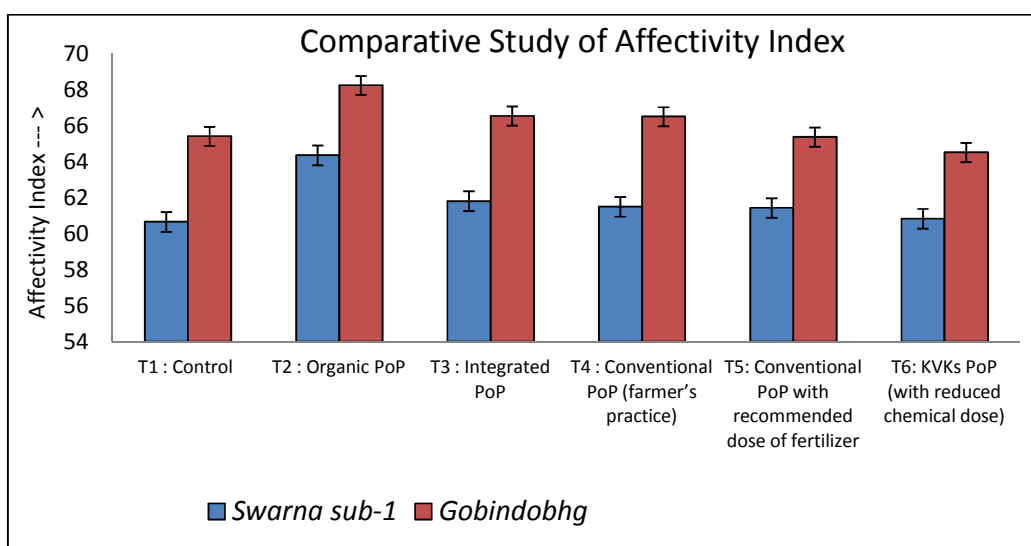


Fig. 1. Comparative study of Affectivity index of paddy under different management practice In case of Swarna sub 1 paddy variety, highest harvest index was found in case of organic treatment plots (HI : 63.2) followed by NPCM treatment plots (HI : 62.8) and integrated treatment plots (HI : 62.0)

Table 2. Agronomic indices for rice (Var: Gobindobhog) at Howrah Krishi Vigyan Kendra Farm, West Bengal, India

Treatments	No of tillers/hills	Productive panicle/m ²	Field grains/panicle	1000 grain wt.(g)	Yield (kg/ha)	Straw Yield (kg/ha)	Harvest Index
Control (T ₁)	8.21 ^d	165.2 ^d	140.2 ^e	16.67 ^{NS}	2363 ^f	1916 ^f	55.21 ^{NS}
Organic Package of Practice (T ₂)	13.21 ^a	204.2 ^a	189.2 ^a	16.89 ^{NS}	3194 ^a	2511 ^a	55.99 ^{NS}
Integrated Package of Practice (T ₃)	12.02 ^{ab}	198.6 ^{ab}	173.4 ^c	16.78 ^{NS}	2906 ^{bc}	2418 ^{ab}	54.54 ^{NS}
Conventional Package of Practice (farmer's practice) (T ₄)	13.01 ^a	201.4 ^a	180.4 ^{ab}	16.82 ^{NS}	2978 ^b	2293 ^c	56.48 ^{NS}
T5: Conventional Farming with recommended dose of fertilizer	10.20 ^c	187.3 ^b	174.6 ^c	16.80 ^{NS}	2726 ^d	2193 ^d	55.40 ^{NS}
T6: KVKs treatment (with reduced chemical dose)	10.89 ^c	181.5 ^c	170.2 ^{cd}	16.71 ^{NS}	2606 ^e	2087 ^e	55.37 ^{NS}

Note : The figures marked with different letters in the same column were significantly different at $P < 0.05$ under Duncan's New Multiple Range Test

Table 3. Variation in soil quality in terms of soil physico-chemical and fertility status at Howrah Krishi Vigyan Kendra Farm, West Bengal, India

Package of Practice	Time of sampling	Soil Physicochemical and Fertility properties						
		pH	EC (dSm ⁻¹)	Org. C (%)	Av. N (kg/ha)	Av. P ₂ O ₅ (kg/ha)	Av. K ₂ O (kg/ha)	Av. SO ₄ (kg/ha)
Control (T ₁)	Before	7.04	0.083	1.39	408.73	41.73	377.20	173.23
	After	6.99	0.088	1.33	379.20	38.20	340.42	239.60
Organic Package of Practice (T ₂)	Before	6.83	0.101	1.28	529.98	46.70	374.94	187.80
	After	7.02	0.128	1.32	532.10	49.41	378.46	224.32
Integrated Package of Practice (T ₃)	Before	7.02	0.087	1.31	484.08	42.20	379.46	206.47
	After	7.08	0.108	1.30	515.10	45.30	380.42	215.18
Conventional Package of Practice (farmer's practice)(T ₄)	Before	6.93	0.097	1.30	46.04	54.38	388.49	220.65
	After	6.90	0.108	1.27	529.98	51.58	369.98	250.81

nutrient for paddy for inducing vegetative growth and reproductive propagation [25]. Rice grown under high management requires large amounts of nitrogen (N). One crop consumes approximately 20-25 kg of nitrogen for every ton of yield, making nitrogen the single most important rice nutrient. Available - N status in soils of experimental plots was medium to high as per standard rating [26]. Except in control plots the available-N status was found to increase in the different experimental plots. Phosphorus not only helps in root growth but

also plays an important role in plant metabolism by supplying energy required for metabolic processes [27]. Like all cereal grains rice requires a considerable amount of phosphorus for vigorous growth and high yield. After completion of the experiment, available phosphate status increased in organic and integrated treatment plots, which might indicate positive influence of compost towards higher availability of phosphate in soil. The effect might be due to compost application in soil, which reduced the capacity of soil minerals to fix P and

increased its availability through release of organic acids, as also suggested by different researchers [28,29].

Potash is essential for the formation of carbohydrate and proteins and acts as a regulator of water content within plant cell [30]. Because of the presence of potassium (K) in most irrigation water, the response of rice to potassium is often not as marked as the responses to nitrogen and/or phosphorus, except in unusual situations (e.g. when certain toxicities are offset by potassium). Available potash varied within 346.89 and 426.89 kg ha⁻¹ in the experimental plots. After experimentation, slight increase in potash status was observed in organic and integrated treatment plots. Similar post compost application effects were also obtained by other workers [28,31]. Increase in the value of soil fertility components under organic and integrated treatment plots pointed towards the positive influence of compost application in soil. Similar observation was found by many other workers [32,33,34,35].

Microbial activity is probably the most important factor that controls nutrient re-cycling in soil. Microorganisms participate in disintegration and decomposition processes leading to the release of nutrients trapped in plant and animal debris, rock and minerals [36]; as well as synthesize and release hormones that are essential for plant growth [37]. Microorganisms in fact are the driving force of nutrient supply in soils [38] and are the primary recipients of increased photo-assimilates from plants growing in elevated atmospheric CO₂. Microbial biomass and soil respiration can

be referred as sensitive indicators of ecosystem development and disturbance. Results indicated that microbial biomass carbon increased significantly only in case of organically treated plots (56.35% increase), while under integrated treatment, the increment was nominal (7.88% increase) (Table 4). However, in case of control and chemical treatment plots, soil microbial biomass value decreased from initial. Comparatively higher soil microbial biomass under organic treatment might have resulted from higher amount of substrates with potential for microbial degradation, being the source of energy and carbon for the soil microbiota [39].

In case of soil respiration however qCO₂ value decreased in organically treated plots (22.34%) followed by control (7.04%) and integrated (6.29%) treatments but increased from initial in conventional treatment plots. Under conventional treatment higher respiratory activity *vis-à-vis* low qMBC value indicates stressful condition for microbial communities, forcing them to use a higher amount of their energetic resources for maintenance and survival, leading to lower incorporation of organic C into microbial biomass however in case of organically treated soil however, initial rise in respiratory quotient shall be mitigated by increase in metabolically activated population as influenced by rise in qMBC value. The results indicated that under conventional chemical practice, microbial community was under stress and due to stress higher energy is needed for maintenance, which could be detected at the microbial community level by a higher CO₂-C evolution rate per cell mass and unit time.

Table 4. Variation in soil quality in terms of soil biological properties status at KVK farm, Howrah, West Bengal

Package of Practice	Time of sampling	Soil biological properties			
		MBC (µgm C/g soil)	Soil Respiration (mg CO ₂ -C per g dry soil/day)	Microbial Quotient (qmic)	Metabolic quotient (qCO ₂)
Control (T ₁)	Before	176.85	0.96	1.28	5.43
	After	134.73	0.68	1.00	5.05
Organic Package of Practice (T ₂)	Before	182.57	0.83	1.43	4.60
	After	285.45	1.02	2.17	3.57
Integrated Package of Practice (T ₃)	Before	174.65	0.91	1.34	5.20
	After	188.40	0.92	1.44	4.88
Conventional Package of Practice (farmer's practice) (T ₄)	Before	176.34	0.91	1.33	5.16
	After	159.36	0.85	1.24	5.30

4. CONCLUSION

The study indicated that Inhana Rational Farming (IRF) Technology can serve as a suitable Package of Practice (POP) towards development of various 'Sustainable Models' for rice cultivation; on the basis of resource availability. Application of compost helped to enhance the soil quality especially in terms of soil biologically properties, which is greatly influenced by the way of soil management under taken. From the study, it was clearly indicated that, application of good quality compost influenced the enhancement of soil biological properties in the shortest period of time that reflected in the crop performance. Higher crop yield (under both rice varieties) as well as high value of other yield parameters under organic crop management, as compared to chemical practice; indicated the potential of this technology towards successful organic rice cultivation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Barik AK, Chatterjee AK, Datta A, Saha S, Nath R, Bera R, Seal A. Evaluation of Inhana Rational Farming (IRF) Technology as an effective organic option for large scale rice cultivation in farmer's field- A case study from Kowgachi-II Gram Panchayat, North 24 Parganas, West Bengal. The International Journal of Science and Technoledge. 2014b;2(5): 183-197.
2. Pandi GGP, Soumia PS, Pandian RTP. Organic Basmati Rice Cultivation, Popular Kheti. 2013;1(4):192-195.
3. Barik AK, Chatterjee AK, Datta A, Bera R, Seal A. Evaluation of Inhana Rational Farming (IRF) technology as an effective organic package of practice- a case study from state horticultural research and development station, Krishnagar, Nadia, West Bengal. Central European Journal of Experimental Biology. 2014c;3(3):1-15.
4. Ponisio LC, M'Gonigle LK, Mace KC, Palomino J, de Valpine P, Kremen C. Diversification practices reduce organic to conventional yield gap. Proc. R. Soc. B. 2015;282:20141396. [Online]. DOI: 10.1098/rspb.2014.1396
5. Seal A, Bera R, Datta A., Saha S., Chowdhury R. Roy, Sengupta K, Barik AK, Chatterjee AK. Evaluation of an organic package of practice towards integrated management of *Solanum tuberosum* and its comparison with conventional farming in terms of yield, quality, energy efficiency and economics. Acta agriculturae Slovenica. 2017;109(2):363–382.
6. Bera R, Seal A, Datta A, Sengupta K. Evaluation of Inhana Rational Farming technology as an organic package of practice for effective and economic vegetable cultivation in farmers' field. Journal of Natural Product and Plant Resources. 2014;4(3):82-91.
7. Mazumdar D, Chatterjee AK, Barik AK, Datta A, Bera R, Seal A. Minimum data set and principle component analysis to assess Inhana Rational Farming in terms of soil quality development leading to crop response- A case study from FAO-CFC-TBI project on organic tea cultivation in Maud T.E., Assam, India. International Journal of Innovation and Research in Educational Sciences. 2014;1(2):128-136.
8. Barik AK, Chatterjee AK, Mondal B, Datta A, Saha S, Nath R, Bera R, Seal A. Adoption of Rational Farming technology for development of a model for exploring sustainable farming practice in farmer's field. The IJST. 2014a;2(4):147-155.
9. Chatterjee AK, Barik AK, De GC, Dolui AK, Mazumdar D, Datta A, Saha S, Bera R, Seal A. 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. The International Journal of Science and Technoledge. 2014;2(6):181-195.
10. Barik AK, Chatterjee AK, Seal A, Datta A, Saha S, Bera R. Evaluation of Inhana Rational Farming (IRF) Technology as a cost effective organic cultivation method in farmer's field. Research & Reviews: Journal of Crop Science and Technology. 2015;5(1):1-16.
11. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt. Ltd; 1973.
12. Walkley AJ, Black IA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934;37:29-38.

13. Subbaiah BV, Asija GL. A rapid procedure for determination of available nitrogen in soil. *Current Science*. 1956;25:259–260.
14. Hanway JJ, Heidal H. 1952. Soil analysis methods as used in Iowa State College. *Agric Bulletin*. Iowa State University, US. 1952;57:1-13.
15. Williams CH, Steinbergs H. Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Aust. J. Agric. Res.* 1959;10:340-352.
16. Vance ED, Brookes PC, Jenkinson DS. An extraction method for measuring soil microbial biomass. *Soil Biol. Biochem.* 1987;19:703-707.
17. Haney RL, Brinton WH, Evans E. Estimating Soil Carbon, Nitrogen, and Phosphorus mineralization from short-term carbon dioxide respiration. *Communications in Soil Science and Plant Analysis*. 2008;39:2706–2720.
18. Weaver RW. Methods of soil analysis Part 2 - microbiological and biochemical properties. No. 5 in the soil science society of America Book Series, Soil Science Soc. of America, Inc; 1994.
19. Fageria NK, Santos AB, Baligar VC. Phosphorus soil test calibration for lowland rice on an Inceptisol. *Agronomy Journal*. 1997;89:737–742.
20. Fageria NK. Yield physiology of rice. *Journal of Plant Nutrition*. 2007;30:843–879.
21. Gravois KA, Helms RS. Path analysis of rice yields and yield components as affected by seeding rate. *Agronomy Journal*. 1992;88:1–4.
22. Ottis BV, RE. Talbert. Rice yield components as affected by cultivar and seedling rate. *Agronomy Journal*. 2005;97: 1622–1625.
23. Ishii R. Roles of photosynthesis and respiration in the yield-determining process. In: *Science of the Rice Plant: Physiology*, eds. T. Matsuo, K. Kumazawa, R. Ishii, K. Ishihara, and H. Hirata. Tokyo: Food and Agriculture Policy Research Center. 1995;2:691–696.
24. Osaki M, Shinano T, Matsumoto M, Ushiki J, Shinano MM, Urayama M, and Tadano T. Productivity of high-yielding crops. V. Root growth and specific absorption rate of nitrogen. *Soil Science Plant Nutrition*. 1995;41:635–647.
25. Yeasmin S, Mominul Islam AKM, Aminul Islam AKM. Nitrogen fractionation and its mineralization in paddy soils: A review. *Journal of Agricultural Technology*. 2012; 8(3):775-793.
26. Bhattacharyya BK. Soil test based fertilizer recommendations for principal crops and cropping sequences in West Bengal. *Bulletin No. 2*. Department of Agriculture. Govt. of West Bengal. Kolkata; 1998.
27. Selvendran RR, Isherwood FA. The effect of artificial wilting on the metabolism of phosphate compounds in tea shoots and strawberry leaves. *Phytochemistry*. 1971; 10(3):525-529.
28. Vasnathi D, Kumaraswamy K. 2000. Effects of manure-fertilizer schedules on the yield and uptake of nutrients by cereal fodder crops and on soil fertility. *J. Indian Soc. Soil Sci.* 2000;48(3):510-515.
29. Sims JT, Schilke KL, Gartley, Megowan, W. *Nat. Res. Environ. Control Dover*. 1991;75.
30. Hoffer GN. Potash in plant metabolism deficiency symptoms as indicators of the role of Pottassium, *Ind. Eng. Chem.* 1938; 30(8):885–889.
31. Gill MPS. National Seminer on developments in soil science *Abstract. J. Indian Soc. Soil Sci.* 1995;146-147.
32. Sarwar G, Schmeisky H, Hussain N, Muhammad S, Ibrahim M, Safdar E. 2008. Improvement of soil physical and chemical properties with compost application in Rice-wheat cropping system. *Pakistan. J. Bot.* 2008;40(1):275-282.
33. Sarwar G, Hussain N, Mujeeb F, Schmeisky H, Hassan G. Biocompost application for the improvement of soil characteristics and dry matter yield of *Lolium perenne* (Grass). *Asian J. Plant Sci.* 2003;2(2):237-241.
34. Hussain N, Hassan G, Arshadullah M, Mujeeb F. Evaluation of amendments for the improvement of physical properties of sodic soil. *International. J. Agric. Biology.* 2001;3:319-322.
35. Mehdi SM, Shakir MA, Sadiq M, Hassan G, Akhtar J, Jamil M. Effect of phosphorus, zinc and farmyard manure in the presence of nitrogen and potash and zinc concentration in rice. *Pakistan. J. Bio. Sci.* 2001;4(4):342-343.
36. Seal A, Bera R, Chowdhury R, Roy Mukhopadhyay K, Mukherjee S, Dolui AK. Evaluation of an organic package of practice towards green gram cultivation and assessment of its effectiveness in

- terms of crop sustainability and soil quality development. Turkish Journal of Agriculture-Food Science and Technology. 2017;5(5):536-545.
37. Gogoi S, Bhuyan MK, Karmakar RM. Dynamics of microbial population in tea ecosystem. J. Indian Soc. Soil Sci. 2003;51(3):252-257.
38. Dolui AK, Goura P, Bera R, Seal A. Evaluation of different on-farm compost quality and their role in made tea productivity and development of acid tea Soil. International Journal of Innovation and Applied Studies. 2014;6(3):549-571.
39. Fernandes SAP, Bettiol W, Cerri CC. Effect of sewage sludge on microbial biomass, basal respiration, metabolic quotient and soil enzymatic activity. Appl. Soil Ecol. 2005;30(1):65–77.

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