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Clean Food' through Adoption of Ecologically and Economically Sustainable Farming Technology with Special Focus on Soil & Plant Health Management

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A B S T R A C T

Today it is no longer a debatable issue that since the "green revolution" of the 1960s has been touted as solutions to the global hunger problem by focusing only on the potentiality of high crop yields have come at the cost of environmental degradation and lowered sustainable food and nutritional security over the long term. Especially in the crop intensified zones, rampant use of chemical fertilizer and pesticides made the soil and overall environmental quality to an alarming stage. Thus, shifting focus towards ecologically and economically sustainable crop cultivation is the only option left for future crop sustainability. In this background, pesticide free 'Clean Food production' with adoption of various good agricultural practices (GAP), mechanical and biological practices amalgamated with innovative organic approach (IRF technology) specially focused towards soil and plant health management have been adopted in some villages of Fathepur Gram Panchayat in the Haringhata Block, Nadia district of West Bengal from 2020. Analysis of soil samples in the study area clearly indicated soil quality depletion with very low organic carbon (< 0.60 %), very poor biological properties, poor microbial biomass carbon (<200 µg.CO2.C/gm dry soil) and poor FDAH (< 50 µg/gm dry soil). Comparative evaluation of crop productivity under Clean Food programme vis-a-vis conventional farmers' field indicated increase in crop yields even in the 1st year of program adoption. Analysis of pesticide residue indicated presence of pesticides residue in less than 4% of the vegetable samples, while in the rest the same were below detection limit (< 0.01 ppm). Post production soil development index indicated enhancement in soil quality which was majorly due to the activation of soil biological properties through the application of compost as well as reduction in the use of herbicides and chemical pesticides. The Clean Food program can be a practical option for sustainable agriculture towards crop sustainability, environmental preservation and empowerment of the small and marginal farmers.

Keywords: Clean Food, Inhana Rational Farming Technology, Soil Resource Mapping, Novcom Compost, Plant Health Management, Colorometric Pesticide Assay Test, Energy Use Efficiency, GHG Mitigation, Soil Quality Development

1. Introduction

Intensification of chemical agriculture, over the years; has led to overall degradation of the fragile agro-ecosystem. High cost of production and diminishing economic returns from agricultural practices are affecting the socio-economic condition of the farmers. Loss of soil fertility, erosion of soil, soil toxicity, diminishing water resources, pollution of underground water, salinity of underground water, increased incidence of human and livestock diseases, and the risk of food toxicity enhances with indiscriminate and disproportionate use of Agro-chemicals (Rahman, 2015).

Application of Chemical fertilizers induced higher crop productivity but at the same time they also led to the alteration of soil physicochemical and biological properties, decline of soil organic matter (SOM) content coupled with a decrease in the quality of agricultural soil (Pahalvi, 2021). On the other hand application of chemical Pesticides caused significant changes in the composition, diversity and basic functioning of important soil micro-flora (Riah et al., 2014), reduced the abundance and diversity of soil organisms, impairing the reproductive capacity and survival of earthworms (Lo, 2010), interfering with enzyme production, altering the soil fertility, nutrient cycling and metabolism and hindered nitrogen fixation due to inhibition of the molecular communication between plants and rhizobia (Ahemad & Khan, 2013).

Thus the depletion of soil productivity and the impaired soil-plant nutrient relationship weakens plant's inherent capacity to sustain biotic and abiotic stress. Application of chemical pesticide further weakens the plant physiological functioning and impairs the metabolism, creating ready food source for the pest and pathogens. Now to overcome the present challenges and constraints there is need to undertake sustainable crop management for which focus has to be imparted towards development of soil and plant health.

In the present Clean Food development project, different good agricultural practices (GAP), various mechanical and biological practices amalgamated with innovative organic approach (IRF technology) for the energization of soil and plant system in order to activate the self-nourishment and self-protection mechanism of plant system. The study aims to mitigate the root cause of un-sustainability which will not only help towards crop sustenance, but also create an environment for gradual reduction of the pest & disease infestation leading to the development of pesticide free 'Clean Food' aiming at livelihood sustenance of the farming community

2. Materials and Methods

A collaborative program was initiated by Nadia Krishi Vigyan Kendra, BCKV, ICAR and Inhana Organic Research Foundation (IORF), Kolkata towards developing pesticide free 'Clean Food'. The program has been ongoing at Fatepur gram panchayat, in the Haringhata block of Nadia district since 2020 with an aim to introduce sustainable crop management, towards development of pesticide free end product with better marketability potential that will enable livelihood sustenance of the farming community specially small and marginal. Factually, they are the worst affected under the ensuing climate change impact and the vulnerable market economy threat during Covid-19 pandemic. In the year 2022, IBM, India came forward to support the objectivity of this Clean Food Initiatives and development of pesticide free safe and sustainable food production.

2.1 Clean Food Program

The program initiated with grid based soil sampling followed by detailed investigation of soil quality and resource mapping (Fig 1 & 2). On-farm production of Novcom compost as a part of soil health management was also started. An integrated approach of plant health management was developed side by side towards sustainable crop growth, higher crop production and gradually reducing the pest/ disease infestation. IRF Plant Health Management was introduced towards activation of the plant physiology for building up plant resilience towards the climate change impact, develop plant immunity and its host-defense mechanism, which is crucial for sustained/ higher crop performance and for reducing the interference of pest and disease. This Unique Approach under IRF Technology activates Plants' Metabolism & Photosynthetic Efficiency in order to curtail the accumulation of ready food source for the pests in the plants' cell sap, so as to curtail the pest infestation and thereby the dependency on chemical pesticides (Bera et al., 2021).

Fig 1 : The 'GOAL' of Clean Food Movement

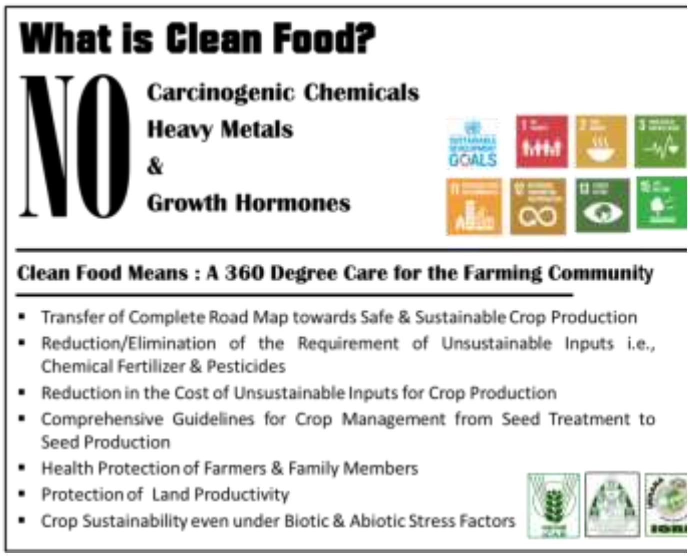

Fig 2 : A Brief note on activity under Clean Food program

2.2 Inhana Rational Farming (IRF) Technology

The Technology works on the 'Energy Element Activation (E.E.A.) Principle' and works towards Energy Infusion into the Soil and Plant so as to enable Ecologically & Economically Sustainable Organic Crop Production. The objective of the plant health management is to reactivate the two inherent qualities of the plant system, i.e. (I) Self-Nourishment & (II) Self-Protection. For this a Focused Approach is undertaken towards Soil & Plant Health Management that simultaneously deflates the pest pressure due to alleviation of factors responsible for pest – parasite interactions.

Energization of Soil System is aimed at enabling the soil to function naturally as an effective growth medium for plants. Soil Energization aimed at rejuvenation of soil micro-flora, is primarily attended by application of on-farm produced Novcom compost (that contains a rich population of self-generated micro flora); different types of herbal concoctions and adoption of cultural practices (Fig 3 & 4). However, the technology emphasizes plant health management as a precursor for resilient plant system that can ensure sustainability even under the changing climatic patterns.

Energization of Plant System is aimed at enabling higher nutrient use efficiency alongside better bio-chemical functions that leads to activation of the plants' host defense mechanism. Plant Energization under this technology is a systemic approach that utilizes a set of potentized and energized botanical solutions developed under Element Energy Activation (EEA) Principle. According to EEA Principle, radiant solar energy is stored in plants and the bound or stored energy components from energy rich plants are extracted on specific day, time, by specific extraction procedure and subsequently potentized so that energy components can be effectively received by plant system for activation of various metabolic functions. Details about the technology in terms of working principles and spraying protocols of the solutions had been done according to the workers who have followed this technology for organic crop production (Chatterjee *et al*., 2014 and Barik *et al*., 2014).

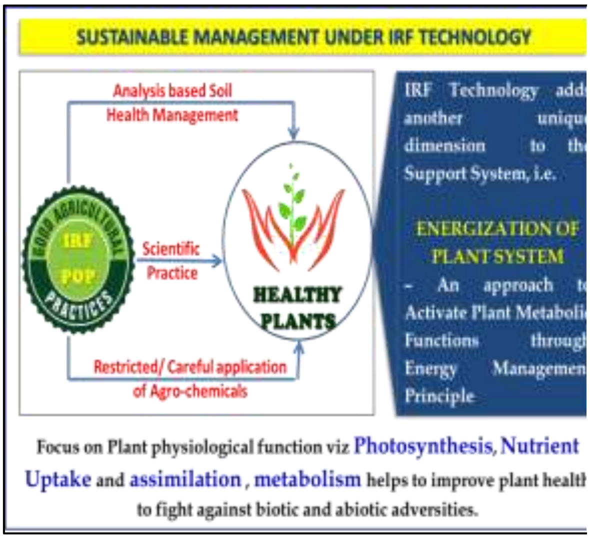

Fig 3 :Flow diagram of IRF Package of Practice towards development of Healthy Plants. (figure was reproduced with the permission from IORF, Kolkata)

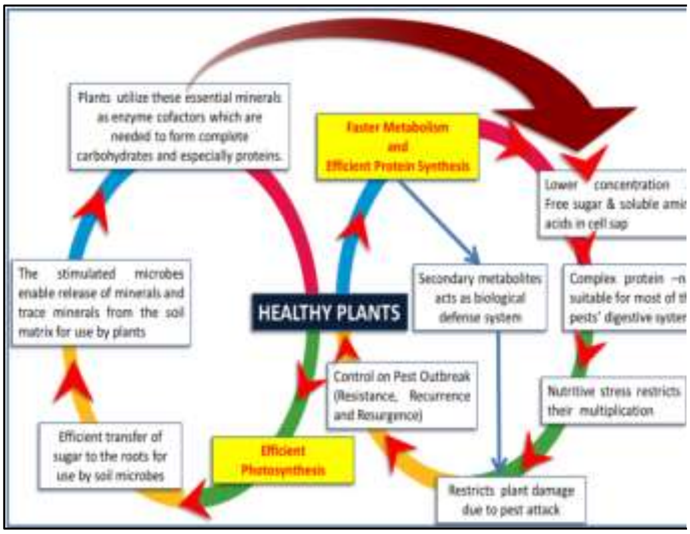

Fig 4 : Pest management through plant management - How the Concept Work under IRF Technology (figure was reproduced with the permission from IORF, Kolkata)

2.3 Novcom Composting Method

Novcom composting, a well recognized scientific method of compost preparation through use of Novcom solution, a biologically activated and potentized extract of Doob grass (Cynodon dactylon), Bel (Sida cordiflolia L.) and common basil (Ocimum basellicium). In this method good quality matured compost was produced on farm by using common farm waste and cow-dung at 80:20 ratio within a period of 21-25 days as per the procedure documented by Bera et al., 2013a. (Fig 5 & 6)

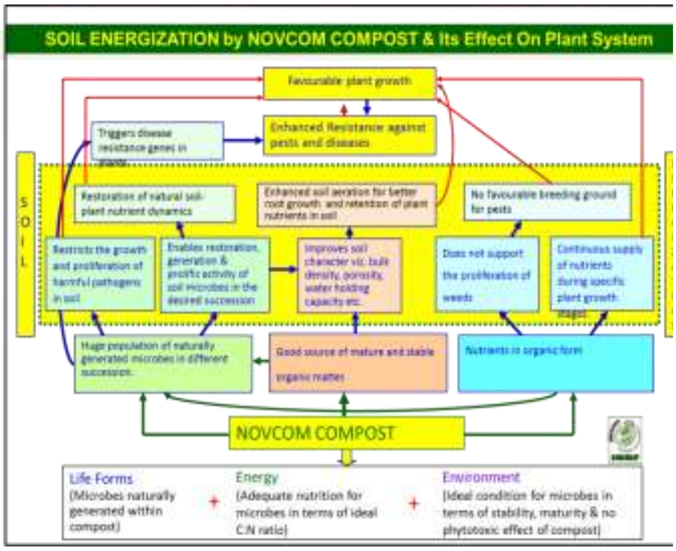

Fig 5 : Soil Energization by Novcom Compost (figure was reproduced with the permission from IORF, Kolkata)

Fig 6 : Demonstration of Novcom compost at Nadia as part of Women training program

2.3.1 Mechanism of Novcom Composting Method under E.E.A.® principle

If the mechanism of Novcom Composting Method is interpreted through E.E.A.® principle, it gives an unique, novel but most convenient system. It is known that all objects of the earth is composed of five elements. Hence, in the first stage of degradation process the elements are to be broken into their individual identity. Then the temperature need to be rise up to 65-70°C by activating the fire element with the help of Apana Prana. In this stage the unfriendly bacteria, fungi or the seeds of unwanted plants are destroyed and thermophillic bacteria start growing up. After a span of time the acinomycyte group of micro-organisms come and break the degraded material into the smaller particles. This function is facilitated by the Space element utilizing Vyana Prana. The process continues at various levels with the help of Fire element and finally the stage of lignin degradation comes. In the complete process Air element plays a very important role by providing the oxygen for respiration of the numerous micro-organisms engaged in the conversion process. The entire process is rapid, intense and programmed that it finishes within 3 weeks only. The technology promises to give solution with the variation of different organic waste and functions in any place anywhere. This does not require any microbial inoculation because the necessary microbes are generated with the ideal environment. Moreover, microbial inoculation is also an unscientific process because these strains are first experimented individually but in the practice, is given in combination. Since, each microbe has individual biological cycle and behaviour that can never match when that is given in combination with other microbes. As a result, very naturally the process does not complete in less than three — four months. Moreover, biodegradation is a natural process where one stage only comes when the previous one is completed. Hence, any effort for preponing any stage will always make the process a complex one. The compost developed with Novcom composting technology provides the energized environment for the regeneration of the soil fauna, as a result application of small quantity of this compost brings a change in the soil in the shortest possible time. Finally one thing is to be remembered that microbes also need the adequate environment to grow and function. Hence, to provide the environment is more necessary than to inoculate them directly in the soil. Novcom only works for that objectivity.

2.4 Soil and Compost Analysis Protocol:

Analysis of compost was done as per standard International protocol (Trautmann and Krasny, 1997). Soil samples were collected from individual treatment plots, air dried, sieved and analyzed for physico-chemical, fertility and microbial status as per standard procedure (Black, 1965).

2.5 Standardization of Colorometric Pesticide Assay Test for evaluation of pesticide residue in vegetables

Colorimetric Assay Test of 5 major groups viz. Organochlorine, Organophosphate, Carbamate, Synthetic Pyrethroids and Nicotinoids will serve to authenticate the non-presence of every single variant out of more than 650 pesticides formulations covering major insecticides, fungicides and Herbicides; whose presence in food products have been indicated round the globe. Not only the pesticide, but also the presence/ absence of Harmful heavy metals viz. Hg2+, Cd2+, Cu2+ and Pb2+ can also be done using the colorimetric qualitative test. Apart from that Triazines, Paraquat and many other known and unknown toxic substances which inhibit our central and peripheral nervous system; if present in food product can also be brought under the scanner through the colorimetric assay test. Through this assay test, pesticide residue can be visually detected up to 0.01 ppm level and up to 0.003 ppm level using the spectrophotometer (Fig 7 & 8). Colorimetric assay tests were done as per the methodology of (i) Organochlorine (Paulini & Rurbaud, 1957), (ii) Organophosphate & Carbamate (Mahaed E. et al. 2014), (iii) Synthetic Pyrethroid (Suate et al., 2020, Mahaed E et al, 2014), (iv) Nicotinoids (Nwanisobi & Egbana, 2015), (v) Heavy metals (Cu, Zn. Hg. As, Cd, Pb) (Mahaed E. et al., 2014), (vi) Phenylpyrazole, Triazine and Paraquat (Mahaed E et al., 2014; Lionetto, 2013).

Fig 7 : Colour Development under Colorometric Pesticide Assay Test at Inhana laboratory, Kolkata.

Fig 8 : Colorometric Pesticide Assay Test done jointly by Nadia KVK and IORF, Kolkata

2.6 Energy Use Efficiency and GHG Emission:

Energy use efficiency, energy productivity, specific energy, energy intensiveness and net energy were calculated as per the standard methodology (Banaeian *et al*., 2011). In order to calculate the potential for greenhouse gas emission, we used ACFA –version 1.0 which was developed by IORF, Kolkata (Bera et al, 2022).

Fig 9 : Landscape view of the project area

Fig 10 : Clean Cabbage cultivation in the project area

3. Results and discussions

3.1 Soil quality and Impact of Intensified Chemical Agriculture:

The soil samples were collected grid wise and analyzed for the various quality parameters (Table 1, 2 & 3) primarily in IORF laboratory at Kolkata. Table 1 represented the soil physical characteristics of the study area (Fig 9 & 10). The soils of the area were mostly sandy clay loam to silty loam. The soils were basically light soils with no limitation in terms of soil depth, coarse fragment, bulk density and aggregate stability.

Table: 1. Soil Physical Properties of the study area

Grid No.	**Particle Size Distribution**			**Texture**	**[1]SIC**	**[2]AS**	**[3]BD**	**[4]SD**	**[5]CF**	**[6]PI**
	Sand	Silt	Clay							
1	17.2	65.4	17.4	[7]sl	1.5	[9]MS	1.45	> 150 cm	No	22
2	17.3	68.5	14.1	sl	2.6	MS	1.48	> 150 cm	No	22
3	16.4	68.2	15.4	sl	0.3	MS	1.47	> 150 cm	No	22
4	18.2	68.2	13.6	sl	1.4	MS	1.45	> 150 cm	No	22
5	17.2	65.4	17.4	sl	3.9	MS	1.44	> 150 cm	No	22
6	25.3	50.4	24.2	sl	4.6	MS	1.45	> 150 cm	No	22
7	17.2	65.4	17.4	sl	3.4	MS	1.46	> 150 cm	No	22
8	17.2	65.4	17.4	sl	1.2	MS	1.46	> 150 cm	No	22
9	15.5	64.0	20.5	sl	1.3	MS	1.47	> 150 cm	No	22
10	18.3	65.8	15.9	sl	3.7	MS	1.47	> 150 cm	No	22
11	18.0	65.0	17.0	sl	2.1	MS	1.48	> 150 cm	No	22
12	16.2	67.4	16.4	sl	0.3	MS	1.46	> 150 cm	No	22
13	17.5	64.1	18.4	sl	0.3	MS	1.47	> 150 cm	No	22
14	17.2	62.5	20.3	sl	0.2	MS	1.45	> 150 cm	No	22

15	17.8	63.2	19.0	sl	1.7	MS	1.43	> 150 cm	No	22
16	36.2	52.2	11.6	[8]scl	2.9	MS	1.42	> 150 cm	No	22
17	37.6	53.1	9.3	scl	0.1	MS	1.43	> 150 cm	No	22
18	35.3	54.3	10.3	scl	5.3	MS	1.45	> 150 cm	No	22
19	35.2	53.0	11.8	scl	0.1	MS	1.45	> 150 cm	No	22
20	35.4	54.0	10.6	scl	0.2	MS	1.46	> 150 cm	No	22
21	36.0	55.7	8.3	scl	0.4	MS	1.45	> 150 cm	No	23
22	37.3	56.4	6.3	scl	0.4	MS	1.46	> 150 cm	No	24
23	38.3	56.6	5.1	scl	0.3	MS	1.46	> 150 cm	No	25
24	37.8	56.2	6.0	scl	0.2	MS	1.46	> 150 cm	No	26
25	38.1	56.0	5.9	scl	0.2	MS	1.44	> 150 cm	No	27

Note : [1]Slaking Index Coefficient, [2]Aggregate Stability, [3]Bulk Density, [4]Soil Depth, [5] Coarse Fragment, [6]Physical Index, [7]Sandy Loam, [8]Sandy Clay Loam,

3.2 Soil Quality Indices

Physical index (PI) value indicate in terms of soil physical quality, it was good to very good for agricultural crops. Soil physico-chemical and fertility parameters study (Table 2) indicate that in terms of soil fertility index (FI), soils were moderate to moderately high in terms of nutrient availability in most of the area. However, interpretation of the analyzed database in details indicate impact of heavy load of chemical fertilizer as average value of Av. NO3 was 111.8 and the ratio of Av NO3 and KMNO4 extractable N was 0.36 which was unusually high (commonly the ratio was < 0.10). Similarly average value of available phosphate was 274 which were also abnormally high. At the same time the organic carbon status was low to very low with average of 0.60 %. Under intensive chemical farming and lack of organic amendments in the soil management program make the soil most vulnerable for future crop sustenance.

Table 2: Physico-chemical & fertility parameters of the study area

Grid No.	**Physicochemical Parameters**								**FI***
	pH	**EC (1:1)**	**Org. C %**	**NO_3^-**	**Av-N**	**Av P_2O_5**	**Av. K_2O**	**Av- SO_4**	
				< --------------------**kg./ha** ---------------------- >					
1	6.05	0.381	0.60	119.48	326.14	239.51	189.73	252.98	23.0
2	5.70	0.347	0.44	108.82	288.51	329.82	149.07	164.17	15.0
3	6.15	0.709	0.63	222.34	297.92	338.19	203.28	446.74	23.0
4	6.84	0.198	0.79	62.09	329.28	340.46	162.62	166.86	27.0
5	6.62	0.232	0.46	72.76	263.42	184.47	121.97	118.41	15.7
6	6.72	0.193	0.57	60.53	329.43	297.34	149.07	153.40	21.4
7	7.37	0.330	0.68	103.49	297.92	232.34	162.62	247.59	24.0
8	6.52	0.320	0.35	100.35	263.42	292.38	271.04	199.15	19.7
9	6.33	0.398	0.74	124.81	316.74	394.11	420.11	285.27	27.0
10	6.99	0.285	0.44	89.38	291.65	318.13	271.04	250.29	21.4
11	7.31	0.274	0.46	85.93	344.96	313.43	298.14	161.47	21.4
12	6.49	0.981	0.55	307.64	291.65	311.57	447.22	269.12	25.0
13	6.88	0.367	0.95	115.09	257.15	313.22	352.35	368.70	26.0
14	7.03	0.211	0.71	66.17	244.61	297.95	203.28	158.78	25.0

15	5.85	0.340	0.30	106.62	250.88	353.43	325.25	148.02	18.9
16	7.10	0.175	0.63	54.88	266.56	312.19	182.95	145.33	25.0
17	7.00	0.385	0.65	120.74	266.56	350.98	176.18	161.47	23.0
18	6.59	0.472	0.55	148.02	310.46	279.18	271.04	196.46	25.0
19	6.68	0.311	0.55	97.53	269.70	286.61	311.70	228.76	25.0
20	6.11	0.254	0.52	78.232	310.46	412.74	474.32	411.76	26.0
21	5.89	0.59	0.79	181.72	398.27	44.58	528.53	503.35	26.0
22	6.43	0.29	0.63	89.32	354.37	157.43	433.66	652.32	27.0
23	6.36	0.32	0.63	98.56	348.10	151.02	433.66	769.69	26.0
24	6.93	0.213	0.77	65.604	332.42	158.26	433.66	550.75	27.0
25	6.98	0.107	0.69	32.956	341.52	142.20	420.45	510.4	26.0

Note : *FI : Fertility Index

Soil biological properties were also studied in depth to investigate the soil biological functioning under such intensive chemical agriculture. Soil microbial biomass (MBC) value indicated low to very low microbial population. Microbial quotient (qMBC) which was the ratio of Cmic/Corg, has been used as an indicator for future changes in organic matter status that might occur in response to alterations in land use and low to moderate status in the study area indicated stress in the microbial world due to intensive usage of synthetic fertilizer and pesticides. The stress factor was further supported by the high values of qCO_2 which usually indicated a stressful condition in disturbed systems.

Fig 11 : Soil sampling from the project area

Fig 12 : Soil Analysis in IORF laboratory at Kolkata

Table 3: Soil Biological properties and Soil Quality Index (SQI) in the study area

Grid No.	Soil Biological Parameters									[10]SQI
	[1]Soil MBC	[2]SR	[3]FDA	[4]qMBC	[5]qCO_2	[6]qFDA	[7]SIR	[8]Qr	[9]MAP	
1	51.49	0.40	38.67	0.86	5.98	0.64	1.28	0.08	3.33	0.38
2	59.06	0.48	39.62	1.34	5.98	0.90	1.47	0.12	8.00	0.37
3	53.87	0.52	39.62	0.86	5.94	0.63	1.34	0.24	3.00	0.37
4	79.59	0.48	43.32	2.15	6.66	0.55	1.23	0.07	8.67	0.55
5	86.72	0.41	20.97	1.49	6.00	0.46	1.15	0.04	7.00	0.41
6	101.46	0.51	39.62	1.81	6.99	0.70	2.27	0.12	9.33	0.48
7	85.04	0.49	20.64	1.69	6.49	0.30	2.80	0.10	6.00	0.45
8	74.61	0.44	18.07	1.42	6.50	0.52	5.73	0.06	6.00	0.47

9	107.06	0.42	46.06	1.53	6.17	0.62	2.34	0.03	8.67	0.55
10	69.32	0.43	17.99	1.01	6.00	0.41	1.83	0.03	6.00	0.50
11	89.15	0.67	27.97	1.76	7.07	0.61	1.42	0.12	6.30	0.50
12	73.84	0.42	29.03	1.98	6.80	0.53	1.08	0.03	8.67	0.56
13	61.61	0.46	39.62	2.86	6.60	0.42	1.91	0.02	4.33	0.55
14	73.10	0.46	28.74	3.56	6.02	0.40	2.84	0.02	5.33	0.53
15	86.30	0.33	16.93	1.04	6.00	0.56	2.69	0.06	4.00	0.46
16	126.41	0.68	27.23	2.96	3.66	0.43	3.34	0.13	8.67	0.52
17	71.34	0.69	20.16	2.64	6.66	0.31	2.11	0.05	8.67	0.49
18	54.13	0.41	28.09	3.89	6.00	0.51	1.24	0.03	4.33	0.53
19	122.68	0.37	39.62	2.23	2.99	0.72	3.90	0.09	4.00	0.51
20	50.66	0.72	22.16	3.01	3.32	0.43	1.20	0.07	8.67	0.53
21	73.84	0.42	29.03	1.98	4.80	0.53	1.08	0.03	8.67	0.56
22	61.61	0.46	39.62	2.86	5.60	0.42	1.91	0.02	4.33	0.55
23	73.10	0.66	28.74	3.56	6.02	0.40	2.84	0.02	5.33	0.53
24	86.30	0.43	16.93	1.04	6.00	0.56	2.69	0.06	4.00	0.46
25	73.84	0.42	29.03	1.98	6.80	0.53	1.08	0.03	8.67	0.56

Note : [1]MBC; Microbial biomass carbon (microgm biomass C/gm dry soil/hr), [2]SR:Soil Respiration, [3]FDA : Soil Fluorescein diacetate hydrolysis activity (µg/gm dry soil), [4] qMBC :Microbial Quotient, [5]qCO2: Metabolic Quotient, [6]qFDA : Total enzymatic activity per unit organic carbon, [7]SIR : Substrate induced respiration, [8]Qr: Microbial Respiration Quotient, [9]MAP : Microbial Activity Potential, , [10]SQI : Soil Quality Index

3.3 Soil Resource Mapping and development of Soil Health Management Outline

Soil resource mapping in terms of soil fertility map, soil quality index map etc will help to develop a suitable soil management policy for the area (Fig 13 & 14). As the study already indicates that the soils in the study area became most venerable with low organic carbon, high fertilizer salt concentrations, low soil microbial presence and the stress condition of the existing microbial pool, it required a sustainable management plan and the resource maps could be an important tool. Inhana Organic Research Foundation in collaboration with Howrah KVK (ICAR) developed Soil Quality Index (SQI) suitable for Indian condition which is the function of soil physical index (PI), soil fertility Index (FI) and soil microbial activity potential and it was calculated as the area of a triangle. Soil Quality Index (SQI) of the soil in the Project Area was moderate (0.46 – 0.60) in majority of area (72.4 % area) followed by poor status in 22.2 % area and moderately high status only in about 5.4 % area.

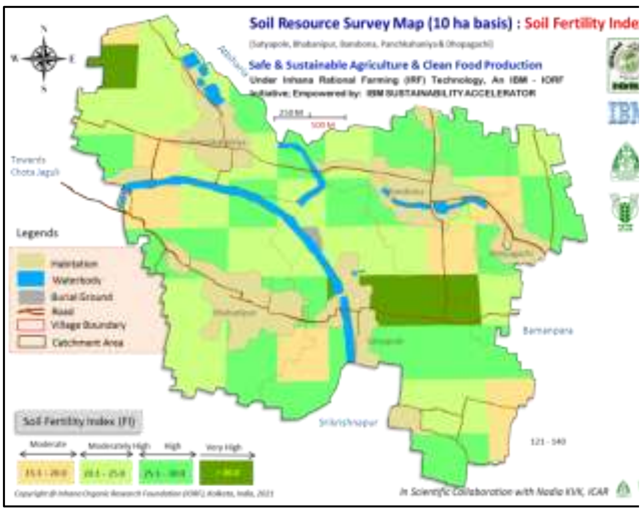

Fig 13 : Soil Fertility Index (FI) map

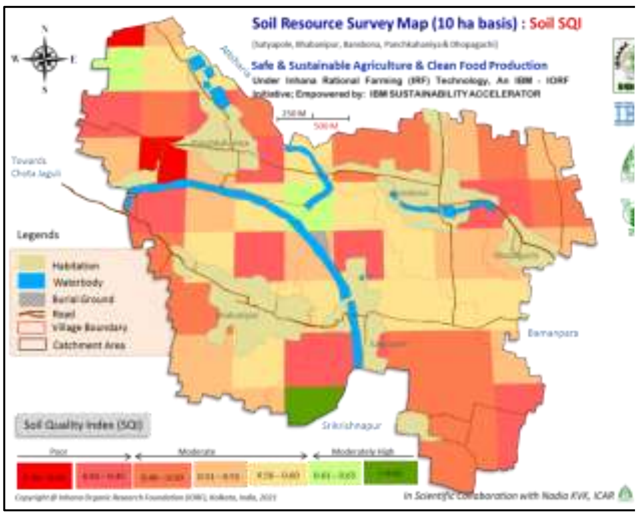

Fig 14 : Soil Quality Index (SQI) map

3.4 On-farm Novcom Composting and its quality components

Novcom compost was prepared in the project area using farm waste and crop residue as the major components. Compost samples were analyzed as per National (FAI, 2007) and International Standards (Australian Std.1999, Thompson *et al*, 2002). 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 45.23 to 58.78 percent, which may be placed in the high value range (40 to 50) (Evanylo, 2006). Evaluation of Novcom compost in terms of pH, organic carbon, nutrient value and C:N ratio indicated quality compost as also found by other workers (Seal *et al*., 2012; Bera *et al* 2013b; Bera *et al* 2013c). Compared with the standard suggested range for N, P, K (Alexander, 1994), the value obtained for Novcom compost were in the upper range, which clearly authenticated its rich nutrient status (Fig 15, 16).

Fig 15 : Development of Novcom poultry compost

Fig 16 : Application of Novcom compost in the project area

Table 4: Quality parameters of Novcom compost

Sl. No.	Parameter	Novcom compost	Sl. No.	Parameter	Novcom compost
1.	Moisture present (%)	61.40	7.	Total Microbial Count[1]	32 x 1016
2.	pH_{water} (1 : 5)	7.74	8.	CO_2 evolution rate ($mgCO_2$–C/g OM/day)	2.04
3.	EC (1 :5) dS/m	2.15			
4.	Organic carbon (%)	28.40	9.	Germination Index (phytotoxicity bioassay)	1.02
5.	Total NPK (%)	3.79			
6.	C/N ratio	13.1 : 1	10.	Compost Quality Index (CQI)	5.41

[1] per gm moist soil;

Total microbial count in the order of 10^{16} signified high generation of microbial population indicating the compost to be of rich quality. Speedy biodegradation within 21 days and comparatively high nutrient content of Novcom compost was influenced by the high and diversified microbial population that was generated naturally within the compost heap during the biodegradation process (Seal *et al.*, 2012). Assessment of phyto-toxicity in terms of Germination index (> 1.0) indicated that the compost enhanced rather than impaired germination and radicle growth (Trautmann and Krasny, 1997).

3.5 Plant Health Management and its Impact on Crop Productivity & Economics:

Productivity of the vegetables under the 'Clean Food' project was documented and compared with the zonal productivity range of the respective vegetables under the conventional farmers' practice (Table 5). Productivity of almost all the vegetables under clean food program was higher than the average productivity of the same under conventional farmers' practice. The findings indicated that adoption of different sustainable management practices helped in increasing the crop productivity even in the 1st year of adoption; which nullified the general myth of crop loss in the absence of any chemical pesticide in crop production. This initiative could be a benchmark study for sustainable management of vegetables and the technological advancement can be transferred to the farmers' field in order to facilitate crop production even in an intensified cropping zone like Nadia, where excessive use of fertilizers and pesticides enhances the risk of soil health deterioration as well as the surrounding ecology.

The cost of vegetable production under the 'Clean Food' program was also compared with that under the conventional farmers' practice which is shown in Table 5. According to the documented data base, the production cost of clean vegetables per ha, was comparable with the cost of conventional farming and in some cases, even lower than that of conventional farmers' practice. However, when assessed in terms of cost per kg cost of cultivation under the

'Clean Food' program (Fig 17 & 18) was found to be lower than that recorded under the conventional farmers' practice; considering that crop productivity under the adopted sustainable practice was higher than the average productivity under conventional farmers' practice.

Fig 17 : Brinjal production under clean Food program at the project area

Fig 18 : Clean vegetable production in the project area

Table 5: Productivity and Economics of major vegetables under Clean Food Development Program vis-a-vis Conventional Practice

Vegetables	Productivity (ton/ha)		Cost of Production of Vegetables (Rs. in Lakh /ha)		Average Cost of Vegetable Production (Rs./kg)		Average Farmers price (Rs/kg) (Source : Sufal Bangla)
	Under Clean Food Program	Under Farmers Practice	Under Clean Food Program	Under Farmers Practice	Under Clean Food Program	Under Farmers Practice	
Brinjal (*Solanummelongena*)	24.0 – 28.4 ton	19.0 – 25.0 ton	1.40 -1.70	1.32 -1.75	4.90 – 7.10	5.30 – 9.20	11 – 35 (Avg. 20)
Chilli (*Capsicum frutescens*L.)	16.2 - 17.5 ton	14 – 18 ton	1.30 -1.40	1.20 -1.38	7.40 – 8.60	6.70 – 9.90	25 – 50 (Avg. 37)
Okra (*Abelmoschu sesculentus)*	9.9 – 10.4 ton	8.0 – 11.0 ton	0.50 – 0.75	0.62 – 0.85	4.80 – 7.60	5.60 – 10.60	14 – 60 (Avg 37)
Tomato (*Solanum lycopersicum*)	18.6 – 20.4 ton	15.0 -18.4 ton	0.60 – 0.80	0.60 – 0.85	2.50 – 4.30	3.30 – 5.70	7 – 40 (Avg. 20)
Bottle gourd (*Lagenaria siceraria*)	28.4 – 33.5 ton	24.2 – 32.0 ton	0.70 – 1.05	0.70 – 1.10	3.60 – 5.40	2.20 – 4.60	7 – 25 (Avg. 11)
Bitter gourd (*Momordica charantia*L.)	18.5 – 22.2 ton	15.0 – 20.0 ton	0.80 – 1.00	0.85 – 1.10	3.10 – 3.90	4.30 – 7.30	22 – 60 (Avg. 35)
Pumpkin (*Cucurbita moschata*(Duch.) Poir)	28.0 – 32.0 ton	25.2 – 30.0 ton	1.00 – 1.10	1.10 – 1.25	2.70 – 3.40	3.70 – 5.00	6 – 20 (Avg. 12)
Red Amaranth (Amaranthus cruentus)	13.4 – 16.8 ton	10.2 – 15.0 ton	0.45 – 0.50	0.40 – 0.50	2.70 – 3.70	2.70 – 5.00	8 – 26 (Avg. 14)
Spinach (*Spinacia oleracea)*	24.4– 27.0 ton	15.0 – 25.0 ton	0.55 – 0.60	0.50 – 0.65	2.00 – 2.50	2.00 – 4.30	6 – 30 (Avg. 14)
French Bean (*Phaseolus vulgaris* L)	11.4 – 12.8 ton	8.0 – 12.0 ton	0.85 – 1.00	0.80 – 1.05	6.60 – 8.80	6.70 – 13.10	14 – 50 (Avg. 40)

3.6 Pesticide residue analysis under colorimetric assay test

Pesticide residue analysis was done as per the colorimetric assay test and the results indicate that under Clean food program, except brinjal, chilli and okra, most of the samples found free from pesticide residue (Fig 19). And most importantly where traces of pesticide is found in vegetable samples under clean food program, that is far less than the EU standard for vegetable and upto 80 % lower than that of from Market source (Fig 20, 21 & 22).

Fig 19 : Pesticide free safe and sustainable cxrop production under 'Clean Food' Program

Table 6: Comparative Pesticide Residue in vegetables grown under Clean Food program vis a vis conventional market vegetables

Vegetables	Major Pesticide Groups							
	Organo Chlorine		Organo-Phosphate		Synthetic Pyrathroids		Nicotinamides	
	< ------------------------ ppm ------------------------ >							
	[1]CF	[2]MV	CF	MV	CF	MV	CF	MV
Brinjal	BDL	BDL	0.016	0.042	0.010	0.044	0.012	0.065
Chilli	BDL	BDL	BDL	0.040	0.012	0.039	0.021	0.031
Okra	BDL	BDL	0.014	0.034	0.012	0.028	BDL	0.021
Tomato	BDL	BDL	BDL	0.021	BDL	0.018	BDL	0.019
Bottle gourd	BDL	BDL	BDL	0.012	0.024	0.021	BDL	0.012
Bitter gourd	BDL	BDL	0.011	0.012	BDL	0.016	BDL	0.014
Pumpkin	BDL	BDL	BDL	0.011	BDL	0.014	BDL	0.012
Red Amaranth	BDL	BDL	BDL	0.011	BDL	BDL	BDL	0.014
Spinach	BDL	BDL	BDL	0.011	BDL	BDL	BDL	0.012
French Bean	BDL	BDL	BDL	0.011	BDL	0.012	BDL	0.024

[1]CF : Vegetables under Clean Food program, [2]MV : Conventional vegetables sourced from Market; Note : Values are avg of only those samples having residue over BDL

Fig 20 : Pesticide residue analysis of vegitable samples through colorimetric assay test under 'Clean Food' Program

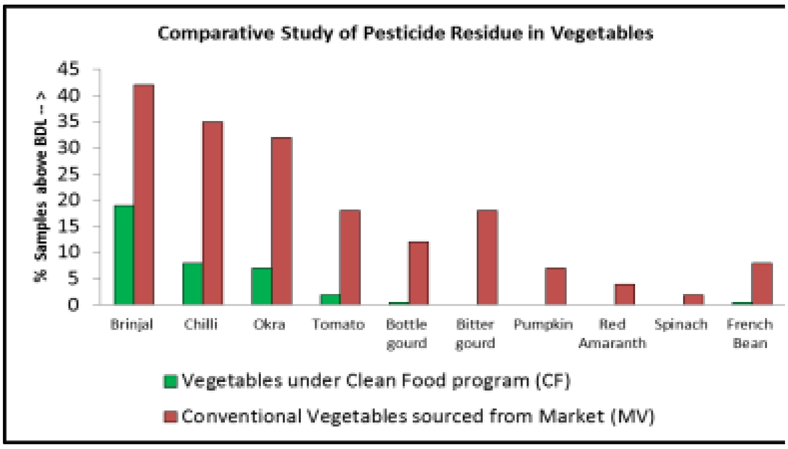

Fig 21: Comparative study of presence of pesticide residue above Below Detectable Limit (BDL < 0.01 ppm).

Fig 22 : Colorimetric assay test at IORF Laboartory, Kolkata.

3.7 Energy Use Efficiency and Reduction of GHG Emission Potential

Agriculture itself is an energy consumer and energy producer in the form of renewable energy. Crop productivity and profitability are closely related with energy consumption. Efficient use of these energies helps to achieve higher production and productivity, and contributes to the economy, profitability and competitiveness of agricultural sustainability (Singh, 1990). In the present study average energy use efficiency under clean food program was about 31 % higher (18 % to 60 % with different crop) than the farmers practice (Fig 23).

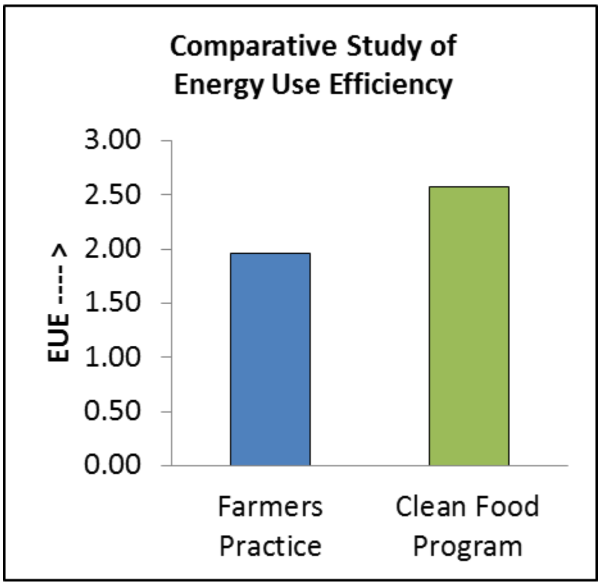

Fig 23: Comparative Study of Energy Use Efficiency under Clean Food Program vis a vis Farmers Practice.

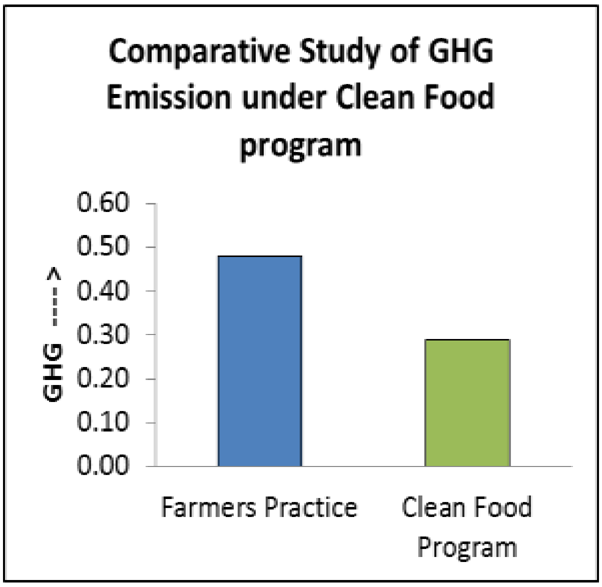

Fig 24: Comparative Study of GHG Emission Potential under Clean Food Program vis a vis Farmers Practice using ACFA –Version-1.0 carbon assessment tool..

In the context of increased emission of greenhouse gases and the abrupt climatic change, energy budgeting in terms of carbon usage has become a point of concern for any industry. It is widely recognized that greenhouse gas emissions from agricultural practices are largely driven by the synthetic fertilizers and the fossil fuels that are used for the different agricultural operations. In the present study the GHG emission potential under the different vegetables were evaluated using ACFA –Version-1.0 carbon assessment tool. (Bera et al,2022). The study showed that total GHG emission potential was significantly lower (40 %) under Clean Food Program primarily due to reduction of N-fertilizer and chemical pesticides (Fig 24).

3.8 Soil Quality Development

Study of soil quality for pre and post experimentation showed increase in soil microbial activity potential and soil quality index under Clean Food program which might be due to application of Novcom compost along with reduction in application of chemical pesticides and herbicides in the area (Fig 25 26, 27 & 28).

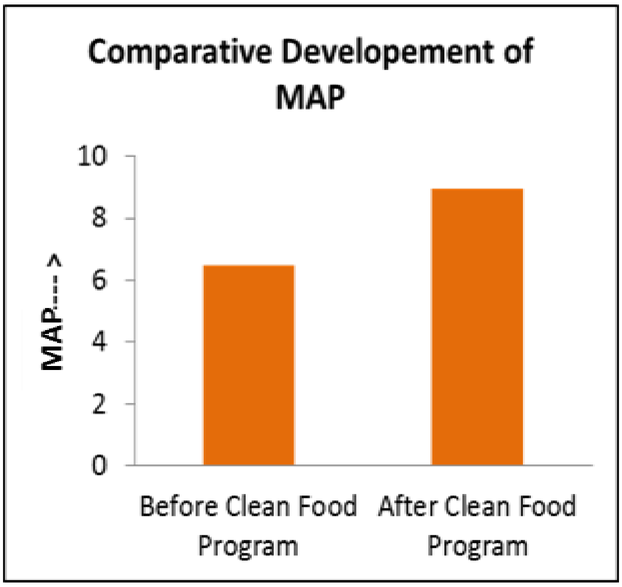

Fig 25 : Comparative study of soil microbial activity potential (MAP) before clean food program and after 1 year of program at the study area

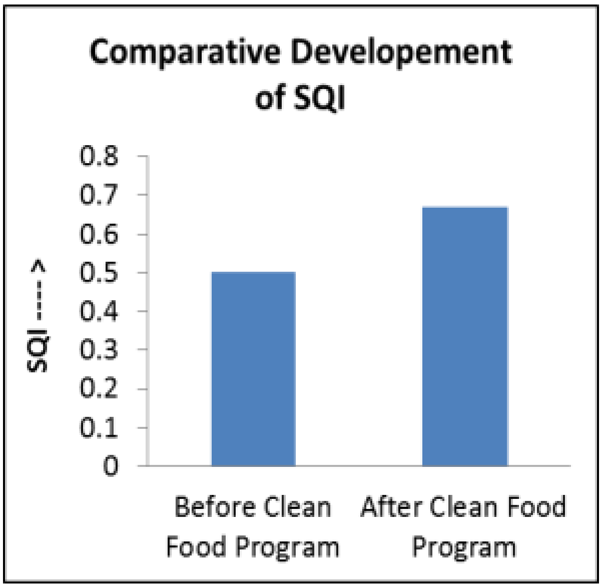

Fig 26 : Comparative study of soil quality Index (SQI) before clean food program and after 1 year of program at the study area

Fig 27 : Distribution of Soil Health Cards to the project farmers under 'Clean Food Program'

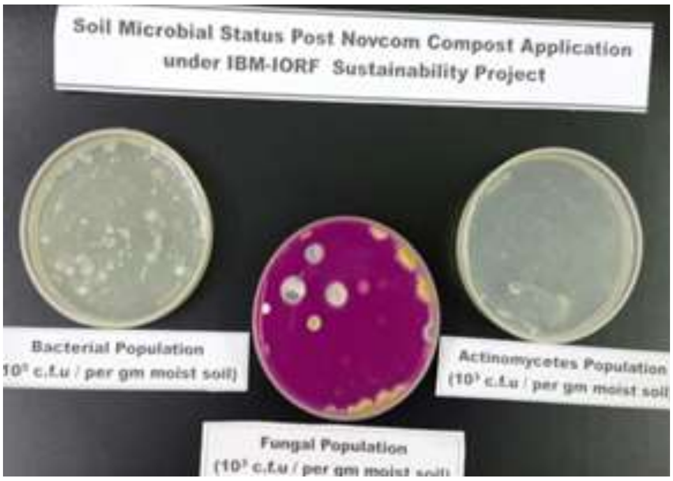

Fig 28 : Analysis of soil microbial population post compost application in the project area.

4. Conclusion

Injudicious use of chemical inputs along with intensive farming system made the soil most vulnerable and need a sustainable management practice for future crop security and sustainability. Clean Food Development program could be the most effective approach looking at the improvement of crop productivity along with improvement of soil quality, reduction of risk of pesticide residue in food, preservation of environment and most importantly creating opportunity for higher income generation.

5. Award and Recognitions

The 'Clean Food' Program has received 4 Recognitions in 2022 viz (i) Winner in the Category ENVIRONMENT under 8th CSR Impact Awards – CSR Box & Dalmia Bharat Foundation, (ii) Winner – Excellence in Climate Change Mitigation under CSR & Sustainability Summit & Awards – ASSOCHAM Southern Region, (iii) Bronze in Category LIVELIHOOD under National CSR & Summit Awards – Vision India Forum & CMAI and (iv) Winner in the Category 'Best Innovative CSR Project' under Corporate Responsibility Summit & Awards – UBS Forums (Fig 29).

Fig 29 : Innovativeness and impact of this 'Clean Food Program' on farming community has been recognized by different forum.

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