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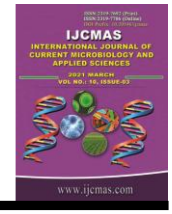

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The Effect of Improved Agricultural Practice on Soil Nutrient Status and Some Beneficial Microbial Status in Rice- Lentil-Okra Cropping System in Gangetic Alluvial Zone of West Bengal, India

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ABSTRACT

The impact of Improved agricultural practice (IAP) with emphasis on soil analysis based organic manure and chemical fertilizer application, replacement of 25% chemical fertilizer with Bio-fertilizers and Integrated Pest Management, was studied for 3 successive years in 5 fields in Rice-lentil – Okra cropping system in Gangetic Alluvial zones of West Bengal, India. IAP was seen to have significant beneficial effects on elevating soil organic carbon content and increase soil pH towards normality. This effect was observed to be integrated with increase in population density of some beneficial soil bacteria, like *Azotobacter, Azospirillum, Rhizobium,* Phosphate Solubilizing bacteria and Potash Solubilizing Bacteria. Nitrogenase activity of soil, as measured by acetylene reduction assay, was found to be enhanced after 3 years of IAP.

Introduction

It is evident that inappropriate use of chemical fertilizer destroys natural fertility of soil to a large extent. For maintaining natural soil fertility, the role of soil micro-organisms is of great importance as a source and sink of mineral nutrients (Jenkinson and Ladd, 1981). Most of the agricultural practices in our country are going on without understanding the microbial processes in soil which is very important for management of agricultural system (Smith and Paul, 1990). Microbial growth depends on the availability of their nutrients in soil and among them, carbon source is the most important. It was shown that application of chemical fertilizer can stimulate the microbial growth and activities by supplying nutrients (Schenner and Connletner, 1996). But farming with chemical fertilizer with low or no organic inputs results poor microbial activity and production potential of soil (Kang *et al.*, 2005).

Not only soil micro-organisms, beneficial soil fauna, like earthworms, are also affected by chemical fertilizers. In an experiment, Rai *et al., (*2014) demonstrated that application of inorganic fertilizer urea very harmful for growth and proliferation of earthworm *Eichenia foetida.*

Indiscriminate, long term and over application of pesticides have severe effect on soil ecology and lead to alteration in or erosion of beneficial or plant probiotic soil micro flora (Kalia and Ghosal, 2011). Sardar and Kole (2005) described that the communities of beneficial microorganisms in soil is declined due to overuse of pesticides, which has as negative impact on available nitrogen, phosphate and potassium in soil. Fungicides, specially copper fungicides, have significant negative effect on earthworm population in soil (Van Zwieten *et al.*, 2004; Eijsackers *et al.*, 2005; Loureiro *et al., 2005)*. Pesticides may alter the soil microbial diversity through selective toxicity or enhancing the growth of some microorganisms by destroying the invertebrate that feds on the microbes (Roger, 1995). Several studies indicate that pesticides might have temporary effects on soil, but, when applied repetitively, could lead to the disappearance or depression of components of microbial community, thus leading to a new equilibrium and changes in the pattern of their microbial activities (Roger, 1995).

In addition to the sustainability issue, modern agriculture has its significant effects on environmental safety, food security and food safety (Grewal *et al.*, 2017). Although there are several levels of check points to control sustainability, environmental safety, food security and food safety, the process must start from the on-farm practices. So, it is important that Improved Agricultural Practice (IAP), or sometimes called as Good Agricultural Practices (GAP), is the best way to ensure the above. IAP, with its emphasis on regulated fertilizer and soil amendment practices, quality assurance of water used for irrigation and pesticide application, hygienic farm management, field sanitation and workers hygiene, integrated pest and disease management practices, sanitation during harvesting and delivery and stockpile management, can provide a situation so that the sustainability of agricultural system, safety of food and environment and farmers income can be ensured. In the Present endeavor the effect of such improved agricultural practice on soil nutrient status and some beneficial microbial status is studied for 3 successive years in rice- lentil-okra cropping system.

Materials and Methods

Five fields were selected for study in Ula village of North 24 Parganas district of West Bengal. The village, having Lat-Long- 22.722748, 88.553066, 9.6 Km from District Headquarter, Barasat. Located in Gangetic alluvial agro climatic zone, the village is of intensive agriculture having cropping intensity 235%.

In each field, there were two treatments- Conventional Method (CM) and Improved Agricultural Practice (IAP). The CM refers to farmer's own practice where there is no regulated use of fertilizer and pesticides. The IAP consists of soil analysis based organic manure and chemical fertilizer application, replacement of 25% chemical fertilizer with Biofertilizers (*Azospirillum*- for rice, *Rhizobium*- for lentil, *Azotobacter* – for orka, and Phosphate Solubilizing Bacteria & Potash Solubilizing Bacteria for all three crops). The fields were endowed with green manuring by applying *Azolla* (@ 500 Kg/ha) in rice field.

Integrated pest Management (IPM) was followed for pest and disease management with emphasis on cultural, mechanical and biological practices. The chemical practices was of last priority and the WHO banded Class 1A, 1B and Class 2 pesticides were avoided. Bothe the treatments were in three replicates and were arranged in Randomized Block Design with minimum 5 ft isolation distance between fields

The soil nutrient status as available N, P, K & some physical characters like pH, EC & OC was studied at initial year and after each year of cropping up to 3 years. The populations of some beneficial soil microorganisms, *Azotobacter*, *Rhizobium*, *Azospirillum*, Phosphate Solubiliizing Bacteria and Potash Solubilizing Bacteria were enumerated by normal dilution [plating technique on specified media. The nitrogenase activity of soil (only from field -03) after 3years of practice was studied through Acetylene Reduction Assay.

Results and Discussion

Significant change of soil pH towards normal was observed after 3 years of IAP implementation in 2 fields where soil pH was low, 5.67 and 5.62. The most promising effects of IAP is increase in soil organic carbon and available nitrogen (Table 1). Other soil characters like EC, available phosphate, available potash and micronutrient content were not affected significantly by Improved Agricultural Practices for three years.

The studied microbial populations, enumerated as colony forming units /g (cfu/g) was highly affected by IAP. Significant increase in the microbial populations were observed in all fields In few instances, significant increase was noted after 1^{st} year, in some instances it was after 2^{nd} year but after 3^{rd} year all studied bacteria were seen to increase in all field, except *Azotobacter* in Field-1 (Table 2).

Positive correlations between available soil nitrogen and nitrogen fixing bacterial populations were found as +0.84 (Soil nitrogen & *Azotobacter* population), +0.76 (Soil nitrogen & *Rhizobium* population) and +0.58 (Soil nitrogen & *Azospirillum* population). The nitrogenase activity was found as nanomole of C_2H_5 produced by g of soil after 24 h incubation which was 0.48 and 0.88 in CM soil and IAP soil after 3 years of practice.

With special emphasis on application of organic manure and biofertilizer, Improved Agricultural Practice improves soil properties including increase in organic carbon content. Significant increase in organic carbon percentage was also observed in soil treated with different dose of *Azotobacter* biofertilizer (Kurrey *et al.,* 2018). Moreover the soil pH was observed to be normal from alkalinity. Kannan *et al.,* (2016) demonstrated that Integrated Nutrient Management in crops using recommended dose of chemical fertilizers and vermicompost leads to increase in organic carbon content in soil.

Liu *et al.,* (2019) showed that soil microbial community is promoted by soil organic matter and nitrogen. Soil pH also plays a significant role on microbial growth (Cao *et al.,*2016). Recent study by Niemiec *et al.,* (2020) showed that organic farms showed better microbial properties from the point of view of crop productivity and soil fertility. Organic farms with animal production, moreover, showed further increase in such microbial activities. Reports are available on promoting effect of long term use of organic manure on soil microbial activities (Ingle *et al.,* 2014; Gudane *et al.,* 2015).

Table.1 Change in physical and chemical properties of soil after 3 years of Improved Agricultural practices

Parameters	Cultivation Practice	Field 1		Field 2		Field 3		Field 4		Field 5	
		Year 0	Year 3	Year 0	Year 3	Year 0	Year 3	Year 0	Year 3	Year 0	Year 3
pH	CM	6.57 (±0.15)	6.43 (±0.15)	6.47 (±0.20)	6.45 (±0.11)	5.67 (±0.61)	5.25 (±0.25)	6.92 (±0.16)	6.85 (±0.14)	5.62 (±0.13)	5.50 (±0.14)
	IAP	6.57 (±0.15)	7.13 (±0.10)[a]	6.47 (±0.20)	7.31 (±0.06)[a]	5.67 (±0.61)	7.13 (±0.10)	6.92 (±0.16)	6.90 (±0.11)	5.62 (±0.13)	6.74 (±0.08)[a]
EC (dSm^{-1})	CM	0.19 (±0.03)	0.18 (±0.02)	0.10 (±0.02)	0.12 (±0.05)	0.19 (±0.08)	0.18 (±0.06)	0.1 (±0.01)	0.10 (±0.01)	0.12 (±0.01)	0.11 (±0.02)
	IAP	0.19 (±0.03)	0.18 (±0.01)	0.10 (±0.02)	0.11 (±0.03)	0.19 (±0.08)	0.17 (±0.07)	0.1 (±0.01)	0.09 (±0.02)	0.12 (±0.01)	0.12 (±0.01)
OC%	CM	0.14 (±0.01)	0.20 (±0.12)	0.30 (±0.08)	0.33 (±0.4)	0.26 (±0.04)	0.28 (±0.05)	0.55 (±0.02)	0.55 (±0.03)	0.13 (±0.02)	0.14 (±0.02)
	IAP	0.14 (±0.01)	0.70 (±0.05)[a]	0.30 (±0.08)	0.75 (±0.03)[a]	0.04 (±0.01)	0.58 (±0.03)[a]	0.55 (±0.02)	0.80 (±0.01)[a]	0.13 (±0.02)	0.54 (±0.04)[a]
Available N (Kg/ha)	CM	99 (±1)	113.33 (±6.66)	165 (±5)	176.67 (±15.28)	171.33 (±6.11)	161 (±9.64)	305.33 (±6.11)	304 (±5.29)	97.33 (±6.43)	100.67 (±2.52)
	IAP	99 (±1)	426.67 (±25.17)[b]	165 (±5)	402.67 (±7.51)[a]	171.33 (±6.11)	328.33 (±7.63)[b]	305.33 (±6.11)	495.67 (±12.50)[a]	97.33 (±6.43)	304 (±12.17)[b]
Available P_2O_5 (Kg/ha)	CM	63 (±1.7)	60 (±2.08)	64 (±2.52)	70 (±2)	44.33 (±7.50)	49 (±6.00)	168.67 (±1.15)	170.33 (±6.81)	88.33 (±3.51)	84.67 (±3.06)
	IAP	63 (±1.7)	92 (±5.69)[a]	64 (±2.52)	108 (±12.53)	44.33 (±7.50)	123.33 (±9.02)[a]	168.67 (±1.15)	288 (±5.29)[a]	88.33 (±3.51)	105.67 (±5.13)
Available K_2O (Kg/ha)	CM	91 (±1.15)	94 (±6.03)	122.33 (±3.21)	111.33 (±14.15)	91 (±2.65)	96 (±5.00)	213.33 (±7.64)	219.67 (±18.01)	117.33 (±2.52)	122 (±3.61)
	IAP	63 (±1.7)	92 (±5.69)	122.33 (±3.21)	149 (±9.02)	63 (±1.7)	135 (±5.00)	213.33 (±7.64)	279.67 (±10.02)	117.33 (±2.52)	147 (±8.19)[a]
Cu	CM	2.14 (±0.15)	2.17 (±0.15)	2.20 (±0.04)	2.40 (±0.10)	1.03 (±0.15)	1.09 (±0.10)	2.15 (±0.05)	2.22 (±0.07)	3.62 (±0.19)	3.66 (±0.11)
	IAP	2.14 (±0.15)	3.09 (±0.04)	2.20 (±0.04)	2.65 (±0.15)	1.03 (±0.15)	1.13 (±0.21)	2.15 (±0.05)	2.85 (±0.15)	3.62 (±0.19)	3.85 (±0.05)
Zn	CM	2.78 (±0.08)	2.75 (±0.25)	2.51 (±0.10)	2.35 (±0.30)	2.03 (±0.25)	2.14 (±0.14)	2.43 (±0.08)	2.45 (±0.09)	0.95 (±0.05)	0.86 (±0.07)
	IAP	2.78 (±0.08)	3.81 (±0.18)	2.51 (±0.10)	2.50 (±0.10)	2.03 (±0.25)	2.23 (±0.15)	2.43 (±0.08))	3.01 (±0.25)	0.95 (±0.05)	1.02 (±0.04)
Mn	CM	63 (±7.21)	65.33 (±5.69)	96 (±7.21)	65 (±7.00)	31 (±2)	33.33 (±2.52)	63.67 (±3.21)	65.67 (±2.08)	32.33 (±1.53)	32.5 (±2.36)
	IAP	63 (±7.21)	103 (±6.24)[a]	96 (±7.21)	99.33 (±6.43)	31 (±2)	52.67 (±2.52)[a]	63.67 (±3.21)	92.67 (±4.72)[a]	32.33 (±1.53)	35.77 (±2.16)

[a]= Significance at 5% level; [b]= significance at 1% level

Table.2 Year wise change of some beneficial microbial populations in conventional practice and Improved Agricultural Practice

Bacteria studied	Cultivation method	Year-0	Year-1	Year-2	Year-3
Field 01					
Azotobacter	CM	2.12 (±0.68)	2.01 (±0.26)	1.86 (±0.55)	1.77 (±0.05)
	IAP	2.12 (±0.68)	2.24 (±0.21)	2.66 (±0.47)[a]	5.63 (±0.32) [a]
Rhizobium	CM	2.75 (± 0.23)	2.67 (± 0.42)	3.00 (± 0.50)	2.67 (± 0.15)
	IAP	2.75 (± 0.23)	3.10 (± 0.17)	4.36 (± 0.55) [a]	7.73 (± 0.40) [b]
PSB	CM	2.4 (± 0.10)	2.5 (± 0.05)	2.50 (± 0.05)	2.43 (± 0.21)
	IAP	2.4 (± 0.10)	3.9 (± 0.55)	5.16 (± 0.76) [a]	7.67 (± 0.76) [a]
KSB	CM	1.6 (± 0.36)	1.93 (± 0.15)	2.00 (± 0.10)	1.83 (± 0.11)
	IAP	1.6 (± 0.36)	2.03 (± 0.21)	1.33 (± 0.57)	4.07 (± 0.51) [a]
Azosprillum	CM	3.00 (± 0.26)	2.86 (± 0.92)	3.20 (± 0.20)	2.23 (± 0.38)
	IAP	3.00 (± 0.26)	4.4 (± 0.10)	5.40 (± 0.52)	6.73 (± 0.40)
Field-02					
Azotobacter	CM	0.60 (± 0.10)	0.63 (± 0.15)	0.58 (± 0.14)	0.53 (± 0.12)
	IAP	0.60 (± 0.10)	0.83 (± 0.15)	2.16 (± 0.28) [a]	4.40 (± 0.52) [a]
Rhizobium	CM	1.50 (± 0.10)	1.47 (± 0.10)	1.25 (± 0.10)	1.30 (± 0.10)
	IAP	1.50 (± 0.10)	2.17(± 0.10)	4.00 (± 0.10) [a]	6.76 (± 0.10) [a]
PSB	CM	4.00 (± 0.52)	4.06 (± 0.51)	4.33 (± 0.57)	3.76 (± 0.73)
	IAP	4.00 (± 0.51)	7.16 (± 0.11)	11.00 (± 1.00) [a]	12.00 (±1.00) [b]
KSB	CM	8.50 (± 0.56)	9.00 (± 1.00)	10.50 (± 0.50)	10.00 (± 1.00)
	IAP	8.50 (± 0.56)	9.67 (± 0.61)	12.66 (± 0.47)	14.33 (± 0.57) [a]
Azosprillum	CM	2.40 (± 0.13)	2.20 (± 0.26)	2.16 (± 0.76)	2.23 (± 0.25)
	IAP	2.40 (± 0.13)	3.06 (± 0.90)	4.33 (± 0.57) [a]	6.93 (± 0.51) [a]
Field -03					
Azotobacter	CM	3.00 (±0.18)	2.90(± 0.51)	2.33 (± 0.57)	2.60 (±0.50)
	IAP	3.00 (± 0.18)	11.30 (± 0.75) [a]	24.00 (± 0.50) [b]	7.50 (± 0.50) [b]
Rhizobium	CM	1.50 (± 0.31)	1.47 (± 0.41)	1.50 (± 0.50)	1.33 (± 0.29)
	IAP	1.50 (± 0.31)	1.73 (± 0.31) [a]	3.33 (± 0.58) [a]	3.67 (± 0.57 [a])

PSB	CM	1.40 (+ 0.32)	1.33 (+ 0321)	1.00 (+ 0.11)	1.17 (+ 0.29)
	IAP	1.40 (+ 0.32)	2.00 (+ 0.50)	3.50 (+ 0.30) [a]	7.17 (+ 0.32) [b]
KSB	CM	1.50 (+ 0.26)	1.40 (+ 0.26)	1.30 (+ 0.57)	1.40 (+ 0.13)
	IAP	1.50 (+ 0.26)	1.50 (+ 0.50)	3.00 (+ 0.20)	6.00 (+ 0.50) [a]
Azosprillum	CM	1.70 (+ 0.43)	1.57 (+ 0.55)	1.50 (+ 0.50)	1.83 (+ 0.38)
	IAP	1.70 (+ 0.43)	2.17 (+ 0.30)	3.33 (+ 0.37)	7.67 (+ 0.47) [a]
Field -04					
Azotobacter	CM	2.55 (+ 0.51)	2.63 (+ 0.35)	2.50 (+ 0.50)	2.40 (+ 0.40)
	IAP	2.55 (+ 0.51)	2.83 (+ 0.49)	5.26 (+ 0.50) [a]	9.50 (+ 0.42) [b]
Rhizobium	CM	0.60 (+ 0.13)	0.50 (+ 0.25)	0.45 (+ 0.18)	0.58 (+ 0.14)
	IAP	0.60 (+ 0.13)	1.47 (+ 0.41)	2.50 (+ 0.50) [a]	6.67 (+ 0.45) [b]
PSB	CM	0.50(+ 0.13)	0.55(+ 0.40)	0.60(+ 0.36)	0.63 (+ 0.15)
	IAP	0.50 (+ 0.13)	1.27 (+ 0.25)	2.33 (+ 0.31) [a]	5.33 (+ 0.21) [b]
KSB	CM	2.20 (+ 0.20)	3.67 (+ 0.57)	3.00 (+ 0.30)	0.63 (+ 0.17)
	IAP	2.20 (+ 0.20)	2.27 (+ 0.64)	3.00 (+ 0.20)	5.33 (+ 021) [b]
Azosprillum	CM	0.20 (+ 0.09)	0.30 (+ 0.17)	0.28 (+ 0.10)	0.40 (+ 0.04)
	IAP	0.20 (+ 0.09)	1.10 (+ 0.17)	2.00 (+ 0.20) [a]	4.33 (+ 0.29) [a]
Field-05					
Azotobacter	CM	0.45 (+ 0.06)	0.5 (+ 0.25)	0.66 (+ 0.29)	0.61 (+ 0.19)
	IAP	0.45 (+ 0.06)	1.18 (+ 0.70)	2.33 (+ 0.35) [a]	5.83 (+ 0.29) [a]
Rhizobium	CM	0.40 (+ 0.08)	0.50 (+ 0.03)	0.41 (+ 0.14)	0.63 (+ 0.15)
	IAP	0.40 (+ 0.08)	1.15 (+ 0.49)	2.50 (+ 0.50) [a]	5.00 (+ 0.50) [a]
PSB	CM	0.40 (+ 0.08)	0.37 (+ 0.11)	0.28 (+ 0.20)	0.50 (+ 015)
	IAP	0.40 (+ 0.08)	0.80 (+ 0.15)	1.50 (+ 0.20) [b]	4.10 (+ 0.36) [a]
KSB	CM	0.50 (+ 0.14)	0.53 (+ 0.15)	0.41 (+ 0.14)	0.73 (+ 0.20)
	IAP	0.50 (+ 0.14)	1.57 (+ 0.40)	1.83 (+ 0.28) [a]	6.17 (+ 0.29) [a]
Azosprillum	CM	0.25 (+ 0.04)	0.30 (+ 0.17)	0.66 (+ 0.28)	0.43 (+ 0.05)
	IAP	0.25 (+ 0.04)	1.10 (+ 0.17)	3.50 (+ 0.30) [b]	4.67 (+ 0.28) [a]

[a]= Significant at 5% level; [b]= Significant at 1% level

Our findings keep pace with the above findings where use of recommended dose of chemical fertilizer (avoiding the indiscriminate use of chemical fertilizer) and organic manures increase the soil organic carbon content and change soil pH towards normality which favors the growth and activities of applied microorganisms (applied as bio-fertilizers). The nitrogen fixing activities of diazotrophic bacteria is manifested to increase in ARA activity of soil and increase in available nitrogen content in soil.

Growth and nitrogenase activities of diazotrophic bacteria is highly affected by herbicides 2,4-Dichlorophenoxy acetic acid and 2,4,5-Trichlorophenoxy acetic acid (Fabra *et al.,* 1997; Chalam *et al.,* 1997; Fox *et al.,* 2001). Santos *et al.*(1995) showed that herbicide Glysophate reduces the growth and activity of *Azotobacter*. Fungicides, like apron, captan, thiram, metalaxyl, mefenoxam and carbendazim also inhibits the growth and nitrogen fixing activity of soil diazotrophic bacteria (Kyei-Boahen *et al.,* 2001; Di Ciocco *et al.,*1997; Chalam *et al.,* 1997, Niewiadomska *et al,* 2004; Monkiedje *et al., 2002*). An intensively used fungicide, mancozeb, is shown to have its negative impact on bacteria involved in nitrogen and carbon cycles in soil (Cernohl *et al.,* 2009). Although some insecticides have stimulating effect on soil microorganisms, a number of insecticides have deleterious effects on soil micro flora (Patnaik *et al.,* 1996). Insecticides of carbamate group, like, carbofuran, methiocarb and carnaryl, were studied to have negative effect on soil microbial community (Sannino and Gianfreda, 2001). Organophosphates, like, dimethoate, diazinon, chlorpyrifos, quinalphos, and malathion, have inhibitory effect on microbial growth (Pandey and Simgh, 2004) and microbial enzymatic activities (Sing and Sing, 2005) in soil.

Most of the pesticides discussed are under WHO Class 1A, Class 1N and Class 2 categories and were avoided in IAP. Moreover, the chemicals were applied when all the other measures for IPM were failed to keep the crop over economic threshold level. Thus the applied bacteria applied as bio-fertilizer could get their favourable soil environment for growth and activities.

The study reveals that Improved Agricultural Practice involving soil analysis based fertilizer application with special emphasis on organic manure and bio-fertilizer, and Integrated pest Management has its positive impact on soil pH, nutrient status specially organic carbon and nitrogen content and soil beneficial microbial community leading to soil fertility. The effect of such practice on quantitative and qualitative aspect of agri-produces needs further study. As the soil properties studied are related to soil fertility, this practice is expected to increase and restore productivity of soil. Minimum application of chemical pesticides, avoiding highly toxic WHO banded pesticides and application of only recommended dose of chemical fertilizer will definitely lead to presence of residual chemicals in the produces.

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