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Optimize Fertilizer Use Management through Soil Health Assessment: Saves Money and the Environment

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ABSTRACT

Keywords

Soil health
Jute-rice
Cropping system
NPK ratio
Fertilizer
Economics

More fertilizer doesn't always mean a higher crop production, if there isn't the right mix of nutrients, water and soil health conditions. Soil Health Card (SHC) assessment provide soil nutrient status of land holding of each farmer and advise corrective dosage of major fertilizers, micronutrient and soil amendments to maintain soil health and obtain a better yield. Our aim to investigate a prototype of a soil health checklist that exemplifies the uses of right fertilizer mixture in jute-rice-potato, jute-rice-lentil and jute-rice-mustard cropping system which would be regarded by farmers as useful and acceptable for monitoring soil health and minimise the soil pollution. Soil samples were collected from 89 farmer's field of the study area and analysed for 10 soil health parameters based on farmer's fertilizer uses and knowledge of local natural resources to examine the total NPK uses/ratio for each cropping system. The study finds that the consumption ratio of nitrogen, phosphorous and potassium was 1.1:2.3:1 in jute-rice-lentil/mustard and 1.2:2.9:1 in jute-rice-potato cropping systems against recommended ratio of 4:2:1. The trends in use of phosphorous and potassium show largely a steady path, whereas consumption of nitrogen shows a declining trend.

Introduction

Crops require right mix of three nutrients viz. nitrogen (N), phosphorus (P), and potassium (K) or NPK. N helps in plant growth and development, P not only accelerates blooming and the growth of roots but also helps plants to withstand stress, and K helps the process of photosynthesis and is essential to plant growth. Fertilizers contribute about 50% of total yield increase for most of crops (Das and Mandal, 2015). But recently, declining or

stagnation of major crop yields has been recorded due to cumulative effects of many soil-related constraints and climatic risks (Sangral, 2015 and Islam and Bhuiyan, 2016).

Imbalanced use of N, P and K leads to the loss of fertility of the soil over a period of time, which affects efficiency of fertilizer use and crop productivity (Pimentel *et al.*, 2006 and Rahman *et al.*, 2012). The problem is more severe in intensively cropped regions where farmers use excessive nitrogen

fertilizer to attain yield levels harvested earlier with less fertilizer (Dwivedi, 2017 and Singh *et al.*, 2013). Excessive use of fertilizer can also harm the environment and human health through emissions of GHG (methane, nitrous oxides, CO₂) and eutrophication caused by the deposits of nitrate and phosphorus in water resources (Bumb and Baanante, 1996).

Gangetic plain region of West Bengal (India) has made a remarkable progress in achieving self-sufficiency in food production due to substantial intensification of cropping system, use of high yield crop varieties, expansion of irrigated areas and increased application of chemical fertilizers. Chemical NPK fertilizers are added to the soil by farmers in very high proportions within a short time period which exceeds the soil assimilative capacity (Patra *et al.*, 2016).

NPK consumption ratio increased to 8.2:3.2:1 in 2013-14 as against recommended ratio of 4:2:1 (Dwivedi, 2017). The situation was grimmer in major agricultural states like Punjab and Haryana where NPK ratios were as high as 31.4:8:1 and 27.7:6.1:1, respectively (GOI, 2016). Though it has improved to 6.1:2.5:1 in 2017-18, it does not necessarily imply that usage of NPK fertilizer in agriculture has come down (Vishandass, 2019).

Imbalanced use of fertilizer without soil testing is creating a hazardous health impact both to soil and human health. Poor soil health significantly affects small and marginal farmers who often lack the education or resources to make the best management decisions for their soils (Testen *et al.*, 2018). It has been recommended by researchers from various disciplines of agriculture and environmental science that involving end-users in learning and decision making are important in managing natural resources

(Bruynand Abbey, 2003). In view of soil health monitoring, a group of farmers under United States Department of Agriculture (USDA) developed a soil health monitoring tool named Soil Health Card (SHC). It is simple and effective extension tool for soil health monitoring. To protect soil health and for sustainable agriculture, the Government of India also launched similar type of Soil Health Cards (SHC) Scheme in the year 2015. SHC provide soil nutrient status of land holding of each farmer and advise corrective dosage of major fertilizers, micronutrient and soil amendments to maintain soil health and obtain a better yield. This SHC carries crop wise recommendation of nutrients and fertilizer required for the individual farms. Participatory processes in developing soil health monitoring procedures can have significant educational value among farmers. With this background, the present study was undertaken to assess a prototype of a soil health checklist that exemplifies the uses of right fertilizer mixture in the locally adopted cropping system which would be regarded by farmers as useful and acceptable for monitoring soil health.

Materials and Methods

This study was conducted by the Central Research Institute for Jute and Allied Fibres (CRIJAF) during the year 2017-18, in jute growing villages of West Bengal (India). A survey was conducted with 89 randomly selected households in four villages (Table 1) of two districts of West Bengal. The survey includes collection of information on agriculture practices and available farm resources. Jute-rice was the dominant cropping system in all sites. The mean annual rainfall was in ranges of 1200 to 1400 mm with maximum average temperature 35.7 °C in May and minimum 12.1 °C in January. A large proportion of farmers are marginal and subsistence landholders (82%).

Sampling and laboratory analysis

Soil samples were collected during February 2018 from 89 farmer's field of the study area (Figure 1) before land preparation of jute cultivation from plough-depth maintaining the ideal soil sampling protocol (Gupta, 2000). Five samples were collected from each farmer's fields and analysed for soil reaction (pH), electrical conductivity (EC), organic carbon (OC), available phosphorus (P), available potassium (K), available sulphur (S), available zinc (Zn), available iron (Fe), available manganese (Mn) and available boron (B) in soil laboratory of CRIJAF, Barrackpore. Soil pH was determined with the help of a glass electrode pH meter in soil-water ratio of 1:2.5 (Jackson, 1962). To measure EC, 1:1 method was used (Smith and Doran, 1996). Organic carbon in soil sample was determined volumetrically by wet oxidation method (Walkley and Black, 1934). Available P, K, S, Zn, Fe, Mn and B were analysed using Pusa STFR meter (IARI, 2016).

Soil health card preparation

At present, soil health card includes 12 parameters viz., pH, EC, OC, N, P, K, S, Zn, Fe, Mn, Cu, Mo and B. In this study, ten soil health indicators were determined based on farmer's fertilizer uses and knowledge of local natural resources. Soil organic carbon was considered as an index of N availability for fertilizer recommendation.

Required dosages of neem coated urea, single super phosphate or di-ammonium phosphate and muriate of potash per hectare were suggested for four crops (rice, potato, lentil and mustard) as preferred by the farmer group along with required doses of organic manure (FYM), gypsum or lime and bio-fertilizer per hectare indicating achievable potential yield per hectare (Figure 2).

Results and Discussion

Soil health indicators used in this study revealed that mean soil pH (6.0-8.5) and EC ($<1.0 \text{ dSm}^{-1}$) were within the acceptable range for optimum plant growth (Table 2). In some farmer's plot, both pH and EC were slightly higher. On village average, organic carbon content was at low level (0.30-0.48%) and needs frequent organic manuring. Soil test levels of P_2O_5 , sulphur and micronutrients were found adequate to achieve yield goals. K_2O contents in surface soil were low ($<110 \text{ kg ha}^{-1}$) in three villages (except Panchkahaniya). Whereas in BelleShankarpur village, sulphur ($<10 \text{ ppm}$) and boron ($<0.2 \text{ ppm}$) contents in surface soil were found deficient. Application of these plant nutrients through gypsum (140 kg ha^{-1} soil application) and borax (0.25% foliar spray) is essential for jute, mustard and rice crop. Low K_2O in soil impairs grain/fruit quality and plants may be sensitive to disease infestation.

The study finds that the use of nitrogen, phosphorous and potassium (N: P: K ratio) did not follow the recommended consumption ratio of 4:2:1 in the area. The average N:P:K ratio was 1.1:2.3:1 in jute-rice-lentil/mustard and 1.2:2.9:1 in jute-rice-potato cropping system (Figure 3). The trends in use of phosphorous and potassium show largely a steady path, whereas consumption of nitrogen shows a declining trend. Although the farmers heard about the on-going SHC scheme, they were quite ignorant about the scheme in details. They had little knowledge about soil sampling procedure and average area covered under soil testing. This also reflects lack of awareness among farmers about use of appropriate fertilizer use technology for enhancing or sustaining crop production. The farmers involved in this study can be characterised in a number of ways, e.g. by location, size of farm, farming practices and experience (Table 1).

Table.1 Location of the study area in West Bengal, India

Village	Village Location (Decimal format)		No. of farmers	Operational land holdings (ha)	Jute area per farmer (ha)	Mean farming experience (years)
	Latitude	Longitude				
Galdaha	22.7700	88.8866	37	0.52	0.36	18
Dwip Media	22.6988	88.8616	19	0.87	0.72	19
BelleShankarpur	22.8622	88.4547	9	0.64	0.44	20
Panchkahaniya	22.9508	88.5863	24	0.72	0.52	16

Note: Mean value of data for each group in the respective village

Table.2 Soil characteristics of study villages in West Bengal, India

Soil characteristics	Village							
	Galdaha (N=37)		Belle Shankarpur (N=9)		Dwip Media (N=19)		Panchkahaniya (N=24)	
	Mean (Range)	SD	Mean (Range)	SD	Mean (Range)	SD	Mean (Range)	SD
pH	8.45 (7.34-9.11)	0.43	7.38 (7.1-8.01)	0.29	8.39 (7.06-8.86)	0.40	7.78 (7.01-8.60)	0.47
EC (dsm⁻¹)	0.54 (0.15-1.03)	0.18	0.37 (0.22-0.56)	0.13	0.62 (0.38-1.40)	0.22	0.41 (0.18-0.56)	0.09
Org. C (%)	0.48 (0.21-0.87)	0.17	0.33 (0.24-0.44)	0.07	0.40 (0.23-0.66)	0.11	0.30 (0.12-0.46)	0.10
Avail. P (kg ha⁻¹)	54.21 (13.7-105)	25.0	33.52 (5.20-67.8)	17.7	46.81 (9-138)	33.9	32.51 (8.7-92.6)	24.9
Avail. K (kg ha⁻¹)	72.97 (13.8-182)	42.9	90.47 (33.7-153)	42.5	70.35 (10.6-122)	30.6	111.30 (32.8-169)	37.1
Avail. S (mg kg⁻¹)	10.21 (0.13-30.1)	8.32	3.53 (1.95-7.46)	1.93	20.72 (17.4-28.7)	2.82	2.85 (0.50-6.08)	1.15
Avail. Zn (mg kg⁻¹)	10.03 (3.9-21.9)	4.25	2.97 (1.21-5.21)	1.16	5.65 (0.30-19.2)	5.59	7.71 (1.20-16.8)	4.64
Avail. Fe(mg kg⁻¹)	41.35 (6.01-92.33)	6.01	7.26 (4.30-12.5)	2.39	19.77 (2.88-103)	23.1	19.65 (2.70-45.1)	11.1
Avail. Mn(mg kg⁻¹)	18.24 (9.16-35.48)	6.73	1.93 (1.10-2.90)	0.66	12.06 (2.72-18.84)	4.39	4.11 (2.27-8.08)	1.75
Avail. B (mg kg⁻¹)	1.19 (0.45-1.89)	0.33	0.19 (0.06-0.29)	0.07	0.88 (0.31-1.24)	0.24	0.51 (0.35-0.69)	0.08

Table.3 Conventional fertilizer uses and SHC fertilizer recommendation in jute-rice-potato/lentil/mustard cropping system in West Bengal

Village	Galdaha			Belle Shankarpur			Dwip Media			Panchkahaniya		
	Urea	SSP	MoP	Urea	SSP	MoP	Urea	SSP	MoP	Urea	SSP	MoP
Jute (RY=35 qha⁻¹)												
Conventional	100	350	120	125	240	150	160	190	100	170	210	120
SHC	200	110	90	220	260	90	220	170	100	240	260	80
Rice (RY= 60 qha⁻¹)												
Conventional	105	375	125	130	250	160	170	195	105	180	225	135
SHC	210	115	100	240	270	100	230	180	100	250	280	90
Potato (RY=200 qha⁻¹)												
Conventional	330	600	190	480	2400	675	-	-	-	330	1800	480
SHC	430	350	285	470	500	280	470	395	285	490	490	245
Lentil (RY=8 qha⁻¹)												
Conventional	40	225	75	110	190	45	-	-	-	50	375	75
SHC	80	170	145	90	390	140	90	250	140	100	410	120
Mustard (RY=11 qha⁻¹)												
Conventional	150	300	75	110	180	45	90	270	105	270	330	90
SHC	155	90	80	170	200	75	170	125	75	190	210	65
Total Fertilizer use per year (in cropping system)												
Jute-rice-potato												
Conventional	575	1325	435	560	1690	630	-	-	-	680	2235	735
SHC	840	575	475	930	1030	470	910	745	485	980	1030	415
Jute-rice-lentil												
Conventional	235	950	310	365	670	355	-	-	-	400	810	330
SHC	490	420	335	550	920	330	540	600	340	590	950	290
Jute-rice-mustard												
Conventional	360	1025	325	365	670	355	420	655	310	620	765	345
SHC	565	315	280	630	730	265	620	475	275	680	750	235

RY: Reference yield; SHC: Soil Health Card (soil test based fertilizer requirement); SSP: Single Super Phosphate; MoP: Muriate of Potash

Table.4 Total fertilizer uses (Conventional & SHC) in jute-rice-potato/lentil/mustard cropping system

Cropping system	NPK use (kg ha ⁻¹ yr ⁻¹)			Total NPK (per year)	NPK ratio		
	N	P	K		N	P	K
Conventional							
Jute-rice-potato	605	1750	600	2955	1.01	2.92	1.00
Jute-rice-lentil	333	810	332	1475	1.00	2.44	1.00
Jute-rice-mustard	441	779	334	1554	1.32	2.33	1.00
SHC recommended							
Jute-rice-potato	915	845	461	2221	1.98	1.83	1.00
Jute-rice-lentil	543	723	324	1589	1.68	2.23	1.00
Jute-rice-mustard	624	568	264	1455	2.36	2.15	1.00

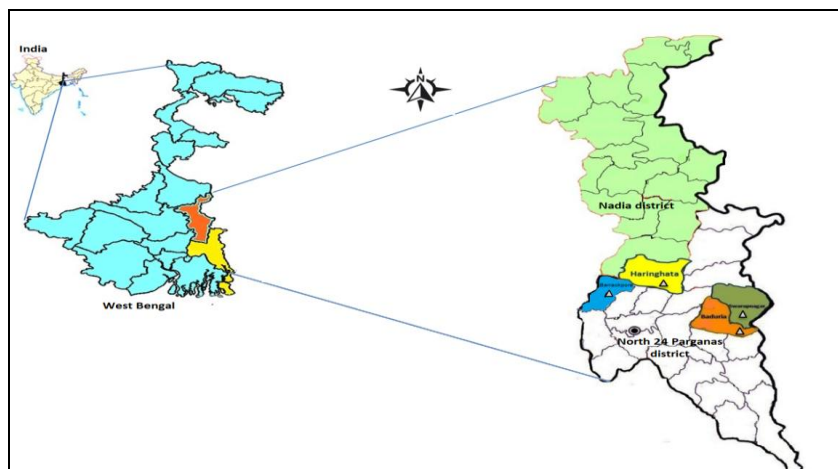


Figure.1 Location of study area for soil health study

ICAR-Central Research Institute for Jute and Allied Fibres Government of India SOIL HEALTH CARD		Farmer's Details		Name of Laboratory ICAR-CRIJAF-KVK N24 Prg Soil Laboratory Nilganj, Barrackpore																																																																																					
Soil Health Card No.: KVK-N24P-II-0040/2018		Name : Subal Sarkar		<table border="1"> <thead> <tr> <th colspan="6">SOIL TEST RESULTS</th> </tr> <tr> <th>S.No.</th> <th>Parameters</th> <th>Test Value</th> <th>Unit</th> <th colspan="2">Rating</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>pH</td> <td>8.57</td> <td>-</td> <td colspan="2">Moderately Alkaline</td> </tr> <tr> <td>2</td> <td>EC</td> <td>0.81</td> <td>dS/m</td> <td colspan="2">Normal</td> </tr> <tr> <td>3</td> <td>Organic Carbon (OC)</td> <td>0.54</td> <td>%</td> <td colspan="2">Medium</td> </tr> <tr> <td>4</td> <td>Available Nitrogen (N)</td> <td>N/A</td> <td>kg/ha</td> <td colspan="2">N/A</td> </tr> <tr> <td>5</td> <td>Available Phosphorus (P)</td> <td>57.7</td> <td>kg/ha</td> <td colspan="2">Normal</td> </tr> <tr> <td>6</td> <td>Available Potassium (K)</td> <td>41.7</td> <td>kg/ha</td> <td colspan="2">Very Low</td> </tr> <tr> <td>7</td> <td>Available Sulphur (S)</td> <td>10.2</td> <td>kg/ha</td> <td colspan="2">Deficient</td> </tr> <tr> <td>8</td> <td>Available Zinc (Zn)</td> <td>11.7</td> <td>ppm</td> <td colspan="2">Sufficient</td> </tr> <tr> <td>9</td> <td>Available Iron (Fe)</td> <td>57.49</td> <td>ppm</td> <td colspan="2">Sufficient</td> </tr> <tr> <td>10</td> <td>Available Manganese (Mn)</td> <td>20.43</td> <td>ppm</td> <td colspan="2">Sufficient</td> </tr> <tr> <td>11</td> <td>Available Copper (Cu)</td> <td>N/A</td> <td>ppm</td> <td colspan="2">N/A</td> </tr> <tr> <td>12</td> <td>Available Boron (B)</td> <td>0.44</td> <td>ppm</td> <td colspan="2">Deficient</td> </tr> </tbody> </table>		SOIL TEST RESULTS						S.No.	Parameters	Test Value	Unit	Rating		1	pH	8.57	-	Moderately Alkaline		2	EC	0.81	dS/m	Normal		3	Organic Carbon (OC)	0.54	%	Medium		4	Available Nitrogen (N)	N/A	kg/ha	N/A		5	Available Phosphorus (P)	57.7	kg/ha	Normal		6	Available Potassium (K)	41.7	kg/ha	Very Low		7	Available Sulphur (S)	10.2	kg/ha	Deficient		8	Available Zinc (Zn)	11.7	ppm	Sufficient		9	Available Iron (Fe)	57.49	ppm	Sufficient		10	Available Manganese (Mn)	20.43	ppm	Sufficient		11	Available Copper (Cu)	N/A	ppm	N/A		12	Available Boron (B)	0.44	ppm	Deficient	
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Sl. No.	Parameter	Recommendations for Soil Applications	No.	Crop & Variety	Reference Yield	Fertilizer Combination-1 for NPK (kg/ha)		Fertilizer Combination-2 for NPK (Kg/ha)																																																																																	
1	Sulphur (S)	--	1	Rice (All variety)	6000 kg/ha	175	Neem Coated Urea (in 3 split)	30	Diammonium Phosphate (16:44:0)																																																																																
2	Zinc (Zn)	--				80	Single Super Phosphate (SSP)	160	Neem Coated Urea (Top dressing)																																																																																
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General Recommendations			2	Potato (All variety)	200 q/ha	360	Neem Coated Urea (in 3 split)	90	Diammonium Phosphate (16:44:0)																																																																																
1	Organic Manure	5000 kg/ha				250	Single Super Phosphate (SSP)	330	Neem Coated Urea (Top dressing)																																																																																
2	Biofertiliser	2 kg/ha				330	Muriate of Potash (MOP)	330	Muriate of Potash (MOP)																																																																																
3	Borax	Soil-5 kg/ha or Spray 0.25%																																																																																							
4	Gypsum	140 kg/ha																																																																																							
This is electronically generated document hence does not require a signature			3	Lentil (All variety)	800 kg/ha	65	Neem Coated Urea (in 3 split)	45	Diammonium Phosphate (16:44:0)																																																																																
						125	Single Super Phosphate (SSP)	50	Neem Coated Urea (Top dressing)																																																																																
						170	Muriate of Potash (MOP)	170	Muriate of Potash (MOP)																																																																																
			4	Mustard/Toria (All Variety)	1100 kg/ha	130	Neem Coated Urea (in 3 split)	20	Diammonium Phosphate (16:44:0)																																																																																
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Figure.2 Soil Health Card provided to each farmer

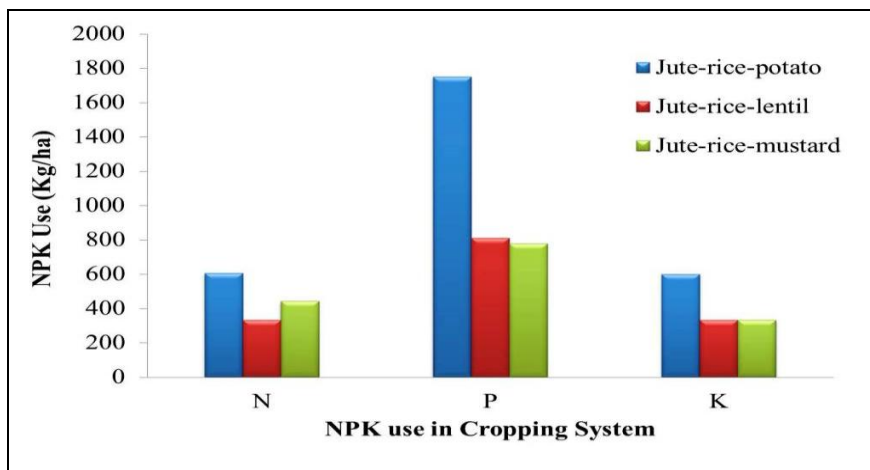


Figure 3.NPK fertilizer use in jute-rice-lentil/mustard/potato cropping system in West Bengal (India)

Major cropping pattern followed in the study area were jute-rice-mustard/potato/lentil except in Dwip Media village where jute-mustard-potato or lentil is not followed due to lowland and heavy soil texture. Jute and paddy (kharif) were grown as rainfed crop. Irrigation was applied only at the time of seed sowing of jute and transplanting of rice seedling.

The average productivity of paddy is 3450 kg ha⁻¹, lentil 725 kg ha⁻¹, mustard 910 kg ha⁻¹ and potato 200 q ha⁻¹. The farmers of the study area were not aware of judicious fertilizer management through use of SHC and therefore, they did not experience any reduction in consumption of chemical fertilizers. The farmers mainly applied complex NPK (10:26:26) fertilizer, Urea, Single Super Phosphate (SSP) and Muriate of Potash (MoP). Micronutrients were generally applied in vegetable crops only.

Farmer applies more amount of NPK complex fertilizer (10:26:26) as compared to Urea, SSP and MoP. Besides NPK_{10:26:26}, they also add SSP and MoP in soil of each crop of jute-rice-potato/lentil/mustard cropping system. Urea was applied only as top dressing. Due to application of complex fertilizer (NPK_{10:26:26}) along with SSP as basal dose, phosphorus content has been increased about 2 to 3 times higher than the required quantity. Whereas, nitrogen dose has been reduced to 1.5 to 2 times than the recommended dose of jute-rice-potato/lentil/mustard cropping system. When P input from fertilizer exceeds P output in crop, P accumulates in soil over time (Kuo *et al.*, 2005). If large amounts of P are supplied then luxury uptake of P may occur, which raises the ratios of P to Fe, Zn and B (Murphy *et al.*, 1981). Large P-inputs decrease soil Zn diffusion rates and enhances Fe immobilization in plant tissues (Haldar and Mandal, 1981). Inappropriate management of phosphate fertilizer can also be resulted in

substantial waste of phosphorus which is a non-renewable inorganic chemical. Urea, the only fertilizer, is sold at uniform sale price and Phosphatic and Potassic fertilizers are sold at indicative maximum retail prices. While the prices of urea are fixed and government subsidy levels float, it is the other way round in case of P and K. The current price of urea at ₹ 5,360 per tonne is low (due to subsidy) in relation to about ₹ 28,440 per tonne of DAP, ₹ 18,980 per tonne of MoP and ₹ 27,000 per tonne of NPK complex fertilizer (NPK_{10:26:26}). If farmer apply NPK_{10:26:26} only to meet the 100% P and K and 40% of N requirement of each crop as basal dose, and Neem Coated Urea as top dressing to meet remaining amount of nitrogen than over use phosphorus can be reduced. In this situation, farmer has to purchase about 4 kg of NPK_{10:26:26} (₹ 110) and 3 kg of Neem Coated Urea (₹ 18) as top dressing to meet 1 kg of NPK requirement for each crop at lower cost (₹ 128) as compared to Urea (2 kg)+SSP (6 kg)+MoP (1.5 kg) which cost about ₹ 600. This combination saves about ₹ 472 per kg of NPK cost. To achieve the potential yield as per soil test value, amount of NPK fertilizer suggested (Table 3) in the given SHC along with deficient amount of sulphur and boron. As per crop requirement in the same cropping system and soil test level (SHC), the N ratio can be increased up to 2.36 times over existing fertilizer use practices (Table 4).

This study and its findings have direct implications for understanding the soil health card for improving soil fertility and crop productivity at the farm level. Soil indicators that assess each soil's ability to support crop production within its capabilities and site limitations can guide the farmers for selecting right fertilizer and its quantity as per their crops in each season. It is important to assess the adoption level of SHC and consequent benefits in soil fertility improvement, yield change and additional economic gains.

Crop-wise recommendation of fertilizers provided in the SHC can help farmers to identify health related issues of soil and judiciously use of fertilizer. Judicious use of fertilizer also minimizes nutrient pollution and helps in building healthy soils. Much greater emphasis is needed on soil health monitoring for better fertilizer recommendation and its proper implementation by the farming community.

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