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Integrated nutrient management in cotton (*Gossypium hirsutum*)–wheat (*Triticum aestivum*) sequence on Vertisol

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ABSTRACT

A field experiment was conducted under irrigated condition on intergrated nutrient management system for cotton (*Gossypium hirsutum* L.) – wheat (*Triticum aestivum* L. emend. Fiori & Paol.) sequence on Vertisol at Rahuri, during 1999–2000 and 2000–2001. Application of 100% recommended dose of fertilizer (RDF) recorded significantly higher seed-cotton yield (20.68 q/ha), stalk yield (47.76 q/ha), nutrient uptake and soil available NPK after cotton over 75% RDF. Similarly, wheat grain yield (45.68 q/ha), straw yield (58.11 q/ha), wheat-equivalent yield (109.03 q/ha), net monetary returns, benefit : cost ratio, nutrient uptake and soil-available NPK after wheat were recorded highest with 100% RDF to cotton. Application of 10 tonnes FYM/ha to cotton recorded the highest cotton wheat and wheat-equivalent yield, nutrient uptake and soil-available NPK after cotton and wheat. However, it was at par with treatment green-manure + *Azotobacter* + phosphate-solubilizing bacteria except for P uptake in cotton. The later treatment gave the highest net monetary returns and benefit : cost ratio. Application of 75% RDF to wheat gave grain and straw yields, wheats equivalent grain yield, nutrient uptake and soil-available NPK after wheat at par with 100% RDF, but the higher net monetary returns and benefit : cost ratio (Rs 2.20). After sequence the net gain of soil-available N was increased with decrease levels of fertilizer and manures to cotton and increased with increased levels of fertilizer to wheat. The magnitude was increased with increased levels of fertilizer and manures with respect to net gain of soil available P. While net loss of soil-available K, the magnitude of reduction was decreased with increased levels of fertilizer and manure.

Key words : Cotton–wheat sequence, Intergrated Nutrient management

The major constraint to normal crop husbandry on Vertisols in Maharashtra includes unfavourable texture and tilth, wide and deep shrindage cracks, low infiltration rate and saturated slow hydraulic conductivity in sub-soil. Because of these constraints it is difficult to sustain fertility and productivity (Yengade *et al.*, 2000). The cropping pattern in Maharashtra was changed with the introduction of short-duration and high-yielding varieties of cotton and wheat. The cotton–wheat has become a common and profitable cropping system in western part of the state. In general, both the crops in sequence receive their recommended fertilizer doses regardless of the fact that whether the previous crop has received the fertilizer dose or not. Nitrogen and phosphorus are the most limiting nutrients on vertisol because of low organic carbon and high phosphorus fixation (Mathur, 1997). Therefore , the present study was undertaken to find out the intergrated effect of microbes, organic and inorganic sources of nutrient on yield of cotton – wheat sequence.

MATERIALS AND METHODS

A field experiment was conducted during 1999–2000 and 2000-2001 at the Mahatma Phule Krishi Vidyapeeth, Rahuri. The soil was fine montmorillonitic (Typic chromuster), alkaline in reaction (pH 8.5), low in available N (143.8 kg/ha), medium in available P (17.93 kg/ha) and high in available K (423.73 kg/ha) Main plot treatment applied to cotton consist of 2 fertilizer levels, viz. 75 and 100% (100:50:50 N, P_2O_5 and K_2O kg/ha) recommended dose of fertilizer (RDF), and 4 levels of manure, viz. control, green-manure + *Azotobacter* + phosphate-solubilizing bacteria, 5 and 10 tonnes FYM/ha. Sub-plot treatments applied to wheat were 50, 75 and 100% (120, 60 and 60 kg N, P_2O_5 and K_2O/ha) recommended dose of fertilizer wherein each levels 25% N was substituted through farmyard manure (FYM). The experiment was replicated thrice in split-plot design with cotton cv. 'NHH 44' and wheat cv. 'NI 9947'. Treatments allotted to plots were fixed for 2 years on same site. Two to three seeds of cotton were dibbled @ 2.5 kg/ha with the spacing of 90 cm × 90 cm on 30 April 1999 and 29 April 2000. Wheat was sown @ 100 kg/ha with spacing 22.5 cm apart on 30 November 1999 and 9 November 2000 respectively. Cotton-seed was treated with *Azotobacter* and phosphate-solubilizing bacte-

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ria culture @ 250 g/10 kg seed before sowing. Sannhemp crop was grown in line opposite side of the ridge, where cotton was dibbled and it was buried after 40 days.

Urea, single superphosphate and muriate of potash were used as fertilizer for both the crops. Full P and K was applied at the time of sowing, to both crops. Nitrogen was applied in 3 splits to cotton at sowing, square initiation and flower initiation. In wheat, half N was applied at sowing and another at 21 days after sowing. Irrigation was applied at 50% soil-moisture depletion, each 5 irrigations were applied to cotton and wheat in first and second years respectively. The total rainfall received during April–October was 718 mm in 53 rainy days and 632.2 mm in 46 rainy days in 1999 and 2000 respectively.

RESULTS AND DISCUSSION

Effect of fertilizers applied to cotton

Seed-cotton and stalk yields were significantly affected by fertilizer treatments (Table 1). Treatment 100% recommended dose of fertilizer (RDF) recorded significantly higher seed-cotton and stalk yield over 75% RDF. Adequate availability of NPK in soil solution results over-all improvement in the yield-attributing characters. Khan and Munir (1996) also reported similar findings. The NPK uptake (Table 2) and soil-available NPK content (Tables 3–5) increased significantly with increased level of 100% RDF over 75% RDF. This might be due to addition of more NPK into soil through fertilizer. Pinjari (1996) reported similar findings.

Application of 100% RDF to cotton recorded significantly higher wheat grain and straw yields over 75% RDF (Table 1) Auti *et al.* (1999) reported similar findings. Gwal *et al.* (1999) reported that influence of fertilizer level on grain and straw yields was significant. Increasing level of soil fertility up to 120, 60 and 60 kg N, P_2O_5 and K_2O/ha significantly increased grain and straw yields. The nutrient uptake (Table 2) and soil, available NPK (Tables 3–5) increased significantly with the increase in the fertilizer level of 100% RDF and subsequently decreased with 75% RDF. Higher application of NPK increased concentration of nutrient in soil solution which ultimately increased soil-available NPK and its uptake in the plant. Narang *et al.*, (1990) reported similar results.

Application of 100% RDF recorded significantly higher wheat–equivalent grain yield, net monetary returns and benefit : cost ratio (Table 1) over 75% RDF. This was owing to higher cotton and wheat yields. Application of 100% RDF gave higher yield per nutrient used which ultimately increased benefit : cost ratio. Similar findings were reported by Maliwal *et al.* (1999).

Effect of manure applied to cotton

Application of 10 tonnes FYM/ha recorded significantly higher seed-cotton and stalk yields over the control; however, it was at par with treatment green-manure + Azotobacter + phosphate-solubilizing bacteria (Table 1). Farmyard manure supply major and minor nutrients along with organic acids and provides good soil physical condition for plant growth. This increased uptake of nutrients increased photosynthesis and finally yield. Kunda and Gaur (1980) found that mixed culture inoculation was found to be superior to single culture and addition of inorganic fer-

Table 1. Effect of different fertilizers and manures on yield and economics of cotton – wheat sequence (mean data of 2 years)

Treatment	Cotton yield (q/ha)		Wheat yield (q/ha)		Wheat-equivalent grain yield (q/ha)	Net monetary returns	Benefit : cost ratio
	Seed	stalk	Grain	Straw			
Fertilizer level (cotton)							
75% RDF	19.3	46.3	42.5	56.5	102.0	43,081	2.1
100% RDF	20.6	47.7	45.6	58.1	109.0	47,850	2.2
CD (P=0.05)	1.0	1.2	1.7	0.8	3.4	882	0.02
Manure level (cotton)							
Control	19.3	46.4	43.1	56.4	102.4	46,010	2.2
GM+AZO+PSB	20.2	47.3	45.3	58.3	107.3	49,212	2.3
5 tonnes FYM/ha	19.3	46.3	42.7	55.2	102.2	42,049	2.0
10 tonnes FYM/ha	21.0	48.1	45.9	58.5	110.1	44,591	2.0
CD (P=0.05)	1.0	1.3	2.3	1.7	4.5	979	0.02
Fertilizer level (wheat)							
50% RDF			40.5	54.3	101.8	44,196	2.1
75% RDF			45.8	58.4	107.0	46,702	2.2
100% RDF			46.3	59.1	107.8	45,499	2.1
CD (P=0.05)			2.5	0.9	1.7	826	0.01

RDF, Recommended dose of fertilizer

GM, Green-manure; AZO, *Azotobacter;* PSB, phosphate-solubilizing bacteria

tilizer improved the yield of cotton remarkably over the control. The nutrient uptake (Table 2) and soil-available NPK content (Tables 3-5) was increased significantly with increase in level of manure. This might be due to the addition of more NPK through farmyard manure and green-manure + *Azotobacter* + phosphate-solubilizing bacteria which was at par. Waghmare (1998) also reported that higher available NPK content in soil and its uptake with the application of 10 tonnes FYM/ha.

Treatment 10 tonnes FYM/ha recorded the highest grain and straw yields over other treatments. It was at par with green-manure + *Azobobacter* + phosphate-solubilizing bacteria. Increase in the yield by supplying nutrient through organic sources like FYM and green-manure was reported. Sarkar *et al.* (1998) reported that higher yield of wheat crop was obtained in rice–wheat system through integrated nutrient management by supplying 50% N through organic sources like FYM or green-manure. The nutrient uptake (Table 2) and soil-available NPK (Table 3 – 5) increased significantly with the increase in the levels of FYM (10 tonnes)/ha and it was at par with treatment green-manure + *Azotobacter* + phosphate-solubilizing bac-

Table 2. Effect of different fertilizers and manures on NPK uptake by cotton and wheat (kg/ha)

Treatment	Cotton						Wheat					
	N uptake		P uptake		K uptake		N uptake		P uptake		K uptake	
	1999	2000	1999	2000	1999	2000	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001
Fertilizer level (cotton)												
75% RDF	35.0	38.8	14.8	18.6	45.8	50.6	88.2	88.0	14.0	18.3	81.5	94.6
100% RDF	47.4	53.7	25.5	27.3	52.6	59.1	101.2	112.1	17.8	24.5	87.9	106.0
CD (P=0.05)	3.9	4.0	1.3	1.2	3.8	3.9	7.0	13.0	2.5	2.9	3.0	5.8
Manure level (cotton)												
Control	36.3	37.9	13.9	19.6	45.8	51.7	85.9	88.1	14.1	17.5	81.2	95.2
GA+AZO+ PSB	43.5	50.5	22.6	30.9	51.0	56.3	100.6	108.2	17.6	22.8	88.6	104.1
5 tonnes FYM/ha	36.0	40.6	15.7	17.2	45.0	50.5	87.1	90.4	14.4	19.3	79.6	96.0
10 tonnes FYM/ha	48.8	56.3	27.8	29.5	55.1	60.8	106.0	113.8	18.4	25.2	88.7	105.8
CD (P=0.05)	5.4	5.9	1.9	1.7	4.2	4.8	8.5	14.2	3.4	3.8	3.9	7.0
Fertilizer level (wheat)												
50% RDF							76.1	71.1	10.8	15.4	73.2	86.7
75% RDF							102.2	110.5	17.9	23.2	88.9	104.7
100% RDF							107.4	121.5	19.4	25.6	91.3	109.8
CD (P=0.05)							5.4	11.0	1.7	2.6	2.8	5.2

GM, Green-manure; AZO, *Azotobacter*; PSB, phosphate solubilizing bacteria

Table 3. Mean soil available N (kg/ha) and net loss or gain after 2 years as affected by different fertilizer and manures

Treatment	1999–2000						2000–2001						Net loss
	Initial available N	Added N	Total available N	Removal of N	Expected balance	Actual balance	Initial available N	Added N	Total available N	Removal of N	Expected balance	Actual balance	or gain after two years
Fertilizer level (cotton)													
75% RDF	119.0	195.1	314.1	88.2	225.9	124.0	121.8	195.1	316.9	88.0	228.8	125.1	6.1
100% RDF	129.2	220.1	349.3	101.2	248.1	130.5	130.2	220.1	350.3	112.1	238.2	131.3	2.0
Manure level (cotton)													
Control	119.5	177.5	297.0	85.9	211.1	124.4	121.1	177.5	298.6	88.1	210.5	124.9	5.4
GM+AZO+ PSB	126.0	222.9	348.9	100.6	248.3	127.9	128.0	222.9	350.9	108.2	242.6	129.6	3.0
5 tonnes FYM/ha	120.0	202.5	322.5	87.1	235.4	126.2	122.7	202.5	325.2	90.4	234.7	127.4	7.3
10 tonnes FYM/ha	130.9	227.5	358.4	106.0	252.4	130.4	132.2	227.5	359.7	113.8	245.9	131.5	0.5
Fertilizer level (wheat)													
50% RDF	124.1	177.6	301.7	76.1	225.6	123.8	126.0	177.6	303.6	71.1	232.5	124.9	0.8
75% RDF	124.1	207.6	331.7	102.2	229.5	128.6	126.0	207.6	333.6	110.5	223.0	129.3	5.1
100% RDF	124.1	237.6	361.7	107.4	254.3	129.7	126.0	237.6	363.6	121.5	242.0	130.4	6.3

GM, Green-manure; AZO, *Azotobacter*; PSB, Phosphate-solubilizing bacteria

teria; might be owing to the residual effect of manure. Narang *et al.* (1990) revealed that application of 120, 13 25 kg and N, P_2O_5 and K_2O/ha to rice and 180, 39 and 75 kg N, P_2O_5 and K_2O/ha to wheat with green manuring to rice increased available NPK in soil after wheat. Sarkar *et al.* (1998) also reported similar findings.

Application of 10 tonnes FYM/ha recorded significantly higher wheat equivalent grain yield , however it was at par with treatment green-manure + *Azotobacter* + phosphate solubilizing bacteria (Table 1). Similar findings were noted by Singh *et al.* (1999) that the application of 50% NPK + 50% N as FYM to cotton and rice followed by wheat (100% RDF) increased the yield of wheat in both cotton and rice sequence owing to residual effect of FYM on wheat. Net monetary returns and benefit : cost ratio were significantly higher with green-maure + *Azotobacter* + phosphate-solubilizing bacteria increased nutrient uptake per unit of nutrient used, also cost per unit of nutrient was lower. These results confirm the findings to Tiwana *et al.* (1999).

Effect of fertilizer applied to wheat

Application of 100% RDF to wheat recorded significantly higher wheat grain and straw yields; however, it was at par with 75% RDF (Table 1). Increased fertilizer levels increased protoplasmic constituents and accelerated the process of cell division and elongation which in turn increase the value of yield attributes and finally the yield. Auti *et al.* (1990) noted similar findings. Deshveer *et al.* (2000) reported that partial substitution of inorganic N and

Table 4. Mean soil available P (kg/ha) and net loss or gain after 2 years as affected by different fertilizers and nanures

Treatment	1999–2000						2000–2001						Net loss
	Initial Available P	Added P	Total available P	Removal of P	Expe-cted balance	Actual balance	Initial available P	Added P	Total available P	Removal of P	Expe-cted balance	Actual balance	or gain after 2 years
Fertilizer level (cotton)													
75% RDF	15.3	93.2	108.5	14.0	94.4	14.6	15.9	93.2	109.9	18.3	90.8	15.8	0.4
100% RDF	15.7	105.7	121.4	17.8	103.6	17.3	17.0	105.7	122.7	24.5	98.2	18.3	2.6
Manure level (cotton)													
Control	15.3	88.7	104.0	14.1	89.9	14.6	15.9	88.7	104.6	17.5	87.1	15.6	0.3
GM + AZO + PSB	15.6	101.6	117.2	17.6	99.5	16.3	16.7	101.6	118.3	22.8	95.4	17.4	1.8
5 tonnes FYM/ha	15.4	98.7	114.2	14.4	99.7	15.4	16.1	98.7	114.8	19.3	95.5	16.8	1.3
10 tonnes FYM/ha	15.7	108.7	124.5	18.4	106.0	17.5	17.2	108.7	126.0	25.2	100.7	18.4	2.6
Fertilizer level (wheat)													
50% RDF	15.5	84.4	100.0	10.8	89.1	14.8	16.5	84.4	100.9	15.4	85.5	15.9	0.3
75% RDF	15.5	99.4	115.0	17.9	97.0	16.3	16.5	99.4	115.9	23.2	92.7	17.4	1.9
100% RDF	15.5	114.4	130.0	19.4	110.5	16.8	16.5	114.4	130.9	25.6	105.3	17.8	2.3

GM, Green manure; AZO, *Azotobacter*; PSB, phosphate-solubilizing bacteria

Table 5. Mean soil available K (kg/ha) and net loss or gain after 2 years as affected by different fertilizer and manures

Treatment	1999–2000						2000–2001						Net loss
	Initial available K	Added K	Total available K	Removal of K	Expe-cted balance	Actual balance	Initial available K	Added K	Total avaiable K	Removal of K	Expe-cted balance	Actual balance	or gain after 2 years
Fertilizer level (cotton)													
75% RDF	429.0	110.1	539.2	81.5	457.6	408.9	429.2	110.1	539.4	94.6	444.8	410.0	–18.9
100% RDF	433.4	122.6	556.1	87.8	468.2	417.2	435.5	122.6	558.1	106.0	452.1	418.6	–14.8
Manure level (cotton)													
Control	428.8	88.7	517.5	81.2	436.3	406.6	428.6	88.7	517.3	95.2	422.1	408.8	–19.9
GM+AZO+PSB	431.2	124.2	555.5	88.6	466.8	414.9	434.0	124.2	558.2	104.1	454.1	416.0	–15.2
5 tonnes FYM/ha	430.3	113.7	544.0	79.6	464.4	411.2	430.1	113.7	543.9	96.0	447.8	413.2	–17.1
10 tonnes FYM/ha	434.7	138.7	573.4	88.7	484.7	419.3	436.7	138.7	575.5	105.8	469.6	419.3	–15.3
Fertilizer level (wheat)													
50% RDF	431.2	101.3	532.6	73.2	459.4	406.7	432.3	101.3	533.7	86.7	447.0	405.1	–26.1
75% RDF	431.2	116.3	547.6	88.9	458.7	414.6	432.3	116.3	548.7	104.7	444.0	416.9	–14.3
100% RDF	431.2	131.3	562.6	91.3	471.2	417.8	432.3	131.3	563.7	109.8	453.9	421.0	–10.2

GM, Green manure; AZO, *Azotobacter*; PSB, phosphate-solubilizing bacteria

P fertilizer to the extent of 40 % by FYM could be effected for enhancing the yield of wheat by 40% on Vertisol. Partial substitutions resulted in an increase in grain yield up to 21.6% over RDF of N and P. The nutrient uptake (Table 2) and soil-available NPK content (Tables 3–5) increased significantly with the increase in the level of fertilizer. Auti *et al.* (1999) also reported that maximum leftover of available NPK was observed in 120, 60 and 60 kg N, P_2O_5 and K_2O/ha.

Treatment 100% RDF was found to be at par with 75% RDF, with respect to wheat equivalent grain yield (Table 1). Maliwal *et al.* (1999) reported that with recommended dose of fertilizer to cotton and wheat increased the wheat equivalent yield. Net monetary returns and benefit : cost ratio were significantly higher with 75% RDF (Table 1). Nutrients used per unit of out were maximum with 75% RDF. Similar results were reported by Tiwana *et al.* (1999). All the interaction effects were found to be non-significant.

Nutrient balance

Though net gain of available N was positive, it increased with the decrease in level of fertilizer and manure to the cotton, but it increased with levels of fertilizer to wheat. The magnitude of net gain in available P was increased with increased levels. The magnitude of reduction of available K was decreased with increased levels of fertilizer and manures to cotton and fertilizer levels to wheat, however it was negative (Table 3). Application of nutrient through organic manure reduces loss of nutrient ultimately increase NPK balance. Shelke *et al.* (1997) reported similar results.

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