

Direct and residual effects of nitrogen management in Bt cotton (*Gossypium hirsutum*)-wheat (*Triticum aestivum*) cropping system

RAMAN JEET SINGH*, I.P.S. AHLAWAT AND B. GANGAIAH

Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

A 2-year field investigation was carried out in New Delhi from 2006 to 2008 on a sandy loam soil having 217 kg/ha of available N. In cotton (*Gossypium hirsutum* L.) 8 treatments comprising combination of 4 N management practices (Control, 100% recommended dose of N (150 kg/ha) through urea (RDN), 75% RDN through urea + 25% RDN through FYM N and 50% RDN each through urea and FYM) and 2 cropping systems - sole cotton and cotton + groundnut (*Arachis hypogaea* L.) intercropping in 1:3 additive series. N management in cotton-wheat cropping system were tested in RBD with 3 replications. For comparison, sole groundnut with recommended N and phosphorus fertilizers was also grown. In *rabi*, cotton plots were sub-divided in to 4 to accommodate levels of N (0, 50, 100 and 150 kg/ ha) to wheat. Groundnut as an intercrop enhanced the productivity of cotton by 0.25 tonne/ha and succeeding wheat by 0.16 tonne/ha. These increases in productivity of cotton and wheat coupled with additional intercrop groundnut yield (0.47 tonne/ha) together enhanced the productivity of cotton + groundnut - wheat systems in seed cotton equivalent yield by 0.58 tonne/ha and net returns by Rs 14,421 /ha over cotton-wheat system. Among N management practices, substitution of 25% RDN through FYM in cotton gave the highest system productivity (4.82 tonne seed cotton equivalent yield/ha) and B: C ratio (2.09) than all N through urea and 50% N through each source. However, net returns and soil N balance were in favour of 50% RDN substitution through FYM besides (Rs 72,748 /ha). Wheat crop responded to 100 kg N/ha fertilization. It was therefore inferred that integration of groundnut as intercrop along with FYM besides 50% N of cotton along with 100 kg fertilizer N/ha to wheat was the most profitable and sustainable N management system.

Key Words: *Bacillus thuringiensis*, Cotton, Cropping system, Groundnut, Nitrogen, Wheat, Yield

Cotton (*Gossypium hirsutum* L.) is an important fiber crop in India on whose success the livelihoods of 60 millions people rests (Ron Herring, 2005). The American bollworm (*Helicoverpa armigera* Hubner) menace was successfully addressed with the introduction of Bt cottons that contain *Cry1Ac* gene from soil bacterium *Bacillus thuringiensis* producing endotoxin conferring inbuilt resistance (Perlak *et al.*, 1990). In view of reduced plant protection cost and higher yield levels in Bt cottons leading to higher net returns, their rapid adoption by the farmers has been rapid and almost 2/3 area has been occupied by them in 2007-08 in the country. Looking to the success of Bt cotton and their higher productivity, it is im-

perative to assess the N requirement and the agronomic efficiency in system mode. Further, wider row spacing of cotton provides scope for intercropping with short stature and short duration grain legumes like groundnut for additional produce and returns (Patil *et al.*, 1996). The determinate nature of Bt cotton enables timely sowing of wheat leading to greater system productivity of this most widely practiced cropping system (1.5 m ha) of north-west plains zone. The ability of groundnut to fix atmospheric N and the current and residual transfer of combined N on succeeding wheat crop (Kairon *et al.*, 1996) calls for evaluating the N requirement of Bt cotton + groundnut-wheat cropping system. Further, the integration of farmyard manure with fertilizers may improve N use efficiency in the cropping system. This is more important in view of ever escalating prices of N fertilizers. The information on integrated N management in Bt cotton-wheat system is meagre, hence the present investigation was done.

¹Corresponding author: (E mail: rdxsingh@gmail.com),

*Present Address : Subject Matter Specialist, KVK, Vivekananda Parvatiya Krishi Anusandan Sansthan, Almora, Uttarakhand-263 601

MATERIALS AND METHODS

Field experiments were conducted in sandy loam soil with pH 7.8 and 8.1 (1:2.5 soil to water) containing 0.42 and 0.46% organic carbon, 227 and 207 kg/ha available N, 12.8 and 13.6 kg/ha available P, and 270 and 282 kg/ha available K in the 0-30 cm soil layer between 2006 and 2007 respectively in New Delhi. The total rainfall received during the cropping period was 629.5 mm in 2006-07 and 489.0 mm in 2007-08. The (9) treatments comprising combination of 2 cropping systems (sole cotton and cotton + groundnut) and 4 fertility levels (control, 100 % recommended dose of N (RDN), 75% RDN + 25 % N through FYM and 50% RDN + 50 % N through FYM) to cotton along with sole groundnut (with recommended N and P were laid out in a randomized block design with 3 replications. In succeeding wheat, the plots were sub-divided into 4 plots to accommodate doses of N (0, 50, 100 and 150 kg/ha) to wheat in a split plot design. In cotton, 150 kg N/ha was used as RDN. Well decomposed farm yard manure (FYM) was uniformly incorporated into the soil 7 days before sowing as per treatments. FYM on dry weight basis contained 0.5-0.2-0.5 % N-P-K respectively. The quantity of P and K being variable owing differential quantities of FYM addition was not balanced. As per treatment 50% N each through urea was applied at sowing and square initiation stage. A uniform dose of 26 kg P/ha through single super phosphate (SSP) was applied at sowing. Cotton 'RCH-134 Bt' was sown by dibbling with 120 cm × 60 cm geometry on 17 June in 2006 and on 2 June in 2007. In sole groundnut 'Punjab Groundnut 1' was in rows 30 cm apart using a seed rate of 100 kg/ha. In intercropped cotton, 3 rows of groundnut were planted in between cotton rows. Groundnut was harvested in last week of October in both the years. Cotton was harvested

in 2 pickings. After cotton harvest, the field was an irrigated and wheat cv. 'Pusa Gold' was sown on 31 December in 2006 and on 7 December in 2007 applied in rows 22.5 cm apart using a seed rate of 125 kg/ha. Nitrogen was applied through urea as per treatments in 2 equal splits at sowing and first irrigation. Other management practices were adopted as per recommendations of the crops under irrigated conditions.

RESULTS AND DISCUSSION

Kharif based cropping systems and their fertility management

Cotton

Intercropping of groundnut with cotton increased the mean number of boll/plant by 3.5 and boll weight by 0.25 g over that of sole cotton. The cumulative effect of more and heavy bolls in intercropped cotton led to the increased mean seed cotton yield by 0.24 tonne/ha over its sole stand. However, the differences in seed cotton yield (SCY) were not marked (Table 1). Groundnut as an intercrop with short and compact stature did not offer competition to cotton, and thus the growth condition of cotton in both sole and intercropping was identical. The positive impact of inclusion of groundnut as an intercrop owing to its ability of biological N fixation and reducing weed menace in between cotton rows favoured development of yield attributes in cotton, leading to higher SCY. These results are in close agreement with the findings of Waterworth (1994). Over the years, intercropped cotton accumulated 13.5kg/ha more N than sole cotton, and of this N, 85% was accumulated in vegetative parts. In the present investigation, higher biological yield coupled with more or less similar nutrient content in intercropped cotton led to

Table 1. Effect of cropping system and fertility level on bolls/plant, boll weight, seed cotton and stalk yield (t/ha) of cotton

Treatment	Opened bolls/ plant		Boll weight (g)		Seed cotton yield		Stalk yield	
	2006	2007	2006	2007	2006	2007	2006	2007
<i>Cropping system</i>								
Sole cotton	49.6	33.7	4.3	3.6	2.94	2.24	5.39	4.04
Cotton + groundnut (1:3)	54.1	36.2	4.6	3.8	3.15	2.53	5.68	4.21
SEm ±	1.6	1.7	0.10	0.10	0.08	0.10	0.15	0.12
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
<i>N dose (kg/ha) and source (% fertilizer N - % FYM N)</i>								
Control (0-0)	39.2	23.3	3.9	3.3	2.16	1.52	4.95	3.31
150 (100-0)	55.2	39.7	4.6	3.7	3.33	2.77	5.72	4.56
150 (75-25)	60.5	40.8	4.9	4.1	3.61	3.05	6.00	4.78
150 (50-50)	52.5	35.9	4.5	3.5	3.06	2.19	5.48	3.86
SEm ±	2.2	1.7	0.15	0.14	0.11	0.14	0.21	0.17
CD (P=0.05)	6.7	5.0	0.45	0.44	0.33	0.44	0.64	0.51

higher uptake of N than sole cotton.

Application of recommended dose of nitrogen (150 kg/ha) irrespective of its source significantly enhanced number and weight of bolls over unfertilized crop. However, the increase in boll weight over control in 2007 was significant only with 25% recommended dose of nitrogen substitution through FYM. Further, cotton receiving N irrespective of share of organic and inorganic sources produced similar number and weight of bolls, with the exception that boll number in 2006 and boll weight in 2007 with 50% RDN + 50% FYM N were lower than that observed with 75% RDN + 25% FYM N. This difference in yield attributes was reflected in SCY. Application of 75% RDN + 25% FYM N gave the highest mean SCY (3.33 tonnes/ha), that was on par with 100% fertilizer N (3.05 tonnes/ha). The SCY with 50% RDN + 50% FYM N was significantly lower when compared with 100% RDN in 2007. Nitrogen fertilized cotton gave 0.78 and 1.08 tonnes/ha of higher stalk yield when compared with unfertilized cotton in 2006 (4.98 tonnes/ha) and 2007 (3.31 tonnes/ha) respectively. The stalk yields of N fertilized cotton irrespective of its sources were similar. The only exception being that 100% RDN gave higher stalk yields than 50% RDN + 50% FYM N in 2007. Over the seasons, 75% RDN + 25% FYM N increased the seed cotton (stalk) yield by 26.0 % over 50% RDN + 50% FYM N and 81.0% over control. It showed that under N limitation, seed cotton yield was more adversely affected than stalk yield. Substitution of 25% N through FYM did not adversely affect the cotton crop. On the contrary, the prolonged supply of N and other nutrients due to slow mineralization of FYM coupled with reduced losses of fertilizer N as it binds with FYM might have reduced the leaching losses. Thus supply of N matching with the crop needs led to development of more yield attributes. However, substitution of 50% fertilizer N through FYM proved counterproductive to some extent as this level of substitution drastically altered the N supply to the crop. The rate of mineralization of FYM failed to release the required N at critical periods of formation of yield attributes. This is in line with findings of Rathinakumari *et al.* (2004).

The SCY and total N uptake were significantly influenced by N fertilization and also by extent of fertilizer N substitution with FYM. Application of 75% RDN + 25% FYM N recorded the highest total N uptake 226.5 kg/ha, of which 34.5% (78.2 kg/ha) was in economic parts (seed and fiber). The N uptake in cotton with 100%RDN was on par with the above treatment in both the years and also with 50% RDN + 50% FYM N in 2006. In unfertilized cotton, 43.7% of total N uptake is diverted towards seed and fiber, whereas it was 35.7 in 100% RDN and 41.5% in 50%RDN substituted through FYM. Thus it is evident that

wherever less N is accumulated in economic parts, the productivity was higher (Table 3).

Groundnut

The performance of groundnut was drastically altered in intercropping with cotton when compared with its sole stand. This is evident from data on yield attributes and yield. Pods/plant was adversely affected in intercropping. Intercropped groundnut, on an average, produced 32.5% pods/plant of its sole crop (91.5). However, the extent of reduction in kernels/pod and 1,000 kernel weight in intercropping was of lesser magnitude when compared to its sole stands. The cumulative effect of reduction in pods/plant, kernels/pod and 1,000 kernel weight kernels in intercropped groundnut led to its lower productivity (44.6%) when compared to its sole cropping (1.065 tonnes/ha). The poor performance of groundnut in intercropping was mainly attributed to lower plant population (45% base population in intercropping as compared to sole groundnut). Further, the shading effect of cotton (90 days after sowing onwards) and competition for resources particularly water and nutrients also contributed to lower values of yield attributes and yield (Table 2). Among the 3 rows of groundnut in intercropped cotton, the contribution of centre row to the yield was the maximum. These results are in accordance with the findings of Subrahmaniyam and Kalaselvan (2005) and Waterworth (1994).

Cotton receiving no N showed superior performance of intercropped groundnut in terms of pods/plant, kernels/pod and pod yield as compared with 75% RDN + 25% FYM N. Further, 100% RDN also had poor performance of groundnut than control in 2007. Groundnut performance in 100% RDN and 75% RDN + 25% FYM N was on par in both the seasons. This could be attributed to the fact that poor performance of cotton in control and 50% RDN + 50% FYM N caused less shady conditions in intercropped groundnut leading to increased number of pod/plant and kernels/pod, and consequently greater pod yields when compared to 75%RDN +25% FYM N and 100%RDN. Similar results were also reported by Kambale *et al.* (2002).

The N uptake followed the similar trend to that of pod yields. Sole groundnut had significantly higher mean N uptake (115.4 kg/ha) than intercropped groundnut (46.7 kg/ha). The higher N uptake in sole groundnut could be ascribed to the fact that it received recommended dose of fertilizers (N, P), while intercropped groundnut survived on nutrients applied to base crop of cotton. Hence, intercropped groundnut faced competition for nutrients from cotton when compared to sole groundnut. N uptake was lower in intercropping because of less pods and biomass yield of groundnut. No N treatment being on par with

50% RDN + 50% FYM N in 2006 recorded higher N uptake over 75% RDN + 25% FYM N and 100% RDN in both the seasons (Table 3). Cotton with no N and 50% RDN + 50% FYM N produced higher yield because of less shading effect by cotton and thus enabled groundnut to acquire more nutrients. Similar results were also reported by Mehta *et al.* (1996). The mean N uptake in intercropped cotton was 79.4 kg/ha higher than sole cotton (149.9 kg/ha), while sole groundnut recorded the least N uptake (115.4 kg/ha).

Residual effects of cropping systems and fertility levels in kharif on succeeding wheat

Wheat after cotton intercropped with groundnut re-

corded more spikes/m² and 1,000 seed weight than after sole cotton. Further, wheat after sole groundnut had 16.3, 4.5 and 2.35 g more number of spike/m², grains/spike, and 1,000 seed weight than after cotton + groundnut. These increases in yield attributes resulted in 0.29 and 0.165 tonnes/ha higher grain yield of wheat after sole groundnut and intercropped cotton + groundnut over that of intercropped cotton + groundnut and sole cotton respectively. Biological yield and harvest index of wheat were also higher after cotton + groundnut system than sole cotton. Biological yield of wheat after sole groundnut, on an average, increased by 0.89 tonne/ha over the groundnut intercropped-cotton. However, harvest index was the lowest in wheat after sole groundnut in 2006, but similar to

Table 2. Effect of cropping system and fertility level on yield attributes of groundnut

Treatment	Pods/ plant		Kernels/pod		Test weight (g)		Pod yield (t/ha)		Biological yield (t/ha)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
<i>Cropping System</i>										
Sole groundnut	90.7	92.2	1.58	1.79	270.0	286.3	1.05	1.08	4.01	4.63
Intercropped (groundnut)	31.2	28.2	1.47	1.50	255.9	253.7	0.49	0.46	2.36	2.22
SEd ±	1.5	2.7	0.02	0.22	4.1	6.5	0.03	0.04	0.12	0.11
CD (P=0.05)	3.5	6.1	0.05	0.05	9.4	15.1	0.06	0.09	0.29	0.27
<i>N dose (kg/ha) and source (% fertilizer N - % FYM N)</i>										
Control (0-0)	35.7	36.0	1.52	1.60	260.9	260.9	0.54	0.58	2.60	2.75
150 (100-0)	30.0	23.4	1.47	1.46	256.8	252.2	0.47	0.40	2.30	1.92
150 (75-25)	28.0	21.7	1.40	1.42	248.2	248.2	0.43	0.39	2.05	1.86
150 (50-50)	31.3	31.7	1.50	1.54	257.7	253.4	0.50	0.47	2.48	2.33
SEm ±	1.4	2.4	0.02	0.02	3.6	5.8	0.02	0.04	0.11	0.10
CD (P=0.05)	4.5	7.7	0.05	0.06	NS	NS	0.07	0.12	0.36	0.34

Table 3. Effect of cropping system and fertility level on total N uptake (kg/ha)

Treatment	Cotton				Groundnut				Cropping system	
	Seed + fiber		Total		Haulm		Total		2006	2007
	2006	2007	2006	2007	2006	2007	2006	2007		
<i>Cropping system</i>										
Sole cotton	66.8	48.9	162.3	137.5					162.3	137.5
Cotton + groundnut	77.9	57.0	200.5	164.6	10.7	9.2	49.4	44.0	249.9	208.6
SEm ±	3.4	2.4	12.8	10.7						
CD (P=0.05)	NS	NS	NS	NS						
<i>N dose (kg/ha) and source (% fertilizer N - % FYM N)</i>										
Control (0-0)	41.9	33.7	94.2	79.2	13.1	11.5	57.4	51.8	151.6	131.0
150 (100-0)	83.4	60.5	218.5	183.3	9.9	8.0	47.9	39.5	266.4	222.8
150 (75-25)	89.4	67.0	237.7	215.3	8.2	7.7	38.7	39.3	276.4	254.6
150 (50-50)	73.6	49.7	174.4	125.5	11.5	9.6	53.8	45.3	222.8	170.8
SEm ±	4.9	3.4	18.0	15.1	0.8	0.7	3.1	2.2		
CD (P=0.05)	14.7	10.3	54.7	45.8	2.6	2.2	9.9	7.1		
Sole groundnut					31.0	29.0	107.8	122.9	107.8	122.9

that of cotton + groundnut in 2007 (Table 4). The mean N uptake in wheat was in both the years. N uptake by wheat was higher by 19.2 and 14.0 kg/ha when grown after sole groundnut than cotton + groundnut and sole cotton respectively (Table). Among residual effect of fertility levels, 50% RDN + 50% through FYM N maintained higher total N uptake over other fertility levels. years (Table 6). Similar results were also reported by Kairon *et al.* (1996) and Das *et al.* (2004).

N applied to cotton recorded higher number of spike/m² in succeeding wheat than unfertilized cotton. 50% RDN + 50% FYM N recorded significantly higher number of spike/m² and 1,000 grain weight than other fertility levels. However, 1,000 grain weight in 50% RDN + 50% FYM N was on par with that of 75% RDN + 25% FYM N. The higher values of yield attributes in all N fertilized treatments resulted in significantly higher grain and biological yield of wheat than unfertilized control. However, 50% RDN + 50% FYM N also had significantly higher grain yield than 100% RDN in 2006-07. Further, the biological yield of wheat with 50% RDN + 50% FYM N was also significantly higher over 100% RDN and 75% RDN + 25% FYM N (Table 4). Wheat following unfertilized

(2006-07) and 75% RDN + 25% FYM N (2007-08) recorded the highest harvest index. The greater residual nutrient availability owing to slow mineralization of N and other nutrients in 50% RDN substitution through FYM might have led to better nutrition of wheat leading to higher dry matter production, yield attributes and yield. Similar results were also reported by Kairon *et al.* (1996).

Direct effect of nitrogen

In wheat, each successive increase of 50 kg N/ha up to 100 kgN/ha resulted in significantly higher number of spike/m², grains/spike, 1,000 grain weight, grain and biological yields of wheat. Application of 150 kg N/ha to wheat, however, significantly decreased wheat yield in 2006-07, and though the trend was similar in 2007-08, but the yield reduction was not marked. All the N rates being on par had significantly higher biological yield when compared with control. Similar trend was observed in wheat grown after sole groundnut. In 2007-08, similar trend was observed with grain yield. In 2006-07, control (20 N) was on par with 150 kg N/ha and recorded significantly higher harvest index over 50 and 100 kg N/ha. However, in 2007-08, control being on par with 100 kg N/ha had

Table 4. Direct and residual effect of nitrogen on yield attributes, yield and harvest index of wheat

Treatment	Spikes/m ²		Grains*/spike	1,000-grain* weight (g)	Grain yield (t/ha)		Biological* yield (t/ha)	Harvest* index
	2006-07	2007-08			2006-07	2007-08		
<i>Cropping system</i>								
Sole cotton	450.7	490.7	49.5	42.4	3.03	3.22	7.57	41.5
Cotton + groundnut (1:3)	489.3	516.0	50.0	43.3	3.18	3.40	7.81	42.5
SEM±	0.9	0.9	0.3	0.2	0.02	0.06	0.04	0.2
CD (P=0.05)	2.7	2.8	NS	0.7	0.06	0.18	0.12	0.5
Sole groundnut	500.9	538.2	54.5	45.6	3.33	3.83	8.69	41.5
<i>N dose (kg/ha) and source (% fertilizer N -% FYM N)</i>								
Control (0-0)	442.2	474.2	48.0	41.3	2.99	3.07	6.35	48.7
150 (100-0)	456.0	504.4	48.6	42.3	3.11	3.34	7.67	42.1
150 (75-25)	476.4	526.7	51.0	43.4	3.12	3.40	7.79	41.9
150 (50-50)	505.3	551.6	51.4	44.3	3.20	3.44	8.09	41.2
SEM ±	1.3	1.3	1.1	0.3	0.03	0.08	0.05	0.2
CD (P=0.05)	3.9	3.8	NS	1.0	0.09	0.25	0.16	0.7
<i>N applied to wheat (kg/ha)</i>								
0	436.9	480.0	49.6	41.2	2.46	2.73	6.00	43.4
50	478.2	515.1	51.1	43.1	3.19	3.55	8.33	40.3
100	505.7	538.7	53.6	46.3	3.59	3.90	9.01	41.5
150	500.0	528.4	51.2	44.3	3.48	3.76	8.76	41.3
SEM±	1.1	1.5	0.5	0.4	0.08	0.08	0.20	0.6
CD (P=0.05)	3.0	4.3	1.5	1.3	0.24	0.24	0.60	2.0

*Mean of 2 seasons

Sole groundnut vs. rest was significant

higher harvest index over 50 and 150 kg N/ha (Table 4). Increase in grain yield with higher N levels was mostly due to improved yield attributes. The higher number of spike/m² with higher N rate might be owing to stimulatory effect of N on tillering through cytokinin synthesis resulting in more number of effective tiller of wheat (Sharma *et al.*, 2000 and Jain, 1999).

Total N uptake in wheat significantly increased with each successive increase in N dose up to 100 kg/ha only. Similar trend was also observed in total N uptake in wheat grown after sole groundnut. Amount of nutrients harvested in grain and straw as well as whole plant increased with the addition of more fertilizer N because of increased grain and straw yields and also nutrient content (Gonita and Joshi, 2000).

System productivity, economics, N uptake in cotton-wheat sequence and its balance

Kharif based cropping systems and their fertility levels

The system productivity expressed as cotton equivalent yields (CEY) of cotton + groundnut - wheat system was significantly higher than sole cotton and sole groundnut. This system recorded 15 and 64.6% higher CEY than sole cotton-wheat and sole groundnut-wheat systems respec-

tively. The net returns and B:C ratio reveal the similar trend (Table 5). Among the N management treatments in *kharif*, substitution of 25% N through FYM in cotton being on par with no FYM (100% RDN) gave significantly higher CEY of the system than 50% N substitution through FYM. All fertilizer treatments recorded significantly higher CEY than unfertilized control. However, the net returns of the system were the highest with 50% FYM N treatment, but this was inferior to 25% FYM N treatment with respect to B:C ratio.

Cotton + groundnut-wheat system had significantly higher total N uptake than cotton-wheat system. Further, groundnut-wheat system recorded the lowest system N uptake and thus had the highest soil N status among the cropping systems. Cotton based systems (sole or inter-cropped cotton) depleted the soil of available N to an extent of 32 kg/ha. The depletion of available N in cotton based cropping systems was due to its uptake in quantities far exceeding their external application through fertilizers etc. Among residual effect of fertility levels, 75% RDN + 25% N through FYM had significantly higher total N uptake over other fertility levels. Further, 100% RDN and 50% RDN + 50% FYM N were on par in respect of N uptake. Generally, After all fertilizer treatments applied to *kharif* crops recorded depletion of available soil N, being

Table 5. Direct and residual effect of nitrogen on system productivity in cotton equivalent yield, and net returns of cotton-wheat system (mean of two years)

Treatment	System productivity (t/ha)	Cost of cultivation (x 10 ³ Rs/ha)	System net returns (x 10 ³ Rs/ha)	net B: C ratio
<i>Cropping system</i>				
Sole cotton	3.88	35.25	54.63	1.55
Cotton + groundnut (1:3)	4.46	35.97	69.07	1.92
SEm ±	0.18			
CD (P=0.05)	0.54			
Sole groundnut	2.71	28.83	30.85	1.07
<i>N dose (kg/ha) and source (% fertilizer N-% FYN N)</i>				
Control (0-0)	3.24	32.50	46.52	1.44
150 (100-0)	4.53	39.73	58.01	1.46
150 (75-25)	4.82	33.54	70.09	2.09
150 (50-50)	4.09	37.12	72.75	1.96
SEm ±	0.25			
CD (P=0.05)	0.74			
<i>N applied to wheat (kg/ha)</i>				
0	3.17	34.81	55.35	1.59
50	3.71	35.46	62.06	1.75
100	4.03	35.85	66.32	1.85
150	3.83	37.05	63.72	1.76
SEm ±	0.09			
CD (P=0.05)	0.26			

Sole groundnut vs rest was significant

Table 6. Direct and residual effect of nitrogen on N uptake (kg/ha) in wheat and cropping system, and soil N status

Treatment	N uptake in wheat		N uptake in cropping system		Soil N status	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
<i>Cropping system</i>						
Sole cotton	64.6	71.9	229.9	171.9	187.4	181.3
Cotton + Groundnut (1:3)	70.3	76.6	320.4	251.6	188.5	182.3
SEm ±	1.1	0.6	16.2	9.4	4.6	4.5
CD (P=0.05)	3.3	1.9	48.3	28.3	NS	NS
Sole groundnut	85.9	89.2	185.5	212.1	227.4	220.6
<i>N dose (kg/ha) and source (% fertilizer N-% FYM N)</i>						
Control (0-0)	63.1	65.2	176.6	147.2	154.9	151.4
150 (100-0)	69.0	74.1	270.3	229.2	182.8	176.0
150 (75-25)	69.3	75.9	373.7	265.7	200.8	194.1
150 (50-50)	74.8	81.8	280.0	204.9	213.3	205.7
SEm ±	1.6	0.9	22.8	13.3	6.5	6.5
CD (P=0.05)	4.6	2.6	68.3	40.0	19.6	19.4
<i>N applied to wheat (kg/ha)</i>						
0	53.7	56.1	223.7	188.7	196.5	190.3
50	74.1	81.4	246.3	214.1	196.5	190.3
100	86.5	90.8	256.4	223.5	201.2	195.0
150	84.5	88.5	254.6	221.2	210.1	203.4
SEm ±	1.7	2.3	2.1	2.2	1.6	1.6
CD (P=0.05)	4.9	6.3	5.9	6.3	4.6	4.6

*Sole groundnut vs. rest was significant

the highest in unfertilized treatment (64.0 kg/ha) and the least in 50% RDN substituted through FYM (7.5 kg/ha). The build up of soil N could be ascribed to slower mineralization of FYM N and also reduced losses of fertilizer and mineralized N through leaching and runoff (Table 6).

Direct effect of nitrogen

In wheat, application of 100 kg N/ha being at par with 150 kg N/ha gave significantly higher CEY of the system than 50 kg N/ha. However, based on net returns and B:C ratio, 100 kg N/ha was found to be the best (Table 5). Total N uptake in cotton-wheat system was significantly higher with each successive increase in N rate to wheat up to 100 kg/ha. This could be attributed to the fact that added nitrogen to soil increased the availability of N to plants, which, in turn, might have promoted shoot and root growth and thereby achieving greater absorption of N from soil. Total N uptake by sole groundnut-wheat sequence was not significantly affected by direct N rates applied to wheat (Table 6).

It was concluded that 50% of RDN substitution in cotton + groundnut through FYM followed by wheat receiving 100 kg N/ha was the best integrated N management from production and soil fertility aspects.

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