

TOTAL PRODUCTIVITY, NUTRIENT UPTAKE AND ECONOMICS OF RICE-WHEAT CROPPING SYSTEM AS INFLUENCED BY *Crotalaria juncea* GREEN MANURING

H.K.Patro*¹, Ajay Kumar², D. K. Shukla³ and B. S.Mahapatra⁴

1. AICRP on Groundnut, OUAT, Bhubaneswar (INDIA)
2. Agronomy, KVK Gaina Aincholi, Pithoragarh, Uttaranchal (INDIA)
3. Agronomist Fertilizer Association of India, New Delhi (INDIA)
4. Central Jute and Allied Fiber Research Institute, Barrackpore, West Bengal (INDIA)

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ABSTRACT

A field experiment was conducted in 2001-2002 and 2002-2003 on the Mollisols of the crop Research Station at Pantnagar University to find out the effect of green manuring of Sun hemp (*Crotalaria juncea*) on total productivity, nutrient removal and economics of rice-wheat cropping system. The experiment was conducted in split-split plot design keeping green manuring stages in main plot, levels of nitrogen to rice in sub plot and levels of nitrogen to wheat crop in sub-sub plot. Application of 150 kg N/ha to rice resulted in yield of 6385 and 6521 in 2001-02 and 2002-03, respectively. The wheat yield due to *Crotalaria juncea* green manuring was 3792 and 3818 in 2001-02 and 2002-03, respectively. Integrated application of *Crotalaria juncea* green manuring and 150kg N/ha to rice and to succeeding wheat crop gave a production of 12.87 and 12.77 tonnes /ha from rice-wheat sequence during 2001-02 and 2002-03 respectively. At this production level and fertilizer use, total removal of 246 kg N/ha, 45.1 kg P/ha and 275.5 kg K/ha was recorded by rice-wheat system. The same treatment also gave highest net return (Rs 49746 and 50852), and benefit: cost ratio (2.132 and 2.139) in 2001-2002 and 2002-03 respectively.

Key Words : Productivity, *Crotalaria juncea*, Rice-wheat, Nutrient uptake, Economics.

INTRODUCTION

Rice and wheat combinedly contribute 77 per cent, of which rice-wheat cropping system shares 29% of national food grain production¹. Over the years there has been stagnation or decline in yield of rice and wheat in rice-wheat cropping system and one of the factors responsible is declining soil fertility, especially the soil organic matter. In rice-wheat system there is noticeable decrease in growth of factor productivity of fertilizers and therefore farmers are forced to increase the rate of fertilizer application to obtain the yield similar to those in earlier years. In this context, low input sustainable agriculture practices such as green

*Author for correspondence

manuring, recycling of crop residues and animal manures are important. Since these practices cannot meet the total nutrient needs of modern agriculture, integrated use of nutrients from fertilizers and organic sources seems to more appropriate.

The green biomass potential, dry matter accumulation and nitrogen contribution of *Crotalaria juncea* has been reported to be higher than traditionally grown *Sesbania aculeata*^{2,4}. The 60 days old crop accumulates about 170 kg N, 20 kg P and 130 kg K/ha⁸.

AIMS AND OBJECTIVES

The total research work was based on the primary data collected through the observation in the

respective laboratory. However some secondary database work has also been done. The aims of present study is to generate information for sustainable yield of rice-wheat system through integrated nitrogen management.

MATERIAL AND METHODS

The experiment was carried out in C-3 block of Crop Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar during 2001-02 and 2002-03. The soil of the experimental plot was classified as Beni silty clay loam under the order mollisol, having pH 7.3, organic carbon 0.805%, available nitrogen 238 kg/ha, total nitrogen 0.089 %, available phosphorus 19.9 kg/ha, available potassium 150 kg/ha, and soil microbial biomass nitrogen 21.0 kg/ha. The experiment was laid out in a split-split plot design keeping *Crotalaria juncea* green manuring in main plot, level of nitrogen applied to rice in sub-plot and level of nitrogen to wheat in sub-sub-plot with three replications during both the years. Three main plots included *Crotalaria juncea* incorporated at 45 days after sowing and 60 days after sowing and control (no green manure application). The three sub plots had 3 levels of nitrogen applied to rice crop (0, 75, 150 kg/ha) and three sub-sub plots also had three levels of nitrogen (0, 75, 150 kg/ha) applied to wheat crop. In all, there were 9 main plots of 14 m x 11 m for green manure crop, 27 sub-plots of 4 m x 11 m for rice crop and 81 sub-sub plots of 4 m x 3 m size for wheat crop. The treatments were replicated thrice.

Crotalaria juncea green manure crop which was incorporated at 60 days stage was sown on 1st May during both the years and *Crotalaria juncea* crop incorporated at 45 days stage was sown on 15 May during both the years. Nitrogen to rice crop was applied in 3 splits (50% at planting, 25% at tillering and 25% at panicle initiation stage) and to wheat crop in two splits (50% at sowing and 50% after first irrigation) Phosphorus @60 kg/ha and Potassium @ 40 kg/ha was applied as basal to both the crops. Seedlings of 20 day old 'Pant Dhan-4' rice were transplanted on 1st July during both the years at a spacing of 20x15 cm. Wheat variety UP-2338 was sown on 14th Nov in 2001-

02 and on 16th Nov in 2002-03 in lines 23 cm apart with 100 kg seed rate. For calculation of agronomic nitrogen use efficiency, apparent nitrogen use efficiency and production efficiency, plots with no application of nitrogen of the respective treatments were taken as control.

RESULTS AND DISCUSSION

Green and dry matter accumulation and nutrients added by green manure

Crotalaria at 60 days stage accumulated higher green biomass and dry matter as compared to *Crotalaria* at 45 days stage. The green biomass production of shoots of 60 day old *Crotalaria* was 33.5 and 35.2 tonnes/ha in 2001-02 and 2002-03 respectively, and dry matter accumulation by shoots of 60 day old *Crotalaria* was 6.63 and 7.04 tonnes/ha in 2001-02 and 2002-03 respectively (**Table 1**). The nitrogen content of 45 days old crop were higher as compared to 60 days old crop. The nitrogen accumulation by *Crotalaria* at 45 days stage was 106 and 112 kg/ha in 2001-02 and 2002-03 respectively, while 60 days old *Crotalaria* accumulated 162 and 177 kg nitrogen/ha in 2001-02 and 2002-03 respectively.

Rice yield attributing character and yield

The *Crotalaria juncea* green manuring at 60 days after sowing (DAS) resulted in significant increase in filled spikelets/panicle of rice during both the years compared to the rice grown in summer fallow plots. Application of 75 and 150 kg N/ha to rice crop resulted in successive significant increase in filled spikelets /panicle during both the years. *Crotalaria juncea* green manuring at 60 days (*Crotalaria*-60) resulted in significant increase in 1000 grain weight during both the years of experimentation. Application of 150 kg N/ha being at par with 75 kg N/ha resulted in significant increase in 1000 grain weight in 2001-02, whereas in 2002-03 levels of nitrogen had no significant differences on 1000 grain weight. Similar increase in yield attributing character due to incorporation of green manure has been reported^{1,5}.

Rice grain yield was maximum in *Crotalaria*-60 days after sowing (DAS) and minimum with summer fallow during both the years. *Crotalaria juncea* incorporated at 60 days resulted in 5.74

Table 1 : Biomass production, nutrient content and nutrient accumulation of *Crotalaria juncea* green manure crop at the time of incorporation

	Crotalaria at 45 days stage		Crotalaria at 60 days stage	
	2001-02	2002-03	2001-02	2002-03
Green Biomass (t/ha)	20.5	21.6	33.5	35.2
Dry matter accumulation (t/ha)	3.78	3.92	6.63	7.04
Nitrogen content (%)	2.81	2.86	2.44	2.51
Phosphorus content (%)	0.29	0.30	0.29	0.30
Potassium content (%)	1.84	1.85	1.86	1.88
Nitrogen accumulation (kg/ha)	106.2	112.1	161.8	176.7
Phosphorus accumulation (kg/ha)	10.9	11.8	19.2	21.1
Potassium accumulation (kg/ha)	69.55	72.5	123.3	132.9

tonnes/ha of rice yield which was higher by 1.09, 2.12 tonnes/ha in 2001-02 and 0.76, 1.87 tonnes/ha during 2002-03 over *Crotalaria juncea* incorporated at 45 days and summer fallow respectively (**Table 2**). This was due to extended supply of available nitrogen and higher available nitrogen status in the soil. Per cent increase in grain yield due to 75 and 150 kg N/ha over control was 48.7 and 108.3 during 2001-2002 and 48.3 and 106.9 during 2001-2002, respectively. The integrated supply of nitrogen through green manure and fertilizer nitrogen leads to higher grain yield, similar findings of increase in grain yield has been reported⁵.

Rice straw yield with *Crotalaria*-60 was significantly higher as compared to *Crotalaria*-45 and fallow treatments during both the years. Per cent increase in straw yield due to *Crotalaria*-60 green manure was 13.7 and 34.7 in 2001-2002 and 9.1 and 37.4 in 2002-2003 over *Crotalaria*-45 and fallow, respectively (**Table 2**). The major effect of green manure is due to its nitrogen contribution, organic matter addition and availability of nutrients other than nitrogen.

Wheat grain yield

Wheat grain yield was maximum in *Crotalaria* green manured plots and minimum in fallow plots

during both the years (**Table 2**). Per cent increase in grain yield of wheat due to *Crotalaria*-60 over *Crotalaria*-45 and fallow treatments, were 15.4 and 38.8 in 2001-2002 and 11.0 and 34.5 in 2002-2003, respectively. Similar response due to residual effect of green manuring to wheat yield was to the tune of 11.6 and 10.6 per cent in sandy soil of Ludhiana and clay loam soil at Pantnagar respectively were observed.^{1,4}

Increasing levels of nitrogen to rice up to 150 kg N/ha brought significant improvement in wheat grain yield during both the years. Application of 75 and 150 kg N/ha to wheat crop showed an increase in grain yield of wheat by 36.8 and 106.2 per cent during 2001-2002; and 44.6 and 105.7 per cent during 2002-2003 over control, respectively. Response to per kg of nitrogen applied at 75 and 150 kg N/ha level was 10.9 and 20.5 kg grain during 2001-2002, and 13.3 and 18.3 kg grain during 2002-2003, respectively.

Grain production in rice-wheat system

Total grain production in rice-wheat cropping system was significantly influenced by *Crotalaria* green manure applied to rice and nitrogen levels applied to both rice and wheat during both the years. Green manuring of *Crotalaria* after 60 days after sowing (DAS) recorded the highest

Table 2 : Yield attributing characters of rice, and grain and straw yield of rice and wheat as influenced by *Crotalaria* green manuring

<i>Crotalaria juncea</i> green manuring	Filled Spiklets/panicle (Rice)		1000 Grain weight (g) (Rice)		Rice Grain Yield (kg/ha)		Rice Straw Yield (kg/ha)		Wheat Grain Yield (kg/ha)		Wheat Straw Yield (kg/ha)	
	01-02	02-03	01-02	02-03	01-02	02-03	01-02	02-03	01-02	02-03	01-02	02-03
No green manuring (Fallow)	82.1	86.5	29.34	29.39	3618	3785	5599	5587	2732	2839	3748	3926
45 DAS	91.9	101.0	29.85	30.25	4648	4895	6633	7038	3285	3439	4300	4559
60 DAS	100.1	104.8	30.35	30.94	5743	5663	7542	7678	3792	3818	4784	5035
SEM ±	1.79	2.75	0.21	0.37	73	94	155	59	34.4	61.7	21.8	51.4
CD (5%)	6.99	10.75	0.82	1.44	285	368	607	232	134.6	241.4	83.3	200.8
N levels to Rice (kg/ha)												
0	78.7	82.9	28.37	29.36	3065	3151	5051	5204	2997	30.71	3911	4177
75	92.4	99.4	29.93	30.31	4538	4672	6580	6785	3245	3306	4212	4390
150	103.0	110.0	31.25	31.91	6385	6521	8143	8315	3567	3719	4711	4955
SEM ±	1.76	2.14	0.27	0.88	79	59	74	106	46.6	23.1	35.3	53.5
CD (5%)	5.41	6.59	0.82	NS	244	181	229	326	143.4	71.3	108.9	164.8
N Levels to wheat (kg/ha)												
0	-	-	-	-	-	-	-	-	2214	2242	3114	3312
75	-	-	-	-	-	-	-	-	3029	3241	4138	4467
150	-	-	-	-	-	-	-	-	4565	4614	5581	5742
SEM ±	-	-	-	-	-	-	-	-	48.8	52.4	30.1	53.6
CD (5%)	-	-	-	-	-	-	-	-	140.1	156.4	86.2	153.6

total grain production during both the years which was significantly higher than *Crotalaria*-45 and fallow treatment (**Table 3**). Successive nitrogen levels applied to wheat significantly increased the total grain production in rice-wheat system up to 150 kg N /ha during both the years. The highest grain production of 128.74 q/ ha in 2001-2002 and 127.76 q/ ha during 2002-2003 was recorded with *Crotalaria*-60 along with 150 kg N /ha applied to rice and wheat in the sequence, followed by grain production of 108.81 q/ha in 2001-02 and 112.6 q/ ha in 2002-023 with *Crotalaria*-45 along with 150 kg N/ha to rice and to wheat in sequence The fallow treatment with 150kg N /ha to rice and wheat resulted in total grain production of 98.3q/ ha and 102.97 q/ ha¹ during 2001-2002 and 2002-2003, respectively. Similar level of productivity in

rice-wheat system has been reported¹⁰.

Agronomic nitrogen use efficiency, apparent nitrogen recovery and production efficiency of rice crop

In fallow treatment higher agronomic nitrogen use efficiency was recorded with 150 kg N/ha as compared to 75 kg/ha (**Fig. 1**). Highest nitrogen use efficiency of 26.0 and 26.5 per cent in 2001-02 and 2002-03 respectively, was observed in the rice crop grown with *Crotalaria*-60 green manure + 75 kg N/ha. The highest apparent nitrogen recovery of the applied nitrogen in rice was recorded with *Crotalaria*-60 with 75 kg N/ha during both the years. In general, the apparent nitrogen recovery was higher when green manure was applied to rice over summer fallow treatment.

Table 3: Total grain production by rice-wheat cropping system as influenced by *Crotalaria* green manuring and fertilizer nitrogen to rice and wheat crop

Treatments to Rice	N Levels to Wheat (kg/ha)					
	2001-2002			2002-2003		
	0	75	150	0	75	150
Fallow	35.78	42.32	60.38	37.32	44.74	62.7
Fallow +N-75	48.45	55.47	74.03	50.12	57.17	75.58
fallow+N-150	73.83	81.91	98.3	77.82	87.81	102.97
Mean (fallow)	52.69	59.90	77.57	55.09	63.24	80.42
<i>Crotalaria</i> -45	54.08	58.93	77.07	55.42	63.87	77.83
<i>Crotalaria</i> -45 +N-75	69.64	74.01	91.21	72.19	80.26	95.64
<i>Crotalaria</i> -45 +N-150	84.70	95.52	108.81	88.60	102.28	112.6
Mean (<i>Crotalaria</i> -45)	69.47	76.15	92.36	72.07	82.14	95.36
<i>Crotalaria</i> -60	64.20	68.83	84.0	63.37	71.24	83.48
<i>Crotalaria</i> -60 +N-75	84.48	97.41	107.58	84.52	94.33	106.87
<i>Crotalaria</i> -60 +N-150	104.37	118.5	128.75	102.72	119.0	127.76
Mean (<i>Crotalaria</i> -60)	84.35	94.91	106.77	83.54	94.86	106.04
Mean (N to rice)	60.62	78.03	98.41	62.22	79.63	102.39
Mean (N to wheat)	68.84	76.99	91.23	70.23	80.08	93.94

	Green Manuring (M)		N to Rice (S)		N to Wheat (SS)		M*S*SS	
	01-02	02-03	01-02	02-03	01-02	02-03	01-02	02-03
SEm	0.94	1.43	1.24	0.69	0.81	0.54	1.69	1.03
CD(5%)	3.68	5.59	3.83	2.13	2.34	1.55	NS	NS

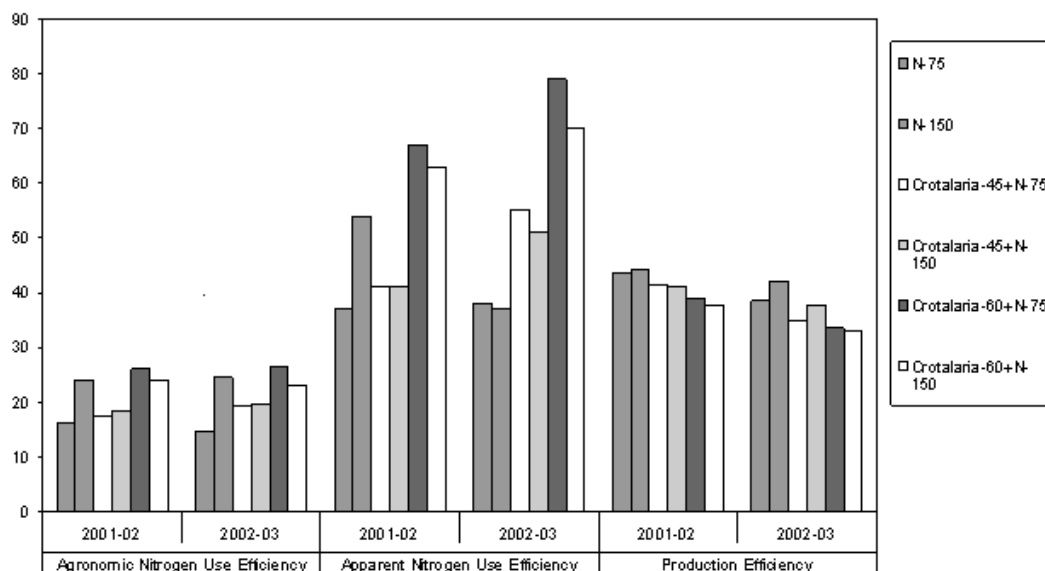


Fig. 1 : Agronomic nitrogen use efficiency, apparent nitrogen use efficiency and production efficiency of rice as influenced by *Crotalaria* green manuring and fertilizer nitrogen

The maximum production efficiency was recorded with 150 kg N/ha applied to rice crop in fallow treatment. Among green manure stages *Crotalaria*-45 with 75 or 150 kg N/ha recorded higher production efficiency over *Crotalaria*-60 green manure stage with 75 or 150 kg N/ha. Agronomic nitrogen use efficiency, apparent nitrogen recovery and production efficiency of wheat crop.

The highest agronomic nitrogen use efficiency of 18.84 during 2001-02 and 21.71 during 2002-03 was recorded with *Crotalaria*-60, followed by 150 kg N/ha to rice and 75 kg N/ha to wheat. Higher Agronomic nitrogen use efficiency was recorded in green manure plots with 75 kg N/ha during 2002-03 as compared to 2001-02, this was due to residual effect of first year green manure (Table 4). The highest apparent nitrogen use efficiency of 60.12 and 71.16 was recorded with the treatment *Crotalaria* -60 and 150 kg N/ha to rice and 75 kg N/ha to wheat in 2001-02 and 2002-03 respectively. Application of green manure before rice crop resulted in higher nitrogen use efficiency because of residual effect of green manure on wheat crop. The maximum production efficiency of 48.58 and 48.03 in 2001-02 and 2002-03 respectively was recorded with 75 kg N/ha applied to wheat in summer fallow plots where no nitrogen was applied to rice, during both the years^{8,9}.

Total nutrient (N + P + K) uptake by rice wheat system

Total nutrient uptake during 2002-2003 was higher than 2001-2002. Total nutrient uptake was significantly influenced by *Crotalaria* green manure and also by nitrogen levels applied to both rice as well as to wheat during both the years.

Crotalaria-60 at 0, 75 and 150 kg N/ha to wheat removed (253.3, 221.5, 290.2 and 274.3, 311.4, 307.8) kg more nutrients over fallow during 2001-2002 and 2002-2003, respectively and was significantly higher than *Crotalaria*-45 and fallow treatments (Table 5). Application of green manure along with 150 kg N/ha to rice and wheat in sequence resulted in 770.2 and 800.8 kg/ha removal of N+P+K by the rice-wheat sequence in 2001-02 and 2002-03 respectively. Scientist also reported the similar uptake of N+P+K in *Sesbania* green manure – rice -wheat cropping system⁹.

Nutrient balance after two years crop cycle

The initial value on total nitrogen, available nitrogen, available phosphorus and available potassium in 0-20 cm soil depth was 2004 kg/ha, 238 kg/ha, 19.9 kg/ha and 150.0 kg/ha respectively. Total nitrogen had a net gain of 23 kg/ha and 70 kg/ha due to application of *Crotalaria* -45 and *Crotalaria*-60 green manure respectively (Table 6). Application of 75 and 150

Table 4 : Agronomic nitrogen use efficiency, apparent nitrogen use efficiency and production efficiency of wheat as influenced by *Crotalaria* green manuring and fertilizer nitrogen Total nutrient (N + P + K) uptake by rice-wheat system

Treatments to Rice	Agronomic nitrogen use efficiency (kg grain /kg N applied)		Apparent Nitrogen Use Efficiency		Production efficiency	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
F - N0 - N75	8.71	9.9	17.93	20.61	48.58	48.03
F - N0 - N150	16.4	16.92	41.92	44.48	39.12	38.05
F - N75 - N75	9.36	9.42	20.38	22.09	45.91	42.63
F - N75 - N150	17.06	16.98	44.06	46.65	38.71	36.4
F - N150 - N75	10.77	13.33	36.38	43.73	29.61	30.49
F - N150 - N150	16.98	16.77	51.05	52.46	33.26	31.91
C45 - N0 - N75	6.46	11.27	16.18	26.71	39.94	42.18
C45 - N0 - N150	15.32	14.94	41.94	43.31	36.53	34.51
C45 - N75 - N75	5.82	12.53	15.91	31.44	36.59	39.86
C45 - N75 - N150	14.38	15.63	39.41	48.3	36.48	32.37
C45 - N150 - N75	14.42	18.24	47.6	62.84	30.3	29.02
C45 - N150 - N150	16.07	16	51.94	56.64	30.94	28.25
C60 - N0 - N75	6.17	10.5	18.04	28.75	34.22	36.51
C60 - N0 - N150	13.2	13.41	39.34	43.15	33.55	31.07
C60 - N75 - N75	17.24	13.08	45.15	36.9	38.18	35.45
C60 - N75 - N150	15.4	14.9	48.19	49.91	31.96	29.86
C60 - N150 - N75	18.84	21.71	60.12	71.16	31.34	30.5
C60 - N150 - N150	16.24	16.69	56.81	61.06	28.59	27.33

Table 5 : Total N+P+K uptake by rice -wheat system as influenced by *crotalaria* green manuring and fertilizer nitrogen to rice and wheat crop

Treatments to Rice	N Levels to Wheat (kg/ha)					
	Total N+P+K uptake by rice-wheat (kg/ha)					
	2001-02			2002-03		
	0	75	150	0	75	150
Fallow	180.5	289.2	327.5	185.1	224.7	334.8
Fallow +N-75	257.2	299.5	420.9	264.7	310.0	434.6
fallow +N-150	381.7	445.4	564.1	400.3	474.2	549.5
Mean (fallow)	273.1	344.7	437.5	283.3	336.3	439.6
<i>Crotalaria</i> -45	264.4	301.9	415.2	279.7	332.9	433.2
<i>Crotalaria</i> -45 +N-75	355.9	395.8	513.9	382.9	444.8	561.6
<i>Crotalaria</i> -45 +N-150	437.7	523.5	634.9	470.3	577.4	673.1
Mean (<i>Crotalaria</i> -45)	352.7	407.1	521.3	377.6	451.7	555.9
<i>Crotalaria</i> -60	317.2	358.9	465.5	331.4	384.2	480.6
<i>Crotalaria</i> -60 +N-75	428.7	514.6	617.5	459.6	526.5	646.5
<i>Crotalaria</i> -60 +N-150	555.6	656.7	770.2	587.3	697.7	800.8
Mean (<i>Crotalaria</i> -60)	433.8	510.7	617.7	459.4	536.1	642.6
Mean (N to rice)	324.5	422.7	552.2	331.8	447.9	581.1
Mean (N to wheat)	353.2	420.8	525.5	373.4	441.3	546.1

	Green Manuring (M)		N to Rice (S)		N to Wheat (SS)		M*S*SS	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
SEm	5.67	6.34	5.90	5.19	3.10	3.22	5.40	6.91
CD (5%)	18.92	24.80	20.40	15.99	9.03	9.25	NS	NS

Table 6 : Balance sheet of total soil nitrogen, soil available N, P and K as influenced by *Crotalaria* green manuring and nitrogen fertilization under rice-wheat cropping system after two years (0-20 cm)

Treatments	Total N (kg ha ⁻¹)		Available N (kg ha ⁻¹)		Available P (kg ha ⁻¹)		Available K(kg ha ⁻¹)	
	Final status	Net gain or loss	Final status	Net gain or loss	Final status	Net gain or loss	Final status	Net gain or loss
Green Manuring								
Initial value	2004	-	238	-	19.89	-	150	-
Fallow	1970	-34	206.7	-31.3	19.71	-0.18	137.5	-12.5
<i>Crotalaria</i> -45	2027	23	235.7	-2.3	20.96	1.07	151.9	1.9
<i>Crotalaria</i> -60	2074	70	257.2	19.2	21.87	1.98	174.3	24.3
Nitrogen levels to rice (kg ha⁻¹)								
0	1981	-23	225.6	-12.4	20.18	0.29	150.4	0.4
75	2021	17	233.7	-4.3	20.53	0.64	154.7	4.7
150	2069	65	240.4	2.4	20.83	0.94	158.7	8.7
Nitrogen levels to wheat (kg ha⁻¹)								
0	1953	-51	206.3	-31.7	19.68	-0.21	143.6	-6.4
75	2016	12	226.3	-11.7	20.99	1.10	154.3	-4.3
150	2102	98	267.1	29.1	21.87	1.98	165.8	15.8

kg N/ha also resulted in positive balance of total nitrogen after two year crop cycle. The available nitrogen showed net gain with the application of 60 days old *Crotalaria juncea* green manure and 150 kg N/ha to rice and wheat. Available phosphorus balance was positive with *Crotalaria*-45 and *Crotalaria*-60 green manure and with 0,75 and 150 kg N/ha to rice and 75 and 150 kg N/ha to wheat. Available potassium balance was positive with green manure and 0, 75, 150 kg N/ha application to rice, but in wheat crop application of 150 kg N/ha resulted in net gain of 15.8 kg/ha in available potassium.

Economics studies

Net return : Net return from rice crop increased with increasing nitrogen levels up to 150 kg/ ha applied to rice and wheat during both the years. Annual net gain from rice-wheat system was in order of *Crotalaria*-60 > *Crotalaria*-45 > fallow during both the years (**Table 7**). Highest net return of Rs 49746 in 2001-2002 and Rs 50852 in 2002-2003 was obtained from rice-wheat system with

Crotalaria-60 along with 150 kg N/ ha to rice and 150 kg N /ha to wheat in the system, followed by *Crotalaria*-60 incorporation to rice along with 150 kg N /ha to rice and 75 kg N/ ha applied to wheat during both the years. The fallow plots with no nitrogen application recorded the lowest net return of 1853 and 2997 Rs/ha/yr during 2001-02 and 2002-03 respectively.

Benefit : cost ratio

Benefit-cost ratio increased with increasing nitrogen levels up to 150 kg/ha to rice along with green manure during both the years (**Table 7**). Increasing level of nitrogen up to 150 kg/ ha to rice and 150 kg/ ha to wheat increased the benefit-cost ratio for rice-wheat system during both the years. The highest annual benefit-cost ratio of 2.132 and 2.139 in 2001-2002 and 2002-2003, respectively from rice-wheat system was with *Crotalaria*-60 green manure incorporation with 150 kg N/ ha applied to rice and wheat during both the years. The lowest B:C ratio of 0.100 and

Table 7 : Net return and benefit cost ratio of rice wheat cropping system as influenced by *Crotalaria juncea* green manuring and fertilizer nitrogen management

Treatment to Rice	Nitrogen to Wheat Kg/ha											
	Net Return (Rs/ha)						Benefit :Cost Ratio					
	2001-02			2002-03			201-02			2002-03		
	0	75	150	0	75	150	0	75	150	0	75	150
Fallow (F)	1853	5167	15625	2997	6931	17506	0.100	0.268	0.781	0.159	0.355	0.865
F + 75 Kg N/ha	7870	11482	22260	9423	13137	23989	0.408	0.574	1.073	0.483	0.649	1.143
F + 150 Kg N/ha	20721	24991	35032	24080	29640	38451	1.036	1.205	1.631	1.189	1.412	1.769
<i>Crotalaria</i> -45	10494	12761	23262	11605	16188	24243	0.523	0.633	1.114	0.564	0.759	1.099
C-45 +75 Kg N/ha	18229	20198	30122	20265	25447	33558	0.876	0.937	1.351	0.951	1.154	1.473
C-45 +150 Kg N/ha	25513	31482	38981	28679	36559	42319	1.184	1.412	1.692	0.301	1.604	1.798
<i>Crotalaria</i> -60	15930	18060	26726	16038	20256	27227	0.782	0.855	1.223	0.770	0.939	1.221
C-60 +75 Kg N/ha	26002	33279	38844	27031	32471	39631	1.231	1.523	1.719	1.254	1.456	1.720
C-60 +150 Kg N/ha	36123	44143	49746	36563	46079	50852	1.653	1.954	2.132	1.639	2.005	2.139

0.159 was recorded in fallow treatment with no nitrogen application to rice and wheat.

CONCLUSION

Application of 150 kg N/ha to rice resulted in yield of 6385 and 6521 in 2001-02 and 2002-03, respectively. The wheat yield due to *Crotalaria juncea* green manuring was 3792 and 3818 in 2001-02 and 2002-03, respectively. Integrated application of *Crotalaria juncea* green manuring and 150kg N/ha to rice and to succeeding wheat crop gave a production of 12.87 and 12.77 tonnes /ha from rice –wheat sequence during 2001-02 and 2002-03 respectively. At this production level and fertilizer use, total removal of 246 kg N/ha, 45.1 kg P/ha and 275.5 kg K/ha was recorded by rice-wheat system. The same treatment also gave highest net return (Rs 49746 and 50852), and benefit: cost ratio (2.132 and 2.139) in 2001-2002 and 2002-03 respectively.

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