Indian Journal of Agronomy **49** (2) : 84–88 (June 2004)

Alley cropping of *subabul* (*Leucaena leucocephala*) for sustaining higher crop productivity and soil fertility of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system in semi-arid conditions

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Received : December 2002

ABSTRACT

A field experiment was conducted during 1992–93 to 1998–99 on sandy-loam soil (Typic Ustochrept) in semi-arid conditions, to evaluate the production potential of rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) system in sole and alley cropping with *subabul* (*Leucaena leucocephala*) under integrated nitrogen supply system. In alley cropped rice–wheat system, loppings of *L. leucocephala* incorporated @ 6 tonnes/ha/year in the soil as green manure before rice and wheat planting added approximately 80 kg organic nitrogen/ha/year to system which replaced 25% mineral fertilizer N. Increasing levels of nitrogen enhanced grain yield of rice and wheat significantly up to 90 kg N/ha, beyond which increase was marginal and non-significant. Further, association of *L. leucocephala* reduced grain yield of rice and wheat by 9.9 and 5.5% compared to sole cropping of rice and wheat respectively. In addition to this, *L. leucocephala* also provided 6–7 tonnes/ha/year green fodder and 5–6 tonnes/ha/year fuel wood and resulted in net saving of Rs 6,539/ha/year at 90 kg N/ha. Green manuring of *L. leucocephala* decreased the pH of soil from 8.74 to 8.43 and bulk density from 1.70 to 1.50 g/cc and soil organic carbon by 39.10, nitrogen content by 24.10, available P_2O_5 by 13.40, available K_2O by 18.40 and infiltration rate by 38.20% under alley cropping, but a slight change in these soil characteristics was also observed under sole cropping of rice–wheat system.

Key words : Alley cropping, *Leuceana leucocephala*, Crop productivity, Soil fertility, Rice–wheat system

Rice–wheat cropping system is practised over a variety of soil and climate with wide range of input use and management. Rice and wheat are exhaustive feeders of nutrients. A system yielding 7 tonnes/ha rice and 4 tonnes/ha wheat may remove as much as 316 kg N, 64 kg P_2O_5 and 401 kg K_2O, apart from significant amounts of different secondary and micronutrients (Hegde and Dwivedi, 1992). *L. leucocephala* a multi-purpose tree can be integrated with rice–wheat cropping sequence to develop food-based fodder and fuel system. Integrating such system has good scope in soil-fertility management for sustainable productivity, particularly in nutrient-deficient areas. Alley cropping of *L. leucocephala* with other crops involves nitrogen fixation which helps in building soil fertility through litter fall, fixation of atmospheric nitrogen and recycling the nutrients from lower soil layer to surface soil. It also provides biomass that can be used either as fodder or green manure to enhance crop yields. However, there is no literature on alley cropping in rice–wheat cropping system in India. Therefore the present study was designed to evaluate production potential of upland rice–wheat cropping system and soil-fertility build up with and without alley cropping of *L. leucocephala.*

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of Project Directorate for Cropping Systems Research, Modipuram, Meerut, Uttar Pradesh (29°4' N and 77°46' E, 237 m above sea-level) from 1992–93 to 1998–99. The average rainfall of Meerut is 810 mm. The soil was sandy loam (Typic Ustochrept), alkaline (pH 8.50), low in organic carbon (0.23%), medium in available P_2O_5 (50.61 kg/ha) and low in available K_2O (102.2 kg/ha). The experiment was laid out in randomized block design with 6 treatments with 4 replications. Six treatments were: (*i*) pure cropping of rice–wheat system without *L. leucocephala* with N, P and K in 120:60:40, (*ii*) alley cropping with N, P and K in 0:60:40, (*iii*) alley cropping with N, P and K in 30:60:40, (*iv*) alley cropping with N, P and K in 60:40:40, (*v*) alley cropping with N, P and K in 90:60:40 and (*vi*) alley cropping with N, P and K in 120:60:40. The graded levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) were applied. The uniform dose of 60 kg P_2O_5/ha and 40 kg K_2O/ha was applied in both the crops of rice and wheat. In alley cropping system, upland rice was grown in the rainy season followed by wheat in the winter season between 2 hedge rows (5 m apart) of *L. leucocephala*. The side branches of *L. leucocephala* lopped at an interval of 30 days to maintain desirable height of *L. leucocephala* during the growth period of intercrops and pruning were utilized as green fodder. The lopping of *L. leucocephala* were incorporated @ 6 tonnes/ha/year into the soil before 20 days of planting of rice and wheat. The hedge rows of *L. leucocephala* were lopped as and when to restrict its height up to 1 m. Leaves of *L. leucocephala* were incorporated as green-manure, containing 4.2% nitrogen, 0.8% phosphorus and 1.4% potassium. In vacant area of inter-spaces of the trees, direct seeding of rice ('Saket 4') and wheat ('HD 2329') were done 20 cm apart using 100 kg seed/ha of each crop. Each year upland rice was planted in the last week of June and harvested in October, whereas wheat was shown in November and harvested in the last week of April. The N, P and K were applied through urea, single superphosphate and murite of potash respectively. Whole amount of P and K was applied basal and nitrogen was applied in 2 equal splits at tillering and panicle initiation of rice and at first irrigation and tillering stage in wheat. Irrigation and plant-protection measures were adopted as per the need of the crop. Soil physico-chemical properties were determined by standard procedure.

RESULTS AND DISCUSSION

Crop yield

Rice and wheat yield differed significantly due to nitrogen application during experimentation (Table 1). An increase in nitrogen increased the grain yield of rice and wheat significantly up to 90 kg N/ha, beyond which the increase was marginal and non-significant. This indicates that application of 90 kg N/ha in combination with *L. leucocephala* lopping was sufficient for obtaining higher yields of rice and wheat. The higher yield was attributable to higher number of tillers/m² (582), grains/panicle (81.36) and 1,000-grain weight (21.51) of rice and tillers/m² (375), grains/ear (60.75) and 1,000-grain weight (39.90) of wheat. Further, there was 12.31% and 5.45% reduction in rice and wheat yields, respectively, compared to pure cropping of rice and wheat. This higher reduction in case of rice was mainly due to luxuriant vegetative growth of *L. leucocephala* in rainy season, while *L. leucocephala* remains dormant and does not compete much with wheat crop in winter. Therefore, as compared to reduction in rice yield due to association of *L. leucocephala* there was marginal reduction in wheat yield. Kang *et al.* (1990) also noticed reduction in grain yield of maize in alley cropping with *L. leucocephala* due to shade caused by association of tree species adjacent to maize rows. The average yield of rice and wheat/m row showed significant increasing trend with increase in mean distance from paired row of *L. leucocephala*. The increase in rice and wheat yield was 13.8 and 16.3 g/m row respectively. Linear regression equation was fitted as:

$$Y = a + bx$$

where Y, rice and wheat yield (g/m row); a and b are the constants; and X, distance in m from the hedge row of *L. leucocephala*.

Rice $Y=41.5+14.1x$ ($R^2=0.88$)

Wheat $Y=52.2+15.4x$ ($R^2=0.89$)

Forage yield

The *L. leucocephala* produced significantly higher green matter with application of 60, 90 and 120 kg N/ha as compared to treatment without nitrogen. There was an increasing trend in green matter with the increase in level of nitrogen. However, there was no significant difference among the green matter obtained with 60, 90 and 120 kg N/ha (Table 2). Nitrogen along with *L. leucocephala* pruning increased the green matter yield up to 90 kg N/ha significantly. The improvement at this level over other levels was in turn due to increase in vegetative growth. Owing to poor quality of soil with low organic carbon and nitrogen content, application of N at different levels increased its availability for plant growth. The observation of this investigation is in conformity with those of Korwar and Radder (1997). The *L. leucocephala* gave significantly higher dry-matter yield with more application of N to the soil (Table 2). Further, dry matter was higher in case of 90 and 120 kg N/ha rather than at other levels of application, but there was no significant difference between dry-matter yield at 90 kg and 120 kg/ha. Therefore, application of 90 kg N/ha was as effective as 120 kg/ha during study. The dry-fodder yield differed significantly due to varying N levels up to 90 kg N/ha in individual years. The mean data showed dry matter gain of 4.6%, 10.4%, 15.5% and 18.5% with 30, 60, 90 and 120 kg N/ha over no N application.

Fire wood and crude protein yield

Nitrogen rates influenced the fire wood yield significantly in alley cropping treatment (Table 3). The highest mean fire wood yield (5.88 tonnes/ha) was recorded with 120 kg N/ha, whereas lowest mean fire wood yield (4.35 tonnes/ha) was obtained with no nitrogen. The increase in fire wood yield was non-significant between no nitrogen and 30 kg N/ha, 30 and 60 kg N/ha, 60 and 90 kg N/ha and 90 to 120 kg N/ha. However, significant difference between no nitrogen and 120 kg N/ha was observed in fire wood yield. The mean data showed that fire wood yield of 2.98, 8.49, 23.01 and 35.80% with 120, 90, 60 and 30 kg N/ha over the control. There was increasing trend in protein content over years under different treatments (Table 3). Increase in protein content was 16.2, 101.6, 93.9, 82.3 and 76.3% at 6 year of study. The response to N was seen with the increase in N level up to 120 kg/ha but there was no significant difference among the crude protein yield content of different treatments except that of between 0 and 120 kg N/ha.

Economic analysis

The *L. leucocephala* provided 13–14 tonnes/ha/year

Table 1. Grain yield of rice and wheat under pure and alley cropping

Treatment	Grain yield (tonnes/ha)													
	I		II		III		IV		V		VI		Mean	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Pure cropping	3.50	3.85	3.75	3.88	4.22	4.22	4.27	4.24	4.30	4.50	4.33	4.60	4.06	4.22
Alley cropping + $N_0P_{60}K_{40}$	2.10	1.82	2.25	2.01	2.12	3.01	2.26	3.04	2.62	3.20	2.65	3.35	2.33	2.74
Alley cropping + $N_{30}P_{60}K_{40}$	2.50	2.41	2.65	2.73	2.80	3.45	3.02	3.48	3.24	3.60	3.28	3.70	2.92	3.23
Alley cropping + $N_{60}P_{60}K_{40}$	2.80	2.82	2.90	2.95	3.26	3.68	3.35	3.73	3.43	3.90	3.48	4.00	3.20	3.51
Alley cropping + $N_{90}P_{60}K_{40}$	3.20	3.27	3.35	3.44	3.49	4.04	3.61	4.04	3.85	4.20	3.88	4.35	3.56	3.89
Alley cropping + $N_{120}P_{60}K_{40}$	3.25	3.46	3.38	3.56	3.68	4.11	3.72	4.15	3.94	4.30	3.97	4.40	3.66	3.99
CD (P=0.05)	0.32	0.40	0.34	0.28	0.22	0.33	0.26	0.29	0.17	0.30	0.37	0.32		

Table 2. Forage yield under alley cropping

Treatment	Forage yield (tonnes/ha)													
	I		II		II		IV		V		VI		Mean	
	GM	DM	GM	DM	GM	DM	GM	DM	GM	DM	GM	DM	GM	DM
Alley cropping + $N_0P_{60}K_{40}$	7.65	2.14	10.71	3.20	12.07	3.81	12.40	3.96	13.20	4.40	13.10	4.50	11.52	3.67
Alley cropping +$N_{30}P_{60}K_{40}$	8.02	2.25	11.47	3.43	12.90	3.97	12.90	4.12	14.70	4.60	14.90	4.65	12.48	3.84
Alley cropping +$N_{60}P_{60}K_{40}$	8.74	2.45	12.71	3.78	13.01	4.14	13.50	4.32	15.90	4.75	15.95	4.85	13.29	4.05
Alley cropping +$N_{90}P_{60}K_{40}$	9.86	2.76	12.99	3.89	13.23	4.28	13.70	4.38	16.20	5.00	16.25	5.10	13.71	4.25
Alley cropping +$N_{120}P_{60}K_{40}$	10.54	2.96	13.13	3.93	13.31	4.29	13.80	4.41	16.50	5.20	16.60	5.30	13.98	4.35
CD (P=0.05)	7.25	2.17	2.20	6.50	0.81	0.26	0.82	0.27	0.75	0.30	0.75	0.30		

GM, Green matter; DM, dry matter

Table 3. Fire wood (tonnes/ha) and crude protein yield (tonnes/ha) under alley cropping

Treatment	Year													
	I		II		III		IV		V		VI		Mean	
	Fire wood	Crude protein	Fire wood	Crude protein	Fire wood	Crude protein	Fire wood	Crude protein	Fire wood	Crude protein	Fire wood	Crude protein	Fire wood	Crude protein
Alley cropping+$N_0P_{60}K_{40}$	2.22	13.38	4.30	20.00	4.80	23.81	5.12	24.75	4.80	27.50	4.85	27.58	4.35	22.84
Alley cropping+$N_{30}P_{60}K_{40}$	2.36	14.06	4.87	21.44	5.11	24.81	5.45	25.75	5.40	28.75	5.50	28.85	4.78	23.95
Alley cropping+$N_{60}P_{60}K_{40}$	2.51	15.31	5.42	23.69	5.60	25.88	6.10	27.00	6.40	29.69	6.50	29.79	5.42	25.23
Alley cropping+$N_{90}P_{60}K_{40}$	3.17	17.25	5.55	24.31	5.77	26.75	6.28	27.38	6.70	31.25	6.78	31.45	5.71	26.40
Alley cropping+$N_{120}P_{60}K_{40}$	3.35	18.50	5.70	24.56	6.01	26.80	6.35	27.56	6.40	32.50	6.98	32.60	5.88	27.09
CD (P=0.05)	2.31	8.56	1.03	13.25	0.41	12.75	0.43	13.05	0.50	11.25	0.50	8.71		

green fodder and 5–6 tonnes/ha/year fire wood and resulted in net saving of Rs 24,042 and Rs 25,046/ha year due to application of N at 90 and 120 kg N/ha over pure cropping of rice–wheat system (Table 4). The return analysis showed that incorporation of *L. leucocephala* as alley cropping in rice–wheat system would be a financially sound strategy by rendering superior returns compared to pure cropping of rice–wheat sequence.

Changes in physical and chemical properties of soil

Soil physical and chemical analyses carried out after third and sixth year of experiment under different alley cropping treatments as affected by nitrogen fertilization (Table 5) indicated that under alley cropping, pH of soil decreased from 8.74 to 8.43 and to 8.16 and electrical conductivity from 0.60 to 0.52 and to 0.49 dS/m respectively. This decrease in soil pH was associated with the incorporation of green levels of *L. leucocephala* into soil which on their decomposition produce carbondioxide which ultimately combines with water and turn into carbonic acid. This carbonic acid possibly decreases pH of the soil. There was considerable increase in organic carbon with the level of increase in nitrogen application along with green manuring of *L. leucocephala*. There was overall 30.40 and 39.10% increase in organic carbon after third and sixth year over the initial value. The mean data of 2 periods (third and sixth year) showed that total nitrogen in soil was higher than initial value by 24.10 and 20.70% respectively. Similarly, available P_2O_5 and K_2O were higher than initial level in soil. The mean data of third and sixth year revealed that available P_2O_5 was higher than initial value by 31.60 and 38.40%. Similarly, available K_2O was higher than initial value by 13.40 and 13.90% respectively. However, slight change in these soil properties was also recorded under pure cropping. The increase in soil organic carbon and nitrogen was due to the addition of organic material through the incorporation of *L. leucocephala* leaves and also due to litter fall. Korwar and Radder (1997) and Singh and Lal (1969) also observed that under *Prosopis cineraria* soil had higher content of organic matter, total nitrogen, available P and available K compared to that of under open field conditions. Bulk density decreased from 1.70 to 1.55 and thereafter to 1.50 g/cc during third and sixth the year of experiment respectively. Bulk density

Table 4. Mean yield of rice, wheat, forage, fuel wood and net returns under pure and alley cropping

Treatment	Grain yield (tonnes/ha)		Green fodder (tonnes/ha)	Fuel wood (tonnes/ha)	Net returns (Rs/ha)
	Rice	Wheat			
Sole crop $N_{120}P_{60}K_{40}$	4.06	4.22			17,824
Alley cropping + $N_0P_{60}K_{40}$	2.33	2.74	11.52	4.35	13,251
Alley cropping + $N_{30}P_{60}K_{40}$	2.92	3.23	12.48	4.78	17,943
Alley cropping + $N_{60}P_{60}K_{40}$	3.20	3.51	13.29	5.42	20,923
Alley cropping + $N_{90}P_{60}K_{40}$	3.56	3.89	13.71	5.71	24,042
Alley cropping + $N_{120}P_{60}K_{40}$	3.66	3.99	13.98	5.88	25,046

Table 5. Physico-chemical changes in soil under pure and alley cropping with *Leucaena lecocephala* after 3 and 6 years

Treatment	pH	EC (dS/m)	Organic C (%)	Total N (%)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Bulk density (g/cc)	Infiltration rate (mm/hr)
			After 3 years					
Pure cropping	8.65	0.60	0.26	0.072	26.2	110.21	1.60	1.65
Alley cropping + $N_0P_{60}K_{40}$	8.54	0.56	0.27	0.061	26.50	111.50	1.58	1.29
Alley cropping + $N_{30}P_{60}K_{40}$	8.41	0.53	0.30	0.063	27.13	112.51	1.56	2.15
Alley cropping + $N_{60}P_{60}K_{40}$	8.42	0.52	0.30	0.070	27.49	113.30	1.55	2.19
Alley cropping + $N_{90}P_{60}K_{40}$	8.40	0.51	0.32	0.075	29.59	115.90	1.54	2.25
Alley cropping + $N_{120}P_{60}K_{40}$	8.41	0.48	0.33	0.078	30.60	116.50	1.53	2.30
			After 6 years					
Pure cropping	8.52	0.57	0.27	0.074	27.20	112.20	1.58	1.69
Alley cropping + $N_0P_{60}K_{40}$	8.45	0.54	0.29	0.064	27.60	113.50	1.53	2.31
Alley cropping + $N_{30}P_{60}K_{40}$	8.40	0.51	0.31	0.066	28.20	114.80	1.55	2.37
Alley cropping + $N_{60}P_{60}K_{40}$	8.36	0.50	0.32	0.072	28.80	115.20	1.52	2.33
Alley cropping + $N_{90}P_{60}K_{40}$	8.31	0.48	0.34	0.078	30.50	117.80	1.53	2.37
Alley cropping + $N_{120}P_{60}K_{40}$	8.25	0.47	0.35	0.081	31.80	118.20	1.54	2.39
Initial value	8.74	0.60	0.23	0.058	22.10	102.20	1.70	0.62

decreased due to *L. leucocephala* leaves incorporation into the soil improved soil texture and overall soil physical conditions. The mean infiltration rate increase by 270.9 and 179% during third and sixth the year of experiment respectively. Bhattarcharji (1989) found that incorporation of leaf litter of *L. leucocephala* into the soil, significantly improved the organic matter content and cation-exchange capacity of the soil which in turn increased per cent of water-stable aggregates, moisture retention capacity of the soil and soil water diffusivity.

Thus, alley cropping with *L. leucocephala* is advantageous in semi-arid conditions of India. On the other hand, inclusion of *L. leucocephala* hedges on cropland adversely affected crop yield but not to the level of significance. Alley cropping of *L. leucocephala* in upland rice–wheat sequence, pruning of *L. leucocephala* incorporated @ 6 tonnes/ha/year into soil as green manure before rice and wheat planting added approximately 80 kg organic nitrogen/ha/year which can replace 25% mineral fertilizer nitrogen and proved to be more remunerative than pure cropping of rice–wheat in term of green manuring, fodder and fuel wood. Further, alley cropping of rice–wheat sequence with *L. leucocephala* was not only found economical but also beneficial in improving and sustaining crop and soil productivity on long-term basis.

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