Indian Journal of Agricultural Sciences **84** (6): 695–701, June 2014/Article

Sustainability of maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system under legumes intercropping and effect of nitrogen level on light distribution, soil temperature and crop productivity

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Received: 11 May 2012; Revised accepted: 26 March 2014

ABSTRACT

Agriculture designs for cropping system with legume intercropping for increased resource use efficiency profitability, productivity and reduced adverse environmental impact are urgently required. A three years field experiment consisting of six cropping treatments applied during both seasons was conducted during 2008-09 to 2010-11 to study the effect of nitrogen and legumes intercropping with maize (*Zea mays* L.) for sustainability of maize-wheat (*Triticum aestivum* L.) cropping system. Results indicate that the photosynthetic active radiation had highest values at noon reaching nearly 1940 µmol/m^2/s for maize and 1620 µmol/m^2/s for intercropped legumes.Intercropping can increase light interception, shading and reduce water evaporation as compared to sole maize.Maize intercropped had higher values of stomatal condutance and leaf temperature than sole crop.The grain yield and yield attributing characters of wheat crop increased significantly under intercropping treatments over respective check. Wheat yield significantly increased up to 160 kg N/ha. However, there was no significant increase in yield of maize beyond 120 kg N/ha.Sole maize-wheat rotation showed a decline in soil organic carbon by 3.7%,while blackgram and cowpea intercropping with maize in paired rows (2:2 row ratio) followed by wheat increased contents of per cent organic carbon in soil as 0.63 and 0.67 respectively,compared to initial values of 0.54 per cent.Plots treated with intercrops/FYM during the rainy season sustained the wheat yield while the check plot showed a decline in wheat yield by 4-9%.

Key words: Crop productivity, Intercropping, Soil temperature, Sustainability

Traditionally soil fertility was maintained through the application of farmyard manure. Manure was largely produced from weeds, crop residue and fodder trees that were fed to tethered animals.Currently farmyard manure is still the primary source of nutrients for maize (*Zea mays* L.) fields, though the use of fertilizers is growing in importance. Since farmers apply all of the manure that they have available on their farms, it is the increased use of fertilizer that is likely to enable increases in maize production in the future. The agricultural scientists has identified chemical fertilizer as major contributing factor for accelerating agricultural growth and has considered it as one of the priority inputs. Fertilizer application per unit area in maize cultivation is lower than in other crops for two reasons. First, most of the maize is produced in the rainy season where transportation of fertilizer is costly. Second, most of the farmers there are subsistent farmers who often do not have cash required to buy expensive fertilizer.Multiple cropping (i.e. intercropping or mixed cropping) plays an important role in agriculture because of the effective utilization of resources, significantly enhancing crop productivity compared with that of monoculture crops (Li *et al.* 1999). Introduction of a grain legume in cereal-based cropping system aims at increased productivity and profitability to achieve food and nutritional security and sustainability (Swaminathan 1998). Intercropping is widely accepted as a sustainable practice due to its yield advantage, high utilization efficiency of light and water, pest and disease suppression (Zhu *et al.* 2000). In the intercrop the degree of resource complementarily, the total yield and the participation of yield between the individual species is determined by both inter- and intraspecific competition, which again is influenced by the availability of environmental resources, the relative frequency of the species and the density of components (Hauggaard *et al.*, 2006). However, the

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intercropped species might utilize the growth resources more efficiently than sole crops, and resources may thus support a greater number of plants. A number of mechanisms exist by which intercrops utilize plant growth resources such as light, water and nutrients more efficiently than the equivalent sole crops (Anil *et al.* 1998).

Human efforts to produce ever-greater amounts of food leave their mark on our environment. Persistent use of conventional farming practices based on extensive tillage, and especially when combined with *in situ* burning of crop residues, have magnified soil erosion losses and the soil resource base has been steadily degraded (Montgomery 2007). Now a days, people have come to understand that agriculture should not only be high yielding, but also sustainable (Naresh *et al.* 2011). Farmers concerned about the environmental sustainability of their crop production systems combined with ever-increasing production costs have begun to adopt and adapt improved management practices which lead towards the ultimate vision of sustainable conservation agriculture. Conservation agriculture addresses a concept of the complete agricultural system, combining three basic principles (1) reduction in tillage, (2) retention of adequate levels of crop residues and surface cover of the soil surface and (3) use of economically viable crop rotations. These conservation agriculture principles are applicable to a wide range of crop production systems. Obviously, specific and compatible management components will need to be identified through adaptive research with active farmer involvement for contrasting agro-climatic production systems.The objective of the study was to identify the effect of nitrogen and legumes intercropping with maize for sustainability of maize-wheat (*Triticum aestivum* L.) cropping system.

MATERIALS AND METHODS

An experiment was conducted for maize-wheat system with legume intercropping in farmers participatory mode in the jurisdiction of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (Uttar Pradesh), India, during 2008-09 to 2010-11.Treatments included: Sole maize (60cm), wheat check grown with FYM @ 10 tonnes/ha, maize intercropped with blackgram/cowpea in paired rows (30/90 cm) in 2:2 row ratio, normal planted maize (60 cm) intercropped in 1:1 row ratio with pigeonpea/blackgram with pure stand of maize as checked under irrigated condition followed by wheat during *rabi* season with three nitrogen levels (80,120 and 160 kg N/ha), applied to maize as well as to wheat.The climate of the area is semi-arid, with an average annual rainfall of 805 mm (75–80% of which is received during July to September), minimum temperature of 4°C in January, maximum temperature of 41 to 45°C in June, and relative humidity of 67 to 83% throughout the year.In general the soils of the experimental sites was sandy loam soil in texture with medium fertility status (86.5, sand, 9.2, silt and 4.3% clay) with p^H 7.4 and had 0.54% organic carbon at the time of initiation of study.Maize and intercrop were sown simultaneously during the I^{st} fourth night of June in each of the three years. Intercropping treatments were randomly allocated to main plots and N levels to subplots to evaluate treatments in split plot design. Nitrogen as per treatment and a uniform dose of P_2O_5 @60 kg/ha to all the treatments were applied through urea and single super phosphate, respectively. 1/3 nitrogen along with full dose of phosphorus was applied as basal while remaining nitrogen was equally top dressed at knee high and tesseling stages. During *rabi* season wheat crop was sown during the II^{nd} fourth night of November in each of the three years.

At maturity, seed and stover/straw samples were analyzed for total N to determine the N uptake. After completion of three sequences, soil samples were analyzed for total N to calculate N-fixation and N balance. Contribution of atmospheric nitrogen through legumes was computed by monitoring the changes in total nitrogen as well as that removed by the crop sequences by using the equation:

NF=NR-NA+N/number of leguminous crops

where, NF, Nitrogen fixed by legume crop (kg/ha); N, change in total N +addition depletion of N in soil (kg/ha); NR, total N removed by sequence (kg/ha); NA, total N applied through fertilizer or manure (kg/ha).

Soil moisture dynamics were studied during every years in all treatments,using TDR probes (three replications per treatment) that measured depth segments (0–20).The measurement system for the TDR used are based upon a cable tester (Tektronix 1502C) coupled to a handheld computer (Husky FS/2) (Thomsen 1994). Soil water content during the growing period was calculated for all treatments.The soil layer above thermometers was used to record soil temperatures.The thermometers were buried in the soil horizontally (at 20 cm depth), between two plants in each of the maize and intercrop rows in a middle row.The measurement of temperature afternoon was made on relatively clear days.

The fraction of PAR intercepted was calculated by taking ten readings in rapid succession above the canopy and ten readings below the canopy at the soil surface using a Ceptometer.The soil surface measurements were taken by placing the ceptometer at right angles to the plant rows.Stomatal conductance and leaf transpiration were measured with a portable photosynthesis system (LI-6000, LICOR,USA).Measurements were made on the flag leaf for maize and on the central mature leaflet for legume crops.

RESULTS AND DISCUSSION

Photosynthetic active radiation (PAR)

A characteristic pattern of light interception was found for each cropping systems.There was significant difference in light interception between the maize pure stands compared to the legume intercrop. In light interception by the maize-wheat monoculture increased linearly, reaching around 80% interception for light above ground and for water is less than in many other intercropping systems.The study showed that maize-wheat intercropping systems had significantly higher energy gain (more radiation intercepted) than pure crop systems.Lower PAR values were observed in Fig 1 in intercropped legumes indicating significant interception by maize leaves during the morning because of planting techniques.The greatest variation between systems occurred at 10 h and 16 h when about 960 μmol/m²/s and 610 μmol/m²/s were intercepted.The highest values were recorded at noon reaching nearly 1940 μmol/m²/s for maize and 1620 μmol/m²/s for intercropped legumes. However, 1°C decreases in canopy temperature in intercropped canopy between 8 h and 10 h was observed. The highest canopy temperature and vapour pressure deficit were recorded in maize in the afternoon showing high evapotranspiration conditions during the experimentation. Maize stomatal conductance and leaf transpiration were also positively affected by intercropping. Between 12 h and 16 h values recorded were significantly higher for maize intercropping than for sole crop and highest differences were computed at 14 h when stomatal conductance and leaf transpiration of intercropped were 0.218 mol/m²/s and 7.09 m mol/m²/s, respectively.In the sole system these variables reached 0.110 mol/m²/s and 5.17 m mol/m²/s.

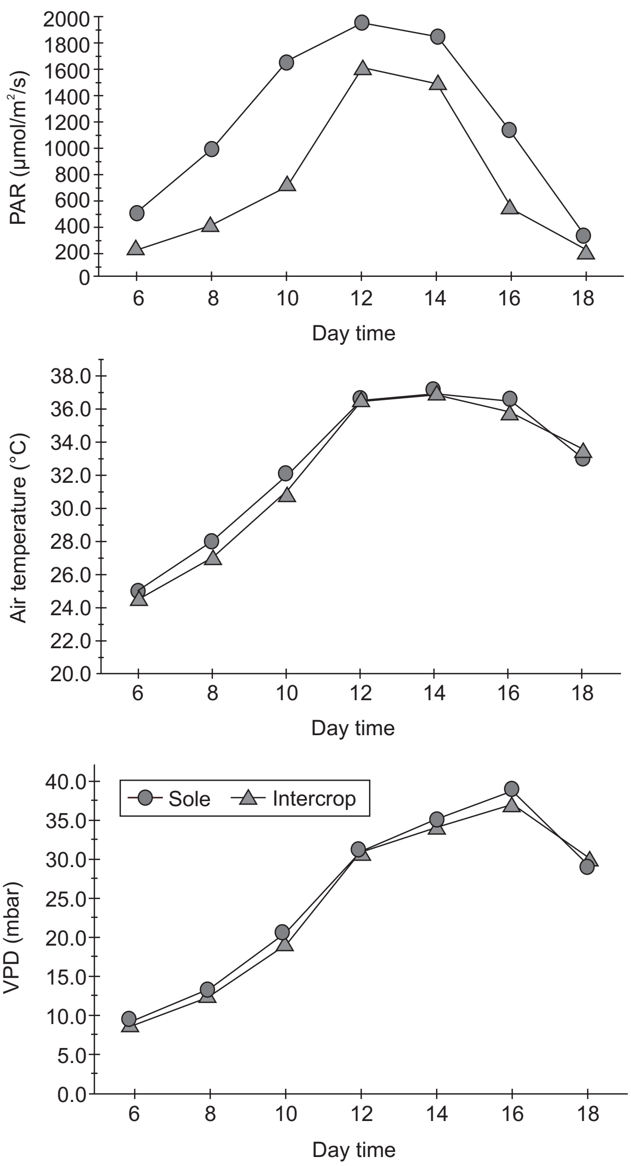

Fig 1 Diurnal fluctuation on photosynthetic active radition (PAR), air temperature (T) and vapour pressure deficit (VPD) in maize and legumes intercropped

Soil moisture content

Soil moisture content in the soil was reduced dramatically in the sole crop of maize due to high evapotranspiration potential; on the contrary soil moisture content in the soil was increased dramatically in the legume intercropping due to low evapotranspiration potential for growth period (Fig 2).However, comparing maize SC and legume intercropping, the patterns of soil water distribution in the soil profiles differed supporting the null hypothesis.Legume intercropping provided better soil cover compared to sole maize,so water evaporation at soil surface was low and soil moisture high compared to sole maize. Distribution of root systems among species and cropping system influenced the water content down the soil profile.Comparing the soil water content of the soil layer the maize + cowpea intercropping tended to display the lowest differences followed by maize + pigeonpea and the highest difference followed by maize+blackgram, showing intermediate and greater differences.The measured soil water contents in the sole maize system were lower than those in the intercropping systems.In intercropping system water uptake from soil surface layers increased due to increased root density in the upper layers, thus decreasing water dissipated by evaporation.

Growth and yield parameters

Various intercropping treatments did vary significantly the growth parameters of maize, namely plant height and drymater accumulation at 90 DAS (g/plant). These parameters also vary significantly with successive increase in nitrogen levels from 80-160 kg N/ha. Mean data for plant height (Table 1) reveals that plant height increased by 8.2 and 14.1% at 80 and 160 kg N/ha respectively, measured

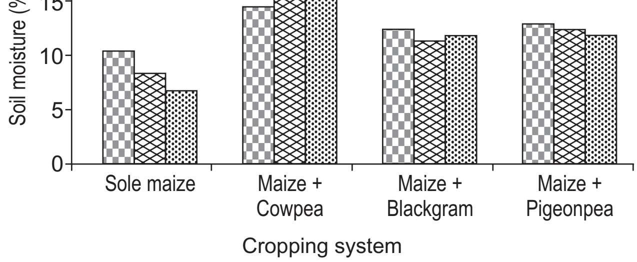

Fig 2 Variation of soil moisture (SM) at different cropping systems.

Table 1 Growth and yield attributing characters of maize as affected by legume intercropping and N levels

Intercropping treatment	Growth and yield attributes											
	Plant height (cm) at harvest				Dry matter at 90 DAS (g/plant)				Shelling %			
	08-09	09-10	10-11	Mean	08-09	09-10	10-11	Mean	08-09	09-10	10-11	Mean
T_1 Sole maize (60 cm narrow beds)- wheat (check)	260.7	258.3	269.8	262.9	120.7	116.4	123.6	120.2	74.1	73.9	72.3	73.4
T_2 Sole maize (60 cm narrow beds with FYM @ 10 t/ha-wheat	277.9	271.2	276.3	275.1	132.7	128.9	136.2	132.6	71.8	72.9	73.6	72.8
T_3 Maize+blackgram paired row in 2:2 row ratio (30/90 cm wide beds)-wheat	253.7	249.6	267.4	256.9	106.2	112.7	119.4	112.8	71.7	73.2	72.8	72.6
T_4 Maize+ cowpea paired row in 2:2 row ratio (30/90 cm wide beds) –wheat	251.6	257.9	258.3	255.9	98.7	114.3	121.6	111.5	73.1	72.6	72.9	72.9
T_5 Maize + pigeonpea alternate rows in 1:1 row ratio (30/30 cm flat beds) – wheat	248.7	253.5	256.7	253.0	118.5	123.4	126.8	122.9	72.3	71.8	72.6	72.2
T_6 Maize + blackgram alternate rows in 1:1 row ratio (30/30 cm flat beds) – wheat	242.2	251.8	257.6	250.5	92.3	109.6	117.9	106.6	71.3	72.6	72.3	72.1
CD (P=0.05)	6.8	9.3	8.6		3.2	5.8	4.7		NS	NS	NS	
Nitrogen levels (kg/ha)												
80	229.7	240.3	249.2	239.7	95.2	103.5	108.4	102.4	71.2	71.5	70.8	71.2
120	254.1	265.4	267.9	262.5	109.3	123.4	127.7	120.1	72.3	73.4	72.8	72.8
160	267.3	274.1	271.6	271.0	112.6	128.6	131.5	124.2	72.4	73.7	73.2	73.1
CD (P=0.05)	3.4	4.09	2.41		3.6	6.11	3.84		0.73	0.69	0.58	

Table 2 Yield attributing characters of wheat as affected by legume intercropping and N level

Intercropping treatment	Yield attributes											
	Spikelets/spike				Number of grains/spike				1000- Grain weight in (g)			
	08-09	09-10	10-11	Mean	08-09	09-10	10-11	Mean	08-09	09-10	10-11	Mean
T_1 Sole maize (60 cm narrow beds)- wheat (check)	11.7	11.4	12.3	11.8	42.6	43.9	44.6	43.7	35.7	36.6	37.8	36.7
T_2 Sole maize (60 cm narrow beds with FYM @ 10 t/ha-wheat	12.8	12.1	13.6	12.8	44.7	45.3	45.8	45.3	36.1	38.3	36.7	37.0
T_3 Maize+blackgram paired row in 2:2 row ratio (30/90 cm wide beds)-wheat	14.3	14.7	15.6	14.9	52.6	53.1	55.3	53.7	41.3	42.7	42.4	42.1
T_4 Maize + cowpea paired row in 2:2 row ratio (30/90 cm wide beds)-wheat	14.8	15.3	16.4	15.5	53.8	54.1	56.6	54.8	42.7	41.9	42.6	42.4
T_5 Maize + pigeonpea alternate rows in 1:1 row ratio (30/30 cm flat beds) – wheat	13.2	13.8	14.6	13.9	48.7	51.0	53.4	51.0	41.3	41.6	42.4	41.8
T_6 Maize +blackgram alternate rows in 1:1 row ratio (30/30 cm flat beds) – wheat	11.9	12.3	12.8	12.3	48.5	49.0	52.5	50.0	39.5	40.8	41.3	40.5
CD (P=0.05)	1.08	1.27	0.93		4.06	6.59	4.35		0.94	1.29	1.65	
Nitrogen levels (kg/ha)												
80	11.1	13.3	13.2	12.5	31.3	36.2	39.7	35.7	35.3	36.8	36.4	36.2
120	13.4	14.7	15.5	14.5	50.6	51.5	52.8	51.6	41.3	42.5	42.8	42.2
160	14.8	15.2	16.4	15.5	52.7	53.4	56.3	54.1	42.9	43.2	43.7	43.3
CD (P=0.05)	1.54	0.65	0.97		2.61	2.11	3.84		2.06	1.52	1.44	

under lowest level of nitrogen (80 kg N/ha).During all the three years, dry matter produced at 90 DAS was maximum at 160 kg N/ha but remained at par with that accumulated at the preceding level of 120 kg N/ha. Mean data for drymatter accumulation at 90 DAS indicated that dry matter increased by 14.7 and 17.6% at 120 and 160 kg N / ha,respectively over the least dry matter of 102.4 g/plant obtained under 80 kg N/ha (Table 1).

Intercropping treatments applied during rainy season brought out significant variation in spikelets per spike in succeeding wheat crop.Spikelets per spike obtained in the plot treated either with FYM or intercrops were significantly superior to that obtained under check plots during respective years (Table 2). Mean data for spikelets per spike calculated for three years indicated that maximum spikelets per spike of 16.4 were counted in the treatment when the crop was raised in the plot where maize+cowpea intercropping was completed, resulting in increase tillers by 3.48%,compared to the check plot (11.8 spikelets/spike).During all the three years, increasing levels of nitrogen significantly increased the spikelets per spike till up to 120 kg N/ha. Mean data for spikelets per spike (Table 2) revealed that they increased by 13.8 and 19.4% at 120 and 160 N/ha, respectively, over the least spikelets (12.5 per spike) counted at 80 kg nitrogen level. Shelling % of maize remained unaffected due to different intercropping treatments in all the three years (Table 2). However, the shelling % of maize significantly improved with increasing levels of nitrogen during all three years of the study. Mean data for shelling % (Table 1) revealed that shelling % was improved by 2.20 and 2.60 at 120 and 160 kg N/ha, respectively, over that calculated under 80 kg nitrogen level (71.20).Different intercropping treatments applied in rainy season brought out significant variation in number of grains per spike and 1000 grain weight in wheat during the year's of study.

The number of grains/spike and 1000 grain weight gradually reduced from 56.6 to 42.6 and 42.6 g to 35.7 g, respectively, during initial and final years of study in the check plot where sole maize during rainy season was raised. While in the case of intercropping treatments, numbers of grains/spike and 1000 grain weight under different intercropping treatments were significantly superior over check plot but were at par during the third year of study.Increasing level of nitrogen significantly increased

Table 3 Grain yield and net monetary returns and soil organic carbon of maize-wheat cropping system as affected by legume intercropping and N levels

Intercropping treatment	Grain yield (q/ha)								B:C ratio	O.C. %
	Maize and intercrops				Wheat					
	08-09	09-10	10-11	Mean	08-09	09-10	10-11	Mean		
T_1 Sole maize (60 cm narrow beds)-wheat (check)	39.13	40.05	40.95	40.04	37.82	36.12	34.46	36.13	1.92	0.52
T_2 Sole maize (60 cm narrow beds with FYM @ 10 t/ha-wheat	42.60	43.45	45.60	43.88	40.35	40.19	41.40	40.65	1.87	0.58
T_3 Maize+blackgram paired row in 2:2 row ratio (30/90 cm wide beds)-wheat	41.85 (2.85)*	42.75 (3.85)*	43.15 (4.45)*	42.58 (3.72)	39.64	38.00	37.90	38.51	2.03	0.63
T_4 Maize+ cowpea paired row in 2:2 row ratio (30/90 cm wide beds)-wheat	40.42 (3.65)*	41.40 (4.35)*	42.65 (5.25)*	41.49 (4.42)	37.95	39.10	38.35	38.47	2.01	0.67
T_5 Maize + pigeonpea alternate rows in 1:1 row ratio (30/30 cm flat beds) – wheat	34.50 (3.24)*	36.65 (4.45)*	37.60 (5.80)*	36.25 (4.49)	38.45	38.30	37.75	38.17	1.98	0.51
T_6 Maize +blackgram alternate rows in 1:1 row ratio (30/30 cm flat beds) – wheat	38.46 (2.82)*	39.35 (3.75)*	40.85 (5.65)*	39.55 (4.07)	39.40	38.30	37.20	38.30	1.96	0.61
CD (P=0.05)	2.54	2.08	3.15		1.92	2.16	2.35			0.049
Nitrogen levels (kg/ha)										
80	24.60 (2.60)	27.35 (2.95)	28.20 (3.15)	26.72 (2.90)	28.25	35.20	32.15	31.87	1.83	0.56
120	40.35 (3.85)	41.85 (4.25)	42.45 (4.85)	41.55 (4.32)	42.80	38.95	39.85	40.53	1.99	0.59
160	41.35 (3.60)	42.80 (4.45)	43.75 (4.95)	42.63 (4.33)	45.80	41.15	41.65	42.87	2.08	0.61
CD (P=0.05)	1.65	2.82	3.73		2.14	2.32	2.23			NS 0.54**

*Figure in parentheses indicate yield of intercrops, **Initial value.

the grains/spike and 1000-grain weight up to 120 kg N/ ha.On mean basis, grains/spike increased by 30.8 and 34.0% at 120 and 160 kg N/ha, respectively, over that observed (35.7 grains) under initial level of nitrogen.Similarly, 1000 grain weight were increased by 14.2 and 16.4% at 120 and 160 kg N /ha, compared with those counted (36.2) at initial nitrogen level.

Yield and economic analysis

Maize yield was significantly affected by different intercropping treatments, where pigeonpea intercropping in contrast to pure stand of maize reduced the maize yield significantly.However, the grain yield of subsequent wheat crop was significantly increased due to different intercropping treatments applied to maize. During the first year of study, wheat yields obtained under the plots treated with FYM (40.35 q/ha) or intercropped with blackgram in 2:2 row ratios (39.64 q/ha) produced significantly superior yield compared to check plot (37.82 q/ha).During the following years, the check plot showed a gradual decline in wheat yield by 4.49 and 8.89 percent, respectively, during 2009-10 and 2010-11.During these years, wheat yields obtained under the plots either treated with FYM or intercrops were significantly higher over that of yield obtained under respective check plots.This increase in wheat yield might be attributed to nitrogen benefit to soil due to blackgram and cowpea intercropping.Wheat yield significantly increased up to 160 kg N/ha.However, there was no significant increase in yield of maize beyond 120 kg N/ha (Table 3). B:C ratio analysis indicated that the B:C ratio of 2.03 was calculated when maize in paired rows was intercropped with blackgram in 2:2 row ratios (30/90 cm wide beds), followed by wheat.Cowpea intercropping in a similar fashion was the next best treatment in sustaining productivity of wheat as compared to the check.These results are in conformity with the findings of Shah *et al.* (1991).

Table 4 Balance sheet of total nitrogen in maize + intercrops-wheat cropping system (kg/ha).

Treatment	Nitrogen levels (Kg/ha)	Mean N removed by crops	Soil N at initiation + N added –N removed	Estimated N after cropping (3 years)	Net soil N balance (Kg/ha)
T_1 Maize (narrow beds) - wheat (check)	80	205	1 037	1 218	-56
	120	259	1 176	1 291	+24
	160	298	1 255	1 337	+56
T_2 Maize (narrow beds) with FYM @ 10t/ha-wheat	80	229	1 010	1 206	-47
	120	297	1 137	1 295	+19
	160	367	1 249	1 367	+89
T_3 Maize+black-gram paired rows in 2:2 row ratio (30/90 cm wide beds) -wheat	80	248	1 135	1 287	+16
	120	305	1 205	1 327	+63
	160	348	1 321	1 388	+121
T_4 Maize+cow-pea paired row in 2:2 row ratio (30/90 cm wide beds)-wheat	80	253	1 174	1 304	+43
	120	318	1 216	1 343	+71
	160	353	1 345	1 399	+139
T_5 Maize + pigeonpea alter-nate rows in 1:1 row ratio (30/30 cm flat beds)–wheat	80	247	1 024	1 232	-41
	120	323	1 145	1 301	+47
	160	364	1 299	1 384	+119
T_6 Maize+black-gram alternate rows in 1:1 row ratio (30/30 cm flat beds)–wheat	80	251	1 046	1 240	-23
	120	341	1 129	1 298	+52
	160	378	1 221	1 346	+93

Nutrient studies

Organic carbon contents varied with different inter-cropping treatments (Table 3). After completion of the study the check plot, having pure maize-wheat rotation, showed a decline in soil organic carbon of 3.70%, while blackgram and cowpea intercropping with maize in paired rows in 2:2 row ratio followed by wheat analyzed increased content of organic carbon in soil as 0.63 and 0.67%, respectively, compared to initial values of 0.54%.Total nitrogen content of soil also increased with increasing level of nitrogen (Table 4) in all the intercropping treatments.The highest total nitrogen (1399 kg/ha) was computed under maize + cowpea (paired rows in 2:2 row ratios (30/90cm) wheat treatment with net positive N balance of 139 kg/ha under 160 kg N/ha level.This increase in N availability might be due to the decaying of nodules in legumes.

From the above it can be concluded that there are opportunities for improving the productivity of maize-wheat system with legumes intercropping in the western Uttar Pradesh. Intercropping is the best cropping system because at this system light interception, soil moisture, soil temperature and yield were higher compared to sole crops. Microclimatic variation in intercropping system have caused favourable environmental conditions for growth and high yield compared to sole crops.The legume-maize intercropping exploited more stored water than a sole maize crop; the beneficial effects of the intercropping appeared to greatly compensate the interception and uptake losses near the legume crops canopy. Intercropping improves water relations compared to the sole situations and intercropped maize is more competitive than cowpea in terms of use of resources, mainly soil water.In intercropping system water uptake from soil surface layers increased due to increased root density in the upper layers, thus decreasing water dissipated by evaporation. However, it is evident from the results, that legumes and legume-maize intercropping are more effective in improving soil water retention and decreased evaporation from the soil surface due to shading and increased the amount of water potentially available for transpiration and growth compared to sole maize.

A yield advantage in intercropping is achieved only when components crops do not compete for the same resources over the same time and space.In these experiments, the degree of below ground competition was not determined, so it is only possible to comment upon above ground competition, showing that the sharing of light by the component crops was important for better utilization of resources, resulting in higher productivity of the intercropping system.The maize canopy alone could not utilize all incoming radiation during the growing period, and the remaining solar radiation was captured by the legumes when grown under maize, showing complementarity in use of resources.Maize+blackgram paired row in 2:2 row ratio (30/90 cm wide beds) followed by wheat having a B:C ratio of 2.03 and increased contents of organic carbon in soil as 0.63 percent compared to initial values of 0.54 per cent. Nitrogen balance under different intercropping treatments was worked out.The buildup of soil N (i.e.121 kg N/ha) was obtained under this intercropping treatment.Thus,blackgram intercropping with maize in paired rows in 2:2 row ratios (30/90 cm wide beds) followed by wheat was found to be the most sustainable for semi-arid region of western Uttar Pradesh.

ACKNOWLEDGEMENTS

Financial assistance by the Uttar Pradesh Council of Agricultural Research,Lucknow under the Resource Conservation Technologies for Sustainable Development of Agrculture project is duly acknowledged.

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