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Performance of soybean (*Glycine max*) intercropped with different cereals under varying levels of nitrogen

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ABSTRACT

A field experiment conducted during 2009 and 2010 at the research farm of the Indian Agricultural Research Institute, New Delhi to study the performance of soybean as influenced by the intercropping of cereals, viz. maize (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench.] and pearl millet (*Pennisetum glaucum* L.) with 0, 50, 75 and 100% of their respective recommended dose of N (RDN) levels. In all 12 intercropping systems in 2:1 ratio of soybean+ maize, soybean+sorghum and soybean+pearl millet with 4 levels of RDN to cereal component crops along with sole soybean were carried out in a randomized block designand replicated thrice. The performance of soybean was greatly influenced by the intercrops as well as N levels. The sole crop of soybean recorded higher number of branches, drymatter accumulation, root biomass; leaf area index, crop growth rate and relative growth rate as compared to soybean grown in intercropping systems. Likewise the yield attributes, yield and harvest index were also higher with sole soybean. Among the intercropping systems, soybean+pearl millet had greater negative impact on performance of soybean as compared to soybean+maize and soybean+sorghum system. The increase in N levels to cereal crops in intercropping systems showed negative impact on the growth and yield attributes, and yield of soybean. The 100% RDN to intercropped cereals had the highest negative effect while the control had the least. The highest gross returns, net returns, B: C ratio and soybean equivalent yield (SEY) were observed under soybean+maize intercropping system along with 100% RDN to intercropped maize in both the years of experimentation. Among the intercropping systems, soybean+maize intercropping systems recorded higher returns and SEY than others.

Key words: Cereals, Equivalent yield, Growth parameters, Intercropping, N levels, Soybean

Intercropping systems have several advantages in increasing yield, land use efficiency, efficiency in utilization of natural resources including light, water and nutrients, and in controlling pests and diseases. Location specific intercropping systems shown high resilience and adaptability. As soybean is cultivated in rainfed conditions in India, the degree of its susceptibility to moisture stresses can be overcome by adopting suitable intercropping systems. Several factors can affect growth of the species used in intercropping including cultivar selection, seeding ratios, and competition between components (Carr *et al*. 2004). Intercropping of soybean with cereals like maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench.), pearl millet (*Pennisetum glaucum* L.) etc. offers great scope for minimizing the adverse impact of moisture stress in lean rainfall years as well as excess moisture during high rainfall years (Layek *et al*. 2012). Besides, these crops with their varied morphology are able to exploit the soil and climatic conditions efficiently as compared to their cultivation as sole crops (Mohta and De 1980). The diverse rooting pattern, growth pattern, differences in nutrient requirement, crop duration etc. tend to impart them a certain degree of ability to come up well even under stressed conditions. The soybean being legume and maize, sorghum and pearl millet being cereals complement each other in intercropping systems and minimize the competition for growth factors (Layek *et al.* 2014). However, the soybean being short statured crop as compared to cereals in intercropping system is likely to suffershading effects of cereals. Under such conditions, soybean growth is likely to be hampered resulting in reduced productivity, impaired quality (Maurya and Rathi 2000).

As cereals like maize, sorghum, pearl millet etc. exhibit varied growth pattern, morphology, requirement of growth

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factors etc., their impact on the base crop soybean in intercropping is also likely to be different (Carr *et al*. 2004).The extent of variability of these crops on soybean will be an important indicator in the selection of suitable cereal intercrop in soybean based intercropping system. Further, as cereals require a large amount of N, it is likely that they may draw some quantity of N fixed by the component crop soybean through biological N fixation (BNF) (Senaratne *et al*. 1993). Legumes, with their adaptability to different climatic conditions,cropping patterns and their ability to fix N, may offer opportunities to sustain productivity (Jeyabal and Kuppuswamy 2001). The extent of N drawn also depends on the degree of N made available to the cereal component. Therefore, it is important to know how much N would be sufficient to cereal components to facilitate them to draw biologically fixed N from the component crop soybean with minimal negative impact on soybean. Keeping all these in points in view, a field experiment was envisaged to study the impact of different cereals raised with different levels of N relative to their respective recommended doses on the performance of soybean.

MATERIALS AND METHODS

A field experiment was carried out for two consecutive years during *kharif* seasons *of* 2009 and 2010 at the research farm of Indian Agricultural Research Institute, New Delhi, situated at latitude of 28^0 40" N, longitude of 77^0 12" E and altitude of 228.6 meters above the mean sea level. The mean annual rainfall of Delhi is 650 mm and of which more than 80% is generally received during the south-west monsoon season (July-September) with mean annual evaporation of 850 mm. The soil of the experimental field was sandy loam in nature (Table 1) with low in available N and medium in available P and K. The soil was slightly alkaline in nature (pH 7.8). The treatments consisted of 12 soybean based intercropping systems, viz. soybean+ maize, soybean+sorghum and soybean+pearl millet grown in 2:1 ratio in additive series raised with 4 levels of N, viz. 0, 50, 75 and 100% of recommended dose to cereal crops on area basis along with sole soybean for comparison. The RDN for soybean is 30 kg/ha while those for maize, sorghum, and pearl millet are 120 kg, 120 kg and 80 kg N/ha, respectively. The total 13 treatments were tried in a randomized block designand replicated thrice.

Table 1 Physicochemical properties of the experimental field

Particulars	Values	
Physical properties		
Sand (%)	65.1	
Silt (%)	16.6	
Clay (%)	18.3	
Textural class	Sandy loam	
Chemical properties		
	Year 2009	*Year 2010*
Available N (kg/ha)	272	278
Available P (kg/ha)	14.7	16.1
Available K (kg/ha)	228.3	242.5
pH	7.8	7.8

All the crops were sown during July with the onset of monsoon and raised as per the recommended package of practices. The sole soybean was raised with a uniform inter row spacing of 45 cm, while, in intercropping systems, an uniform 30 cm inter row spacing between two rows of soybean as well as between rows of soybean and intercrop was followed. There was marked difference in the rainfall received during the individual years. In 2009, a total 490 mm spread over fewer rainy days was received while in 2010, a total 750 mm of well distributed rainfall was received during the cropping season. In 2009, crops experienced a drought like situation in the initial weeks of establishment needing several gap fillings. All the growth parameters were recorded at regular interval, while yield parameters and yield were recorded at harvest. Leaf area index (LAI) was measured by a canopy analyzer (Model: LI 1400, USA), while calculations of crop growth rate (CGR) and relative growth rate (RGR) were carried using the formulae of Hunt (1978). Apparent N balance was determined based on the inputs (N added through fertilizer and estimated biological N2 fixation) and outputs (N uptake by soybean + cereal intercropping system) for the intercropping systems and expressed as kg/ha.

The experimental data pertaining to each parameter of study were subjected to statistical analysis by using the technique of analysis of variance (ANOVA) and their significance was tested by "F" test at 0.05 probabilities (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Growth parameters

The growth parameters, viz. plant height, number of branches, drymatter accumulation, leaf area index (LAI), root biomass, number and biomass of nodules were generally higher during the year 2010 as compared to 2009 owing to higher amount and uniform distribution of rainfall (Table 2). In general the plant height of Soybean grown in intercropping systems was higher but number of branches and dry matter accumulation was lower as compared to sole soybean in both the years. Among the intercrops, pearl millet resulted in higher plant height and least number of branches and lower drymatter accumulation of soybean as compared to other cereal intercrops. Among the N levels provided to intercrops, 100% recommended dose of N (RDN) recorded higher plant height of soybean and less number of branches among different intercrops of soybean. The increase in doses of N to intercrops had resulted decrease in drymatter accumulation of soybean. Similar results were observed in both the years of experimentation. The poor soybean growth due to intercropping in additive series was also reported by Maurya and Rathi (2000). The competition for solar radiation resulted increase in plant height of soybean in intercropping systems as compared

Table 2 Growth attributes and physiological indices of soybean as influenced different cereal intercrops with varying levels of N

Treatment	2009						2010					
	Plant height (cm) at harvest	Number of branches/plant at harvest	Dry matter accumulation (g/m^2) at harvest	LAI at 90 DAS	CGR at 60-90 DAS	RGR at 60-90 DAS	Plant height (cm)	Number of branches/ plant	Dry matter accumulation (g/m^2)	LAI at 90 DAS	CGR at 60-90 DAS	RGR at 60-90 DAS
Sole soybean$_{30N}$	42.7	3.33	539.0	2.78	7.03	0.0091	48.7	4.07	676.5	3.18	8.47	0.0081
Soybean$_{30N}$ + maize$_{0N}$	45.7	2.67	434.0	2.05	5.69	0.0086	54.0	3.13	494.5	2.20	6.28	0.0077
Soybean$_{30N}$ + maize$_{30N}$	46.7	2.47	374.8	1.76	5.33	0.0086	56.0	2.87	429.5	1.93	5.83	0.0081
Soybean$_{30N}$ + maize$_{45N}$	46.7	2.40	361.0	1.53	4.93	0.0085	56.3	2.87	425.5	1.73	5.37	0.0079
Soybean$_{30N}$ + maize$_{60N}$	47.0	2.27	358.2	1.50	4.67	0.0082	57.0	2.73	422.7	1.64	4.79	0.0072
Soybean$_{30N}$ + sorghum$_{0N}$	45.7	2.60	418.5	2.04	5.33	0.0079	54.7	3.07	487.0	2.27	6.23	0.0078
Soybean$_{30N}$ + sorghum$_{30N}$	46.0	2.33	361.5	1.68	4.72	0.0078	56.0	2.87	420.5	2.06	5.87	0.0083
Soybean$_{30N}$ + sorghum$_{45N}$	46.3	2.27	352.0	1.57	5.18	0.0074	56.3	2.67	414.5	1.85	5.85	0.0084
Soybean$_{30N}$ + sorghum$_{60N}$	46.3	2.07	349.0	1.58	5.24	0.0067	57.0	2.73	410.0	1.79	5.81	0.0084
Soybean$_{30N}$ + pearlmillet$_{0N}$	45.7	1.93	340.5	1.55	3.06	0.0079	57.3	2.20	383.3	1.79	4.12	0.0068
Soybean$_{30N}$ + pearlmillet$_{20N}$	47.0	1.87	307.0	1.48	3.25	0.0069	58.3	1.93	361.0	1.65	3.83	0.0067
Soybean$_{30N}$ + pearlmillet$_{30N}$	47.7	1.67	306.0	1.42	3.15	0.0067	58.7	1.93	355.5	1.55	3.63	0.0066
Soybean$_{30N}$ + pearlmillet$_{40N}$	48.0	1.67	310.5	1.43	2.87	0.0063	59.3	1.93	354.0	1.60	3.33	0.0062
SEm+	0.9	0.08	11.2	0.07	0.40	0.0004	0.9	0.08	18.4	0.11	0.47	0.0006
LSD (P=0.05)	2.6	0.24	32.6	0.22	1.15	0.0011	2.7	0.24	53.6	0.33	1.38	NS

DAS: Days after sowing, LAI: leaf area index, CGR: crop growth rate, RGR: relative growth rate

to sole soybean. Further, as the competition intensifies the number of branches also tend to be reduced owing to lack of space and reduced availability of resources like nutrients and water (Rathiya and Lakpale 2005).

The soybean in intercropping systems recorded significantly lower LAI and CGR relative to sole crop. The lowest LAI and CGR of soybean were observed due to intercropping with pearl millet followed by sorghum and maize. Increase in levels of N decreased the CGR up to 50% RDN at increasing rate and relatively at slower rate afterwards. In 2009, the highest RGR was observed in sole crop of soybean, while in 2010, all the treatments were found to be at par. When the photosynthates are diverted towards elongation of stem to increase the plant height (etiolation), the primary sources such as leaves needed to enhance the photosynthesis reduced it leading to reduction in LAI. Thus, the leaf area index in soybean in intercropping systems was relatively less as compared to that of sole soybean.

Root and nodule biomass

The root biomass of soybean was at par among different cropping systems and N levels at 30 days after sowing (DAS) in both the years of experimentation (Table 3). At later stages (45 and 60 DAS), the root biomass of soybean was higher in sole crop as compared to its intercropping systems. The nodules biomass increased between 30 and 45 DAS and decreased thereafter in both the years of experimentation. In general sole soybean recorded higher nodule biomass as compared to that of intercropped soybean. Soybean intercropped with pearl millet recorded the least root biomass and nodule biomass as compared to those of other treatments. The increasing N levels decreased the root and nodule biomass differentially with each incremental dose of N. The competition in the rhizosphere for space, moisture and nutrients among the intercrops creates a limitation which decreased the number of nodules and nodule biomass (Akunda 2001).

Yield attributes and yield

The yield parameters, viz. pods/plant, seeds/pod and seed index and yield of soybean were observed to be higher in the year 2010 relative to 2009 (Table 4). The difference in yield parameter between two years could be ascribed to higher and uniform rainfall distribution in 2010 as compared to 2009 which faced drought like situation owing to lesser total rainfall and fewer rainy days.

All the yield parameters were significantly superior in sole soybean as compared to those of soybean in different intercropping systems except for seed index in soybean in 2010 with maize under no N (Table 4). The optimum plant height, higher number of branches/plant, LAI and root biomass ascertained that the sole crop could express its full potential through increased yield parameters. The maize and sorghum being wide spaced as well as non-tillering type had relatively lesser competition to soybean as

Table 3 Root biomass (g/plant) and nodule biomass (mg/plant) of soybean as influenced by different cereal intercrops with varying levels of nitrogen

Treatment	2009						2010					
	Root biomass (g/plant)			Nodule biomass (mg/plant)			Root biomass (g/plant)			Nodule biomass (mg/plant)		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
Sole soybean$_{30N}$	0.56	1.36	2.37	270.4	508.1	406.7	0.61	1.49	2.59	306.1	611.3	451.3
Soybean$_{30N}$ + maize$_{0N}$	0.55	1.19	1.85	264.4	443.4	329.3	0.60	1.29	2.03	295.7	522.3	346.3
Soybean$_{30N}$ + maize$_{30N}$	0.54	1.17	1.82	190.0	390.2	274.3	0.62	1.27	1.91	218.0	447.0	288.0
Soybean$_{30N}$ + maize$_{45N}$	0.54	1.17	1.74	147.4	365.4	242.0	0.57	1.17	1.84	152.8	439.3	271.7
Soybean$_{30N}$ + maize$_{60N}$	0.52	1.13	1.73	133.1	355.2	244.7	0.56	1.16	1.76	150.1	438.7	268.3
Soybean$_{30N}$ + sorghum$_{0N}$	0.56	1.16	1.98	253.7	403.3	308.7	0.61	1.26	2.14	293.0	476.0	332.3
Soybean$_{30N}$ + sorghum$_{30N}$	0.53	1.13	1.77	171.3	351.3	254.3	0.58	1.25	1.92	195.3	417.9	278.0
Soybean$_{30N}$ + sorghum$_{45N}$	0.51	1.07	1.75	128.1	348.8	248.3	0.54	1.06	1.82	143.3	401.2	272.0
Soybean$_{30N}$ + sorghum$_{60N}$	0.52	1.02	1.74	116.8	329.9	243.0	0.53	1.09	1.71	114.7	392.7	266.7
Soybean$_{30N}$ + pearlmillet$_{0N}$	0.54	1.08	1.67	219.3	368.3	255.7	0.58	1.15	1.77	286.7	407.3	279.3
Soybean$_{30N}$ + pearlmillet$_{20N}$	0.51	0.98	1.61	136.4	344.3	238.7	0.56	1.04	1.73	191.7	376.7	262.3
Soybean$_{30N}$ + pearlmillet$_{30N}$	0.50	0.96	1.62	107.4	339.0	230.0	0.52	0.99	1.67	124.4	367.0	253.7
Soybean$_{30N}$ + pearlmillet$_{40N}$	0.49	0.94	1.60	98.9	322.3	219.7	0.53	0.90	1.64	106.8	363.0	221.7
SEm+	0.03	0.05	0.07	6.61	15.84	9.80	0.03	0.08	0.09	8.58	14.68	12.18
LSD (P=0.05)	NS	0.16	0.21	19.28	46.23	28.61	NS	0.23	0.27	25.05	42.84	35.56

DAS: Days after sowing

Table 4 Yield attributes and yield of soybean as influenced by different cereals intercrops with varying levels of N

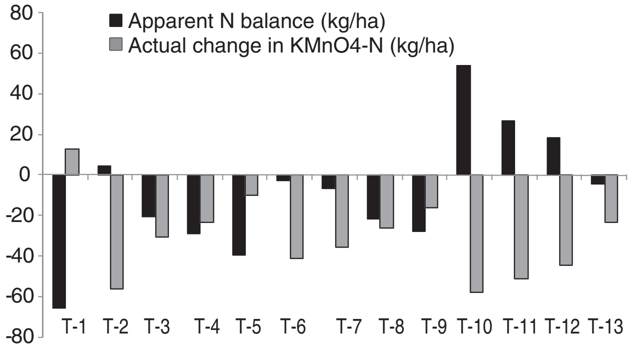
Treatment	2009						2010					
	Pods/ plant	Seeds/ pod	Seed index (g/100 seed)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Pods/ plant	Seeds/ pod	Seed index (g/100 seed)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Sole soybean$_{30N}$	20.1	2.47	11.88	1.31	4.12	31.95	24.3	2.53	12.24	1.85	5.19	35.68
Soybean$_{30N}$ + maize$_{0N}$	17.0	2.23	11.38	1.09	3.83	28.60	20.6	2.37	11.95	1.45	4.46	32.55
Soybean$_{30N}$ + maize$_{30N}$	15.0	2.03	11.09	0.98	3.83	25.89	17.8	2.27	11.37	1.25	4.17	29.96
Soybean$_{30N}$ + maize$_{45N}$	14.6	2.07	10.92	0.95	3.87	24.60	16.6	2.20	11.29	1.22	4.15	29.38
Soybean$_{30N}$ + maize$_{60N}$	14.3	2.10	10.84	0.91	3.73	24.47	15.4	2.23	11.13	1.17	4.00	29.19
Soybean$_{30N}$ + sorghum$_{0N}$	17.1	2.23	10.97	1.01	3.63	28.00	19.8	2.37	11.37	1.38	4.34	31.77
Soybean$_{30N}$ + sorghum$_{30N}$	14.8	2.10	11.11	0.89	3.54	25.29	17.4	2.30	11.38	1.19	3.98	29.91
Soybean$_{30N}$ + sorghum$_{45N}$	14.7	2.10	11.08	0.86	3.57	24.52	16.2	2.23	11.22	1.16	3.83	30.45
Soybean$_{30N}$ + sorghum$_{60N}$	14.3	2.13	11.08	0.82	3.25	25.28	14.1	2.13	11.25	1.14	3.87	29.35
Soybean$_{30N}$ + pearlmillet$_{0N}$	11.7	2.03	11.38	0.65	2.50	26.13	13.0	2.23	11.68	0.83	2.79	29.58
Soybean$_{30N}$ + pearlmillet$_{20N}$	11.0	2.00	11.33	0.62	2.66	23.42	11.2	2.13	11.66	0.80	2.96	27.15
Soybean$_{30N}$ + pearlmillet$_{30N}$	10.8	1.97	11.19	0.58	2.44	23.34	11.1	2.10	11.31	0.78	2.81	27.71
Soybean$_{30N}$ + pearlmillet$_{40N}$	10.7	1.97	10.95	0.56	2.44	23.20	9.7	2.10	11.15	0.75	2.72	27.49
SEm+	0.5	0.06	0.15	0.03	0.21	0.90	0.6	0.04	0.18	0.04	0.15	0.70
LSD (P=0.05)	1.5	0.18	0.44	0.08	0.60	2.63	1.8	0.12	0.53	0.11	0.43	2.05

compared to pearl millet. The seed index was higher in soybean intercropped with maize under no N. The higher values of pods and seeds/plant and seed index of soybean were observed when the intercropped cereal crops were grown under no N, while the increasing levels gradually declined the values of these yield parameters. This may be attributed to better growth of cereal intercrops with increasing levels of N, which in turn resulted increase in competition to soybean ultimately resulting decrease in yield parameters.

The sole crop of soybean recorded the highest seed and biological yield and harvest index in both the years of experimentation as compared to its intercropping systems. Similar types of results were also reported by Singh *et al*. (2007). In maize/soybean strip intercropping, West and Griffith (1992) observed a 26% increase in maize and a 27% yield reduction in soybean while Ghaffarzadeh *et al*. (1994) reported that strip intercropping had 20–24% greater maize yields and 10–15% smaller soybean yields in adjacent border rows in maize/soybean intercropping. Among the different cereal intercrops grown with soybean, pearl millet drastically reduced the seed yield of soybean as compared to maize and sorghum in both the years of experimentation. The seed yield of soybean was further decreased with increase in levels of N up to 50% RDN in maize and sorghum. In 2009, the N levels to intercrops did not affect the biological yield of soybean significantly. However, in 2010, similar result was noticed in soybean + pearl millet cropping system to N levels, but the biological yield of soybean in soybean+maize, under no N to maize was significantly higher as compared to 100% RDN to maize. Further the biological yield of soybean in soybean+ sorghum intercropping system under 75% and 100% RDN was significantly lower as compared to no N to sorghum. The pearl millet intercropping reduced the harvest index of soybean to maximum extent as compared to other intercrops.

Nitrogen budgeting

The highest N uptake was observed with soybean+ maize under 100% RDN in 2009 and with soybean+ sorghum under 100% RDN in 2010, while the lowest uptake was observed in soybean+pearl millet under no N to intercropped pearl millet in both the years. The actual available N in soil after the harvest of crops was the highest in sole soybean in both the years. And among the intercropping systems, the highest available N was observed in soybean+ maize under 100% RDN in both the years. The least available N were recorded in soybean+ pearl millet under no N in 2009 and soybean+ maize under no N in 2010. The maximum negative balance was observed in soybean+ pearl millet cropping system under no N in 2009 and soybean+ maize under N in 2010. However, the apparent N balance was higher with sole soybean followed by soybean + maize/sorghum/pearl millet under 100% RDN to cereal intercrops (Fig. 1). The apparent N balance was negative in sole soybean, while the actual change was positive in both the years. This may be attributed to ability



T1- Sole soybean$_{30N}$
T2- soybean$_{30N}$ + maize$_{0N}$
T3- soybean$_{30N}$ + maize$_{30N}$
T4- soybean$_{30N}$ + maize$_{45N}$
T5- soybean$_{30N}$ + maize$_{60N}$
T6- soybean$_{30N}$ + sorghum$_{0N}$
T7- soybean$_{30N}$ + sorghum$_{30N}$
T8- soybean$_{30N}$ + sorghum$_{45N}$
T9- soybean$_{30N}$ + sorghum$_{60N}$
T10- soybean$_{30N}$ + pearlmillet$_{0N}$
T11- soybean$_{30N}$ + pearlmillet$_{20}$
T12- soybean$_{30N}$ + pearlmillet$_{30N}$
T13- soybean$_{30N}$ + pearlmillet$_{40N}$

Fig 1 Apparent N balance and actual change in $KMnO_4$–N (kg/ha) in soil as influenced by intercrops in soybean and their N levels vis-à-vis sole soybean.

of soybean to fix atmospheric N_2 in association with *Rhizobium*. The positive apparent N balance in soybean+pearl millet at 0, 50 and 75 % RDN to intercropped pearl millet in both 2009 and 2010 may be attributed to reduced N uptake *vis-à-vis* applied and biological N fixation in soybean.

Economics

The grain yield of intercropped cereals (maize, sorghum and pearl millet) increased gradually with incremental dose of N application (Table 5). While increasing levels of N gradually decreased the yield of soybean. To estimate the potential benefit from different intercropping systems, the system yield was converted into soybean equivalent yield (SEY). The higher SEY was recorded in soybean+maize under 100% RDN to intercropped maize followed by soybean+maize under 75% RDN to intercropped maize. Higher soybean equivalent yields in cereal + legume intercropping were also reported by Mohta and De (1980) and Khokhar *et al*. (2004). The higher SEY from intercropping situation was also reported by Singh *et al*. (2008) and Gare *et al*. (2009). This is mainly due to higher productivity of both soybean and maize in their intercropping systems as compared to other combinations. The lowest value of SEY was observed in soybean+pearl millet under no N to intercropped pearl millet. Here again the stiff competition among the intercrops, suppressive effect of pearl millet on soybean and non-availability of N to intercropped pearl millet (Layek *et al.,* 2014) had cumulative effect leading to lesser productivity of both the crops leading to lower values of SEY.

The highest gross and net returns being at par with 75% RDN to intercrop was observed with soybean+maize with 100% RDN to intercropped maize (Table 5). Higher returns with soybean+maize intercropping as compared to

Table 5 N dynamics in soil as influenced by different soybean based intercropping systems (Pooled average of 2009 and 2010)

Treatment	Residual $KMnO_4$-N after harvest (kg/ha)	N added (kg/ha)			Initial $KMnO_4$-N status (kg/ha)	Total N inputs (kg/ha)	Total N uptake (kg/ha)	Total N outputs (kg/ha)	Apparent N balance (kg/ha)	Actual change in $KMnO_4$-N (kg/ha)
	(A)	BNF (B)*	Urea (C)	Total (D)	(N)	(E=N+D)	(F)	(G=A+F)	(E-G)	(A-N)
Sole soybean$_{30N}$	290.25	90	30	120	277.5	397.5	173.1	463.35	-65.85	12.75
Soybean$_{30N}$ + maize$_{0N}$	221.05	80	30	110	277.5	387.5	162.15	383.2	4.3	-56.45
Soybean$_{30N}$ + maize$_{30N}$	246.95	70	60	130	277.5	407.5	181.1	428.05	-20.55	-30.55
Soybean$_{30N}$ + maize$_{45N}$	253.75	60	75	135	277.5	412.5	188.05	441.8	-29.3	-23.75
Soybean$_{30N}$ + maize$_{60N}$	267.65	50	90	140	277.5	417.5	189.75	457.4	-39.9	-9.85
Soybean$_{30N}$ + sorghum$_{0N}$	235.9	80	30	110	277.5	387.5	154.55	390.45	-2.95	-41.6
Soybean$_{30N}$ + sorghum$_{30N}$	241.6	70	60	130	277.5	407.5	172.7	414.3	-6.8	-35.9
Soybean$_{30N}$ + sorghum$_{45N}$	251.4	60	75	135	277.5	412.5	183.2	434.6	-22.1	-26.1
Soybean$_{30N}$ + sorghum$_{60N}$	261.15	50	90	140	277.5	417.5	184.05	445.2	-27.7	-16.35
Soybean$_{30N}$ + pearlmillet$_{0N}$	219.65	80	30	110	277.5	387.5	113.55	333.2	54.3	-57.85
Soybean$_{30N}$ + pearlmillet$_{20N}$	226	70	50	120	277.5	397.5	145.05	371.05	26.45	-51.5
Soybean$_{30N}$ + pearlmillet$_{30N}$	232.6	60	60	120	277.5	397.5	146.6	379.2	18.3	-44.9
Soybean$_{30N}$ + pearlmillet$_{40N}$	253.8	50	70	120	277.5	397.5	148.4	402.2	-4.7	-23.7

Table 6 Soybean equivalent yield and economics of soybean based intercropping systems as influenced by nitrogen levels

Treatment	2009					2010				
	Intercrop yield(t/ha)	SEY (t/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio (₹ / ₹)	Intercrop yield(t/ha)	SEY (t/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio (₹ / ₹)
Sole soybean$_{30N}$		1.31	18155	7685	0.73		1.85	25757	15287	1.46
Soybean$_{30N}$ + maize$_{0N}$	0.59	1.45	20154	7204	0.56	0.65	1.84	25582	12632	0.98
Soybean$_{30N}$ + maize$_{30N}$	1.37	1.81	25167	11857	0.89	1.51	2.16	29969	16659	1.25
Soybean$_{30N}$ + maize$_{45N}$	1.57	1.91	26416	12926	0.96	1.75	2.28	31686	18196	1.35
Soybean$_{30N}$ + maize$_{60N}$	1.71	1.95	27073	13403	0.98	1.92	2.33	32371	18701	1.37
Soybean$_{30N}$ + sorghum$_{0N}$	0.54	1.34	18641	6191	0.50	0.54	1.75	24282	11832	0.95
Soybean$_{30N}$ + sorghum$_{30N}$	1.32	1.69	23524	10714	0.84	1.32	2.08	28872	16062	1.25
Soybean$_{30N}$ + sorghum$_{45N}$	1.52	1.79	24773	11783	0.91	1.52	2.20	30637	17647	1.36
Soybean$_{30N}$ + sorghum$_{60N}$	1.55	1.76	24424	11254	0.85	1.55	2.20	30574	17404	1.32
Soybean$_{30N}$ + pearlmillet$_{0N}$	0.58	1.00	13953	2313	0.20	0.63	1.21	16769	5129	0.44
Soybean$_{30N}$ + pearlmillet$_{20N}$	1.23	1.37	18978	7098	0.60	1.46	1.68	23403	11523	0.97
Soybean$_{30N}$ + pearlmillet$_{30N}$	1.41	1.42	19795	7795	0.65	1.51	1.69	23479	11479	0.96
Soybean$_{30N}$ + pearlmillet$_{40N}$	1.43	1.43	19814	7694	0.63	1.53	1.67	23261	11141	0.92
SEm+		0.03	454	454	0.04		0.04	550	550	0.03
LSD (P=0.05)		0.09	1324	1324	0.11		0.12	1606	1606	0.10

sole cropping of maize was also recorded by Mohta and De (1980) and Shivay *et al*. (2001). The lowest values of these were observed in soybean+pearl millet under no N to intercropped pearl millet. It may be the result of acute competition between the crops and also the lower productivity in pearl millet under no N leading to overall lower productivity as these values are directly dependent on the productivity. The B:C ratio was the highest in soybean+maize under 100% RDN in 2009 however in 2010, it was the highest with sole soybean (Table 6). The highest B:C ratio under 100% RDN to intercropped cereals was also reported by Khokhar *et al*. (2004) and Sawargaonkar *et al*. (2008). The lowest B:C ratio was observed in soybean+pearl millet under no N. This variability is attributed to lower yield of soybean and better performance of soybean+maize in 2009 and better performance of sole soybean in 2010 owing to higher and well distributed rainfall as reflected in higher seed yield of soybean.

On the basis of the present investigation, it may be concluded that growth and yield parameters and yield of soybean were negatively influenced due to intercropping with cereals as compared to sole crop of soybean. Among the cereals, pearl millet had greater negative impact on soybean in comparison to sorghum and maize. Application of N to intercrops found to suppress the growth and yield parameters and yield of soybean. However, the highest SEY, gross and net returns were observed under 100% RDN to intercropped maize in soybean+maize intercropping system and remained higher than that of sole soybean.

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