

## Growth pattern, physiological indices and productivity of different soybean (*Glycine max*) based intercrops as influenced by nitrogen nutrition

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### ABSTRACT

A field experiment was carried out during *kharif* 2009 and 2010 to study the performance of maize (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench] and pearl millet [*Pennisetum glaucum* (L.) R.Br. Emend Stuntz] intercropped in soybean [*Glycine max* (L.) Merrill] in 1:2 ratio in additive series with varying levels of nitrogen (N) vis-à-vis the sole stand of intercrops and soybean with recommended dose of N at the research farm of Indian Agricultural Research Institute, New Delhi. Application of 75-100% of recommended dose of N (RDN) to maize intercropped with soybean recorded higher values of growth parameters. Sorghum plant height, dry matter, leaf area index (LAI) and crop growth rate (CGR) were significantly influenced upto 75% RDN in intercropped stand and they were comparable to higher N level and sole sorghum. Plant height, dry matter accumulation, LAI and CGR of intercropped pearl millet was at par with sole stand. Of these parameters, plant height and dry matter accumulation found increasing with increasing levels of N upto 50% RDN, while LAI and CGR of intercropped pearl millet increased significantly upto 75% RDN. The seed yield per cob, seed index and the seed yield of intercropped maize was maximum with 100% recommended dose of nitrogen (RDN) indicating that there was no significant contribution of BNF from intercropped soybean to maize. In case of sorghum, the test weight and biological yield recorded significantly higher values from 50% RDN to intercropped sorghum onwards and comparable to sole crop with 100% RDN. The grain yield on plant population basis was higher with 75% RDN to intercropped sorghum. In pearl millet, the ear length and test weight increased significantly only up to 50% RDN, however the grain yield was significantly superior up to 75% RDN in 2009 and upto 50% RDN to intercropped pearl millet during 2010.

**Key words :** Intercropping systems, Maize, Nitrogen management levels, Pearl millet, Sorghum, Soybean

Intercropping is an important agronomic practice to insure against the failure of crops owing to unexpected abiotic and biotic stresses. It results in ensuring some yield under such situations in one or other component crops. Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources (Tsubo *et al.*, 2005). The reasons are mainly that resources, such as water, light and nutrients can be utilized more effectively than in the respective sole cropping systems (Li *et al.*, 2006). In recent years, the significance of intercropping of cereals in leguminous crops has been recognized by many researchers due to complementary effect of each other in growth habit, nutrient management and quality of the produce. While legumes are able to meet

their nitrogen requirement through biological nitrogen fixation (BNF) a part of it is also made available to companion cereal intercrops. Further, the slow growth and wider space between the cereals in the initial stages of crop growth is fully exploited by the short statured legumes like mungbean, urdbean, cowpea, soybean etc. The deep and tap root system of legumes further complement the shallow and fibrous root system of cereals leading to greater below ground and above ground adjustment in exploiting the rhizosphere as well as micro environment above the soil surface. The cereals too get benefited in the intercropping system with legumes by way of lesser competition for resources owing to their diversified growth requirements.

However, in intensive intercropping systems like additive series, where the base crop population is maintained at 100% and intercrops are introduced through modified crop geometry, there is likelihood of some influence of base crops on the performance of intercrops. This may affect the normal growth and physiological processes of

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the intercrops leading to below par performance. Further in intercropping systems involving legumes as base crop and cereals as intercrops, one needs to tailor optimum dose of nitrogen keeping in view the contribution of BNF from legume component to the cereal companion (Lupwayi and Kennedy, 2007). Here it is necessary to understand the actual nitrogen requirement vis-à-vis the nitrogen in sole crops of cereals. Often due to better nitrogen supply and also the reduce intra-crop competition, the cereals are likely to exhibit better growth and physiological parameters as compared to sole crops with recommended dose of nitrogen. This hypothesis of lesser nitrogen requirement to cereals in intercropping system with legume is although looks pragmatic, needs to be carefully assessed keeping in mind the large variability existing among the major cereals crops.

Soybean being a rainy season crop provides a greater scope for intercropping of cereal crops like maize, sorghum, pearl millet *etc* as they have similar climatic requirements. Maize is cultivated in an area of 8.17 million ha and a total production of 19.73 million tonnes with an average productivity 2414 kg/ha. Sorghum is mostly grown under rainfed and dryland condition occupying 7.53 million ha area with a production of 7.25 million tonnes at an average productivity of 962 kg/ha. Pearl millet is cultivated in area of 8.75 million ha producing 8.89 million tonnes of grains with an average yield of 1015 kg/ha (GOI, 2010). Maize has compatibility with several crops of different growth habit leading to development of various intercropping systems. Sorghum is equally important crop in both kharif and rabi seasons. The low productivity of sorghum has been attributed to the fact that large area is under rainfed situation. Under such situation, inclusion of grain legumes as intercrops can increase the productivity of the system (Elmore and Jackobs, 1986). Besides maize and sorghum, the tillering habit and drought escaping mechanisms of pearl millet make it a suitable crop especially for marginal lands with limited moisture conditions. Introducing or improving an intercropping system with these crops can significantly benefit the smallholder by increasing yield on a limited amount of land, reducing risk of total crop failure, and maximizing the efficiency of labor utilization. Since the early growth of soybean is bit slower and with little modification in row orientation like paired row planting, there is a possibility of introducing cereal crops. As cereals are more nitrogen requiring crops, their nitrogen requirement needs to be estimated to achieve greater nutrient economy. In intercropping systems, the compatibility of crops for expressing their full potential is necessary. The understanding of the growth pattern and physiological parameters gives an idea of success or failure of the system, in realizing better productiv-

ity later on.

Keeping all these points in view, an attempt was made to study the growth, physiology and productivity of maize, sorghum and pearl millet intercropped in soybean as influenced by varying levels of nitrogen to intercrops as compared to their sole crops with recommended dose of nitrogen.

## MATERIALS AND METHODS

A field experiment was carried out during *kharif* 2009 and 2010 at the research farm of the Indian Agricultural Research Institute, New Delhi. The soil of the experimental field was sandy loam in nature, slightly alkaline in reaction (pH 7.8), low in available N and medium in available phosphorus and potassium. The treatments consisted of four sole crops viz. soybean, maize, sorghum and pearl millet with 100% recommended dose of N (RDN) viz. 30, 120, 120 and 80 kg N/ha, respectively; maize + soybean, sorghum + soybean and pearl millet + soybean in 1:2 ratio having a common inter-row spacing of 30 cm with four levels of N viz. 0, 50, 75 and 100% RDN given to intercropped cereals on plant population basis in the form of urea. The base crop of soybean 'DS 9712' was sown using a seed rate of 75 kg/ha with full dose of N, P and K (30:60:40 kg N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O/ha) in the form of urea, single super phosphate and muriate of potash, respectively given as basal. Maize 'HQPM 1', Sorghum 'Hytech 3201' and pearl millet 'Pusa composite 383' were sown with an intra-row spacing of 20 cm as per the intercropping systems. Sowing of all the crops was taken up with the onset of monsoon in July. A seed rate of 20 kg/ha for maize, 12 kg/ha for sorghum and 5 kg/ha for pearl millet was used for sowing. All the seeds were properly covered with soil after sowing for preventing them from bird damage. The 100% recommended dose of P and K to intercrops was applied as basal at the time of sowing, while N was applied in 3 equal splits in case of maize and sorghum at sowing, 30 days after sowing (DAS) and 60 DAS, and 2 equal splits in case of pearl millet at sowing and 30 DAS. Thinning of excess plants and gap filling was carried out 15 days after sowing to maintain optimum plant population.

Biometric observations viz. plant height and dry matter were recorded in maize and sorghum at 30, 60, 90 DAS and at harvest. In pearl millet these parameters were recorded 30, 60 DAS and at harvest. The physiological indices viz. leaf area index (LAI), crop growth rate (CGR) and relative crop growth (RGR) were computed at suitable intervals for maize, sorghum and pearl millet as per the standard procedures. All the yield parameters of intercropped cereals were recorded at harvest. Grain yield and biological yield were recorded at harvest and harvest index

was worked out by dividing the grain yield with biological yield.

All the costs involved in carrying out farm operations and inputs were worked out individually for each treatment and taken as cost of cultivation. The revenue generated from the crops by way of seeds and stovers was taken as gross return and the difference between gross return and cost of cultivation was taken as net return. The ratio between net return to cost of cultivation was computed as benefit: cost ratio (B:C ratio). Soybean equivalent yield (SEY) of different crops was worked out by taking into account price of the produce of individual intercrops and soybean to compare the crops grown in intercropping situation.

$$\text{Soybean equivalent yield} = \frac{\text{Yield of intercrop} \times \text{market price of intercrop}}{\text{Market price of soybean}}$$

The data recorded on various parameters were analyzed as per the analysis of variance technique for randomized block design (Cochran and Cox, 1957).

## RESULTS AND DISCUSSION

The growth parameters and physiological indices viz. plant height, dry matter accumulation, leaf area index (LAI), crop growth rate (CGR) and relative growth rate (RGR) were recorded at regular interval in all the intercrops. In general these were observed to be higher in 2010 as compared to 2009 owing better climatic conditions.

### *Growth parameters*

The growth parameters of intercrops responded differentially to levels of nitrogen applied (Table 1). In maize, the plant height and dry matter increased with each level of N applied, however, the increase in plant height was significant only up to 75% RDN. It was at par with 100% RDN as well as sole maize. This increase in plant height may be due to higher N availability with higher levels of N to intercropped maize. The intercropping per se had no significant influence. The dry matter accumulation also recorded significant increase with N application up to 75% RDN at harvest in 2009. However, in 2010, significant increase was noticed up to 100% RDN. The higher amount of rainfall and its uniform distribution led to better response in terms of dry matter accumulation in maize up to 100% RDN, as moisture and N nutrition have complementary effect is observed in many crops.

The plant height of sorghum at harvest increased significantly up to 75% RDN to intercropped sorghum indicating that crop required higher N as it became older. It was at par with 100% RDN and sole sorghum. This differential requirement of N in sorghum may be attributed to

increased N demand in later stages of crop growth. The dry matter accumulation was higher with 75% RDN to intercropped sorghum. It was at par with 100% RDN and sole sorghum. This is again due to ability of sorghum to make full use of applied N even at lower level due to wider space and complementary effect of intercropped soybean. The ability to higher solar radiation capture with lesser intercrop competition might have helped it to achieve higher dry matter accumulation even at 75% RDN comparable to 100% RDN and sole sorghum. Similar type of result was also reported by Ghosh *et al.* (2009).

The growth parameters viz. plant height and dry matter accumulation in intercropped pearl millet increased significantly among all levels of N applied to intercropped pearl millet. This being at par with sole pearl millet was found significantly superior to intercropping pearl millet grown without N. Since pearl millet is highly tolerant to moisture stress and able to grow under low nutrient availability of soil, the application of N elicited better response in plant growth. As pearl millet is quite efficient in making use of applied nutrients, its growth attributes got boosted even with 50% RDN to it. Further being more dominant between intercrops, it might have drawn nutrients applied to soybean also.

### *Physiological indices*

The LAI and CGR of intercropped maize (Table 1) exhibited variable response to applied N. Since maize required higher doses of N and was quite responsive to each incremental dose, its response was observed up to 100% RDN during 60-90 DAS in 2009 but in 2010, the response in CGR was significantly higher up to 75% RDN. In case of LAI, the response was significantly higher up to 75% RDN in 2009 where in 2010 it was upto 100%. This clearly shows that the maize responds to higher levels of N. The wider spacing and lesser competition from intercrop might have helped it to achieve higher CGR with higher levels of N in intercropping system.

The leaf area index (LAI) recorded at 75% RDN to intercropped sorghum was at par with 100% RDN and sole sorghum in both the years of experimentation. This may be attributed to better foliar development even with 75% RDN due to less intercrop competition and wider space available for better spread of crop as soybean was not able to compete with it for solar radiation. The crop growth rate could not show a definite trend. The CGR responded to applied N to sorghum from 50% RDN in 2009 to 75% RDN in 2010. The increase of these indices with N levels was also reported by Raghuvanshi *et al.* (2004). This variability may be due to varying moisture available at different stages of crop growth following different rainfall patterns. As relative growth rate (RGR) of sorghum might be

controlled by genetic characters did not show differential response to N levels to intercropped sorghum and all treatments were found to be at par with each other.

The LAI of pearl millet significantly increased upto 75% RDN to intercropped pearl millet in both the years of experimentation. In case of CGR at 30-60 DAS, it responded only upto 50% RDN in 2009 but in 2010 it responded upto 75% RDN to intercropped pearl millet. As pearl millet is tillering in nature and puts up higher foliage and dry matter accumulation, the response to N applied also depended on the moisture available status at that point of time. This variability may be due to incidence of better availability of moisture owing to varied rainfall pattern in individual years. However, the relative growth rate was not affected by N levels to intercropped pearl millet. This may be described by genetic nature of pearl millet to achieve incremental growth in biomass to initial N levels. However, all the growth parameters were statistically at par with sole pearl millet. This may be due to optimum space and nutrient levels provided to sole crop and non-existence of competition unlike in other intercropping systems.

#### Yield attributes

In maize, the number of cobs per plant was not influenced by the N levels in both the years (Table 2). It may probably be due to the fact that the number of cobs per plant is a genetic parameter and does not get influenced by management factors. However, grain weight per cob showed significant increase up to 100% RDN to applied maize. The doses of N might increase the growth and in turn the photosynthetic area which in turn might have resulted in increased grain weight per cob with bigger size grain and more number of grains per cob. The seed index increased up to 75% RDN to intercropped maize. And further increase in N level did not increase the seed index the both the years. As seed index is also governed by genetic character, the management factors have limited impact on such traits. It is thus only 75% RDN to intercropped maize was sufficient to achieve higher values.

The test weight of sorghum being at par at 50%, 75%, and 100% RDN to intercropped sorghum and sole sorghum recorded significant higher values over no N applied. The ear length and test weight of pearl millet increased significantly up to 50% RDN to pearl millet. They being at par with all the treatments were found signifi-

**Table 1.** Growth and physiological parameters of of intercrops in soybean as influenced by nitrogen levels vis-à-vis their sole crops with recommended nitrogen application

Treatment	2009					2010				
	Plant height at harvest (cm)	Drymatter accumulation at harvest (g/plant)	LAI at 60 DAS	CGR at 30-60 DAS	RGR at 30-60 DAS	Plant height at harvest (cm)	Drymatter accumulation at harvest (g/plant)	LAI at 60 DAS	CGR at 30-60 DAS	RGR at 30-60 DAS
<i>Maize</i>										
Sole maize <sub>120N</sub>	167.3	129.67	2.34	1.49	0.0192	185.7	141.6	2.80	1.69	0.0169
Soybean <sub>30N</sub> + maize <sub>0N</sub>	133.0	78.67	1.57	0.90	0.0184	137.3	87.0	1.79	0.98	0.0162
Soybean <sub>30N</sub> + maize <sub>30N</sub>	153.3	111.00	1.93	1.25	0.0193	159.3	123.5	2.25	1.29	0.0159
Soybean <sub>30N</sub> + maize <sub>45N</sub>	165.7	126.33	2.28	1.35	0.0185	175.0	139.3	2.47	1.49	0.0159
Soybean <sub>30N</sub> + maize <sub>60N</sub>	169.7	134.00	2.41	1.55	0.0195	187.0	147.8	2.76	1.70	0.0163
SEM±	3.2	3.58	0.08	0.05	0.0008	3.3	2.7	0.08	0.07	0.0009
CD (P=0.05)	10.6	11.67	0.25	0.17	NS	10.9	8.7	0.26	0.23	NS
<i>Sorghum</i>										
Sole sorghum <sub>120N</sub>	203.4	174.67	2.26	1.17	0.0120	221.6	197.4	2.58	1.44	0.0128
Soybean <sub>30N</sub> + sorghum <sub>0N</sub>	158.4	102.33	1.61	0.76	0.0112	167.8	123.9	1.61	0.87	0.0118
Soybean <sub>30N</sub> + sorghum <sub>30N</sub>	184.7	154.83	1.89	1.05	0.0121	192.8	170.3	2.12	1.23	0.0128
Soybean <sub>30N</sub> + sorghum <sub>45N</sub>	200.4	176.83	2.12	1.12	0.0115	214.3	193.0	2.46	1.49	0.0137
Soybean <sub>30N</sub> + sorghum <sub>60N</sub>	205.9	180.67	2.27	1.21	0.0116	219.3	202.6	2.65	1.52	0.0128
SEM±	4.44	4.80	0.07	0.07	0.0008	5.38	4.2	0.10	0.08	0.0006
CD (P=0.05)	14.48	15.65	0.23	0.23	NS	17.54	13.7	0.34	0.25	NS
<i>Pearlmillet</i>										
Sole pearl millet <sub>80N</sub>	205.3	980.9	3.62	15.74	0.0144	214.6	1137.3	4.04	18.78	0.0154
Soybean <sub>30N</sub> + pearl millet <sub>0N</sub>	174.2	545.3	2.69	11.10	0.0137	181.9	611.6	3.11	12.46	0.0140
Soybean <sub>30N</sub> + pearl millet <sub>20N</sub>	203.3	935.3	3.28	14.43	0.0140	208.1	999.9	3.70	16.11	0.0148
Soybean <sub>30N</sub> + pearl millet <sub>30N</sub>	205.1	985.1	3.66	16.39	0.0150	213.7	1133.2	4.08	19.02	0.0158
Soybean <sub>30N</sub> + pearl millet <sub>40N</sub>	209.3	991.5	3.68	16.44	0.0146	217.9	1141.3	4.27	19.62	0.0154
SEM±	5.13	40.7	0.11	0.85	0.0006	4.7	39.2	0.11	0.85	0.0006
CD (P=0.05)	16.73	132.8	0.37	2.76	NS	15.3	127.9	0.35	2.77	NS

cantly superior to control. This improved performance even with 50% RDN to intercropped pearl millet might be due to better availability of N complied with wider spacing with lesser inter plant competition as soybean was less competitive. Besides, pearl millet might have also been benefited by biological nitrogen fixation (BNF) of soybean. Such better performance of cereal intercrops due to legumes in system also reported in the intercropping systems of legumes + cereals (Lupwayi and Kennedy 2007).

#### Grain yield, biological yield and harvest index

The grain yield of intercropped maize (Table 3) was significantly higher with 100% RDN to intercropped maize in both the years of experimentation. It was even significantly higher in intercropped maize (50%) on plant population basis to sole maize (100%). This may be due to the fact that intercropped maize received more N as compared to sole maize, to match with the better growing environment with wider spacing, higher availability of solar radiation due to reduced competition with soybean. However, the biological yield increased up to 50% RDN to in-

tercropped maize indicating that the biological yield including the vegetative growth may be well with lesser amount of added N under better growing conditions like less competition and wider space in intercropping with soybean. The higher harvest index with 100% RDN to intercropped maize may be due to the fact that harvest index is a ratio between grain yield to biological yield and all those treatments increasing grain yield at similar biological yield found to exhibit higher harvest index. Thus in this condition when higher grain yield was obtained with 100% RDN to intercropped maize, highest harvest index was also obtained compared to sole maize. It may be explained by in fact that besides comparable N, the intercropped maize had wider spacing resulting in better solar radiation capture and probably may be some complementally effect from soybean to maize in intercropping system. Although individual levels showed some variables they were statistically at par in both this years. This may be due to the fact that test weight may be same but the total yield may be varying with varying level of N.

The grain yield of sorghum increased significantly up

**Table 2.** Yield parameters of intercrops in soybean as influenced by nitrogen levels vis-à-vis their sole crops with recommended nitrogen application

Treatment	2009			2010		
	Cobs/plant	Grain weight (g/cob)	Seed index (g/100 seed)	Cobs/plant	Grain weight (g/cob)	Seed index (g/100-seed)
<i>Maize</i>						
Sole maize <sub>120N</sub>	1.13	62.33	23.25	1.17	73.33	24.22
Soybean <sub>30N</sub> + maize <sub>0N</sub>	1.03	24.00	20.66	1.03	23.00	21.31
Soybean <sub>30N</sub> + maize <sub>30N</sub>	1.10	47.67	22.24	1.13	56.00	23.38
Soybean <sub>30N</sub> + maize <sub>45N</sub>	1.10	55.33	23.18	1.17	70.67	24.37
Soybean <sub>30N</sub> + maize <sub>60N</sub>	1.17	62.00	23.35	1.17	76.67	24.50
SEm±	0.06	1.54	0.34	0.08	1.73	0.51
CD (P=0.05)	NS	5.03	1.12	NS	5.63	1.65
<i>Sorghum/Pearlmillet</i>						
	Test weight (g/1,000-seed)			Test weight (g/1,000-seed)		
Sole sorghum <sub>120N</sub>	27.30			28.60		
Soybean <sub>30N</sub> + sorghum <sub>0N</sub>	22.43			26.47		
Soybean <sub>30N</sub> + sorghum <sub>30N</sub>	26.44			27.35		
Soybean <sub>30N</sub> + sorghum <sub>45N</sub>	26.88			27.97		
Soybean <sub>30N</sub> + sorghum <sub>60N</sub>	27.64			28.76		
SEm±	0.37			0.62		
CD (P=0.05)	27.30			28.60		
<i>Pearlmillet</i>						
	Ear length (cm)	Test weight (g/1,000-seed)		Ear length (cm)	Test weight (g/1,000-seed)	
Sole pearl millet <sub>80N</sub>	25.47	5.95		27.50	6.08	
Soybean <sub>30N</sub> + pearl millet <sub>0N</sub>	20.00	5.48		22.50	5.55	
Soybean <sub>30N</sub> + pearl millet <sub>20N</sub>	23.68	5.84		26.17	5.92	
Soybean <sub>30N</sub> + pearl millet <sub>30N</sub>	25.30	5.99		27.33	6.09	
Soybean <sub>30N</sub> + pearl millet <sub>40N</sub>	25.80	5.97		27.33	6.17	
SEm±	0.66	0.11		0.48	0.08	
CD (P=0.05)	2.16	0.35		1.56	0.27	

to 75% RDN; thereafter it was at par with 100% RDN. And both were significantly higher as compared to 0 and 50% RDN to intercropped sorghum. The higher grain yield in sorghum even with 75% RDN may be due to better overall growth and yield parameters observed in absence of stiff competition from intercropped soybean. As plant population of intercropped soybean was 50% of sole sorghum, this could not be compared for grain yield. The biological yield although increased slightly with each incremental dose of N, the differences were statistically at par among 50%, 75%, 100% RDN to intercropped sorghum and sole sorghum. As sorghum did not face severe competition from intercropped soybean and had wider space available for capturing solar radiation, it could express its full potentiality even with lower levels of N of 50% RDN. Such better performances of component crops in intercrops with lower levels of N are also observed by Ghosh et al. (2009). The harvest index was significantly higher with 75% RDN to intercropped sorghum in both the years. Since it is a ratio between grain yield to biological yield, the variable responses to grain and biological yield at various levels of N reflected here. Since higher grain yield was observed at 75% RDN, higher harvest index was noticed at the same level of N. However, as more

N is required for grain formation, unlike biological yield, this increased harvest index was observed at 75% RDN to sorghum.

The grain yield in pearl millet was significantly higher up to 75% RDN to intercropped pearl millet in 2009 and up to 50% RDN in 2010. This being at par with remaining higher levels of N to intercropped pearl millet and sole pearl millet were significantly higher as compared to other treatments. This better performance may be described to better response of pearl millet even at lesser N due to wider space available leading better utilization of solar radiations and some contribution of BNF from soybean. This increased grain yield was made possible by increased growth and yield parameters as reflected by increased values of these attributes even at 50% and 75% RDN to the intercropped pearl millet. The variable yield responses in 2009 and 2010 may be attributed to variability in rainfall. The scanty and less rainfall in first year could not help pearl millet to achieve higher grain yield at lower level of N, on the contrary in 2010, the better spread and higher rainfall helped pearl millet to achieve higher grain yield at even 50% RDN to it. This is again due to synchrony between moisture available and N nutrient.

The biological yield of pearl millet was significantly

**Table 3.** Grain yield, biological yield and harvest index of intercrops in soybean as influenced by nitrogen levels vis-à-vis their sole crops with recommended nitrogen application

Treatment	2009			2010		
	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
<i>Maize</i>						
Sole maize <sub>120N</sub>	2.99	8.04	37.23	3.94	10.44	37.80
Soybean <sub>30N</sub> + maize <sub>0N</sub>	0.59	2.82	21.00	0.65	3.26	20.00
Soybean <sub>30N</sub> + maize <sub>30N</sub>	1.37	4.25	32.17	1.51	4.78	31.55
Soybean <sub>30N</sub> + maize <sub>45N</sub>	1.57	4.44	35.38	1.75	4.80	36.53
Soybean <sub>30N</sub> + maize <sub>60N</sub>	1.71	4.55	37.67	1.92	4.91	39.10
SEm+	0.04	0.15	0.70	0.04	0.21	0.70
CD (P=0.05)	0.13	0.49	2.27	0.12	0.68	2.27
<i>Sorghum</i>						
Sole sorghum <sub>120N</sub>	2.74	8.56	31.96	2.74	8.56	31.96
Soybean <sub>30N</sub> + sorghum <sub>0N</sub>	0.54	3.45	18.89	0.54	3.45	18.89
Soybean <sub>30N</sub> + sorghum <sub>30N</sub>	1.32	4.50	29.37	1.32	4.50	29.37
Soybean <sub>30N</sub> + sorghum <sub>45N</sub>	1.52	4.82	31.63	1.52	4.82	31.63
Soybean <sub>30N</sub> + sorghum <sub>60N</sub>	1.55	4.92	31.46	1.55	4.92	31.46
SEm+	0.06	0.15	0.34	0.06	0.15	0.34
CD (P=0.05)	0.19	0.48	1.10	0.19	0.48	1.10
<i>Pearlmillet</i>						
Sole pearl millet <sub>80N</sub>	2.41	9.33	25.78	2.81	10.39	27.05
Soybean <sub>30N</sub> + pearl millet <sub>0N</sub>	0.58	3.54	16.41	0.63	3.75	16.85
Soybean <sub>30N</sub> + pearl millet <sub>20N</sub>	1.23	5.24	23.48	1.46	5.97	24.49
Soybean <sub>30N</sub> + pearl millet <sub>30N</sub>	1.41	5.48	25.85	1.51	5.71	26.38
Soybean <sub>30N</sub> + pearl millet <sub>40N</sub>	1.43	5.50	25.93	1.53	5.63	27.22
SEm±	0.04	0.24	0.59	0.06	0.26	0.42
CD (P=0.05)	0.12	0.78	1.94	0.19	0.84	1.36

higher up to 50% RDN to intercropped pearl millet in both the years of experiments. As pearl millet is better equipped to face the moisture stress irrespective of rainfall variation, it was able to put up better growth leading to better utilization of applied N up to 50% RDN. The harvest index responded significantly up to 75% RDN to intercropped N. This may be due to higher N need for conversion of photosynthates into economic part i.e. grain. This being at par with 100% RDN and sole pearl millet showed that in intercropping system, there is beneficial effect to dominant crop due to wider space and synergistic effect of intercropped legume component in this case soybean.

Since the plant population in intercropped pearl millet was 50% of sole pearl millet, the grain yield of intercropped pearl millet could not be compared. On comparisons to half of sole pearl millet grain yield, all N levels applied to intercropped pearl millet recorded higher values indicating higher yield in intercropped pearl millet.

#### *Economics and soybean equivalent yield*

The seed yield of soybean was in lower in 2009 as compared to 2010 (Table 4). The sole crop of soybean recorded significantly higher seed yield as compared to soybean in different intercropping system. The increased yield in sole soybean was mainly due to increased growth parameters and their positive influence on the yield parameters. Among the different 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 de-

creased with increasing levels of N up to 50% of RDN in maize and sorghum. The seed yield of soybean intercropped with pearl millet decreased significantly when provided with 100% RDN in comparisons to no N to pearl millet in 2009, but in 2010 all the levels of N given to pearl millet recorded seed yield of soybean at par with each other.

The higher soybean equivalent yield (SEY) is higher in soybean+maize with 100% RDN to intercropped maize (Table 4) followed by soybean+maize with 75% RDN to intercropped maize. These were better as compared to all other intercropping combinations with varying levels of N. Similar type of result was also reported by Khokhar et al. (2004). The higher soybean equivalent yield in intercropping situation was also reported by Gare et al. (2009). This may be mainly due to higher productivity of both soybean and maize in their intercropping systems as compared to other combinations. It might also be due to least adverse effect of intercrops on each other and higher response of maize to applied N up to 100% RDN. The lowest values of these parameters were observed in soybean+pearl millet with 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 had cumulative effect leading to lesser productivity of both the crops leading lower values of this parameter.

The cost of cultivation was lowest with sole soybean and it increased with intercrops and increasing levels of N to intercrops. Maize among the intercrops and the highest

**Table 4.** Yield of component crops and economics of soybean based intercropping systems as influenced by nitrogen levels

Treatment	2009						2010					
	Soybean Yield (t/ha)	Intercrop yield (t/ha)	SEY (t/ha)	Cost of cultivation ( $\times 10^3$ ₹/ha)	Net returns ( $\times 10^3$ ₹/ha)	B:C ratio (₹/₹)	Soybean yield (t/ha)	Intercrop yield (t/ha)	SEY (t/ha)	Cost of cultivation ( $\times 10^3$ ₹/ha)	Net returns ( $\times 10^3$ ₹/ha)	B:C ratio (₹/₹)
Sole soybean <sub>30N</sub>	1.31		1.31	10.5	7.7	0.73	1.85		1.85	10.5	15.3	1.46
Soybean <sub>30N</sub> + maize <sub>0N</sub>	1.09	0.59	1.45	12.9	7.2	0.56	1.45	0.65	1.84	13.0	12.6	0.98
Soybean <sub>30N</sub> + maize <sub>30N</sub>	0.98	1.37	1.81	13.3	11.9	0.89	1.25	1.51	2.16	13.3	16.7	1.25
Soybean <sub>30N</sub> + maize <sub>45N</sub>	0.95	1.57	1.91	13.5	12.9	0.96	1.22	1.75	2.28	13.5	18.2	1.35
Soybean <sub>30N</sub> + maize <sub>60N</sub>	0.91	1.71	1.95	13.7	13.4	0.98	1.17	1.92	2.33	13.7	18.7	1.37
Soybean <sub>30N</sub> + sorghum <sub>0N</sub>	1.01	0.54	1.34	12.4	6.2	0.50	1.38	0.54	1.75	12.5	11.8	0.95
Soybean <sub>30N</sub> + sorghum <sub>30N</sub>	0.89	1.32	1.69	12.8	10.7	0.84	1.19	1.32	2.08	12.8	16.1	1.25
Soybean <sub>30N</sub> + sorghum <sub>45N</sub>	0.86	1.52	1.79	13.0	11.8	0.91	1.16	1.52	2.20	13.0	17.7	1.36
Soybean <sub>30N</sub> + sorghum <sub>60N</sub>	0.82	1.55	1.76	13.2	11.3	0.85	1.14	1.55	2.20	13.2	17.4	1.32
Soybean <sub>30N</sub> + pearl millet <sub>0N</sub>	0.65	0.58	1.00	11.6	2.3	0.20	0.83	0.63	1.21	11.6	5.2	0.44
Soybean <sub>30N</sub> + pearl millet <sub>20N</sub>	0.62	1.23	1.37	11.9	7.1	0.60	0.80	1.46	1.68	11.9	11.5	0.97
Soybean <sub>30N</sub> + pearl millet <sub>30N</sub>	0.58	1.41	1.42	12.0	7.8	0.65	0.78	1.51	1.69	12.0	11.5	0.96
Soybean <sub>30N</sub> + pearl millet <sub>40N</sub>	0.56	1.43	1.43	12.1	7.7	0.63	0.75	1.53	1.67	12.1	11.1	0.92
SEm $\pm$	0.03		0.03		0.45	0.04	0.04		0.04		0.6	0.03
CD (P=0.05)	0.08		0.09		1.3	0.11	0.11		0.12		1606	0.10

level of N i.e. 100% RDN to intercrops recorded the highest cost of cultivation. This may attributed to the higher cost of seeds of maize and increasing cost of N with each incremental dose of N. The highest gross return and net returns being at par with 75% RDN to intercrop was observed with soybean+maize with 100% RDN to intercropped maize. Similar type result was also confirmed by Shivay *et al.* (2001). The lowest values of these were observed in soybean+pearlmillet with no N to intercropped pearlmillet. The highest gross and net returns may be explained by the fact that maize responds to higher levels of N with matching productivity with least impact on the intercrop soybean leading higher overall return. On the contrary the lowest the lowest gross and net returns with soybean + pearlmillet was the result of acute competition between the crops and also the lower productivity in pearlmillet with no N leading to overall lower productivity as these values are directly dependent on the productivity. The B:C ratio was highest in soybean+maize with 100%RDN. Similar result also confirmed by Khokhar *et al.* (2004) and Sawargaonkar *et al.* (2008), whereas, Meena *et al.* (2006) recorded highest B:C ratio up to 75% RDN. Lowest B:C ratio observed in soybean+pearlmillet with no N in 2009. In 2010, the highest B:C ratio was observed in sole soybean while the lowest B:C ratio observed again in soybean+pearlmillet with no N. This variability is attributed to lowest yield of soybean and higher 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.

Growth, physiological parameters and yield of maize can be enhanced with the application up to 100% RDN to intercropped maize indicating that there is little contribution of BNF from soybean. While the sorghum responded significantly up to 75% RDN indicating a contribution of 25% RDN from the base crop of soybean. The grain yield of intercropped pearlmillet showed variable response to applied N between 50% and 75% RDN. Indicating that base crop of soybean provided about 25-50% RDN to intercropped pearlmillet.

It is concluded that there is a need to supply 100% RDN to maize while 75% RDN and 50% RDN was sufficient for sorghum and pearlmillet, respectively when they are grown as intercrops in soybean.

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