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Research Paper

Effect of nitrogen fertilization on yield, intercropping indices and produce quality of different soybean (*Glycine max*) + cereal intercropping systems

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ABSTRACT

A field experiment was carried out during the rainy (*kharif*) *seasons* of 2009 and 2010 at New Delhi, to study the effect of nitrogen levels on yield, competition and produce quality of soybean [*Glycine max* (L.) Merr.] and intercrops. The sole crop of soybean recorded higher seed yield as compared to intercropping. Among the intercropping systems, soybean + maize (*Zea mays* L.) recorded the highest yield of soybean. Incremental N levels to cereal crops showed negative impact on the yield of soybean. While the yield of intercropped maize significantly increased with up to 100% recommended dose of nitrogen (RDN), the yield of intercropped sorghum [*Sorghum bicolor* (L.) Moench.] and pearlmillet [*Pennisetum glaucum* (L.) R.Br. Stuntz] increased only up to 75 and 50% RDN respectively. Soybean + maize intercropping supplied with 100% RDN gave the highest net returns and soybean-equivalent yield. The aggressivity and competitive ratio were higher for pearlmillet and sorghum than maize. The protein and nitrogen content in seed, N content in stover and total N uptake in intercropped maize were higher with 75–100% RDN, while these parameters increased only up to 75% RDN in intercropped sorghum. In pearlmillet, protein and N content in seed were significantly higher with 75% RDN, while total uptake of N was higher with 50% RDN than lower N levels. The optimum doses of N for intercrops were 66.6 and 70.7 kg/ha for maize, 54.0 and 56.7 kg/ha for sorghum and 35.5 and 31.6 kg/ha for pearlmillet, in 2009 and 2010 respectively.

Key words : Cereals, Intercropping systems, Optimum dose, Protein content, Soybean

Intercropping systems have proved to be better than sole crops in terms of yield because intercropping makes better use of one or more agricultural resources both in time and in space (Ofori and Stern, 1987). In intercropping systems involving legume and cereals, there are many processes both competitive and complementary to the component crops (Layek *et al.,* 2014). The competition for growth factors viz. space, light, moisture, nutrients etc., negatively influence the performance of component crops, while the differing growth habits, rooting patterns, nutrient preferences etc. will complement each other with appropriate management strategy. The quality parameters of the crop produces often tend to be affected by the above-said processes. The provision for nutrient requirement of component crops and their judicious management notwithstanding, there will be considerable effect on the quality of the produce, especially nutrient content, protein content etc. There is a need for detailed studies on such parameters to overcome any negative influence on such quality parameters of the produce.

When the nutrient requirement of intercrops is taken care of through adequate and suitable nutrient-management practice, there is a need to establish the optimum requirement of individual crops to arrive at the most economical dose or optimum dose to realize the higher monetary returns from the costly nutrients. Soybean can obtain its N from the soil, from N_2 fixation, or both. Indeed, it is frequently reported that seed yields and total seed N are highest when N is obtained from both fertilizer N and N_2 fixation (Imsande, 1989). Quantifying the beneficial or competitive effects of soil resources, particularly nutrient use in intercropping is still an important issue for research. Studies on the fertilizer management and optimum fertilizer schedule have been mainly done on sole cropping.

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Fertilizer recommendations based on the sole cropping may not meet the nutrient requirement of the component crops in an intercropping system, because competition exists between component crops for nutrient use and it is more pronounced in the intercropping system as compared to sole cropping. The intercropping of cereals like maize, sorghum and pearlmillet in soybean is gaining lot of attention in recent years owing to their morphological differences and growth pattern (Shivay *et al.,* 1999). The differing rooting-systems and nutrient requirement complement the cereals in the soybean. However, the nitrogen requirement of cereals being higher, the optimum nitrogen doses needs to be determined in the intercropping system keeping in view the nitrogen-sparing effect of the soybean acquired through biological nitrogen fixation (BNF). In the additive design, the species can be grown such that the overall relative density exceeds 100% potentially inducing the most productive intercrops. Cereal + legume intercropping probably reduces competition for nitrogen (N), since the legume depends mainly on its own N_2 fixation while the cereal uses the mineral N available (Ofori and Stern, 1987). Legumes, with their adaptability to different cropping patterns and their ability to fix N_2, may offer opportunities to sustain productivity (Jeyabal and Kuppuswamy, 2001). When maize and sorghum are intercropped with leguminous crops, they are believed to draw same contribution from legume components. Soybean + pearlmillet can be important intercropping system in northern plains zone, as these two crops are already being grown in sole cropping system. The differential growth habits, crop durations and crop phenology make them ideally suited for intercropping systems. However, pearlmillet being very fast-growing cereal needs higher doses of N right from the beginning. Thus the conditions of BNF from soybean to pearlmillet may not be sufficient to meet the N requirement of pearlmillet. Thus there is a need to estimate the N requirement of cereals grown as intercrops in soybean.

Therefore a field experiment was carried out to study the yield, competition and quality of the produce and to estimate the optimum dose of nitrogen of the maize, sorghum and pearlmillet intercropped in soybean.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of Indian Agricultural Research Institute, New Delhi, during the rainy (*kharif*) 2009 and 2010 to study the effect of nitrogen levels on the quality of produce of intercropped maize, sorghum and pearlmillet in soybean and their effect on the soil nitrogen balance. The soil of the experimental field was sandy loam with low in available N and medium in available phosphorus (P) and potassium (K). The climate during the 2 years of experimentation was variable with 490 mm rainfall in 2009 and 750 mm rainfall in 2010. The treatments consisted of sole soybean, sole maize, sole sorghum, sole pearlmillet with 100% recommended dose of N (RDN) and maize + soybean, sorghum + soybean and pearlmillet + soybean in 1:2 ratio under additive series with 4 levels of N applied to intercropped cereals, viz. 0, 50 ,75 and 100% RDN, on plant-population basis.

Soybean (var. 'DS 9712'), maize (var. 'HQPM 1'), sorghum (var. 'Hytech 3201') and pearlmillet (var. 'Pusa Composite 383') were sown with the onset of monsoon during July. A common inter-row spacing of 45 cm was followed for all the sole crops, while a common inter-row spacing of 30 cm was followed for all the crops in intercropping systems. Full dose of N, P and K to soybean (30:60:40 kg N:P_2O_5:K_2O/ha), full dose of P and K along with one-third N as per treatment to maize and sorghum and half N to pearlmillet was given as basal application at the time of sowing. The remaining two-third of N to maize and sorghum was applied in 2 equal splits at 30 days after sowing (DAS) and at 60 DAS, while in pearlmillet remaining half N was given only at 30 days. The crops were raised as per the normal package of practices except for treatments. The N content in seed and stover of all the crops were estimated from the samples collected at harvesting as per the standard procedures (Prasad *et al*., 2006) and the protein content were computed using factor 5.75 multiplied by N content in seed. The optimum N dose was computed by the regression analysis of data. All the observations recorded were statistically analysed as per analysis of variance techniques (ANOVA) and critical differences were estimated at 0.05 probabilities.

Soybean equivalent yield (SEY): Yields of all the crops were converted to SEY taking into account of the prevailing MSP of the produce of individual intercrops and soybean using the following formula:

SEY = Yield of intercrop × price of intercrop (₹)/price of soybean (₹)

Competition ratio (CR): It was computed to measure the competitive ability of the crops (Willey and Rao, 1980) and computed with the following formula:

$$CR_{soybean} = (LER_{soybean}/LER_{intercrop})\ (Zba/Zab)$$

$$CR_{intercrop} = (LER_{intercrop}/LER_{soybean})\ (Zab/Zba)$$

LER, land equivalent ratio;

Zab, sown proportion of soybean in combination with intercrops;

Zba, sown proportion of intercrop in combination with soybean.

Aggressivity (A): Agressivity indicates the relative yield increase in "a" crop is greater than that of "b" crop in an intercropping system (McGilchrist, 1965) and expressed as:

$$A_{soybean} = Yab/(Yaa \times Zab) – Yba/(Ybb \times Zba)$$

$$A_{intercrops} = Yba/(Ybb \times Zba) – Yab/(Yaa \times Zab)$$

Where Yab, the yield of soybean in intercropping; Yba, the yield of intercrop in intercropping; Zab, sown proportion of soybean in intercropping; Zba, sown proportion of intercrop in intercropping; Yaa, the yield of soybean in sole cropping; Ybb, the yield of intercrop in sole cropping.

If the value of A is zero, both crops are equally competitive. If the value of A is positive then soybean is dominant over intercrops. If the value is negative then intercrops are dominant over soybean.

RESULTS AND DISCUSSION

Yield of soybean, intercrops and soybean-equivalent yield and economics

Sole crop of soybean recorded significantly higher seed yield than soybean in different intercropping systems (Table 1). Muoneke *et al.* (2007) also reported higher seed yield of soybean in sole cropping than intercropping with cereals. Among the different intercrops, pearlmillet drastically reduced the soybean yield as compared to maize and sorghum. The seed yield of soybean was further decreased with increasing levels of N up to 50% of recommended dose of nitrogen (RDN) in maize and sorghum. While the grain yield of intercropped maize increased up to 100% RDN to intercropped maize, grain yield of sorghum increased significantly in intercropped sorghum up to 75% RDN and it was at par with 100% RDN. The higher grain yield in sorghum even with 75% RDN may be owing to less competition and additional nitrogen supplied through BNF from intercropped soybean. Ghosh *et al.* (2009) also observed such better performances of component crops in intercrops with lower levels of N. The grain yield in pearlmillet (Table 1) was significantly higher up to 75% RDN to intercropped pearlmillet in 2009 and up to 50% RDN in 2010. This better performance may be described to better response of pearlmillet even at lesser N due to wider space available leading better utilization of solar radiations and some contribution of BNF from soybean (Ofori and Stern, 1987). As pearlmillet 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 (Layek *et al.*, 2014). Soybean + maize with 100% RDN recorded higher values of soybean-equivalent yield (SEY). Since the yield reduction in the component crops due to intercropping was the lowest in this combination, it resulted in higher values of these indices. Likewise, the lowest yield of component crops in soybean + pearlmillet with no N resulted in lowest value of SEY. The highest net return in soybean + maize with 100% RDN were mainly because of higher economic yield of both soybean and maize.

Competition ratio and aggressivity

The competition ratio (CR) showed inverse relationship between the component crops. Soybean in soybean + maize with no N recorded the highest CR. This was mainly due to lesser competition exerted by the intercropped maize with no N (Table 1). As the N levels applied to intercropped maize increased, the CR of soybean started declining. Conversely, the lowest CR recorded with

Table 1. Yield, competition ratio (CR) and aggressivity (A) of soybean as well as intercropped cereals as influenced by varying levels of N (pooled data of 2 years)

Treatment	Soybean yield (t/ha)	Intercrop yield (cereal) (t/ha)	Soybean equivalent yield (t/ha)	Net returns (₹/ha)	CR		A	
					Soybean	Intercrops	Soybean	Intercrops
Sole $soybean_{30N}$	1.58	0.00	1.58	11,486	1.12	0.91	–0.33	0.33
$Soybean_{30N}$ + $maize_{0N}$	1.27	0.62	1.65	9,918	0.43	2.37	–1.36	1.36
$Soybean_{30N}$ + $maize_{30N}$	1.12	1.44	1.99	14,258	0.36	2.81	–1.64	1.64
$Soybean_{30N}$ + $maize_{45N}$	1.09	1.66	2.10	15,561	0.31	3.20	–1.83	1.83
$Soybean_{30N}$ + $maize_{60N}$	1.04	1.82	2.14	16,052	1.05	0.97	–0.39	0.39
$Soybean_{30N}$ + $sorghum_{0N}$	1.20	0.54	1.55	9,012	0.38	2.70	–1.50	1.50
$Soybean_{30N}$ + $sorghum_{30N}$	1.04	1.32	1.89	13,388	0.32	3.27	–1.79	1.79
$Soybean_{30N}$ + $sorghum_{45N}$	1.01	1.52	2.00	14,715	0.30	3.40	–1.84	1.84
$Soybean_{30N}$ + $sorghum_{60N}$	0.98	1.55	1.98	14,329	0.53	1.96	–0.71	0.71
$Soybean_{30N}$ + $pearlmillet_{0N}$	0.74	0.61	1.11	3,721	0.23	4.52	–1.83	1.83
$Soybean_{30N}$ + $pearlmillet_{20N}$	0.71	1.35	1.53	3,664	0.20	5.18	–2.03	2.03
$Soybean_{30N}$ + $pearlmillet_{30N}$	0.68	1.46	1.56	4,012	0.19	5.39	–2.07	2.07
$Soybean_{30N}$ + $pearlmillet_{40N}$	0.66	1.48	1.55	3,958	0.06	0.21	0.08	0.08
SEm±	0.04	0.08	0.04	233	0.15	0.61	0.22	0.22
CD (P=0.05)	0.10	0.20	0.11	678	1.12	0.91	–0.33	0.33

no N in intercropped maize showed increasing trend with N application and reached the highest with 100% RDN. Among the intercrops, the pearlmillet with 100% RDN recorded the lowest CR of soybean. This may be due to luxuriant growth of pearlmillet with 100% RDN and severest competition to intercropped soybean. Such relationships among the component crops in intercropping systems were also been reported by Dhima *et al*. (2007). The intercropped cereals showed positive aggressivity, while the soybean showed the negative aggressivity in both the years. The aggressivity (A) value also followed the same trend like CR and highest value of A of soybean recorded in sole soybean. A value of intercrops were recorded to be positive and increased with the incremental levels of N to intercropped cereals. The aggressivity of soybean was negative; thus, it is considered as the less-dominant crop in the system while cereals intercropped in soybean is considered to be more dominant crop due to their positive aggressivity value. Among the intercrops, pearlmillet was most aggressive as compared to maize and sorghum mainly owing to its high-tillering ability.

Optimum dose of N to intercrops

The optimum dose of N on 50% plant-population basis to intercrops in soybean varied with crops (Table 2). The optimum dose of nitrogen for maize was 66.6 and 70.7 kg/ha, for sorghum was 54 and 56.7 kg/ha and for pearlmillet was 35.5 and 31.6 kg/ha during 2009 and 2010, respectively. Maize being highly nutrient-exhaustive crop recorded higher level of nitrogen as optimum than sorghum and pearlmillet, while pearlmillet with short duration and lower productivity showed the lowest dose of nitrogen as optimum among the three. Conversely, the contribution of nitrogen through sparing effect from soybean was lesser to maize followed by sorghum. The highest contribution of nitrogen from soybean was observed in case of pearlmillet leading to lesser amount of optimum dose. The variability in the optimum dose of crops during the years is mainly

Table 2. Estimated optimum dose of nitrogen with corresponding yield of intercrops in soybean on 50% plant-population basis

Crop	Optimum dose (kg/ha)		Optimum grain yield (t/ha)		Linear regression equation	
	2009	2010	2009	2010	2009	2010
Maize	66.6	70.7	1.74	1.96	$Y = -0.234X^2+32.60X+591.8$ $R^2=0.991$	$Y = -0.241X^2+35.5X+651.5$ $R^2=0.991$
Sorghum	54.0	56.7	1.55	1.77	$Y=-0.320X^2+36.01X+538.3$ $R^2=0.992$	$Y = -0.335X^2+39.4X+607.8$ $R^2=0.995$
Pearlmillet	35.5	31.6	1.44	1.56	$Y=-0.634X^2+47.70X+538.5$ $R^2=0.986$	$Y = -0.883X^2+57.2X+636.3$ $R^2=0.992$

Y, Yield (kg/ha); X, N dose (kg/ha); R^2, coefficient of determination

Table 3. Nitrogen content and uptake, protein and oil content and their yield in soybean as influenced by different intercrops with varying levels of nitrogen (pooled data of 2 years)

Treatment	N content (%)		Total N uptake (kg/ha)	Protein		Oil	
	Seed	Stover		Content (%)	Yield (kg/ha)	Content (%)	Yield (kg/ha)
Sole soybean$_{30N}$	6.22	2.45	173.1	38.9	611.1	19.7	311.1
Soybean$_{30N}$ + maize$_{0N}$	6.03	2.19	139.1	37.7	477.2	19.2	244.0
Soybean$_{30N}$ + maize$_{30N}$	6.17	2.42	138.4	38.6	428.8	18.9	211.0
Soybean$_{30N}$ + maize$_{45N}$	6.22	2.47	139.7	38.9	421.5	18.5	200.6
Soybean$_{30N}$ + maize$_{60N}$	6.30	2.54	137.1	39.4	408.5	18.4	191.2
Soybean$_{30N}$ + sorghum$_{0N}$	6.01	2.16	131.9	37.5	448.0	19.5	232.9
Soybean$_{30N}$ + sorghum$_{30N}$	6.18	2.43	130.0	38.6	399.9	19.1	198.4
Soybean$_{30N}$ + sorghum$_{45N}$	6.20	2.60	132.4	38.8	392.3	18.8	190.5
Soybean$_{30N}$ + sorghum$_{60N}$	6.28	2.66	129.9	39.3	383.1	18.6	182.9
Soybean$_{30N}$ + pearlmillet$_{0N}$	6.02	2.25	87.3	37.6	277.9	19.5	143.7
Soybean$_{30N}$ + pearlmillet$_{20N}$	6.15	2.43	94.6	38.4	273.2	18.8	133.9
Soybean$_{30N}$ + pearlmillet$_{30N}$	6.24	2.53	91.2	39.0	262.3	18.6	125.4
Soybean$_{30N}$ + pearlmillet$_{40N}$	6.29	2.62	91.7	39.3	257.1	18.5	120.9
SEm±	0.10	0.04	5.48	0.55	12.30	0.15	7.00
CD (P=0.05)	NS	0.11	15.99	NS	35.85	0.55	20.45

due to the climatic conditions prevailed in the years and their interaction with the crop. The higher optimum dose in the second year in case of maize and sorghum was owing to better growth following higher rainfall in that year. While the reverse is true for pearlmillet, as it could withstand the drought-like situation in the first year.

Nitrogen content in seed and stover of soybean

The N concentration in soybean seed and stover were higher in soybean intercropped with cereal intercrops with 100% RDN (Table 3). However, the differences in N content in seed were at par with each other among all the treatments. In general, the N content in seed and stover was higher with sole soybean next only to soybean intercropped with cereals with 100% RDN. This may attributed to increased availability of N to soybean intercropped with cereals provided with 100% RDN. The total uptake of N by soybean was however higher in sole soybean. This might be due to increased seed and biological yield in sole soybean as compared to soybean in intercropping system. As total uptake is a function of N content in seed and stover and their total yield, the increased seed yield and biological yield recorded higher total uptake in sole soybean (Ramesh *et al.,* 2003).

Protein and oil content (%) in soybean and their yield

The protein content and oil content being higher in sole soybean resulted in their higher yield in sole crop compared to intercrop (Table 3). Intercrops in soybean owing to their variable competition recorded significant difference in the yield of protein and oil. The pearlmillet recorded the lowest protein and oil yield of soybean followed by sorghum and maize. The N levels to intercropped cereals too had variable impact on the protein and oil yield of soybean intercropped with them. The highest values of protein and oil yields were observed with no-N to cereals and they decreased with increasing levels of N up to 100% RDN. This may be explained by the fact that the increasing levels of N improved the growth of cereals and it in turn affected the performance of soybean leading to reduced protein and oil yield.

Protein content in seed, N content in seed and stover and total N uptake of intercrops

The highest N as well as protein content in grains of maize intercropped with soybean was observed when supplied with 100% RDN (Table 4). And these values were found to be at par with sole maize and intercropped maize with 75% RDN. It may be due to the fact that inter-

Table 4. Protein content in seed, nitrogen content in seed and stover and total nitrogen uptake of intercrops in soybean as influenced by nitrogen levels vis-à-vis their sole crops (pooled data of 2 years)

Treatment	Protein content in seed (%)	N content in seed (%)	N content in stover (%)	Total N uptake by intercrops (kg/ha)
Maize				
Sole maize$_{120N}$	10.2	1.78	0.64	95.4
Soybean$_{30N}$ + maize$_{0N}$	9.5	1.65	0.52	23.1
Soybean$_{30N}$ + maize$_{30N}$	9.9	1.73	0.59	42.7
Soybean$_{30N}$ + maize$_{45N}$	10.2	1.78	0.63	48.4
Soybean$_{30N}$ + maize$_{60N}$	10.4	1.80	0.66	52.7
SEm±	0.10	0.02	0.01	1.93
CD (P=0.05)	0.33	0.06	0.04	6.30
Sorghum				
Sole sorghum$_{120N}$	10.9	1.90	0.60	93.7
Soybean$_{30N}$ + sorghum$_{0N}$	9.8	1.80	0.47	22.2
Soybean$_{30N}$ + sorghum$_{30N}$	10.4	1.77	0.54	41.7
Soybean$_{30N}$ + sorghum$_{45N}$	11.0	1.87	0.62	49.5
Soybean$_{30N}$ + sorghum$_{60N}$	11.2	1.93	0.65	52.8
SEm±	0.16	0.03	0.01	1.27
CD (P=0.05)	0.50	0.09	0.04	4.14
Pearlmillet				
Sole pearlmillet$_{80N}$	11.4	1.98	0.64	97.8
Soybean$_{30N}$ + pearlmillet$_{0N}$	10.1	1.75	0.52	26.3
Soybean$_{30N}$ + pearlmillet$_{20N}$	10.8	1.88	0.60	50.4
Soybean$_{30N}$ + pearlmillet$_{30N}$	11.3	1.96	0.65	55.4
Soybean$_{30N}$ + pearlmillet$_{40N}$	11.5	2.00	0.67	56.7
SEm±	0.17	0.03	0.02	2.37
CD (P=0.05)	0.55	0.10	0.05	7.72

cropped maize derived certain percentage of its N content from the associated legume plants. The N content in stover of intercropped maize increased significantly up to 75% RDN. The total N uptake was observed to be highest in sole maize by virtue of 100% higher plant population as compared to intercropped maize. In sorghum, the protein content and N content in seed increased significantly up to 75% RDN. The highest value of these parameters recorded in 100% RDN applied to intercropped sorghum but it was at par with 100% RDN to sole sorghum. However, the total N uptake increased significantly up to 75% RDN to intercropped sorghum. The highest protein content, N content in seed and stover in intercropped pearlmillet were recorded with 100% RDN to intercropped pearlmillet. The total uptake of N was the highest in sole pearlmillet. However, among soybean + pearlmillet intercropping systems, the total N uptake was significantly higher only up to 50% RDN to pearlmillet as compared to soybean + pearlmillet with no nitrogen. The increased protein content in seed, N content in seed and stover and total uptake to increasing levels of N may be attributed to the fact that all these factors are directly influenced by N applied and their increase obviously enhanced their values (Kumar *et al*., 2007).

On the basis of 2 year study, it was noticed that 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 and pearlmillet responded significantly up to 75% and 50% RDN respectively, indicating a contribution of 25% RDN and 50% RDN from the base crop of soybean. The protein content, N content and total N uptake showed positive response to applied N between 50% and 75% RDN to intercropped cereals. So, it was 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 in 2:1 additive series.

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