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Research Paper

Effect of conservation agricultural practices and nitrogen management on growth, physiological indices, yield and nutrient uptake of soybean (*Glycine max*)

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ABSTRACT

A field experiment with soybean [*Glycine max* (L.) Merr.] under soybean–wheat (*Triticum aestivum* L.) cropping system was conducted during the rainy (*kharif*) seasons of 2014 and 2015 at the Indian Agricultural Research Institute, New Delhi, to assess the effect of conservation agricultural practices and nitrogen management on growth, physiological indices, yield and nutrient uptake of soybean. The experiment was laid out in a split-plot design with 4 conservation agricultural practices, viz. zero tillage without residue (ZT–R), zero tillage with soybean residue (ZT + SR), zero tillage with soybean and wheat residue (ZT + SWR) and conventional tillage without residue (CT–R), in main plots and 4 nitrogen-management practices, viz. 100% recommended dose of nitrogen (RDN) as basal (N_1), 125% RDN as basal (N_2), 100% basal + 25% top-dressing at flowering stage (N_3) and 75 % basal + 25% top-dressing at flowering stage (N_4), in subplots. The results showed that growth parameters, physiological indices as well as nitrogen (209.2 kg/ha), phosphorus (20.2 kg/ha) and potassium (89.4 kg/ha) uptake were significantly higher in ZT + SWR than the other treatments. The ZT + SWR resulted in 14% and 11% higher grain yield and 22% and 21% higher profitability than ZT–R and CT – R, respectively. And among the nitrogen-management practices, N_2, being at par with N_3, showed significantly higher growth and better physiological indices at all the growth stages. However, significantly the highest nitrogen (201.8 kg/ha), phosphorus (19.6 kg/ha) and potassium uptake (88.2 kg/ha) were obtained with basal application of 125% recommended dose of nitrogen (N_2). Significantly higher seed (1.96 t/ha) and stover yields (4.06 t/ha) were recorded with N_2 than the other nitrogen-management practices.

Key words : Conservation agriculture, Nitrogen, Nutrient uptake, Residue, Soybean, Zero tillage

Soybean, designated as 'golden bean' rich in protein (40%) and moderate in cholesterol-free oil (20%), has established its tremendous potential as an industrial vital and viable oilseed crop in India. At present, it covers an area of about 11.62 million ha with a production of 8.64 million tonnes and productivity of 781 kg/ha (SOPA, 2015). Soybean builds up the soil fertility by atmospheric nitrogen fixation and it leaves residual nitrogen equivalent to 45 to 60 kg/ha for the succeeding crop (Kumar *et al*., 2012). The symbiotic relationship between soybean and rhizobium reduces production costs and makes soybean a good rotational crop for use with high nitrogen-consuming crops (Biswas and Gresshoff, 2014). Furthermore, it would help enhance production of edible oil as India is producing only 55% of its edible oil requirement (Hari Ram *et al*., 2013). However, in soybean-based cropping system, hardly 10–15 days time is available between harvesting of soybean and timely sowing of wheat. Moreover, delayed sowing of wheat adversely affects the crop resulting in lower yield. Of late, conservation agriculture (CA) systems have gained importance to facilitate early sowing of crops with reduced production costs.

The CA practice such as zero tillage and residue mulching is an ecological approach for soil surface management and seedbed preparation (Jain *et al*., 2007). It is energy-efficient and beneficial to environment as compared to conventional practices. However in CA, the requirement of nutrients may differ from conventional agriculture practices. In the initial 3–4 years of adoption, zero tillage re-

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duces N mineralization by decreasing decomposition of soil organic matter, while the crop residues influence N dynamics from immobilization and volatilization (Singh *et al*., 2015). Several studies reported a reduction in fertilizer N-use efficiency with zero tillage. Gangwar *et al*. (2006) reported an additional requirement of 25–30 kg N/ha in residue incorporated ZT plots. Thus proper nitrogen management in conservation agriculture is needed to ensure proper crop growth and development. The present study was therefore designed to determine the effect of different conservation agricultural practices and nitrogen management on growth, physiological indices, yield and nutrient uptake of soybean under soybean–wheat system in North-Western Indo Gangetic Plains of India.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2014 and 2015 at the research farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi, (28.4°N, 77.1°E, 228.6 m above mean sea-level). The soil was a sandy clay loam in texture, neutral in reaction (*p*H 7.6), low in organic carbon (0.38 %), low in available N (150 kg/ha), medium in available P (11.2 kg/ha) and available K (245 kg/ha). The total rainfall during the study period was 451.0 and 710.7 mm during 2014 and 2015 respectively. The experiment was laid out in a split plot design with 3 replications in a fixed lay out. The main plot treatments consisted of 4 conservation agricultural practices, viz zero tillage without residue (ZT–R), zero tillage with soybean residue in the preceeding crop (ZT + SR), zero tillage with soybean wheat residue (ZT + SWR) (soybean residue is applied to the previous crop and wheat residue to soybean crop) and conventional tillage without residue (CT–R), while the subplot treatments were 4 nitrogen-management practices, viz. 100% recommended dose of nitrogen (RDN) as basal (N1), 125% RDN as basal (N2), 100% basal + 25% top-dressing at flowering stage (N3) and 75 % basal + 25% top-dressing at flowering stage (N4). Under conventional tillage, the plots were ploughed 4–5 times (2 disc harrowing + 2 cultivators + 1 planking), while in zero tillage the crop was sown without any tillage operations. Wheat residues @ 3 tonnes/ha were applied to the soybean crop. Soybean 'Pusa 9712' was sown in rows at 35 cm apart. The N, P and K were given in the form of urea, single superphosphate and muriate of potash, respectively in soybean @ 25 : 60 : 40 N, P_2O_5 and K_2O. In soybean Pendimethalin @ 0.75 kg a.i./ha was applied as pre-emergence followed by 2 hand-weedings at 20 days after sowing (DAS) and 40 DAS to control the weeds. The growth parameters, crop-growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were calculated using standard formula (Radford, 1967). Soil samples after harvesting were taken and analyzed for available nitrogen (Subbiah and Asija, 1956), available phosphorus (Olsen *et al.*, 1954) and available potassium (Standford and English, 1949), and uptake value was calculated by multiplying the content by grain and stover yield of crop. The data of both the years were pooled and analyzed by ANOVA and treatment differences were expressed for Least Significant Differences (LSD) at 5% probability to determine the significance among the treatment means.

RESULTS AND DISCUSSION

Growth attributes and physiological indices

Growth parameters of soybean, viz. plant height, leaf-area index (LAI) and dry-matter accumulation (DMA), were influenced significantly by different conservation agricultural practices. The ZT + SWR recorded significantly higher plant height (70 cm), LAI (3.5) and DMA (27.7g/plant) at harvesting than ZT + SR, CT–R and ZT–R. The magnitude of increase in DMA by ZT + SWR over CT–R and ZT–R was 10% and 13% respectively. Similarly, crop-growth rate, relative growth rate and net assimilation rate were also found numerically superior at 30–60 DAS and 60–90 DAS under ZT + SWR (Table 1). However, significant increase in CGR and NAR was observed only at 30–60 DAS. This improvement in growth parameters of soybean in zero-tilled residue-applied plots was ascribed to higher soil moisture conservation and improved soil physical conditions as residue cover conserved soil moisture and improved the microenvironment of soil, thus created conducive environment for plant growth and development (Choudhary *et al*., 2016).

Soybean growth parameters were influenced significantly by different nitrogen-management practices. The highest plant height, LAI and dry-matter/plant were recorded with basal application of 125% RDN (N2), which were significantly higher than basal application of 100% RDN (N1) and 75% basal + 2% top-dressing at flowering stage (N4), but remained at par with 100% basal + 25% top-dressing of nitrogen at flowering stage (N3). This shows that the top-dressing of nitrogen at flowering stage does not add additional advantage over basal application of nitrogen. The various physiological indices were not significantly influenced by nitrogen management except the RGR at 60–90 DAS and NAR. The increase in growth attributes with increasing N levels was owing to more number of leaves and their better growth under adequate nitrogen (Sharma *et al.*, 2012). Nitrogen influenced the total photosynthesis of plants through its effect on the leaf area. All these might have cumulatively produced higher dry matter under the highest level of nitrogen (Watson, 1952). Similar results were reported by Raja (2001), where an increase in DM accumulation was observed with higher level of nitrogen owing to better crop growth, in terms of plant height and LAI.

Nutrient uptake

The nutrient uptake by seed and stover of soybean estimated at harvesting stage and total uptake were significantly affected by different conservation agricultural practices and nitrogen management (Table 2). The maximum N, P and K uptake in seed and stover and total uptake was obtained with ZT + SWR, it was significantly superior to ZT + SR, ZT–R and CT–R. ZT–R and CT–R were found at par with each other. The ZT + SWR enhanced the total nitrogen uptake by 17%, total P uptake by 23.1% and total K uptake by 19.5% over ZT–R and CT–R respectively. Improved soil physical, chemical and biological properties after decomposition of crop residues resulted in the maximum availability of nutrients and better nutrient uptake. Among the nitrogen-management practices, the maximum N, P and K uptake in seed, stover and total uptake was observed with basal application of 125% RDN, it was on a par with 100% basal+ 25% top-dressing and significantly superior to 100% RDN treatments. This increase in uptake of nutrients may be attributed to higher N, P, K content, higher dry-matter production and higher seed yield/ha which was owing to continuous supply of essential plant nutrients to plants throughout crop-growth period at higher fertility levels (Morshed *et al*., 2008).

Yield and profitability

The conservation agricultural practices and N management had significant effect on seed yield of soybean (Table 3). Significantly maximum seed yield was recorded with ZT + SWR (2.0 t/ha). It was followed by ZT + SR and CT – R. And the lowest seed yield was recorded with ZT – R (1.7 t/ha). The magnitude of increase in seed yield with ZT + SWR over ZT – R and CT – R was 18% and 11% respectively. This increment might be owing to improved growth parameters in ZT + SWR which could be attributed to the better utilization of soil moisture, nutrients uptake and less fluctuation in the soil temperature under residue conditions. Similar trend was also found in stover yield. The yield increase under residue application might be owing to additional nutrient release through residue application to the tune of 25.5–107.4 kg N, 1.35–2.76 kg P and 90.6–188.7 kg K/ ha during decomposition and its sustained release to meet the requirement of crop growth (Tsuji *et al*., 2006).

Among the nitrogen-management practices, basal application of 125% RDN resulted in significantly higher seed yield (1.94 and 1.95 t/ha) and stover yield (4.16 and 3.96 t/ha). It was on a par with 100% basal + 25% top-dressing and significantly superior to basal application of 100% RDN and 75% basal + 25% top-dressing. The seed-yield improvement with N2 was 9.4, 5.3 and 10% over N1, N3 and N4 respectively. Higher N levels might have enhanced the manufacturing and storage of photosynthates which attributed to higher growth and yield parameters

Table 1. Effect of conservation agricultural practices and nitrogen management on growth parameters and physiological indices in soybean (pooled mean data of 2 years)

Treatment	Growth parameters at physiological maturity			Crop-growth rate (g/g/day)		Relative growth rate (mg/g/day)		Net assimilation rate (g/m^2 leaf area/day)	
	Plant height (cm)	Dry-matter accumulation (g/plant)	Leaf-area index	30–60 DAS	60–90 DAS	30–60 DAS	60–90 DAS	30–60 DAS	60–90 DAS
Conservation agricultural practices									
ZT – R	63.5	24.2	3.0	10.6	7.1	67.6	15.1	7.4	2.5
ZT + SR	64.5	25.7	3.3	11.2	8.6	67.8	17.1	7.6	2.8
ZT + SWR	70.1	27.7	3.5	12.6	8.2	70.6	15.2	8.1	2.5
CT – R	64.5	24.9	3.1	11.1	7.7	68.0	15.8	7.5	2.6
SEm±	1.04	0.29	0.04	0.21	0.32	0.76	0.74	0.14	0.10
CD (*P*=0.05)	3.62	1.01	0.13	0.71	NS	NS	NS	0.47	NS
Nitrogen management									
N1 (100% basal)	62.7	24.42	3.16	10.86	7.16	67.47	15.04	7.87	2.38
N2 (125% basal)	68.9	26.98	3.38	11.96	8.93	69.60	16.74	7.41	2.80
N3 (100% basal + 25% top-dressing)	68.1	26.66	3.25	11.79	8.50	69.27	16.34	7.46	2.77
N4 (75% basal + 25% top-dressing)	62.9	24.40	3.17	10.88	7.11	67.55	15.03	7.90	2.38
SEm±	1.03	0.31	0.04	0.21	0.41	0.62	0.75	0.17	0.14
CD (*P*=0.05)	3.02	0.89	0.12	0.61	1.20	1.80	NS	NS	NS

Details of treatments are given under Materials and Methods and consequently in higher yield. Similar results were also reported by Morshed *et al*. (2008), who stated that application of 25% higher N over recommended could give maximum seed yield, protein content and nutrient uptake by soybean seed.

Economic analysis revealed that significantly highest net returns were obtained in ZT + SWR followed by ZT + SR and ZT–R which in turn on a par with CT–R. This might be owing to higher seed and stover yields under ZT + SWR compared to the other treatments. There are several reports showing savings in irrigation water, labour and production costs, and higher net economic returns in no tillage compared with conventional tillage systems (Karunakaran and Behera, 2016). Among the nitrogen-management practices, basal application of 125% RDN fetched the maximum net returns (28.3 ×10^3 ₹/ha) and benefit: cost ratio (1.16) over other nitrogen-management practices. This might be owing to higher seed and stover yields at higher nitrogen doses.

Protein content and protein yield

Protein content in soybean responded positively to the

Table 2. Effect of conservation agricultural practices and nitrogen management on nitrogen (N), phosphorous (P) and potassium (K) uptake (kg/ha) in seed and stover of soybean (pooled mean data of 2 years)

Treatment	N uptake by seed (kg/ha)	N uptake by stover (kg/ha)	Total N uptake (kg/ha)	P uptake by seed (kg/ha)	P uptake by stover (kg/ha)	Total P uptake (kg/ha)	K uptake by seed (kg/ha)	K uptake by stover (kg/ha)	Total K uptake (kg/ha)
Conservation agricultural practice									
ZT – R	106.2	65.3	171.5	7.5	8.1	15.6	9.8	61.1	70.9
ZT + SR	115.7	75.2	190.9	8.5	9.1	17.6	13.1	71.0	84.2
ZT + SWR	130.6	78.6	209.2	10.0	10.3	20.2	14.8	74.6	89.4
CT – R	110.4	66.9	177.3	8.1	8.2	16.2	11.5	63.3	74.7
SEm±	2.53	0.60	2.09	0.14	0.22	0.30	0.37	1.33	1.45
CD (*P*=0.05)	8.77	2.07	7.24	0.50	0.76	1.05	1.28	4.59	5.02
Nitrogen management									
N1 (100% basal)	107.4	67.1	174.6	7.8	7.9	15.7	11.0	63.1	74.1
N2 (125% basal)	125.6	76.3	201.8	9.6	9.9	19.6	14.2	73.9	88.2
N3 (100% basal + 25% top-dressing)	122.1	75.5	197.6	9.0	9.6	18.6	13.0	69.8	82.8
N4 (75% Basal + 25% top- dressing)	107.8	67.1	174.9	7.7	8.2	15.9	11.0	63.1	74.0
SEm±	2.18	1.04	2.31	0.18	0.20	0.25	0.40	1.24	1.38
CD (*P*=0.05)	6.36	3.03	6.74	0.52	0.57	0.72	4.03	3.62	4.03

Details of treatments are given under Materials and Methods

Table 3. Effect of conservation agricultural practices and nitrogen management on yield, quality and profitability of soybean (pooled mean data of 2 years)

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Protein content (%)	Protein yield (kg/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Conservation agricultural practice						
ZT – R	1.7	3.7	38.7	663.7	22.2	0.93
ZT + SR	1.8	3.9	39.9	723.2	24.9	1.04
ZT + SWR	2.0	4.0	41.1	816.3	28.4	1.15
CT – R	1.8	3.8	38.9	690.0	22.5	0.90
SEm±	0.03	0.03	0.31	15.83	0.82	0.03
CD (*P*=0.05)	0.11	0.11	1.06	54.79	2.85	0.12
Nitrogen management						
N1 (100% basal)	1.7	3.7	38.7	671.4	22.3	0.92
N2 (125% basal)	2.0	4.1	40.0	784.8	28.3	1.16
N3 (100% basal + 25% top-dressing)	1.9	3.9	40.6	763.2	25.7	1.05
N4 (75% Basal + 25% top-dressing)	1.7	3.7	39.1	673.8	21.7	0.89
SEm±	0.03	0.05	0.26	13.62	0.82	0.03
CD (*P*=0.05)	0.09	0.16	0.75	39.76	2.39	0.10

Details of treatments are given under Materials and Methods conservation agricultural practices and nitrogen management. The ZT + SWR resulted in significantly higher protein content and yield in soybean crop than the other conservation agricultural practices. The protein content and protein yield in ZT + NR and CT + NR were statistically similar. Younesabadi *et al*. (2013) also reported that CT and NT did not differ significantly with respect to protein content as well as protein yield in soybean. Among the nitrogen-management practices, 100% basal + 25% top-dressing resulted in significantly higher protein content which was on a par with basal application of 125% RDN. Nitrogen (N) is often the most limiting factor in crop production and affects amino acid composition of protein and in turn its nutritional quality. Increasing nitrogen supply to crops generally resulted in increased grain yield, grain protein content and protein yield.

Conservation agricultural practices involving zero tillage and application of crop residues of soybean and wheat @ 3.0 t/ha enhanced the growth parameters, nutrient uptake and yield of soybean. Top-dressing of nitrogen fertilizer at flowering stage of soybean did not show any added advantage over basal application. Our findings indicate that zero tillage with soybean and wheat residues along with application of 25% higher recommended dose of nitrogen either as basal or as top-dressing can be a viable alternative to conventional practices for sustainable production in Indo-Gangetic plains of India.

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