https://doi.org/10.56093/ijas.v90i10.107988

Indian Journal of Agricultural Sciences **90** (10): 2037–40, October 2020/Short Communication

Productivity and economics of soybean (*Glycine max*) as influenced by different tillage practices and phosphorus fertilization under conservation agriculture

SOMANATH NAYAK[1], U K BEHERA[2], S L MEENA[3] and Y S SHIVAY[4]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 18 December 2019; Accepted: 29 January 2020

Key words: Conservation agriculture, Economics, Phosphorous fertilization, Soybean, Tillage, Yield

Soybean (*Glycine max* (L.) Merr.), the most important oilseed crop of twenty first century is occupying premier position among the oilseed crops. Rightly known as 'Golden bean' rich in protein (40%) and moderate in cholesterol free oil (20%) has established its tremendous potential as an industrially vital and viable oilseed crop in India. It is used as a good source of unsaturated fatty acids, minerals (Ca and P) and vitamins A, B, C and D. Furthermore, it would help to enhance production of edible oil as India is producing only 55% of its edible oil requirement (Ram *et al.* 2013). Globally soybean is being cultivated on 125.67 million hectares (m ha) area, producing 362.87 million tonnes (mt) grain, with 2.89 t/ha average productivity (USDA 2019). It contributes 48.2 and 60% to the world-oilseed acreage and production, respectively. At present India ranks fourth in acreage and fifth in production in world. It is being grown on 9.51 m ha with 10.98 mt productions and 1.21 t/ha productivity (DAC&FW 2018). Being a legume, it fixes 125–150 kg N/ha and shows considerable residual effects on the succeeding crop, by improving physical conditions and fertility of soil, which is of special importance for Indian soil (Kalwe and Rani 2005).

Phosphorus is an important plant nutrient which is needed in relatively large amounts by legumes for growth and nitrogen fixation and has been reported to promote leaf area, biomass, yield, nodule number, nodule mass, etc., in a number of legumes (Kasturikrishna and Ahlawat 1999). Large quantities of P fertilizer may be required for successful soybean production. Meeting P requirement of soybean not only maximizes its production but also benefits succeeding crop like wheat because of residual effect of P and advantage as a result of better N-fixation under optimum P (Sharma and Vyas 2001). However, conservation agricultural practices which are based on no vertical perturbation of soil (zero and conservation tillage), with crop residue management and biological diversification influence the fate of plant nutrients in cropping systems. Although, lots of works has been done on effect of nutrient management on soybean production, however limited findings are available regarding phosphorus fertilization under conservation agriculture and its effect on soybean productivity and economics. Thus, the present study was therefore designed to determine the effect of different tillage practices and phosphorus fertilization on productivity and economics of soybean under conservation agriculture.

A field study was conducted during rainy (*kharif)* season of crop year 2017 at research farm of the ICAR–Indian Agricultural Research Institute, New Delhi. The farm is situated at 28°38'N latitude, 77°10'E longitude and at an altitude of about 228.6 m above mean sea level. The mean maximum temperature is 40 to 45°C in the month of June, while the mean minimum temperature is 1.9°C in the month of January. The mean annual rainfall is about 650 mm, of which nearly 80% is received during the monsoon period from July to September. The mean annual pan evaporation is about 850 mm. The soil of the experimental site was sandy clay loam in texture (sand 61.7%, silt 11.9% and clay 26.4%) with the *p*H of 7.9 (1:2.5 soil and water ratio). The soil had 0.38% initial organic carbon and 152 kg/ha alkaline permanganate oxidizable N which was low, 11.2 kg/ha available phosphorus (P) and 224 kg/ha 1 N ammonium acetate exchangeable K which were of medium type in soil fertility rating. The experiment was laid out in split plot design with three replications including conservation agricultural practices in main plots and phosphorus fertilization in sub-plots. Main plot treatments were viz. conventional tillage without residue (CT–R); zero tillage without residues (ZT–R); zero tillage with wheat residues @ 3 t/ha (ZT + R); zero tillage–bed with wheat residues @ 3 t/ha (ZT–B + R). Sub-plot treatments were as basal

[1]Ph D Scholar (nayaksomnath672@gmail.com), [2]Principal Scientist (ukb2008@gmail.com), [3]Principal Scientist (dr_slmeena@yahoo.co.in), [4]Principal Scientist and Ex–Professor (ysshivay@iari.res.in), Division of Agronomy, ICAR–Indian Agricultural Research Institute, New Delhi.

application of 0, 40, 80 and 120 kg P_2O_5/ha corresponding to 0, 17.2, 34.5 and 52.5 kg P/ha, respectively. Different tillage practices as mentioned for the main plot were followed and in zero tillage plots one blanket spray of paraquat was made one week before sowing of the crop. The soybean variety Pant Soybean (PS 1225) was developed from Govind Ballabh Pant University of Agriculture and Technology, Pantnagar and has maturity duration is about 121 days and also has multiple disease resistance had been used in this experiment. The seeds were sown by zero till seed drill at the seed rate of 80 kg/ha at an inter row spacing of 45 cm and in bed at 35 cm row to row spacing (two row per bed). Sowing on bed was done through bed planter. The N, P and K were given in the form of urea, single super phosphate and muriate of potash, respectively. The entire dose of N and K was applied as basal that was 40 and 45 kg/ha of N and K_2O, respectively. The different doses of phosphorus were applied in sub-plots as per treatment details. All fertilisers were band placed manually during sowing time. Then well dried crop residues of wheat of previous crop season were applied @ 3 t/ha to soybean crop by spreading the material uniformly a week after the sowing of crop. The oven dried crop residues were analysed for its chemical composition before application. Total N, P and K concentration of wheat residues were 0.42, 0.045 and 1.55% respectively, which added 12.6, 1.35 and 46.5 kg/ha N, P and K, respectively. Thinning, gap filling, irrigation, weed management and other cultural practices were done as per standard procedures. At the time of maturity the net plots, leaving three border rows on each side were harvested and yield attributes per plant were counted. Then after, sun-drying, threshing and cleaning the seed yield was recorded. Stover yield was obtained by subtracting seed yield from the total biomass yield. Yields were expressed in tonnes/ha as in manuscript. Cost of cultivation, gross returns, net returns and B:C were calculated based on the prevailing market prices of the inputs during the crop season. All the data obtained from the experiment were analyzed statistically using the F-test as per the standard statistical procedure (Gomez and Gomez 1984) and least significant difference (LSD) values (P=0.05) were used to determine the significance of difference between treatment means. Linear polynomial fitting was done between yield attributing character and yield and coefficient of determination (R^2) was determined with the help of MS Excel.

Different tillage practices and phosphorus fertilization had marked influence on yield attributes, such as number of branches/plant, pods/plant, seeds/pod and 1000–seed weight of soybean (Table 1). Crop establishment techniques did not show any significant influence on number of branches/plant, seeds/pod and 1000–seed weight of soybean during the study of the experiment. However, the highest numbers of pods/plant (89.3) were observed with ZT–B + R and it was significantly superior to ZT + R, ZT–R and CT–R. The highest seed yield (2.28 t/ha) was recorded with ZT–B + R and it was significantly higher than ZT + R (2.16 t/ha), ZT–R (2.03 t/ha) and CT–R (1.91 t/ha). The yield improvement with ZT–B + R was 16.2%, 11.0% and 5.3% compared to CT–R, ZT–R and ZT + R, respectively. The highest stover yield (3.94 t/ha) was obtained with ZT–B + R and

Table 1 Effect of different tillage practices and phosphorus fertilization on yield attributes, yields and economics of soybean grown under conservation agriculture

Treatment	Yield attributes				Yields		Economics			
	Branches/ plant (Nos.)	Pods / plant (Nos.)	Seeds/ pod (Nos.)	1000–seed weight (g)	Seed (t/ ha)	Stover (t/ha)	Cost of cultivation (× 10³₹/ha)	Gross returns (× 10³₹/ha)	Net returns (× 10³₹/ ha)	B:C ratio
Tillage practices										
CT–R	8.0	75.7	2.5	106.0	1.91	3.32	31.4	54.5	23.6	1.74
ZT–R	8.0	80.2	2.5	106.0	2.03	3.28	29.0	57.9	28.9	2.00
ZT + R	8.2	85.3	2.5	107.0	2.16	3.80	29.9	61.6	31.7	2.06
ZT-B + R	8.2	89.3	2.5	108.5	2.28	3.94	29.9	65.0	35.1	2.18
SEm±	0.13	1.43	0.04	1.81	0.03	0.04	0.35	1.02	0.58	0.03
CD (P=0.05)	NS	4.31	NS	NS	0.11	0.12	1.22	3.08	1.75	0.10
Phosphorus levels										
0 kg/ha	7.75	80.5	2.5	104.2	1.81	3.42	27.0	51.6	24.6	1.91
40 kg/ha	8.10	83.7	2.5	106.7	1.99	3.49	29.0	56.6	27.6	1.95
80kg/ha	8.25	88.0	2.5	108.3	2.31	3.69	31.0	65.8	34.8	2.12
120 kg/ha	8.20	87.9	2.5	108.3	2.27	3.74	33.0	64.8	31.8	1.96
SEm±	0.11	1.39	0.04	1.77	0.03	0.04	0.44	0.94	0.52	0.03
CD (P=0.05)	NS	4.18	NS	NS	0.10	0.12	1.55	2.83	1.58	0.09

CT–R, Conventional tillage without residue; ZT–R, Zero tillage without residues; ZT + R, Zero tillage with wheat residues @ 3 t/ha; ZT–B + R, Zero tillage-bed with wheat residues @ 3 t/ha

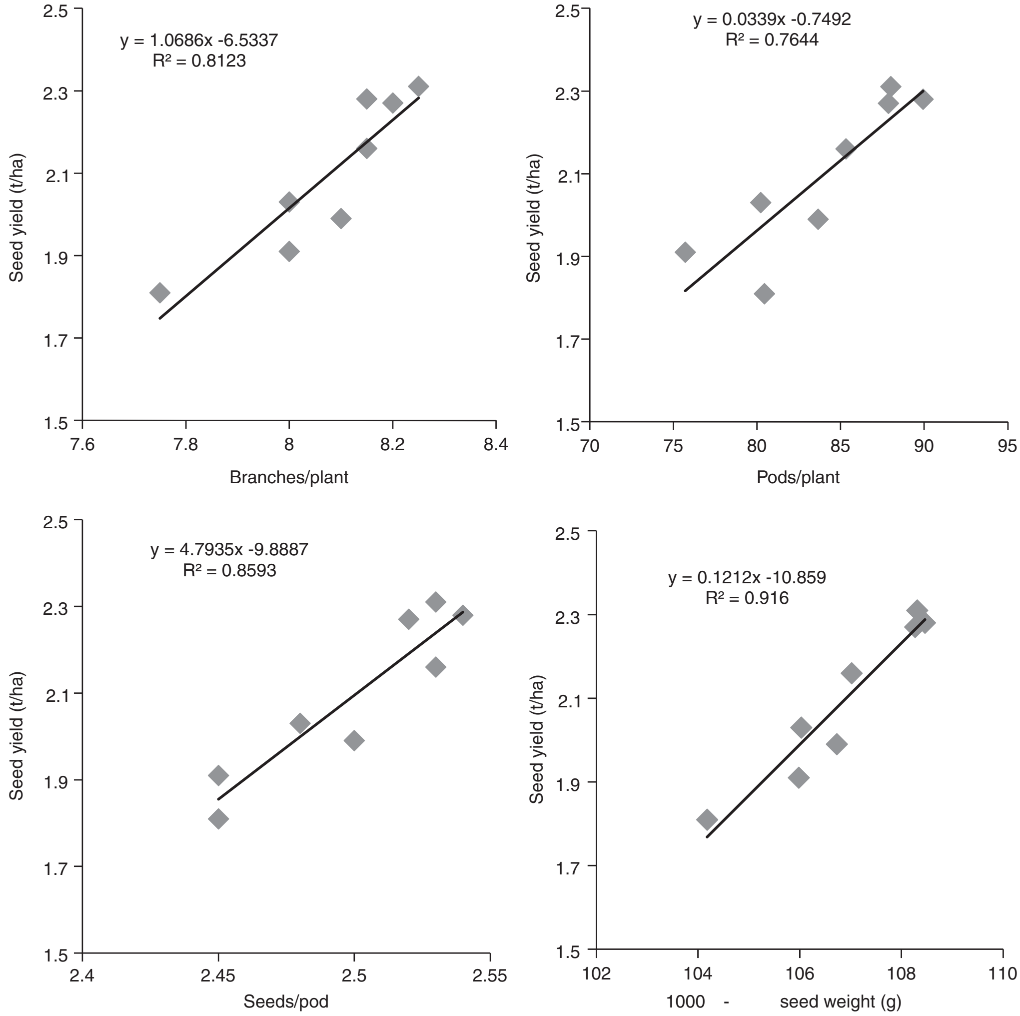

Fig 1 Correlation between soybean seed yield with yield attributes.

it was followed by ZT + R (3.80 t/ha), ZT–R (3.28 t/ha) and CT–R (3.32 t/ha). The higher yield attributes and seed yield in ZT–B + R was due to better crop establishment, soil moisture condition, fertilizer placement, moisture conservation, less lodging, field drainage and decreased water logging. This finding is in agreement with that of Ram *et al.* (2011) and Naresh *et al.* (2014). Conservation tillage plus (+) straw mulching had resulted in relatively higher and stable yield than rest of the two treatments. Residue application along with conservation tillage had increased the moisture supply and it facilitated the higher nutrient uptake and its translocation which resulted in improved yield (Zhou *et al.* 2018). Karunakaran and Behera (2016) also reported higher yield, nutrient uptake and resource use efficiency in soybean–wheat cropping system with surface retention of residues of one crop to other crop.

There were non–significant difference in case of number of branches/plant due to application of 40, 80 and 120 kg P_2O_5/ha. Application of 80 kg P_2O_5/ha gave significantly maximum number (88) of pods/plant and it was statistically on par with 120 P_2O_5/ha (87.9). The 1000–grain weight did not influence significantly due to different P levels, even though the application of 80 kg P_2O_5/ha recorded the highest 1,000–grain weight (108.3 g). Application of 80 kg P_2O_5/ha gave significantly higher seed yield (2.31 t/ha) which was statistically on par with application of 120 kg P_2O_5/ha (2.27 t/ha). The yield improvement with application of 80 kg P_2O_5/ha was 21.6 and 13.9% over 0 and 40 kg P_2O_5/ha, respectively. Application of 120 kg P_2O_5/ha recorded significantly the highest stover yield (3.74 t/ha) and it was statistically similar with 80 kg P_2O_5/ha. There was no significant interaction effect between crop establishment techniques and P fertilization on yield attributes and yields of soybean during the experimentation. The significant increase in yield attributes and grain yield due to basal application of P to soybean was consistent with increasing the rates up to 80 kg P_2O_5/ha. The higher seed yield due to phosphorus application might be due to improvement in plant growth as P plays important role in plant metabolism. Moreover, phosphorus application resulted in higher yield attributes and positive correlation between yield attibutes and seed yield was found with R^2 ranging from 0.76 to 0.91 (Fig 1). These results are in agreement with the findings of Aulakh *et al.* (2003) who reported the significant increase in grain yield due to direct application of P to soybean up to 80 kg P_2O_5/ha. However, application of 120 kg P_2O_5/ha didn't show any increment in yields over 80 kg P_2O_5/ha. This might be due to genetic potential of crop or phosphate fixation in soil or antagonistic effect of phosphorus over other essential plant nutrients.

Economic analysis with respect to cost of cultivation, gross returns, net returns and B:C ratio of soybean was significantly influenced by different tillage practices and phosphorus fertilization during the study of experiment (Table 1). The highest cost of cultivation was recorded with CT–R (31400 ₹/ha) which was followed by ZT–B + R, ZT + R and ZT–R. The lowest cost of cultivation was recorded with ZT–R (29000 ₹/ha) which was statistically on par with ZT + R and ZT–B + R. The significantly highest gross (65000 ₹/ha) and net returns (35100 ₹/ha) were obtained with ZT–B

+ R followed by ZT + R, ZT–R and CT–R. The ZT–R resulted in 7.6% lesser cost of cultivation than CT–R. Similarly, ZT + R and ZT–B + R resulted in 4.7% lesser cost of cultivation than CT–R. The highest B:C ratio (net returns per ₹ invested) of 2.18 was realized from the treatment involving ZT–B + R which was followed by ZT + R. The highest cost of cultivation was recorded with CT–R and lowest with ZT + R and ZT–B + R. This might be due to saving in cost for tillage practices (Jat *et al.* 2014). The use of ZT significantly reduces energy costs, mainly by reducing tractor costs associated with conventional methods (Erenstein and Farooq 2009). Zero tillage saved 7.6% cultivation cost compared to conventional tillage under no crop residue application situations. Similarly, ZT–B + R gave higher net returns of 11500 ₹/ha compared to conventional tillage without crop residue which was 34% higher. This was due to higher seed and stover yield under ZT–B + R compared to 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 (Ladha *et al.* 2009).

Among the phosphorus fertilization, the highest cost of cultivation (33000 ₹/ha) was recorded with application of 120 kg P_2O_5/ha followed by 80, 40 and 0 kg P_2O_5/ha application. The highest gross (65800 ₹/ha), net returns (34800 ₹/ha) and B:C ratio (2.12) were accrued with basal application of 80 kg P_2O_5/ha and this was followed by 120, 40 and 0 kg P_2O_5/ha. This was due to higher seed and stover yield with application of 80 kg P_2O_5/ha but crop didn't respond to 120 kg P_2O_5/ha significantly and it ultimately increased fertilizer input cost.

SUMMARY

Based on our findings, it can be concluded that soybean crop can be successfully raised with conservation agricultural (CA) practices with a reasonably high level of productivity and profitablity. The higher productivity and profitability was recorded under conservation agricultural practices involving zero-tillage-bed with wheat crop residue of 3.0 t/ha. The yield improvement of soybean with ZT–B + R was 16.2%, 10.96% and 5.3% compared with CT–R, ZT–R and ZT + R, respectively. The significantly highest gross (65000 ₹/ha), net returns (35100 ₹/ha) and B:C ratio (2.18) were obtained with ZT–B + R. Among phosphorus fertilization practices, soybean responded well up to 80 kg P_2O_5/ha (34.5 kg P/ha) as basal application with increase in crop productivity and profitablity. Yield improvement with 80 kg P_2O_5/ha was 21.6% and 13.9% compared to 0 and 40 kg P_2O_5/ha, respectively. However, application of 120 kg P_2O_5/ha (52.5 kg P/ha) didn't show any significant increment in productivity and profitablity over 80 kg P_2O_5/ha.

REFERENCES

Aulakh M S, Pasricha N S and Bahl G S. 2003. Phosphorus fertilizer response in an irrigated soybean–wheat production system on a subtropical, semiarid soil. *Field Crops Research* **80**: 99–109.

Directorate of Economics and Statistics, 2018. Retrieved fromhttp://eands.dacnet.nic.in/

Erenstein O and Farooq U. 2009. A survey of factors associated with the adoption of zero tillage wheat in the irrigated plains of south Asia. *Experimental Agriculture* **45**: 133–47.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research,* edn 2. An International Rice Research Book. A Willey-Interscience publication, John Willey & Son, New York.

Jat R K, Sapkota T G, Singh R G, Jat M L, Gupta M K and Raj K. 2014. Seven years of conservation agriculture in a rice–wheat rotation of Eastern Gangetic plains of South Asia: yield trends and economic profitability. *Field Crops Research* **164**: 199–210.

Kalwe S P and Rani R. 2005. Nutrient management in soybean. *Indian Journal of Fertilisers* **1**(3): 47–51.

Karunakaran V and Behera U K. 2016. Tillage and residue management for improving productivity and resource-use efficiency in soybean (*Glycine max*)–wheat (*Triticum aestivum*) cropping system. *Experimental Agriculture* **52**(4): 617–34.

Kashturikrishna S and Ahlawat I P S. 1999. Growth and yield response of pea (*Pisum sativum*) to moisture stress, phosphorus, sulphur and zinc fertilizers. *Indian Journal Agronomy* **44**: 588–96.

Ladha J K, Kumar V, Alam M M, Sharma S, Gathala M, Chandana P, Saharawat Y S and Balasubramanian V. 2009. Integrating crop and resource management technologies for enhanced productivity, profitability, and sustainability of the rice–wheat system in South Asia. (In) *Integrated Crop and Resource Management in Rice–Wheat System of South Asia*, pp 69–108 J K Ladha, Yadvinder-Singh and D Hardy (Eds). Los Banos, Philippines.

Naresh R K, Rathore R S, Yadav R B, Singh S P, Misra A K, Kumar V, Kumar N and Gupta R K. 2014. Effect of precision land levelling and permanent raised bed planting on soil properties, input use efficiency, productivity and profitability under maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system. *African Journal of Agricultural Research* **9**(36): 2781–89.

Ram H, Singh Y, Saini K S, Kler D S and Timsina J. 2013. Tillage and planting methods effects on yield, water use efficiency and profitability of soybean–wheat system on a loamy sand soil. *Experimental Agriculture* **49**(4): 524–42.

Ram H, Singh G, Aggarwal N and Kaur J. 2011. Soybean (*Glycine max*) growth, productivity and water use under different sowing methods and seeding rates in Punjab. *Indian Journal of Agronomy* **56**(4): 377–80.

Sharma S C and Vyas A K. 2001. Residual effect of phosphorus fertilization and farmyard manure on productivity of succeeding wheat (*Triticum aestivum*) after soybean (*Glycine max*). *Indian Journal of Agronomy* **46**(3): 416–20.

USDA. 2019. World Agricultural Production. Foreign Agricultural Service, Circular Series WAP 7–19, July 2019 United States Department of Agriculture. https://apps.fas.usda.gov/psdonline/circulars/production.pdf

Zhou L, Xingfa L, Qian Y, Xuan Y, Song C and Yuying S. 2018. In search of long–term sustainable tillage and straw mulching practices for a maize–winter wheat–soybean rotation system in the Loess Plateau of China. *Field Crops Research* **217**: 199–210.