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Research Paper

Effect of different sowing times and potash levels on insect pest populations, nutrient availability, uptake, yield and economics of soybean (*Glycine max*)

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) seasons of 2012–15 at Kasabe Digraj, Sangli, Maharashtra, to study the effect of different sowing times and potash levels on insect-pest populations, nutrient availability, uptake, yield and economics of soybean [*Glycine max* (L.) Merr.]. The treatments consisted of 3 sowing times, viz first, second fortnight of June and first fortnight of July as a main treatments; and 0, 15, 30 and 45 K_2O kg/ha as subtreatments. The stem length tunnelling percentage, caused by stem fly and *Spodoptera* significantly increased with the late sowing and ranged between 12.84 –14.12 among the sowing times. The reduction in population of aphids, *Spodoptera* and stem tunneling was recorded in 45 K_2O kg/ha applied to soybean as compared to the control. The effect of different sowing times was found non-significant on soil properties except electrical conductivity (EC). Different levels of potash given to soybean exerted significant influence on EC of soil, available nitrogen (N), phosphorus (P) and also potassium (K) in soil after crop harvest. The highest EC of soil and available K were recorded in treatment where potash was applied @ 45 kg/ha as compared to rest of the levels of this nutrient tried and at par with application of potash @ 30 kg/ha in respect of EC, available N, P and K content in soil. Significantly highest total uptake of N, P and K of soybean was observed in the first fortnight of June as compared to the first fortnight of July. The highest total uptake of N, P and K by soybean was recorded in treatment with potash applied @ 45 kg/ha as compared to the remaining levels of potash. Significantly highest grain yield (1.99 t/ha) of soybean was registered in plot sown during the first fortnight of June over all those sown thereafter. Similarly, it also remained highest in treatment receiving potash @ 45 kg/ha. The sowing of the soybean crop during the first fortnight of June resulted in significantly higher net monetary returns of ₹15.49 × 10^3/ha with significantly highest benefit: cost (B:C) ratio of 1.58. The benefit: cost ratio of potash applied @ 30 and 45 kg/ha remained at par. Application of 5 tonnes FYM/ha with 50, 75 and 45 kg N, P_2O_5 and K_2O kg/ha to soybean sown in first fortnight of June is recommended as a revised fertilizer nutrient dose for medium deep black soils for minimizing insect-pest populations, getting higher yield, monetary returns and maintaining soil fertility.

Key words: Economics, Insect pest populations, Nutrient uptake, Potash levels, Soil fertility status, Sowing times, Soybean, Yield

Globally, soybean [*Glycine max* (L.) Merr.] continues to rank first amongst various oilseed crops. In India, soybean has emerged as main oilseed crop within a short span of time. Rising demand for oil and protein has stimulated soybean production mainly by increasing land use, as very modest growth in productivity has been achieved. With the improvement of productivity through the adoption of optimum sowing times, high-yielding varieties and multiple cropping systems, fertilizer use has become more and more important to increase oil crop yield and quality. The slow pace of growth in soybean productivity is more or less linked to imbalanced, inadequate nutrition and sowing times. The time of sowing has a considerable influence on growth and yield of soybean. Early sowing in the season may encourage higher vegetative growth which may invite various diseases and insects-pests. However, delayed sowing may shrink the vegetative phase, which in turn reduces dry-matter accumulation leading to poor partitioning to reproductive parts and ultimately poor realization of the potential yield. The area, production and productivity in Maharashtra for last 21 years revealed that the area under soybean cultivation is increasing rapidly in the state. It is a common practice in western Maharashtra to rotate soybean with sugarcane. The fertilizer dose of sugarcane is much higher that of soybean. In view of this, there is a

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possibility of low or high fertilizer dose of soybean. Rao *et al.* (1999) reported that cereals deplete more soil K whereas legumes depend more an applied K for their K needs. Long-term experiments conducted in India showed decline in crop yields as a result of potassium deficiency (Rupa *et al.,* 2003). As most of the rainy (*kharif*) season soybean is grown under rainfed conditions, it experiences water and temperature stresses of varying degrees, particularly at the stage of pod filling. Yield is thus ultimately affected and the relevance of K nutrition in alleviating stress conditions assumes great importance (Tomar and Dwivedi, 2008). In view of this, there is a possibility of low or high fertilizer application to soybean as most of the farmers do not apply the fertilizer based on soil-test report. The recommended dose of fertilizer for soybean (50, 75, 0 N-P_2O_5-K_2O kg/ha) is devoid of potassium. However, potassium has been described as the 'quality element', ensuring optimum quality of agricultural produce. Much larger quantities of K are needed for this physiological function than for its biochemical role in plants (Mengel and Kirkby, 1980). The annual consumption of N, P and K fertilizer per ha is in the ratio 8.5, 6.9 and 1 against an ideal of 4, 2 and 1. Hence an experiment was conducted with an objective to study the effect of different sowing times and potash levels on insect- pest populations, nutrient availability, uptake, yield and economics of soybean.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (*kharif*) seasons of 2012–13 to 2014–15 at Agricultural Research Station, Kasabe Digraj, Sangli, Maharashtra, India. The soil was calcareous belonging to Sawargaon series of isohyperthermic family of *Vertic haplustepts*. Climatically the area belongs to semi-arid zone with an average rainfall of 420 mm. The initial experimental soil was alkaline (*p*H 8.01), having electrical conductivity (EC) 0.17 dS/m, calcareous ($CaCO_3$ 7.88 %), clayey in texture with bulk density of 1.10 Mg/m^3, hydraulic conductivity 0.35 cm/hr and soil-available N (alkaline $KMnO_4$), P (Olsen P) and K (NH_4OAc) contents were 204, 8.55 and 550 kg/ha respectively. The experiment was laid out in a split-plot design and replicated 3 times. The treatments consisted 3 sowing times, viz. first fortnight of June, second fortnight of June and first fortnight of July as a main treatments and 4 levels of potash, viz. 0, 15, 30 and 45 kg/ha, as a subtreatments. The basal dose of recommended dose fertilizer N and P_2O_5 @ 50 and 75 kg/ha and levels of K were applied for soybean as per the treatments. The sources of N, P and K were urea, single superphosphate and potassium chloride, respectively. Farmyard manure (FYM) 5 t/ha was applied 15 days before sowing of soybean to all the plots. 'Phule Agrani' soybean was sown as per the sowing times with spacing of 45 cm × 5 cm (row × plant). The standard agronomic package of practices was adopted. Aphids were counted on 5 random plants in each treatment from 3 leaves/plant (top, middle and bottom) in thrice at weekly intervals after incidence. In case of stem fly, 10 plants were removed 30 days after sowing, again at harvesting and dissected to measure the tunneling length. The total stem length and tunneling length percentage were worked out. In case of *Spodoptera*, the number of larvae/m row length was counted in each plot. The initial representative soil samples (0–15 cm soil depth) were collected from experimental site and also at the time of harvesting from each treatment plot every year. These samples were analysed for various chemical parameters. Soil samples were analysed for *p*H and EC in 1 : 2.5 soil suspension (Jackson, 1973), available N by the alkaline permanganate method (Subbiah and Asija, 1956), available P (Olsen-P) by 0.5 M $NaHCO_3$ extraction (Olsen *et al.,* 1954), available K (NH_4OAc-K) by 1 N neutral NH_4OAc extraction on flame photometer (Knudsen *et al.,*1982). The plant and grain samples were collected at the time of harvesting and analyzed for total N by microkjeldahl method in $H_2SO_4 : H_2O_2$ (1 : 1) digestion (Parkinson and Allen, 1975), total P by vanadomolybdate yellow colour method in nitric acid $H_2SO_4 : HClO_4 : HNO_3$ (1 : 4 : 10) digestion (Jackson, 1973), total K on flame photometer in $H_2SO_4 : HClO_4 : HNO_3$ (1 : 4 : 10) (Chapman and Pratt, 1961). The statistical analysis was carried out by procedure suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Insect pest populations

The population density of aphids, *Spodoptera* and stem tunneling caused by stem fly affected significantly among the sowing times (Table 1). The population of aphids and *Spodoptera* reduced significantly with late sowing. It varied between 5.00 and 15.32/leaf and 1.39 to 2.04/m row length in respect of aphids and *Spodoptera,* respectively. The reduction in aphids with late sowing is attributed to better rains, whereas in case of *Spodoptera* it may be due to loss of foliage/ reduced chlorophyll content of leaves. The trend in respect of stem fly was reverse to that of aphids and *Spodoptera.* The stem length tunneling percentage significantly increased with late sowing and ranged between 12.84 and 14.12 among the sowing times. Early sowing also helped to reduce stem tunneling caused by stem fly significantly over the control. The population of aphids and *Spodoptera* also significantly varied as per levels of potassium applied to soybean as compared to the control. The aphids ranged from 8.62 and 11.44/leaf. The application of 45 K_2O kg/ha remained at par with 30 K_2O

kg/ha in respect of aphids. The number of *Spodoptera* larvae ranged from 1.17 to 2.10. The reduction to the extent of 8.03, 24.45 and 44.3% about percentage of stem length tunneling, number of aphids/leaf and number of *Spodoptera*/m row length was achieved in @ 45 K_2O kg/ha in addition to application of 5 t FYM /ha with 50, 75 and 45 kg N, P_2O_5 and K_2O/ha over the control. This might be owing to the function of K in the development of thicker outer walls in the epidermal cells, providing protection against insect attack. The attacks of insects like blue beetle, grey semilooper, girdle beetle and stem fly were clearly reduced with K applications to soybean and this increased the yield (Bansal *et al.,* 2001). The higher incidence of stem fly, aphids and *Spodoptera* was recorded in soybean when poorly supplied with K.

Grain and straw yields

Significantly highest grain yield (1.99 t/ha) and straw yield (2.49 t/ha) was registered with the first fortnight of June over all those sown later (Table 2). The higher reduc-

Table 1. Effect of sowing times and potash levels on number of aphids /leaf, percentage of stem length tunneling caused by stem fly and *Spodoptera* population in soybean (pooled over 3 years)

Treatment	Number of aphids/leaf	Percentage of stem length tunneling caused by stem fly	*Spodoptera* population/m row length
Sowing times			
First fortnight of June	15.32[a]	12.23 (20.40)[b]	2.07[a]
Second fortnight of June	8.62[b]	13.33 (21.35)[a]	1.57[b]
First fortnight of July	5.50[c]	13.95(21.72)[a]	1.39[b]
SEm.±	0.31	0.14	0.08
CD (P=0.05)	0.97	0.42	0.25
Potash levels (kg/ha)			
0 K_2O	11.41[a]	14.11(22.03)[a]	2.14[a]
15 K_2O	10.10[a]	13.2 (21.45)[a]	1.92[a]
30 K_2O	9.13[b]	12.98 (20.88)[b]	1.51[b]
45 K_2O	8.62[b]	12.34 (20.26)[b]	1.14[c]
SEm±	0.31	0.21	0.10
CD (P=0.05)	0.86	0.58	0.29

Means followed by the same letters (a,b,c,d) in a column are not different at 0.05 probability level; The arcsin values indicated in column inside bracket.

Table 2. Effect of sowing times and potash levels on yield and economics of soybean (pooled over 3 years)

Treatment	Yield of soybean (t/ ha)		Net monetary returns	Benefit:
	Grain	Straw	(× 10^3 ₹/ha)	cost ratio
Sowing times				
First fortnight of June	1.99[a]	2.49[a]	15.49[a]	1.58[a]
Second fortnight of June	1.56[b]	1.95[b]	4.80[b]	1.30[b]
First fortnight of July	0.87[c]	1.09[c]	-11.76[c]	0.77[c]
SEm±	0.026	0.032	0.64	0.03
CD (P=0.05)	0.082	0.095	1.99	0.09
Potash levels (kg/ha)				
0 K_2O	1.38[d]	1.73[d]	1.19[d]	1.17[b]
15 K_2O	1.49[c]	1.81[c]	2.24[c]	1.20[b]
30 K_2O	1.51[b]	1.89[b]	3.52[b]	1.24[a]
45 K_2O	1.57[a]	1.96[a]	4.41[a]	1.26[a]
SEm±	0.009	0.011	0.22	0.01
CD (P=0.05)	0.026	0.032	0.62	0.03
Soybean market price (₹/kg):			22.50 in 2012; 25.00, 2013; 31.00, 2014	
Muriate of potash (₹/kg):			17 in 2013	

Means followed by the same letters (a,b,c,d) in a column are not different at 0.05 probability level.

tion in grain yield of soybean was recorded 56.20% in the first fortnight of July sown and 21.77% in the second fortnight of June sown crops compared to first fortnight of June. The findings confirm the results of Billore *et al.* (2009), who reported superiority of timely planting of soybean to the late planting in respect to all the parameters along with grain yield. Jaybhay *et al.* (2016) also reported that 28.18% loss in yield by sowing the crop on 20 July compared to the optimal time of sowing on 20 June. The significantly highest grain yield (1.57 t/ha) and straw yield (1.96 t/ha) of soybean were recorded in treatment with potash applied @ 45 kg/ha as compared to rest of the levels of potash. The increase in grain yield of soybean was recorded 4.47% when potash was applied @ 15 kg/ha, 9.24% in @ 30 kg/ha and 13.35% in @ 45 kg/ha as compared to without application of potash. The lowest grain and straw yields of soybean were recorded under treatment receiving no potash application. The pooled grain and straw yields of soybean were increased with the increase in rate of potash application. Singh *et al.* (2015) also reported that the yield of wheat increased significantly with the increasing levels of K up to 60 kg K_2O/ha. The increase in yield with increased K in treatments allowed rapid assimilation of absorbed NH_4^+ in plants maintaining a low non-toxic level of NH_3. This has led to increased uptake of N at higher levels of N resulting in increased yield (Dibb and Welch, 1976). Potassium is known as one of the nutrients which is closely involved in metabolic processes and improves yield (Imas and Magen, 2007; Basseto *et al.,* 2007).

Economics

The sowing of the soybean crop during the first fortnight of June gave significantly net monetary returns with significantly highest benefit: cost ratio of 1.58 (Table 2). The benefit: cost ratio when potash applied @ 30 and 45 kg/ha remained non-significant. Singh *et al.* (2015) also noticed that the application of 60 kg K_2O/ha resulted in significantly highest net returns and benefit: cost ratio.

Nutrient availability

The effect of different sowing times were found non-significant on *p*H, available N, P and K in soil after harvesting of soybean except EC (Table 3). The slightly highest *p*H, electrical conductivity (EC), available N and K were observed with soil utilized for sowing in the first

Table 4. Effect of sowing times and potash levels on total nutrient uptake by soybean (pooled over 3 years)

Treatment	Total nutrient uptake (kg/ha)		
	N	P	K
Sowing times			
First fortnight of June	112[a]	14.3[a]	41.0[a]
Second fortnight of June	87[b]	11.1[b]	31.8[b]
First fortnight of July	49[c]	6.2[c]	17.8[c]
SEm±	1.53	0.20	0.55
CD (P=0.05)	4.71	0.61	1.68
Potash levels (kg/ha)			
0 K_2O	76[d]	9.6[c]	27.8[d]
15 K_2O	81[c]	10.2[b]	29.4[c]
30 K_2O	85[b]	10.8[a]	31.0[b]
45 K_2O	89[a]	11.4[a]	32.5[a]
SEm±	0.97	0.17	0.40
CD (P=0.05)	2.69	0.47	1.12

Means followed by the same letters (a,b,c,d) in a column are not different at 0.05 probability level.

Table 3. Effect of sowing times and potash levels on soil *p*H, electrical conductivity and available nutrients in soil after harvesting of soybean (pooled over 3 years)

Treatment	pH	EC (dS/m)	Available nutrients (kg/ha)		
			N	P	K
Sowing times					
First fortnight of June	8.18	0.24[b]	240	14.80	529
Second fortnight of June	8.16	0.26[ab]	238	14.38	529
First fortnight of July	8.15	0.29[a]	229	15.28	526
SEm±	0.39	0.01	3.77	0.56	10.48
CD (P=0.05)	NS	0.04	NS	NS	NS
Potash levels (kg/ha)					
0 K_2O	8.21	0.25[b]	222[c]	12.40[c]	508[c]
15 K_2O	8.16	0.25[b]	235[ab]	14.96[b]	520[abc]
30 K_2O	8.14	0.27[a]	240[ab]	15.83[ab]	536[ab]
45 K_2O	8.13	0.28[a]	246[a]	16.10[a]	548[a]
SEm±	0.31	0.01	3.67	0.51	10.27
CD (P=0.05)	NS	0.02	10.16	1.42	28.47

Means followed by the same letters (a,b,c,d) in a column are not different at 0.05 probability level.

fortnight of June as compared to the other sowing times. Significantly highest EC of soil was observed in the first fortnight of June as compared to first fortnight of July (0.24 dS/m). The effect of different levels of potash given to soybean exerted significant influence on EC of soil, available N, P and K in soil after crop harvesting whereas *p*H of soil showed non-significant effect. The soil *p*H was decreased, while EC of soil increased with the increase in rate of potash application. The highest EC of soil (0.28 dS/m) and available K (548 kg/ha) were recorded in where was potash applied @ 45 kg/ha as compared to rest of the levels of this nutrient. The potash application @ 45 kg/ha remained at par with 30 kg/ha in respect of EC, available N, P and K content in soil. The increase in available N, P and K content in soil might be owing to beneficial effect of organic manure on growth because of additional supply of plant nutrients as well as improvement in physical and biological properties of soil. Available nutrient in soil after harvesting was maximum with the application of 100% RDF + FYM 5 t/ha with 45 kg K_2O/ha. Addition of organic manures not only supplies most of the essential plant nutrients, but also improves the soil structure by providing binding substances to soil aggregates leading to increase in cation-exchange capacity and water-holding capacity of the soil. Besides this, the organic manures improve the efficiencies of applied fertilizers. The decomposition and mineralization of organic manure is a slow process which could match the nutrient requirement of a crop (Dadhich and Somani, 2007; Singh *et al.,* 2007). The lowest EC of soil and available N, P and K was recorded in treatment with no potash application and remained at par with @ 15 kg/ha. It is indicative of the fact that potash @ 15 kg/ha was insufficient in improving soil properties and its available nutrient status after harvesting of soybean, this might be owing to fixation of K in soil. The interaction between sowing time of soybean and application of different levels of potash is non-significant, both of the factors being independent.

Nutrient uptake

The significantly highest total N, P and K uptake of soybean was recorded in the first fortnight of June as compared to other sowing times. The sowing dates were significantly differ among themselves for total N, P and K uptake of soybean. The effect of different levels of potash given to soybean exerted significant influence on total N, P and K uptake of soybean (Table 4). The highest total uptakes of N, P and K by soybean were recorded in treatment where potash was applied @ 45 kg/ha as compared to rest of the levels of potash. The potash application @ 45 kg/ha remained at par with 30 kg/ha for total uptake of P of soybean. The different levels of potash were differed significantly among themselves for total N and K uptake of soybean. The total N, P and K uptake of soybean was increased with the increase in rate of potash application. The higher uptake of nutrients under different treatments and their interactions might be owing to increased total biomass and per cent nutrient contents in those treatments. Potassium plays an important role in ensuring efficient utilization of N. The lowest total N, P and K uptake of soybean was recorded in treatment with potash was not applied. The insufficient K supply, NO_3^- accumulates in the root, being partially reduced and converted into amino acids. As a consequence, with increased K depletion the yield and N-use efficiency decrease. The application of potassium was significantly increased nutrient uptake from soil (Kumar *et al.,* 2015). Jat *et al.* (2013) also reported that an improvement in N, P and K content and their uptake of sorghum were noticed with 100% NPK over the control. The interaction between sowing time of soybean and application of different levels of potash was non-significant, both of the factors being independent.

It can be concluded that the sowing of the soybean in the first fortnight of June with application of 45 kg K_20/ha in addition to general recommended dose of fertilizer (50–75 N kg, P_2O_5 kg/ha and 5 t FYM/ha) to soybean for getting better yield, monetary benefits and maintenance of soil fertility.

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