Original Research Article

Effect of phosphorus, sulphur andgibberellic acidon growth, root nodules and yield of soybean [*Glycine max* (L.) Merrill]

Abstract

An experiment conducted during *kharif* season 2020 at Instructional Farm, College of Agriculture, Ummedganj, Kota. The experiment comprised 24 treatment combinations, having four levels of phosphorus *viz*., 0, 20, 40 and 60 kg ha^{-1}, three levels of sulphur viz., 15, 30 and 45 kg ha^{-1} and foliar spray of gibberellic acid *viz*., no spray and spray of GA_3 @ 75 ppm laid out in sub-sub split plot design with three replications. Results showed that application of 60 kg P_2O_5 ha^{-1} had significant effect on plant height, dry matter accumulation plant^{-1}, branches plant^{-1} at 30, 60 DAS and at harvest, while root nodules plant^{-1} and their dry weight at 45 DAS andseed yield (1956 kg ha^{-1})over application of 20 kg P_2O_5 ha^{-1} and control. However, it was found at par with application of 40 kg P_2O_5 ha^{-1}.

Application of 45 kg sulphur ha^{-1} had significantly higher plant height (cm) at 60 DAS and at harvest, dry matter accumulation (g plant^{-1}) at 30, 60 and at harvest stages, branches plant^{-1} at 30, 60 and at harvest stage, number of root nodules and their dry weight (g) and seed yield (1742 kg ha^{-1}) which was found at par with application of 30 kg sulphur ha^{-1} over 15 kg sulphur ha^{-1}. Application of gibberellic acid @ 75 ppm as foliar spray gave significantly higher plant height (cm) at 60 DAS and at harvest stage, dry matter accumulation (g plant^{-1}) at 60 DAS and at harvest, branches plant^{-1} at 30, 60 DAS and harvestand seed yield (1770 kg/ha)over control.

Key Words: Growth, root nodules, seed yield, phosphorus, sulphur and gibberellic acid.

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Introduction

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In India oilseed crops constitute the second largest agricultural produce, next to food grain and these crops are the important sources of fats and oils. The oil and economic end product of oilseed crop is an integral part of human diet. Beside the dietary needs, the vegetable edible oil has numerous mechanical, industrial, medicinal and therapeutic uses too.

Soybean has paramount importance in human and animal nutrition, because it is a major source of edible vegetable oil and high protein feed as well as food in the world. Soybean is considered as miracle crop because it contains 38-42 per cent good quality protein, 23 per cent carbohydrates, 18-20 per cent oil, rich in poly unsaturated fatty acids, good amount of minerals and vitamins especially B-complex and tocopherols. It provides high amounts of phyto-chemicals and good quality dietary fibre which enables to protect human body against cancers and diabetes (Chouhan, 2007).

India ranks fifth in the world in area and production after USA, Brazil, Argentina and China. Soybean has emerged as an important oilseed crop in India. On the national basis, soybean occupied an area of 12.09 million ha with production and productivity of 11.22 metric tonnes and 928 kg ha^{-1}, respectively (DAC & FW, 2019-20). Soybean is grown as a major oilseed crop mainly in south-eastern parts of Rajasthan during *kharif* season. It covers 1.12 million ha with an annual production and productivity of 0.52 metric tonnes and 469 kg ha^{-1} respectively in the state(DAC & FW, 2019-20). Six districts namely Kota, Bundi, Baran, Jhalawar, Sawai madhopur and Karauli of state come under the jurisdiction area of Agriculture University, Kota. Soybean crop has an area of 7.26 lakh ha with annual production 3.43 lakh tones and average productivity is 636 kg ha^{-1}(DOA, 2019-20), which is quite less than its potential yield is owing to various stresses during growing season.

Plants require phosphorus for growth throughout their life cycle, especially during the early stages of growth and development. In soybean, the demand for phosphorus is the greatest during pod and seed development stage where more than 60 per cent of phosphorus tends up in the pods and seeds (Usherwood, 1998). Its uptake and utilization by soybean are essential for ensuring proper nodule formation and improving yield and quality of the crop.Sulphur plays a pivotal role in various plant growth and development processes being a constituent of sulphur containing amino acids, cystine and methionine, and other metabolites *viz.*, lutathione and phytochelators.

Sulphur is used as soil amendment for amelioration, as plant nutrient for increasing yield and quality of crop produce, as chemical agent to acidulate other nutrient and pesticides (Kanwar and Mudahar, 1986).A higher susceptibility of crops to certain diseases was observed in sulphur deficient soils (Schnug*et al.*, 1995). It is also implicated in oil biosynthesis in soybean seed (Fazli*et al.*, 2005). Still the studies on effect of sulphur in soybean are very meagre. The sulphur is required in high amount by the oilseeds and hence has been identified as key nutrient responsible for high production.Plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-

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assimilates there by helping in improve the physiological efficiency, photosynthetic ability, effective partitioning of accumulates from source to sink and ultimately enhance productivity of the soybean crop (Solamani*et al.*, 2001). Gibberellic acid constitutes a group of tetracyclic diterpenoids, involved in plant growth and development. A well-known phyto-hormone has numerous physiological effects on plants including seed germination, growth, stem elongation, leaf expansion, photosynthesis, flowering, cell expansion and also increase in activities of many key enzymes like carbonic anhydrase, nitrate reductase in field crops (Aftab *et al*., 2010).

Material and Methods

An experiment was conducted during *kharif*season 2020 at Instructional Farm, College of Agriculture, Ummedganj, Kota (Rajasthan), which is situated at South-Eastern part of Rajasthan. In Rajasthan, this region falls under Agro-climatic zone V B (Humid South eastern Plains) of Rajasthan. This zone possesses typical sub-tropical conditions with maximum and minimum temperatures ranged between 34.2°C to 38.0°C and 18.6°C to 24.0 °C during *Kharif*, 2020. The total amount of rainfall received during crop growing was 551 mm. The soil of experimental site was clay loam in texture, slightly saline in reaction. The experimental soil was medium in available nitrogen (264 kg ha^{-1}) and phosphorus (21.7 kg ha-1) while high in potassium (388 kg ha-1) and sufficient in DTPA extractable micronutrients with pH (7.61) and EC (0.52 dS m^{-1}). Source of nutrients applied were urea for nitrogen, DAP for phosphorus and mutate of potash for potassium.

The experiment consisted of twenty-four treatment combinations including four levels of phosphorus (control, 20, 40 and 60 kg/ha)allocated in main plots, three levels of sulphur (15, 30 and 45 kg/ha)in sub plots and two levels of foliar application of gibberellic acid (foliar spray of GA3 @ 75 ppm and no spray of GA3) in sub- sub plotswere under taken in sub-sub split plot design with replicated thrice. Data on growth parameters like plant height, dry matter accumulation, branches $plant^{-1}$, root nodules, nodules dry weight and seed yield were recorded as per standard procedures. Plant samples were collected from each of the plots. The data were statistically analysed by adopting appropriate method of standard analysis of variance (Gomez and Gomez, 1984).

Results and Discussion

Effect of phosphorus

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Growth parameters

Data presented in Table 1revealed that plant population of soybean at 30 DAS and at harvest was not significantly affected by any of the treatment combination. Thus, plant population was almost uniform in all the treated plots.The phosphorus fertilization failed to bring perceptible variation in plant height at 30 DAS, while variation in plant height due to difference level of fertilizer was significant at 60 DAS and at harvest. Significantly tallest plant height (55.97 cm) at 60 DAS and (75.93 cm) at harvest was recorded with the application of 60 kg P_2O_5 ha^{-1}which remained statistically at par with 40 kg P_2O_5 ha^{-1} and over 20 kg P_2O_5 ha^{-1} and control. Application of 60 kg P_2O_5 ha^{-1} gave significantly higher dry matter accumulation (3.56,12.02 and 16.63 g $plant^{-1}$) at 30, 60 DAS and at harvest, respectively which was closely followed by application of 40 kg P_2O_5 ha^{-1}(3.15, 10.68 and 15.20 g $plant^{-1}$) over application of 20 kg P_2O_5 $ha^{-1}$and control. The higher number of branches (2.98, 4.49 and 5.15 $plant^{-1}$) at 30, 60 DAS and at harvest was recorded with the application of phosphorus 60 kg ha^{-1} over application of 20 kg phosphorus ha^{-1} and control. However, it was found at par with application of phosphorus 40 kg ha^{-1}(2.69, 4.01 and 4.67 $plant^{-1}$) at 30, 60 DAS and at harvest. The maximum number of root nodules $plant^{-1}$(52.02) at 45 DAS was recorded with application of 60 kg P_2O_5 ha^{-1} which was closely followed by 40 kg P_2O_5 ha^{-1} over control. Significantly higher dry weight of root nodules (84.44 mg $plant^{-1}$) at 45 DAS was recorded with the application of 60 kg P_2O_5 ha^{-1}which was closely followed by application of 40 kg P_2O_5 ha^{-1} dry weight of root nodules (80.02 mg $plant^{-1}$) over application of 20 kg P_2O_5 ha^{-1} and control (Table 2).

Plant height may be increased due to uptake of nitrogen and phosphorus by the plants, which was made available phosphorus through nitrogen fixation and phosphorus solubilisation by the beneficial microorganisms (Singh *et al*., 2016).Phosphorus promotes root growth, cell formation, leaf development, seed formation and accelerates early maturity of crop which may result to increment in branches, root nodulesof plant (Miranda *et al.*, 2013). This might be due to the fact that application of phosphorus results profuse growth of roots which ultimately resulted formation of a greater number of large size root nodules (Singh *et al.*, 2010).Each increment in phosphorus fertilizer levels recorded significantly variations in leaf area index and green leaves $plant^{-1}$ at 45 DAS. This reveals that increasing phosphorus level enhanced the soil phosphorus availability and consequently it's mining by soybean crop plants which led to higher size of photosynthetic apparatus. This statement is endorsed by significantly higher chlorophyll content and leaf area index at different growth stages of the cropby many workers including (Chavan *et al.*, 2008).

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Yield

A reference datawas recorded during experimentation and data presented in Table 2. Data further showed that various level of phosphorus fertilizer significantly influenced seed yield of soybean. The maximum seed yield (1956 kgha^{-1}) was recorded with the application of 60 kg P_2O_5 ha^{-1} over application of 20 kg P_2O_5 ha^{-1} and control seed yield (1559 and 1176 kg ha^{-1}). However, it was found at par with application of 40 kg P_2O_5 ha^{-1} seed yield (1877 kg ha^{-1}). Phosphorous application accelerated the production of photosynthates and their translocation from source to sink, which ultimately gave the higher values of yield contributing characters. Increase in yield contributing characters has also been reported by Meena *et al.* (2006) and Kumar *et al.* (2007). This was mainly due to fact that the better availability of nitrogen and phosphorus caused well developed root system having higher nitrogen fixing capacity resulting better growth and development of plants and better diversion of photosynthates towards sink, even use of single or combination of fertilizers might be much advantageous for farmers (Singh *et al.*, 2017).

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Effect of sulphur

Growth parameters

Data presented in Table 1 revealed that plant population of soybean at 30 DAS and at harvest was not significantly affected by any of the treatment combination. Thus, plant population was almost uniform in all the treated plots. Data further indicated that plant height at 30 DAS was remained significantly unaffected with application of sulphur. Significantly highest plant height (53.05 cm) at 60 DAS and (73.57 cm) at harvest was recorded with the application of 45 kg sulphur ha^{-1} which was closely followed by 30 kg sulphur ha^{-1} at 60 DAS (49.88 cm) and at harvest (70.45 cm).Significantly highest dry matter accumulation (3.15,10.58 and 15.16 g plant^{-1}) at30, 60 DAS and at harvest was recorded with the application of 45 kg sulphur ha^{-1}, which was closely followed by application of 30 kg sulphur ha^{-1} (2.90, 9.99 and 13.87 g plant^{-1}) at 30, 60 DAS and at harvest over application of 15 kg sulphur ha^{-1}. Significantly higher number of branches (2.78, 4.0 and 4.83 plant^{-1}) at 30, 60 DAS and at harvest was recorded with the application of 45 kg sulphur ha^{-1}which was closely followed by application of 30 kg sulphur ha^{-1} (2.54, 3.75 and 4.44 branches plant^{-1}). Minimum number of branches plant^{-1} was recorded under application of 15 kg sulphur ha^{-1}Table 2. Application of 45 kg sulphur ha^{-1}was recorded significantly higher root nodules plant^{-1} (49.09) at 45 DAS over application of sulphur 15 kg ha^{-1} (42.49) root nodules plant^{-1}. However, it was found at par with the application of 30 kg sulphur ha^{-1} root nodules plant^{-1}

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(46.30). Application of 45 kg sulphur ha^{-1}was recorded significantly higher dry weight of root nodules (80.84 mg plant^{-1}) at 45 DAS over application of 15 kg sulphur ha^{-1}. However, it was found at par with the application of 30 kg sulphur ha^{-1}dry weight of root nodules (75.33 mg plant^{-1}).

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This may be due to better root development and profuse nodulation on account of increased *rhizobial* activity in the rhizosphere under sulphur and bio fertilizers availability. This finally resulted in the formation of bolder and more number of root nodules. The positive response of sulphur on nodulation was also observed by Watimongla and Gohain (2012). The plant height and branches improved by sulphur alone or combined with nitrogen whereas, nitrogen alone decreased number of pods plant^{-1} thus showing non-significant ($P \leq 0.05$) variation in grain yield as compared to control. The results corroborate the findings with sulphur application of 40 kg ha^{-1} enhanced the plant height and branches in soybean (Ganeshamurthy,1996).The sulphur fertilizer levels recorded significantly variations in leaf area index and green leaves plant^{-1} at 45 DAS. This reveals that increasing sulphur level enhanced availability of sulphur in soil and consequently it's mining by soybean crop plants which led to higher size of photosynthetic apparatus. This statement is endorsed by significantly higher chlorophyll content and leaf area index at different growth stages of the crop. The increase in green leaves plant^{-1} and leaf area index with sulphur levels has been ascribed to more dry matter accumulation, this might be due to high accumulation of net photosynthates. The results obtained are consistent with findings reported by Meena *et al.* (2011).

Yield

Data was recorded during experimentation and data presented in Table 2showed that various level of phosphorus fertilizer significantly influenced seed yield of soybean. The maximum seed yield (1742 kg ha^{-1}) was recorded with the application of 45 kg sulphur ha^{-1} over application of 15 kg sulphur ha^{-1} seed yield (1500 and 1176 kg ha^{-1}). However, it was found at par with application of 30 kg sulphur ha^{-1} seed yield (1684 kg ha^{-1}).The yield increased under sulphur fertilization might be ascribed to increased pods plant^{-1} and seeds pod^{-1} with heavier seeds. Thus, significant improvement in yield obtained under sulphur fertilization seems to have resulted owing to increased concentration of sulphur in various parts of plant that helped maintain the critical balance of other essential nutrients in the plant and resulted in enhanced metabolic processes. Vyas *et al.* (2006) also noticed increased yield of soybean with application of sulphur. Sulphur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through development of reproductive structures and production of assimilates to fill economically important sink (Sharma and Singh, 2005). The seeds pod^{-1} and seed yield improved by sulphur alone or combined with nitrogen whereas, nitrogen alone decreased number of pods plant^{-1} thus showing non-significant variation in seed yield as compared to control. The results corroborate the findings with application of 40 kg sulphur ha^{-1} enhanced the pod plant^{-1} and test weight (g) in black gram (Singh and Aggarwal, 1998).

Effect of gibberellic acid

Growth parameters

Data presented in Table 1 revealed that plant population of soybean at 30 DAS and at harvest was not significantly affected by any of the treatment combination. Thus, plant population was almost uniform in all the treated plots. Application of foliar spray of GA_3 @ 75 ppm failed to bring about significant variation in plant height over control at 30 DAS, while the effect of application of foliar spray of GA_3 @ 75 ppm was significant (51.96 cm) at 60 DAS and (72.45 cm) at harvest over no spray. A critical examination of data shows that the foliar spray of GA_3 @ 75 ppm failed to bring about significant variation in dry matter accumulation over control at 30 DAS. The significantly highest dry matter accumulation (10.05 and 14.42 g plant^{-1}) at 60 DAS and at harvest was recorded with the application of foliar spray of GA_3 @ 75 ppm over control. The given data (Table 2) further indicated that application of foliar spray of GA_3 @ 75 ppm failed to bring about significant variation in number of branches plant^{-1} over control at 30 DAS. Significantly highest branches at 60 DAS and at harvest was recorded with the application of foliar spray of GA_3 @ 75 ppm (3.87 and 4.54 plant^{-1}), respectively over control.Application of foliar spray of GA_3 @ 75 ppm and no spray of GA_3 was did not significantly affected root nodules plant^{-1}. The dry weight of root nodules was not significantly affected with the application of foliar spray of GA_3 @ 75 ppm and no spray.

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Gibberellic acid is the most widely used plant growth regulator which increases stem elongation along with plant height, growth, dry matter accumulation as well as yield in various crops (Akter*et al.*, 2007 and Emongor, 2007). However, very few works have been done on the application of gibberellic acid on french bean in Bangladesh (Noor, 2014).

Yield

Data further (Table 2) indicated that application of foliar spray of GA_3 @ 75 ppm was gave significantly higher seed yield (1770 kg ha^{-1}) over no spray of gibberellic acid seed yield (1514 kg ha^{-1}) of soybean. Foliar application of plant growth regulators strengthened physiological relationship between source and sink resulting in effective partitioning and translocation of photosynthates from leaves to seeds within the plant. The application of growth regulators increased the test weight of soybean. This might be due to mark increased the vegetative growth, photosynthetic pigment which could increase in photosynthesis and increased the seed weight. The similar observation reported by Sapkal*et.al* (2011) the application of GA_3 @ 50 ppm increased seed weight in soybean. The foliar application of GA_3 increased the test weight (Vikaria*et al.*, 2013) and (Anandha*et al.*,2004).

On the basis of one year experimentation results concluded that soybean fertilized with 40 kg P_2O_5 ha^{-1} in combination with 30 kg sulphur ha^{-1} and foliar spray of GA_3 @ 75 ppm was found beneficial for improving productivity of soybean. These results are only suggestive and require further experimentation to arrive at more consistent and final conclusion.

Conclusion

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Reference

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Table 1. Effect of phosphorus, sulphur and gibberellic acid on growth parameters of soybean.

Treatments	Plant population (mrl^{-1})		Plant height (cm)			Plant dry matter accumulation (g $plant^{-1}$)		
	At 30 DAS	At harvest	At 30 DAS	At 60 DAS	At harvest	At 30 DAS	At 60DAS	At harvest
A. Phosphorus (kg ha^{-1})								
0	10.31	10.20	21.2	43.40	64.15	2.12	7.21	10.13
20	10.35	10.25	21.96	48.08	67.32	2.74	9.08	13.14
40	10.42	10.31	22.62	52.83	72.45	3.15	10.68	15.20
60	10.49	10.40	23.18	55.97	75.93	3.56	12.02	16.63
SEm±	0.24	0.23	0.50	1.02	1.15	0.06	0.17	0.30
CD at 5%	NS	NS	NS	3.54	3.98	0.20	0.61	1.05
B. Sulphur (kg ha^{-1})								
15	10.33	10.22	21.54	47.27	65.82	2.62	8.67	12.61
30	10.40	10.30	22.42	49.88	70.45	2.90	9.99	13.87
45	10.44	10.36	22.76	53.05	73.57	3.15	10.58	15.16
SEm±	0.12	0.14	0.38	1.00	1.01	0.05	0.20	0.16
CD at 5%	NS	NS	NS	3.02	3.05	0.15	0.62	0.49
C. Gibberellic acid								
No spray	10.37	10.20	21.87	48.16	67.45	2.83	9.44	13.13
GA_3 @ 75 ppm	10.41	10.38	22.61	51.96	72.45	3.95	10.05	14.42
SEm±	0.13	0.13	0.27	0.78	1.02	0.04	0.14	0.15
CD at 5%	NS	NS	NS	2.28	2.99	NS	0.42	0.44

Table 2. Effect of phosphorus, sulphur and gibberellic acid on growth and yield of soybean.

Treatments	Branches ($plant^{-1}$)			Nodules at 45 DAS (No. $plant^{-1}$)	Nodules dry weight at 45 DAS (mg $plant^{-1}$)	Seed yield (kg ha^{-1})
	At 30 DAS	At 60 DAS	At harvest			
A. Phosphorus (kg ha^{-1})						
0	1.92	2.85	3.65	38.35	64.89	1176
20	2.37	3.45	4.18	44.21	73.36	1559
40	2.69	4.01	4.67	49.26	80.02	1877
60	2.98	4.49	5.15	52.02	84.44	1956
SEm±	0.05	0.05	0.11	0.69	1.23	37.28
CD at 5%	0.17	0.20	0.38	2.39	4.28	129.00
B. Sulphur (kg ha^{-1})						
15	2.14	3.35	3.95	42.49	70.87	1500
30	2.54	3.75	4.45	46.30	75.33	1684
45	2.78	4.00	4.83	49.09	80.84	1742
SEm±	0.04	0.06	0.09	0.80	0.97	30.87
CD at 5%	0.14	0.19	0.28	2.40	2.91	92.57
C. Gibberellic acid						
No spray	2.41	3.53	4.28	45.14	74.53	1592
GA_3 @ 75 ppm	2.56	3.87	4.54	46.78	76.83	1693
SEm±	0.04	0.06	0.05	0.68	0.97	25.77
CD at 5%	NS	0.19	0.17	NS	NS	75.23