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Productivity and Profitability of Soybean [*Glycine max* (L.) Merrill] Influenced by Phosphorus, Sulphur and Gibberellic acid

BAHNU PRATAP GHASIL[1], HARPHOOL MEENA[2], MANOJ[1], RAJENDRA K. YADAV[2], SUNITA YADAV[3], SHANKAR LAL YADAV[4], VINOD K. YADAV[1] AND GOVIND K. YADAV[5]

College of Agriculture - Ummedganj, Agriculture University, Kota (Rajasthan)-324001

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ABSTRACT

An experiment conducted during kharif 2020 at Instructional Farm, College of Agriculture, Ummedganj, Kota (Rajasthan) on soybean. The experiment consisted of twenty four treatment combinations viz. four levels of phosphorus (0, 20, 40 and 60 kg ha^{-1}), three levels of sulphur (15, 30 and 45 kg ha^{-1}) and two levels of gibberellic acid (foliar spray of GA_3 @ 75 ppm and no spray) were under taken in split plot design with three replications. Application of 40 and 60 kg phosphorus ha^{-1} were found at par with each other in respect of seed yield (1877 and 1956 kg ha^{-1}), straw yield (3250 and 3427 kg ha^{-1}) and biological yield (5175 and 5383 kg ha^{-1}), respectively over 0 and 20 kg phosphorus ha^{-1}. The maximum net returns (₹ 46771 ha^{-1}) and B: C ratio (1.51) were fetched with 60 kg phosphorus ha^{-1}, which was closely followed by application of 40 kg phosphorus ha^{-1} over 0 and 20 kg phosphorus ha^{-1}. The application of 45 kg sulphur ha^{-1} gave significantly higher seed, straw and biological yield (1742, 3083 and 4824 kg ha^{-1}) which was found at par with 30 kg sulphur ha^{-1}(1684, 3000 and 4681 kg ha^{-1}) over 15 kg sulphur ha^{-1}. The maximum net return (₹ 36385 ha^{-1}) and B:C ratio (1.18) was fetched with application of 30 kg sulphur ha^{-1} closely followed by 45 kg sulphur ha^{-1}. Significantly higher seed, straw and biological yield (1770, 3002 and 4736 kg ha^{-1}) was recorded under application of gibberellic acid @ 75 ppm as foliar spray over no spray. Maximum net return (₹ 37769 ha^{-1}) and B: C ratio (1.16) was fetched with the application of gibberellic @ 75 ppm as foliar spray over control. It is concluded that the application of 40 kg phosphorus ha^{-1}, 30 kg sulphur ha^{-1} and foliar spray of gibberellic acid @ 75 ppm is profitable dose for obtaining higher seed yield of soybean, net returns and B: C ratio in the experiment.

Keywords: Economics, gibberellic acid, phosphorus, sulphur and yield.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is an important oilseed and food grain legume crop. Soybean is considered as miracle crop because it contains 38-42 per cent good quality protein, 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 fiber which enables to protect human body against cancers and diabetes (Chouhan, 2007; Meena *et al.,* 2021). Its oil is also used as a raw material in manufacturing antibiotics, paints, varnishes, adhesives and lubricants etc. 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, soybean occupies an area of 11.33 million ha with production and productivity of 13.79 metric tonnes and 1217 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 0.93 million ha with an annual production and productivity of 1.17 metric tonnes and 1254 kg ha^{-1} respectively in the state (DAC & FW, 2019-20). Improved application technology of phosphorus fertilizer is required to optimize crop yields and reduce the environmental impacts of phosphorus. The soybean yield attributes were significantly influenced by the phosphorus fertilizer source in addition to zinc. Its uptake and utilization by soybean are essential for ensuring proper nodule formation and improving yield and quality of the crop. Phosphorus fertilizer sources have been shown to positively influence on soybean yields (Gonyane and Sebetha, 2022). 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 content in the pods and seeds (Jadon *et al.,* 2019).

**Corresponding author:hpagron@redimail.com, [1]College of Agriculture-Ummedganj, Agriculture University, Kota (Raj.)-324001,[2]Agricultural Research Station-Ummedganj, Agriculture University, Kota (Raj.)-324001, [3]ICAR-Indain Agricultural Research Institute, New Delhi-110012, [4]Agricultural Research Sub Station, Khanpur, Jhalawar, Agriculture University, Kota (Raj.), [5]Departemnt of Soil Science and Agricultural Chemistry, SKNAU, Jobner (Raj.)-303701*

Sulphur is essential for synthesis of proteins, vitamins and sulphur containing essential amino acids and is also associated with nitrogen metabolism. The good yield of soybean can be achieved by balanced and adequate supply of phosphate, sulphur and other deficient, nutrients (Suman *et al.,* 2018). Sulphur is used as soil amendment for amelioration, as plant nutrient for increasing yield and quality of crop produce. Still the studies on effect of sulphur in soybean are very meagre. Sulphur is required in high amount by 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-assimilates there by help in improvement of physiological efficiency, photosynthetic ability, effective partitioning of accumulates from source to sink, which ultimately enhance productivity of 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 increases in activities of many key enzymes like carbonic anhydrase, nitrate reductase in field crops (Aftab *et al.,* 2010).

MATERIALS AND METHODS

An experiment conducted on soybean during *kharif* 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 season was 551 mm. The soil of experimental site was clay loam in texture, slightly alkaline 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}) with pH (7.6) and EC (0.52 dS m^{-1}). Source of nutrients were applied urea for nitrogen, TSP for phosphorus, mutate of potash for potassium and elemental sulphur for sulphur.

The experiment consisted of twenty-four treatment combinations including four levels of phosphorus (0, 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 spray of gibberellic acid (gibberellic acid @ 75 ppm and no spray) in sub- sub plots were under taken in sub-sub split plot design with three replication. Data on yield parameters like number of pods per plant, seeds per pod, test weight, seed yield, straw yield and biological yield were recorded as per standard procedures. Plant samples (grain and straw) were collected after harvesting from each plot. The data were statistically analysed by adopting appropriate method of standard analysis of variance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of phosphorus on yield attributes and yield

A perusal of data presented in Table 1 and depicted in fig. 1 showed that the application of increasing levels of phosphorus fertilizer significantly increase yield attributes and yield of soybean. The maximum (45.85 pods $plant^{-1}$) was recorded with the application of 60 kg phosphorus ha^{-1} in soybean over application of 20 kg phosphorus ha^{-1} (36.20 pods $plant^{-1}$) and control (25.72 pods $plant^{-1}$). However, it was found at par with the application of 40 kg phosphorus ha^{-1} (43.39 pods $plant^{-1}$). Application of 60 kg phosphorus ha^{-1} gave significantly higher (2.30 seeds pod^{-1}) but it was found at par with the application of 40 kg phosphorus ha^{-1} (2.21 seeds pod^{-1}) over application of 20 kg phosphorus ha^{-1} and control (2.09 and 1.96 seeds pod^{-1}) in soybean. The maximum test weight (102.79 g) was recorded under application of 60 kg phosphorus ha^{-1} over application of 20 kg phosphorus ha^{-1} (92.90 g) and control (83.26 g). However, the test weight (99.10 g) was found at par with the application of 40 kg phosphorus ha^{-1} in soybean.

The maximum seed yield (1956 kg ha^{-1}) was recorded with the application of 60 kg phosphorus ha^{-1} over application of 20 kg phosphorus ha^{-1} and control (1559 and 1176 seed yield kg ha^{-1}). However, the seed yield (1877 kg ha^{-1}) was found at par with the

Table 1: Effect of phosphorus, sulphur and gibberellic acid on yield attributes of soybean

Treatments	Pods plant^{-1}	Seeds Pod^{-1}	Test weight (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Net return (₹/ha)	B:C ratio
Phosphorus (kg ha^{-1})									
0	25.72	1.96	83.26	1176	2182	3358	34.72	16410	0.54
20	36.20	2.09	92.90	1559	2924	4425	35.53	31545	1.03
40	43.39	2.21	98.10	1877	3267	5175	36.06	43902	1.43
60	45.85	2.30	102.79	1956	3428	5383	36.52	46771	1.51
SEm±	0.68	0.04	1.86	37.28	63.86	78.88	0.60	1291.1	0.04
CD at 5%	2.57	0.17	6.46	129.00	221.00	272.98	NS	4469.3	0.12
B. Sulphur (kg ha^{-1})									
15	31.51	1.90	89.29	1500	2750	4250	35.03	32039	1.15
30	38.63	2.23	95.27	1684	3017	4681	35.69	36385	1.18
45	43.21	2.29	98.98	1742	3083	4824	36.40	35547	1.05
SEm±	0.56	0.04	1.86	30.87	46.71	59.81	0.51	1207.2	0.04
CD at 5%	1.69	0.14	5.59	92.57	140.04	179.33	NS	3619.6	0.11
C. Gibberellic acid									
No spray	41.14	2.05	92.22	1592	2884	4497	35.27	31545	1.09
Foliar spray of GA_3 @ 75 ppm	43.80	2.23	96.80	1693	3016	4672	36.14	37769	1.16
SEm±	0.69	0.03	1.54	25.77	44.89	47.45	0.35	825.4	0.03
CD at 5%	2.01	0.11	4.52	75.23	131.03	138.50	NS	2410.2	0.08

application of 40 kg phosphorus ha^{-1} of soybean. Significantly higher straw yield (3427 kg ha^{-1}) was observed under application of 60 kg phosphorus ha^{-1}, but it was found at par with 40 kg phosphorus ha^{-1} (3250 kg ha^{-1}) over application of 20 kg phosphorus ha^{-1} and control (2918 and 2182 kg straw yield ha^{-1}), respectively. The application of 60 and 40 kg phosphorus ha^{-1} were found at par with each other in terms of biological yield (5383 and 5175 kg ha^{-1}) over application of 20 kg phosphorus ha^{-1} and control (4425 and 3358 kg biological yield ha^{-1}) of soybean. The harvest index of soybean did not significantly affected with increasing levels of phosphorus fertilizer.

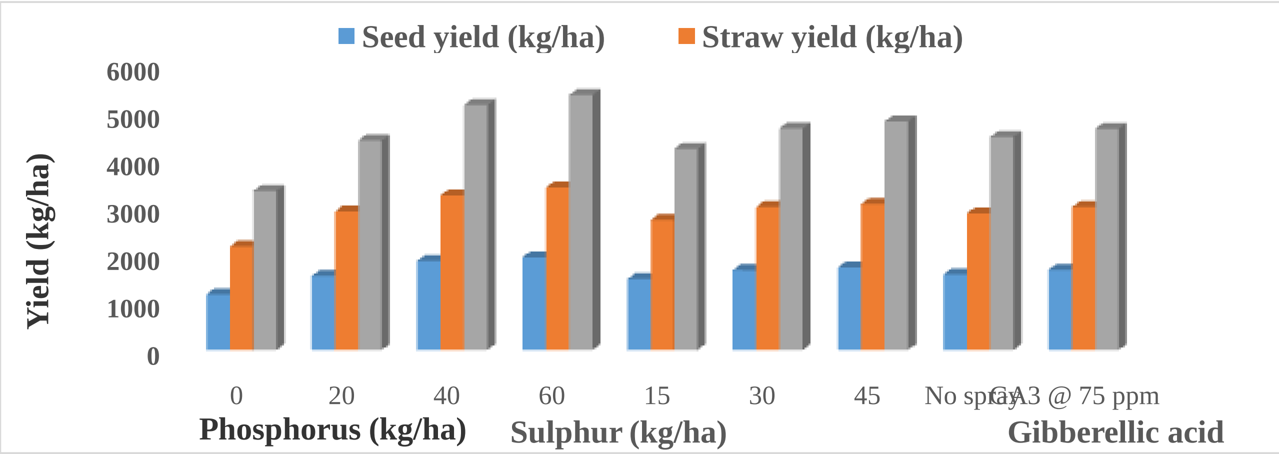

Fig. 1: Effect of phosphorus, sulphur and gibberellic acid on yield of soybean

Phosphorous application accelerated the production of photosynthates and their translocation from source to sink, which ultimately gave the higher values of yield attributing characters. Increase in yield attributing characters has also been reported by Meena *et al.* (2006) and Kumar *et al.* (2007). This was mainly due to the 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 (Singh *et al.*, 2017).

Effect of phosphorus on economics

A perusal of data presented in Table 1 and depicted in fig. 2 showed that the application of increasing levels of phosphorus fertilizer significantly increase monetary returns of soybean. The minimum net return (₹ 16410 ha^{-1}) was obtained under control, which increased remarkably under increasing phosphorus treatments. The net return was maximum (₹ 46771 ha^{-1}) under application of 60 kg phosphorus ha^{-1} followed by 40 kg phosphorus ha^{-1} (₹ 43902 ha^{-1}). Significantly higher B: C ratio (1.51) was recorded under application of 60 kg phosphorus ha^{-1} followed by 40 kg phosphorus ha^{-1} (1.43) over 20 kg phosphorus ha^{-1} (1.03) and least in control plots (0.54).

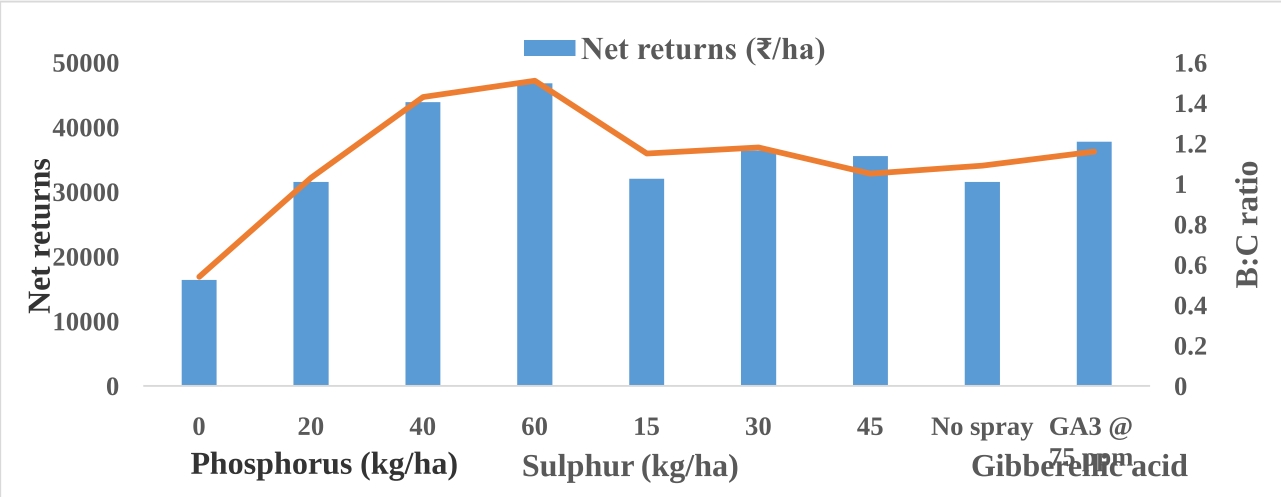

Fig. 2: Effect of phosphorus, sulphur and gibberellic acid on economics

Application of 60 kg phosphorus ha^{-1} showed mark improvement in seed yield and thus gaining more profit in terms of net returns and B:C ratio over rest of treatments. The monetary returns in terms of gross return, net return and B:C ratio significantly increased with increasing levels of phosphorus. The computation of cost of cultivation is important because it decides the option for the farmers to choose the production practices, according to their investment capacity. Similar findings were also reported by Munda *et al.* (2018) and Raghuveer *et al.* (2017). The findings are in closed agreement with similarly finding of (Dhage *et al.*, 2014).

Effect of sulphur on yield attributes and yield

A reference to data presented in Table 1.0 and fig. 1.0 pertaining to various yield attributes *viz.* pods plant^{-1}, seeds plant^{-1} and test weight (g) were recorded during experimentation. The maximum (43.21 plant^{-1}) and minimum (31.51 plant^{-1}) number of pods was recorded with the application of 45 and 15 kg sulphur ha^{-1}. However, numbers of pods were at par with each other in plots receiving 45 and 30 kg sulphur ha^{-1}. Significantly higher number (2.29 seeds pod^{-1}) was recorded with application of 45 kg sulphur ha^{-1} over 15 kg sulphur ha^{-1} (1.90 seeds pod^{-1}). However, it was found at par with application of 30 kg sulphur ha^{-1} (2.23 seeds pod^{-1}) in soybean. The application of 45 and 30 kg sulphur ha^{-1} were found at par in terms of test weight (98.98 and 95.27 g), but it was found significantly superior over 15 kg sulphur ha^{-1} test weight (89.29 g) of soybean seed. Application of 45 kg sulphur ha^{-1} gave significantly higher seed yield (1742 kg ha^{-1}) over 15 kg sulphur ha^{-1} (1500 kg ha^{-1}) seed yield. However, it was found at par with 30 kg sulphur ha^{-1} (1684 kg ha^{-1}) seed yield of soybean. Significantly highest straw yield (3083 kg ha^{-1}) was recorded under application of 45 kg sulphur ha^{-1} over 15 kg sulphur ha^{-1} straw yield (2750 kg ha^{-1}). However, it was found at par with 30 kg sulphur ha^{-1} (3000 kg ha^{-1}) straw yield of soybean. Under application of 45 kg sulphur ha^{-1} was recorded significantly higher biological yield (4824 kg ha^{-1}) which was found at par with 30 kg sulphur ha^{-1} (4681kg ha^{-1}). However, it was found significantly superior over application of 15 kg sulphur ha^{-1} (4250kg ha^{-1}) biological yield of soybean.

Application of various levels of sulphur fertilizer did not significantly influence harvest index (per cent) of soybean. 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).

Effect of sulphur on economics

Data pertaining to net return and B:C ratio was recorded during experimentation and data presented in Table 1.0 and graphically depicted in fig 2.0. Data shows that net return was minimum (₹ 32039 ha^{-1}) under application of 15 kg sulphur ha^{-1}, which increased remarkably under different sulphur treatments. The net return was maximum (₹ 36385 ha^{-1}) under application of 30 kg sulphur ha^{-1} followed by 45 kg sulphur (₹ 35547 ha^{-1}). The B: C ratio (1.05) was minimum under application of 45 kg sulphur ha^{-1}, which increased remarkably under different sulphur treatments. The B: C ratio (1.18) was maximum under 30 kg sulphur ha^{-1} followed by application of 15 kg sulphur ha^{-1} (1.15). Application of 45 kg sulphur ha^{-1} showed mark improvement in seed yield and thus gaining more profit in terms of net returns and benefit: cost ratio over application of 15 kg sulphur ha^{-1}. The findings are in agreement with study of (Tandon *et al.,* 2007) that showed high profit as shown by increased value of B:C ratio in soybean under field condition. The beneficial effects of sulphur fertilization were also reported by Nath *et al.* (2018).

Effect of gibberellic acid on yield attributes and yield

Data pertaining to various yield attributes *viz*. pods plant^{-1}, seeds plant^{-1} and test weight (g) were recorded during experimentation and data presented in Table 1.0 and graphically depicted 1.0. Significantly higher number of pods (39.11 plant^{-1}) was recorded with foliar spray of gibberellic acid @ 75 ppm over no spray in soybean. The application of foliar spray of gibberellic acid @ 75 ppm gave significantly higher number of seeds (2.23 pod^{-1}) over no spray (2.05 seeds pod^{-1}) in soybean. Significantly higher test weight (96.80 g) was recorded with application of foliar spray of gibberellic acid @ 75 ppm over without spray of gibberellic acid test weight (92.22 g) of soybean seed. Application of gibberellic acid @ 75 ppm foliar spray of was recorded higher seed yield (1770 kg ha^{-1}) over no spray (1514 kg ha^{-1}) in soybean. The maximum straw yield (3002 kg ha^{-1}) was recorded with foliar spray of gibberellic acid @ 75 ppm over no spray (2886 kg ha^{-1}). The foliar spray of gibberellic acid @ 75 ppm gave significantly higher biological yield (4736 kg ha^{-1}) over no foliar spray. The harvest index (per cent) of soybean did not significantly affect with foliar spray of gibberellic acid @ 75 ppm and no spray.

The application of growth regulators increased the test weight of soybean. This might be due to mark increase in vegetative growth, photosynthetic pigment which could improve in photosynthesis and increase the seed weight. The application of gibberellic acid @ 50 ppm increased seed weight in soybean was reported by (Sapkal *et al.,* 2011). The foliar application of gibberellic increased the test weight (Vekaria *et al.,* 2013). 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. Gibberellic acid may induce the development of xylem and phloem and in turn, increase the flow and deposition of assimilation products in seeds.

Effect of gibberellic acid on economics

A perusal of data pertaining to net return and B:C ratio was recorded during experimentation and data presented in Table 1.0 and graphically depicted in fig 2.0. Data further revealed that the minimum net return (₹ 31545ha^{-1}) was recorded under no spray and maximum (₹ 37769 ha^{-1}) under foliar spray of gibberellic acid @ 75 ppm. The maximum B: C ratio (1.16) was observed under foliar spray of gibberellic acid over no spray (1.09). Application of gibberellic acid @ 75 ppm showed mark improvement in seed yield and thus gaining more profit in terms of net returns and benefit: cost ratio over control. The findings are in agreement with two foliar sprays of gibberellic acid at flowering and pod development stages gave higher B:C ratio. Increased seed yield owing to application of gibberellic acid significantly increased the gross and net monetary returns. The results confirm the findings of (Aziz *et al.,* 2012).

It is concluded that the application of 40 kg phosphorus ha^{-1}, 30 kg sulphur ha^{-1} and foliar spray of gibberellic acid @ 75 ppm is profitable dose for obtaining higher seed yield of soybean, net returns and B: C ratio in the experiment. Hence this dose of phosphorus, sulphur fertilization and gibberellic acid is proved as productive and beneficial to the farmers for obtaining higher returns in the clay loam soils of zone Vth of Rajasthan.

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