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Correlation-Regression Studies on Independent and Dependent Variables and Quality of Soybean [Glycine max (L.) Merrill] as influenced by Phosphorus, Sulphur fertilization, and Plant Growth Regulator

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ABSTRACT

An experiment was conducted during kharif season in 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 GA3 @ 75 ppm laid out in sub-sub split -plot design with three replications. Application of 40 and 60 kg P2O5 ha-1 were found at par with each other in respect of seed yield (1877 and 1956 kg ha-1), respectively over control and 20 kg P2O5 ha-1. Application of 60 kg P2O5 ha-1 was produced significantly higher protein content (40.44 %) and protein yield (787 kg ha-1) in soybean seed over rest of the phosphorus levels. The data further revealed that under application of 60 kg P2O5 ha-1 was recorded maximum oil content (21.01 %) and oil yield (413 kg ha-1) over 20 kg P2O5 ha-1 and control. However, it was found at par with application of 40 kg P2O5 ha-1.

Application of 45 kg sulphur ha-1 gave a significantly higher seed yield (1742 kg ha-1), which was found at par with 30 kg sulphur ha-1(1684 kg ha-1) over the application of 15 kg sulphur ha-1. The maximum protein content (40.30 %) and protein yield (700 kg ha-1) were recorded with the application of 45 kg sulphur ha-1, which was found at par with 30 kg sulphur ha-1 over the application of 15 kg sulphur ha-1. Results revealed that under application of 45 kg sulphur ha-1 was recorded maximum oil content (20.67 %) and oil yield (364 kg ha-1) over 15 kg sulphur ha-1. However, it was found at par with the application of 30 kg sulphur ha-1. A significantly higher seed yield (1770 kg ha-1) was recorded under application of GA3 @ 75 ppm as foliar spray over no spray. The maximum protein content (39.36 per cent) and protein yield (695 kg ha-1) were recorded with the application of GA3 @ 75 ppm as foliar spray over control in soybean. The data further revealed that foliar spray of GA3 @ 75 ppm gave maximum oil content (20.08 per cent) and oil yield (359 kg ha-1) in soybean over control. Phosphorous and sulphur is an important macronutrient required for plants, animals as well as human. Their deficiency in soil is a worldwide concern for production of food crops. The gibberellic acid constitutes a group of tetracyclic diterpenoids, involved in plant growth and development. Therefore, present investigation was done to study influenced of phosphorus, sulphur and gibberellic acid on nutrient content and uptake of soybean.

Keywords: *Oil content, protein content, phosphorus, sulphur and growth regulator*

INTRODUCTION

Soybean [Glycine max (L.) Merrill] is an important oilseed and food grain legume crop. It 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. It is highly nutritious containing higher a amount of 22-24% protein, 1.3% fat and 60% carbohydrates on a dry weight basis and it is a rich source of calcium and iron. On a 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 [1]. Inadequate fertilizer use and the emergence of multiple-nutrient deficiencies due to poor recycling of organic resources and unbalanced use of fertilizers are important factors to be considered for the low productivity of soybean [2].

Phosphorus fertilizer sources have been shown to positively influence soybean yields [3]. Diammonium phosphate fertilizer source is known to significantly increase the number of pods per plant in the case of common beans, while the lowest number of pods per plant has been recorded in cases where there have been no applications of phosphorus fertilizer [4]. The triple superphosphate, rock phosphate phosphorus and monoammonium phosphate resulted in higher seed mass across the planting seasons [3].

Sulphur is essential for the synthesis of proteins, vitamins and

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containing essential amino acids and is also associated with nitrogen metabolism. A good yield of soybean can be achieved by a balanced and adequate supply of phosphate, sulphur and other deficient, nutrients [5]. Sulphur is used as a soil amendment for amelioration, as a plant nutrient for increasing yield and quality of crop production, as a chemical agent to acidulate other nutrients and pesticides [6]. It is also implicated in oil biosynthesis in soybean seed [7]. The sulphur is required in high amounts by the oilseeds and hence has been identified as a 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 helping in improve the physiological efficiency, photosynthetic ability, effective partitioning of accumulates from source to sink and ultimately enhance productivity of the soybean crop [8]. Gibberellic acid constitutes a group of tetracyclic diterpenoids, involved in plant growth and development [9].

MATERIALS 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. This zone possesses typical sub-tropical conditions with maximum and minimum temperatures ranged between 34.2C to 38.0C and 18.6C to 24.0 C during Kharif, 2020. The total amount of rainfall received during crop growing was 551 mm. The soil of the experimental site was clay loam in texture, and 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 plots were under taken in sub-sub split- plot design with replicated thrice. Data on yield parameters like the 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.

Oil content in seeds from each net plot sample was determined by the Soxhlet ether extraction method [10] expressed as per cent oil content in seed. Oil yield was worked out by multiplying the seed yield with the oil content for each corresponding treatment.

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Oil content in seed (\%)} \times \text{Seed yield (kg ha}^{-1}\text{)}}{100}$$

The protein content in the seed was calculated by multiplying per cent nitrogen in the seed by the factor 6.25 [11] and expressed as per cent protein content. Protein yield was worked out by formula,

$$\text{Protein yield (kg ha}^{-1}\text{)} = \frac{\text{Protein content in seed (\%)} \times \text{Seed yield (kg ha}^{-1}\text{)}}{100}$$

In order to test the significance of variation in experimental data obtained for various treatment effects, the data were statistically analyzed as described by [12]. The critical differences were calculated to assess the significance of treatment mean wherever the F' test was found significant at a 5 per cent level of probability. To elucidate the nature and magnitude of treatment effects, summary tables along with SEm + and CD (P=0.05) were prepared. To assess the relationship, correlation and regression coefficients between the dependent variable (Y) such as grain yield of soybean and the independent variables (X) such as pods plant-1, dry weight plant-1, number of grains pod-1, test weight, N, P, K and S uptake were computed using the method given by [13]. The regression equations were also fitted and tested for significance.

RESULTS AND DISCUSSION

Effect of phosphorus on quality parameters

A reference to data revealed that various levels of phosphorus fertilizer had a significant effect on protein content and protein yield in soybean seed (Table 1.0). The maximum protein content (40.4 %) in soybean seeds was recorded with application of 60 kg P2O5 ha-1 over the application of 20 kg P2O5 ha-1 (38.6%) and control (36.4%). However, it was found at par with the application of 40 kg P2O5 ha-1 protein content (40.0%) in soybean seed. The maximum protein yield (788 kg ha-1) was recorded with the application of 60 kg P2O5 ha-1, which was found at par with 40 kg P2O5 ha-1 (752 kg ha-1) over the application of 20 kg P2O5 ha-1 and control (604 and 431 kg ha-1). Significantly highest oil content (21.0%) was recorded with the application of 60 kg P2O5 ha-1 over the application of 20 kg P2O5 ha-1 (19.75%) and control (18.68%) in soybean seed. However, it was found at par with the application of 40 kg P2O5 ha-1 oil content (20.7 %) in soybean seed. The highest oil yield (413 kg ha-1) was recorded with the application of 60 kg P2O5 ha-1 over 20 kg P2O5 ha-1 (308 kg ha-1) and control (220 kg ha-1) in soybean seed. However, it was found at par with the application of 40 kg P2O5 ha-1 oil yield (390 kg ha-1) in soybean seed.

Protein and oil content (%) and their yield (kg ha-1) increased due to increasing levels of phosphorus fertilization in soybean. To determine the impact of numerous levels of phosphorous and nitrogen on soybean a field test was laid out by [14]. The increase in oil content with phosphorus application could be due to the fact that phosphorus helped in the synthesis of fatty acids and their esterification by accelerating biochemical reactions in glyoxalate cycle [15].

Effect of phosphorus on grain yield

Reference data was recorded during experimentation and data is presented in Table 1.0. Data further showed that various levels of phosphorus fertilizer significantly influenced seed yield of soybean. The maximum seed yield (1956 kg ha-1) was recorded with the application of 60 kg P2O5 ha-1 over the application of 20 kg P2O5 ha-1 and control seed yield (1559 and 1176 kg ha-1). However, it was found at par with the application of 40 kg P2O5 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. An increase in yield contributing characters has also been reported by [16] and [17]. 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 [18].

Effect of sulphur on quality parameters

Data pertaining to oil, protein content and yield in soybean seed were recorded during experimentation and data are presented in Table 1.0. The maximum protein content was recorded under the application of 45 kg sulphur ha-1 (40.5%), which was at par with 30 kg sulphur ha-1 (39.8 %) over the application of 15 kg sulphur ha-1 (36.8 %) protein content in soybean seed.

The highest protein yield (700 kg ha-1) was recorded with application of 45 kg sulphur ha-1 over the application of 15 kg sulphur ha-1 (566 kg ha-1). However, it was found at par with the application of 30 kg sulphur ha-1 (665 kg ha-1) protein yield in soybean seed. The maximum oil content (20.6 per cent) was recorded with the application of 45 kg sulphur ha-1 over 15 kg sulphur ha-1 (19.4%). However, it was found at par with the application of 30 kg sulphur ha-1 (20.0 per cent) in soybean seed. The maximum oil yield (364 kg ha-1) was recorded with the application of 45 kg sulphur ha-1, which was closely followed by 30 kg sulphur ha-1 (341 kg ha-1). However, it was significantly superior over the application of 15 kg sulphur ha-1 oil yield (293 kg ha-1) in soybean seed.

In the present investigation oil and protein content (%) and their yield (kg ha-1) increases as increasing the levels of sulphur up to 45 kg ha-1. The significantly increased oil and protein content (%) and their yield (kg ha-1) were found with the application of 45 kg sulphur ha-1, however oil yield was statically at par with 30 kg sulphur ha-1. These results are in close conformity with the above findings, it was clear that yield attributing characters were greatly affected by the sulphur application. It might be due to involvement of sulphur in the synthesis of fatty acids and also increases protein quality through the synthesis of certain amino acids such as cysteine, cystine and methionine. The results supported the earlier findings of [19] and [20] in soybean. The increasing levels of sulphur significantly improved the quality of soybean in terms of protein and oil content. There was an increase in oil content with the application of 45 kg sulphur ha-1 by 3.22 and 7.81 per cent over the rest of the treatments. Similarly, increase in protein content with application of 45 kg sulphur ha-1 by 3.18 and 6.54 per cent was noticed over rest of treatments. An increase in oil content due to sulphur application can be attributed to the key role played by sulphur in the biosynthesis of oil in oilseed plants. The increase in protein content may be accounted for the increase in synthesis of sulphur containing amino acids. Such beneficial effects of sulphur fertilization were also reported by [21] and [22].

Effect of sulphur on grain yield

Data were recorded during experimentation and data presented in the Table 1.0 showed that various levels 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 the plant that helped maintain the critical balance of other essential nutrients in the plant and resulted in enhanced metabolic processes. [23] 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 [24]. The seeds pod-1 and seed yield improved by sulphur alone or combined with nitrogen whereas, nitrogen alone decreased a number of pods plant-1 thus showing non-significant variation in seed yield as compared to the control. The results corroborate the findings with the application of 40 kg sulphur ha-1 enhanced the pod plant-1 and test weight (g) in black gram [25].

Effect of gibberellic acid on quality parameters

Data pertaining to oil, protein content and yield in soybean seed were recorded during experimentation and data are presented in Table 1.0. A perusal of data indicated that application of foliar spray of GA3 @ 75 ppm did not significant effect on protein content in soybean seed. Under application of foliar spray of GA3 @ 75 ppm was recorded significantly higher total protein yield (695 kg ha-1) over no spray (592 kg ha-1) in soybean seed. Data indicated that application of foliar spray of GA3 @ 75 ppm was did not significant effect on oil content in soybean seed. Application of foliar spray of GA3 @ 75 ppm was recorded significantly higher oil yield (359 kg ha-1) in the seed of soybean over control.

Significantly highest oil and protein content (%) and their yield (kg ha-1) was recorded with foliar application of GA3 @ 75 ppm in soybean. Similar finding by more protein content in seed might be due to improvement the translocation of photosynthates to the seed. The oil content was found non-significant with the application of GA3 75 ppm but recorded markedly higher values in oil content thus ultimately recording significant higher oil yield over no spray. It was increased to the tune of 17.32 per cent over no spray. Similar observation was reported by [26] in the treatment foliar spray of GA3 @ 125 ppm increased oil content in soybean seed.

Effect of gibberellic acid on grain yield

Data further (Table 1.0) indicated that the application of foliar spray of GA3 @ 75 ppm gave a 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 the 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. A similar observation reported by [27] the application of GA3 @ 50 ppm increased seed weight in soybean. The foliar application of GA3 increased the test weight [28].

Interaction effect between phosphorus and sulphur

It was found significant with respect to protein yield kg ha-1 (Table 1.0 a). Significant maximum protein yield (857 kg ha-1) was noted at 60 kg P2O5 ha-1 along with 45 kg sulphur ha-1, which was at par with 60, 40 kg P2O5 ha-1 along with 30 kg sulphur ha-1, over 40, 20 kg P2O5 ha-1and control along with 15, 30 and 45 kg sulphur ha-1, irrespectively and rest of treatment combinations. It was found significant concerning oil yield kg ha-1 (Table 1.0 b). Significantly maximum oil yield (484 kg ha-1) was noted at 60 kg P2O5 ha-1 along with 45 kg sulphur ha-1 over 40, 20 kg P2O5 ha-1 and control along with 15, 30 and 45 kg sulphur ha-1, irrespectively and rest of treatment combinations.

The increase in protein and oil content due to 20 kg sulphur ha-1 was 11.26 and 24.17 per cent, respectively. The increase in oil content with sulphur application might be due to the fact that sulphur helped in oil synthesis by enhancing the level of thioglucosides [15]. The interaction between phosphorus and sulphur was found significant. All the sulphur levels increased both oil and protein contents significantly at every level of phosphorus. The maximum protein and oil content were recorded with a treatment combination of 80 kg P2O5 and 40 kg sulphur ha-1. Soybean responded more to sulphur in increasing oil and protein content of the seed, as also reported by [29].

Correlation and regression studies on independent and dependent variables Correlation

Correlation coefficients were worked out between the seed yield of soybean and the number of pods plant-1, seeds pod-1, dry matter accumulation (g plant-1) and test weight (g). The values calculated are presented in Table 2.0. The results of correlation coefficients revealed that the seed yield was significantly and positively correlated with a number of pods plant-1 (0.903)*, the number of seeds pod-1 (0.712)*, dry matter accumulation (0.948)* and test weight g (0.766)*. Correlation coefficients were worked out between the straw yield of soybean and plant height (cm) and dry matter accumulation (g).The results of correlation coefficients revealed that the straw yield was significantly and positively correlated with plant height (0.739)* and dry matter accumulation (0.913)*.Correlation coefficients were worked out between the biological yield of soybean and seed yield, straw yield, total nitrogen, phosphorus, potassium and sulphur uptake. The results of correlation coefficients revealed that the biological yield was significantly and positively correlated with seed yield (0.964)*, straw yield (0.962)*, total nitrogen uptake (0.984)*,total phosphorus uptake (0.987)*, total potassium uptake (0.975) *and total sulphur uptake (0.938)*.

Regression

The regression studies were also made to draw the regression equations between dependent and independent variables. Linear relationship appeared to exist between seed yield and independent variables. Equations (Table 2.0) show that with the increase in one unit in a number of pods plant-1, seeds pod-1, dry matter accumulation (g) and test weight (g), the corresponding seed yield increased by 33.83, 952.23, 118.33 and 26.67, respectively. The regression studies were also made to draw the regression equations between dependent and independent variables. A linear relationship appeared to exist between straw yield and independent variables. Equations shows that with the increase in one unit in plant height (cm) and dry matter accumulation (g), the corresponding straw yield increased by 58.50 and 167.41, respectively. The regression studies were also made to draw the regression equations between dependent and independent variables. A linear relationship appeared to exist between biological yield and independent variables. Equations shows that with the increase in one unit in seed yield, straw yield, total nitrogen, phosphorus, potassium and sulphur uptake, the corresponding biological yield increased by 2.30, 1.57, 21.14, 199.78, 49.05 and 135.81, respectively.

Table 1.0: Effect of phosphorus, sulphur and gibberellic acid on oil content, protein content and their yield and seed yield in soybean.

Treatments	Protein content (%)	Protein yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})	Grain yield (kg ha^{-1})
A. Phosphorus (kg ha^{-1})					
0	36.45	431	18.68	220	1176
20	38.67	604	19.75	308	1559
40	40.08	752	20.70	389	1877
60	40.44	787	21.01	413	1956
SEm±	0.40	13.39	0.24	8.59	37.28
CD at 5%	1.38	46.35	0.83	29.58	129.00
B. Sulphur (kg ha^{-1})					
15	37.38	565	19.40	293	1500
30	39.04	665	20.03	341	1684
45	40.30	700	20.67	364	1742
SEm±sd	0.40	12.18	0.21	8.64	30.87
CD at 5%	1.21	36.52	0.62	25.91	92.57
C. Gibberellic acid					
No spray	38.46	592	19.99	306	1592

Foliar spray of GA_3 @ 75 ppm	39.36	695	20.08	359	1693
SEm±	0.38	12.04	0.16	6.01	25.77
CD at 5%	NS	35.14	NS	17.56	75.23

Table 1.0a: Interactive effect of phosphorus and sulphur on protein yield of soybean.

Treatment	**Sulphur levels (kg ha^{-1})**		
Phosphorus levels (kg ha^{-1})	**15**	**30**	**45**
0	374	423	495
20	528	596	687
40	667	826	762
60	692	812	857
SEm±	24.36		
CD at 5%	71.12		

Table 1.0b: Interactive effect of phosphorus and sulphur on oil yield of soybean

Treatment	**Sulphur levels (kg ha^{-1})**		
Phosphorus levels (kg ha^{-1})	**15**	**30**	**45**
0	200	225	236
20	278	299	347
40	344	411	389
60	345	427	484
SEm±	15.91		
CD at 5%	46.45		

Table: 2.0: Correlation coefficients and liner regression equation showing relationship between independent variables (X) and dependent variables (Y)

Dependent variable (Y)	**Independent Variables (X)**	**Correlation (R)**	**Correlation Coefficient (r^2)**	**Regression equation (Y= a + by-X)**
Seed yield (kg ha^{-1})	DMA (g)	0.948*	0.895	11.263 + 118.332
	Pods plant^{-1}	0.903*	0.816	363.159+ 33.839
	Seeds pod^{-1}	0.712*	0.507	-401.033 + 952.234
	Test weight (g)	0.766*	0.586	-879.48 + 26.67
Straw yield (kg ha^{-1})	Plant height (cm)	0.739*	0.546	-1148.158 + 58.505
	DMA (g)	0.913*	0.834	637.291 + 167.419
	Seed yield	0.964*	0.929	796.979 + 2.307
	Straw yield	0.962*	0.926	-42.775 + 1.572
	Total nitrogen uptake	0.984*	0.969	1195.913 + 21.148

Biological yield (kg ha-1)	Total phosphorus uptake	0.987*	0.974	1606.440 + 199.685
	Total potassium uptake	0.975*	0.952	204.474 + 49.050
	Total sulphur uptake	0.938*	0.879	2420.628+ 135.814

DMA = Dry matter accumulation **Significant at 5 per cent level of significance*

CONCLUSION

Based on one- one year experimentation results concluded that soybean fertilized with 40 kg P2O5 ha-1 in combination with 30 kg sulphur ha-1 and foliar spray of GA3 @ 75 ppm was found beneficial for improving seed yield and quality of soybean. These results are only suggestive and require further experimentation to arrive at more consistent and final conclusion.

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