Research Article

Effect of Phosphorus and Sulphur on Yield and Yield Components of Sesame

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Abstract | Agro-climatic conditions and soils of Pakistan are quite conducive for the sesame crop production. However, area allocated and average production is still far below than the other countries of the world. One of the reasons of its low productivity in Pakistan is the low, inadequate and improper fertilizers management. Among the various factors influencing crop production, phosphorus (P) and sulphur (S) boost its yield and quality. A field trial was conducted in summer 2012 using phosphorus @ of 0, 25, 50 and 75 kg ha^{-1} and sulphur @ of 0, 15, 30 and 45 kg ha^{-1}, respectively on the yield contributing parameters of sesame. Pods plant^{-1}, grain yield, plant height, and harvest index (HI) were observed highest using P @ 50 kg ha^{-1}, while flowering and maturity were delayed when no P and S applied. Pods plant^{-1}and biological yield were recorded highest at sulphur level 45 kg ha^{-1}. The HI attained its peak at 75 kg P ha^{-1} with no sulphur application. It was concluded that solicitation of phosphorus and sulphur @ 50 kg ha^{-1} and 45 kg ha^{-1}, respectively resulted in significantly higher yield contributing parameters of sesame; therefore, recommended for the locality.

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Introduction

Sesame (*Sesamum indicum* L.) is a crop of family pedaliaceae and is grown as a short-day plant in subtropical and tropical areas around world. It is grown mostly in dry lands because of its quality of drought tolerance. It is also the most nutritious livestock feed and its seed cakes are one of the quality sources for vitamins, minerals like calcium and phosphorous (Malik et al., 2003). Seed of sesame has high concentration of oil (43-55%) and its oil is highly stable and resistant to rancidity (Alpaslan et al., 2001). Beside oil its seeds also contain protein (20-30%) and the oil is rich in all essential fatty acids (Park and Kang, 2004), however oleic and linoleic acid are the most abundant (Kang et al., 2000; Kim et al., 2002). Seeds of Sesame also contain sesamolin, which is a compound which inhibits the growth of leukemia cells in human (Ryuv et al., 2003). It also contains vitamins and minerals (Malik et al., 2003). This important crop is the queen of vegetable oils (Haruna and Abimiku, 2012).

Proper nutrition is a key towards improved crop production. The yield of sesame in developing countries of the world is very high as compare to

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Pakistan. The main reason behind the low productivity of sesame is the improper crop nutrition. Among the drought tolerant crops sesame is considered as one of them (Alpaslan et al., 2001). In Pakistan also, it is mostly grown in rainfed areas and thus less care is taken during the cropping season and the farmers give relatively less importance to sesame crop in comparison with wheat. Being an oil seed crop it requires nitrogen in relatively low amount, however requires the other nutrients a bit more than the other crops. The second most indispensable and deficient macro-nutrient after nitrogen is phosphorous (P). It stimulates early root growth and better root development. It plays a primitive role in plant growth as it is involved in many physiological processes and is the component of the major products formed during the physiological processes occurring in plants. Moreover, it has considerably increased the crops' quality and tonnage (Singh et al., 2000).

Sulphur (S) is the fourth most required element after nitrogen, phosphorus and potassium among the essential macro nutrients (Lewandowska and Sirko, 2008). Sulphur plays a significant role in the formation of chlorophyll (Singh et al., 2000) and is an essential part of different organic compound in plant tissues i.e. oil glands, which store oil and different vitamins like B1 (Thirumalaisamy et al., 2001; Jaggi et al., 2000). It is a major component that adds in oil and protein level of seed and hence, improvement of oilseed crops yield and quality (Yadav et al., 1996). Sesame requires more quantity of sulphur i.e. almost equal to phosphorus level as compare to other crops (Scherer, 2001). The response of oilseed crops to sulphur application is though gradual, however quite positive under intensive copping system (Ghosh et al., 2002). Increasing the application of sulphur and phosphorus significantly increase sesame yield and yield components up to certain upper limits. In contrast, appreciable reduction in the sesame yield has been found with severe increase of S and P levels. Hence, phosphorus and sulphur have key role in the boost of sesame yield and yield attributes.

Keeping in view the importance of both the nutrients, the present study could be a step forward in this direction. Our objectives were, to study the core and interactive responses of various P and S rates on the yield contributing parameters of sesame.

Materials and Methods

Experimental site description

The field experiment on sesame under different phosphorus and sulphur rates was conducted at the Research Farm of The University of Agriculture Peshawar, during summer season 2012. The experimental site has continental type of environment and is situated 1600 km from Indian Ocean towards north, with an altitude of 350 m. The soil of the site in which the experiment was conducted is clay loam according to USDA classification system, alkaline in reaction with electrical conductivity of 0.08 dSm^{-1}. The soil nitrogen, phosphorus and potassium content were 1%, 4.52 mg kg^{-1} and 70.2 mg kg^{-1}, respectively. The soil was low in organic matter (<1.0%).

Treatment details and experimental design

The experiment consisted of two factors i.e. phosphorus and sulphur with four levels each, using RCB design replicated four times. Phosphorus was supplied from DAP @ 75, 50, 25 and 0kg ha^{-1} and sulphur from ammonium sulphate source @ 45, 30, 15, and 0kg ha^{-1}, respectively.

Crop management

The field was first ploughed with cultivator and then using rotavator a fine seed bed was prepared. Seed of local variety of 'Black Sesame' was planted @ 4 kg ha^{-1}. The crop was planted on 30 June while harvested on 23 October. Each experimental plot was 2.4 m wide and 3 m long with 6 number of rows, 40 cm apart from each other. Both the nutrients P and S different rates were incorporated at seed bed preparation time on 29th June, 2012 in DAP and Ammonium sulphate form, respectively. However, nitrogen was compensated from urea to feed up 120 kg N ha^{-1} to each experimental unit. Weeds were eradicated by manual weeding with hoe.

Soil analysis

Kjeldahl apparatus was used for the determination of soil nitrogen content (Bremmer and Malvany, 1982). Soil P, K, Zn and Fe content were figured out via AB-DTPA solution method (Soltanpour and Schwab, 1977). Spectrophotometer, flame photometer and atomic absorption spectroscopy, respectively were used. Soil organic matter content was worked out by Walky-Black procedure (Nelson and Sommers, 1996). For soil extract EC and pH, EC meter and pH meters were used to record the data (Black, 1965; McClean, 1982).

Table 1: *Chemical properties of the experimental field.*

Soil properties	Values
N content (Kjeldhal method)	0.1%
P content (AB-DTPA)	4.52mg kg^{-1}
K content (AB-DTPA)	70.2 mg kg^{-1}
Available sulphur	6.24 ppm ha^{-1}
Organic matter (Walky black)	1.53%
pH (1:5)	8.67
Electrical conductivity (1:5)	0.08dSm^{-1}

Procedure for data collection

Days to maturity were recorded when more than 75% of the plants in every plot showed signs of maturity (all pods were dry). At maturity stage five plants randomly tagged were measured (cm) from the base to top through meter rod to record plant height. Pods $plant^{-1}$ was taken on same plants in each plot and averaged was find out. The yield data was recorded on four central rows in each experimental unit. The rows were harvested, dried in open sun and weighed to record the biological and grain yields in kg ha^{-1} using Equation 1 and 2, respectively, while harvest index was calculated using Equation 3.

$$\text{Biological yield } (kgha^{-1}) = \frac{weight\ of\ four\ central\ rows}{area\ of\ four\ central\ rows} \times 10000 \quad ...(1)$$

$$Grain\ yield(kgha^{-1}) = \frac{Grain\ yield\ of\ four\ central\ rows}{area\ of\ four\ central\ rows} \times 10000 \quad ...(2)$$

$$Harvest\ index(\%) = \frac{Grain\ yeild}{Biological\ yield} \times 100 \quad ...(3)$$

Data were statistically analyzed using ANOVA techniques. LSD test was used for means comparisons' at 0.05 probability level (Jan et al., 2009).

Results and Discussion

Days to maturity

Statistically significant variations in days to maturity in response to different phosphorus (P) and sulphur (S) rates were noticed in sesame crop (Table 2). Control treatment delayed maturity (96 days) and P application hastened maturity. Higher P levels (50 and 75 kg ha^{-1}) hastened the maturity (94 days). In case of S, maturity was delayed with no S application and maturity was observed early with S incorporation regardless of its quantity. The P x S interaction was statistically non-significant, contrary to the findings of Muhamman et al. (2009) who stated that days to maturity of sesame had no significant response to phosphorus application.

Plant height

Statistically significant response was shown by both P and S to the plant height of sesame. The interactive effect of P and S was found statistically non-significant (Table 2). ANOVA showed significantly high statured plants (186 cm) in P treated plots irrespective of their levels as compare to control plots (172 cm). Earlier findings also testify the positive impact of phosphorous on plant height (Muhamman et al., 2008; Shehu et al., 2010). Application of sulphur indicated no significant variations in plant height of sesame, due to its no probable role in vegetative growth of crop. Furthermore, our results contradicted with the outcomes of (Raja et al., 2007) and (Okpara et al., 2007). They observed sulphur application improves the plant height significantly.

Table 2: *Days to maturity, plant height and pods $plant^{-1}$ of sesame as affected by various levels of phosphorus and sulphur.*

P (kg ha^{-1})	Days to maturity	Plant height (cm)	Pods $plant^{-1}$
0	96a	172b	59b
25	95b	185a	71a
50	94c	186a	69a
75	94c	185a	69a
LSD (0.05)	0.73	7.36	8.34
S (kg ha^{-1})			
0	96a	179	53b
15	95b	180	73a
30	95b	182	69a
45	95b	187	73a
LSD (0.05)	0.73	ns	8.34
Interactions			
S x P	ns	ns	ns

ns: non-significant.

Pods $plant^{-1}$

Significant response of P and S was detected in pods $plant^{-1}$ of sesame (Table 2). Incorporation of phosphorus @ 25 kg ha^{-1} developed more pods $plant^{-1}$ (71) which were statistically similar to pods $plant^{-1}$ (69) recorded at both 50 and 75 kg ha^{-1} phosphorus, while control plots had the lowest pods $plant^{-1}$ (59). Likewise, 15 kg ha^{-1} S resulted in highest number of pods $plant^{-1}$ (73), statistically similar to 30 (69) and 45 (73) kg S ha^{-1}, respectively. The pods $plant^{-1}$ was found lowest (53) in plots where both P and S were not added. Interaction of P × S was non-significantly found. Heidari et al. (2011) also reported 10.62% more pods in each plant of sesame as a result of sulphur. Sulphur application might improve soil properties and nutrient availability by acidification process

(Havlin et al., 2007) and increase nutrient uptake by the plants. The positive response of P incorporation on pods plant^{-1} of sesame in our experiment is in contrast with the outcomes of Olowe and Busari (2000) and Muhammad et al. (2009) who concluded no significant effect of varying P from 45 to 60 kg ha^{-1}. However, our findings verified the findings of Deshmuhk et al. (1990). Similarly, Shehu et al. (2010) also testified significant rise in number of pods with P @ 45 kg ha^{-1}. These outcomes were also in accordance with the outcomes of Raja et al. (2007), Mian et al. (2011) and Haruna and Usman (2005). They also reported positive effect of P incorporation on pods plant^{-1}.

Grain yield

Economic yield data of sesame as tested under various rates of P and S are presented in Table 3. The table showed that grain yield of sesame increased positively with the increase of P dose and its interaction with S at 5% level of probability. Statistically similar higher grain yields (1545 and 1452 kg ha^{-1}) were observed at 50 and 75 kg P ha^{-1}. Control plots produced significantly lower grain yield (1183 kg ha^{-1}).

In case of phosphorus and sulphur interaction, significantly higher economic yield (1607 kg ha^{-1}) was recorded for 50 kg P ha^{-1} with 30 kg S ha^{-1}, while significantly lower economic yield (783 kg ha^{-1}) was recorded in controlled experimental units.

Table 3: *Grain yield, biological yield and harvest index of sesame as affected by various levels of phosphorus and sulphur.*

P (kg ha^{-1})	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
0	1183c	6521	18b
25	1381b	6559	21a
50	1545a	6893	23a
75	1452ab	7042	21a
LSD (0.05)	128	ns	2.68
S (kg ha^{-1})			
0	1304	5733c	23a
15	1393	6707b	21ab
30	1443	7097ab	21ab
45	1422	7479a	19b
LSD (0.05)	ns	717.7	2.68
Interactions			
S x P	*(Figure 1)	ns	*(Figures 2, 3)

*Ns: Non-significant *: significant (P≤0.05). Mean values of the same category followed by different letters are significantly different from each other.*

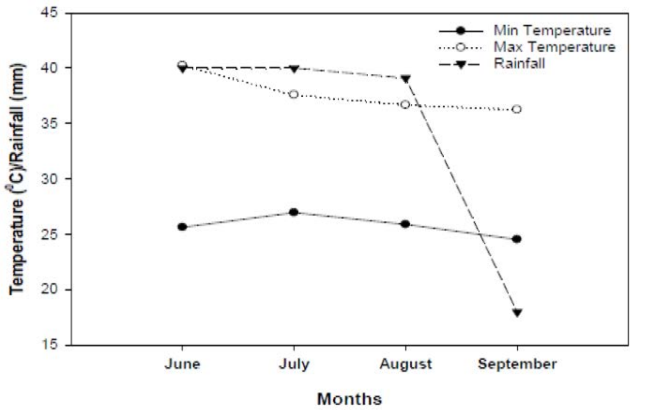

Figure 1: *Total rainfall (mm) and mean maximum and minimum temperature (°C) for crop growth period in Peshawar (Pakistan Meteorological Department).*

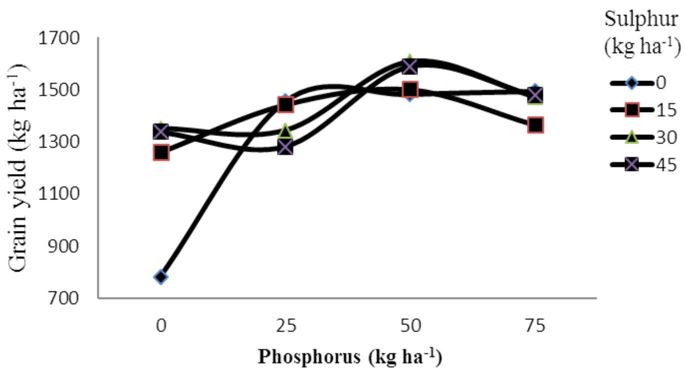

Figure 2: *Effect of sulphur and phosphorus on grain yield of sesame.*

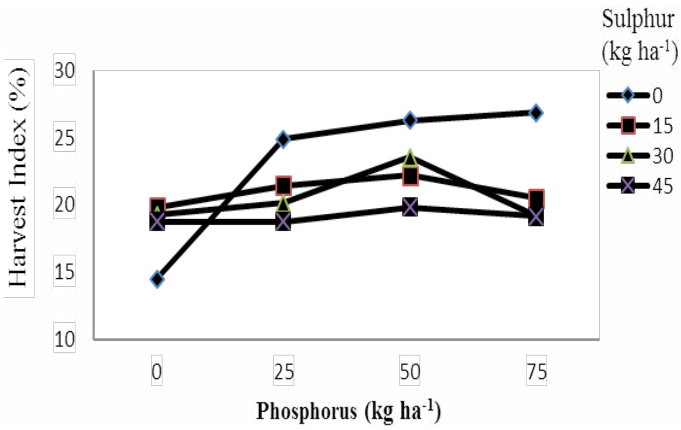

Figure 3: *Effect of sulphur and phosphorus on harvest index (%) of sesame.*

These outcomes are also in agreement with Shehu et al. (2010) who found that phosphorus application affected economic yield significantly. Okparaet al. (2007), Shehu et al. (2010), Mian et al. (2011) and Haruna and Usman (2005) also elaborated significant yield increase due to increased P incorporation. The significant response of grain yield to phosphorus application might be due to that adequate P results in higher economic yield production and improved crop quality (Douglas, 2008). Phosphorus application at 80 kg P ha^{-1} performed better in enhancing the growth and productivity of sesame crop (Haruna and Usman, 2005). Our results are in contrast with those of Olowe and Busari (2000) and Muhammad et al. (2009) who concluded no significant effect of increasing P beyond 45 up to 60 kg ha^{-1}, but corroborated with the findings of Deshmuhk et al. (1990). Sulphur effect on economic yield of sesame was found non-significant. Mondal et al. (2012) reported that sulphur application significantly affects grain yield, also supported by Wadile et al. (2005), Okpara et al. (2007) and Heidari et al. (2011) who reported that sulphur application decreased soil pH and enhanced nutrient uptake that leads to grain yield improvement. Raja et al. (2007) concluded that growth and yield of sesame were enhanced with increasing sulphur level. In contrast, appreciable reduction in the sesame yield was found with the increase in sulphur and phosphorus fertilization.

Biological yield

Effect of phosphorus and sulphur various doses and their interaction on biological yield data are presented in Table 3. The table shows significant effect of sulphur levels on biological yield of sesame crop. Sulphur @ of 45 kg ha^{-1} produced significantly higher biological yield (7479 kg ha^{-1}), statistically similar (7097 kg ha^{-1}) at 30 kg ha^{-1} S applied plots. Significantly lower yield (5733 kg ha^{-1}) was achieved in control plots. Phosphorus doses and its interaction with sulphur showed non-significant effect on the biological yield of sesame. Heidari et al. (2011) also revealed that sesame respond positively by 12.91% increase in its biological yield. This improvement with S application might be the reason that it causes improvement in soil physico-chemical properties and hence nutrients availability.

Harvest index

Phosphorus and sulphur effect and P x S on harvest index data of sesame are presented in Table 3. The table shows that harvest index (HI) of sesame was considerably influenced by various phosphorus and sulphur levels and their interaction. In case of phosphorus, higher HI (23%) was noted from 50 kg P ha^{-1} applied plots which were similar statistically (21%) from 25 and 75 kg P ha^{-1} applied plots. Likewise, significantly lower HI (18%) was recorded in plots which were kept control. In case of sulphur, higher HI (23%) was noted in control plots which were similar statistically (21%) from 15 and 30 kg S ha^{-1}treated plots. Similarly, significantly lower HI (19%) was noted from 45 kg ha^{-1} P applied treatments. In case of P x S effect of P and S, higher HI (27%) was noted for 75 kg P ha^{-1} with no sulphur applied, while significantly lower (14%) was noted in plots which were kept control. These findings were also supported by Okpara et al. (2007), Mian et al. (2011), Shehu et al. (2010) and Haruna (2011). They concluded that incorporation of phosphorus significantly affects economic yield. As HI is positively correlated with economic yield, therefore increase in gain yield also increases the harvest index.

Conclusions and Recommendations

The findings achieved concluded that solicitation of phosphorus and sulphur @ 50 kg ha^{-1} and 45 kg ha^{-1} resulted in significantly improved yield components of sesame. It is therefore, recommended that solicitation of phosphorus @ 50 kg ha^{-1} accompanied with 45 kg S ha^{-1} resulted in highest grain yield of sesame.

Novelty Statement

The contribution of oilseeds to fulfil the Pakistan's edible oil demand is far below; hence, major dependence is on import to meet the domestic demand of the larger population. Improvement through agronomic management is a step forward in meeting the domestic demand as sesame has the highest oil content (46-64%) with 25% protein.

Author's Contribution

Muhammad Younis: Conducted the field experiment
Shahen Shah: Overall research team supervision, manuscript development and submission
Inamullah: Planned, designed and supervised the research
Rozina Gul: Data analysis and draft revision
Arshad Jalal: Results and discussion write-up
Farhan Khalil: Tabulation and figures development
Iqbal Hussain: Review of literature, and methodological support
Muhammad Adnan Fahad: Data collection and provided statistical tools for analysis

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