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MK Jat
CCS HAU, Regional Research Station, Bawal, Haryana, India

PK Yadav
CCS HAU, Regional Research Station, Bawal, Haryana, India

R Singh
CCS HAU, Regional Research Station, Bawal, Haryana, India

Abha Tikkoo
CCS HAU, Regional Research Station, Bawal, Haryana, India

RS Dadarwal
CCS HAU, Regional Research Station, Bawal, Haryana, India

Corresponding Author:
MK Jat
CCS HAU, Regional Research Station, Bawal, Haryana, India

Response of phosphorus in sesame (*Sesamum indicum* L.) on coarse textured soils of South West Haryana

MK Jat, PK Yadav, R Singh, Abha Tikkoo and RS Dadarwal

Abstract
A field experiment was carried out on coarse textured medium phosphorus status soil of CCS HAU Regional Research Station, Bawal (Haryana) at three different locations during *Kharif* 2015 to 2017. The experiment was laid out in randomized block design with three replications. There were five graded levels of phosphorus application *viz.*, 0, 10, 20, 30, and 40 kg P_2O_5 ha^{-1}. The results revealed that sesame cv. HT- 1 seed yield increased significantly with application of 20 kg P_2O_5/ha. The increase in mean seed and stalk yield was 6.06, 13.17, 15.38 and 18.04 per cent and 6.20, 14.28, 17.62 and 19.85 per cent due to application of 0, 10, 20, 30 and 40 kg P_2O_5/ha, respectively over control. The mean P-uptake was also increased with P application. The mean P-use efficiency varied from 14.12 to 20.30 per cent being maximum (20.30%) with application of 20 kg P_2O_5/ha. The mean post-harvest available P status was 9.90, 11.30, 12.68, 13.52 and 14.08 kg ha^{-1} at 0, 10, 20, 30 and 40 P_2O_5/ha, respectively. The mean economic data analysis revealed that benefit cost ratio was also increased in the tune of 1.06, 1.11, 1.17, 1.18 and 1.19 with the application of 0, 10, 20, 30 and 40 kg P_2O_5/ha, respectively. The findings of this study concluded that the application of 20 kg P_2O_5 ha^{-1} found to be optimum for the cultivation of sesame crop on coarse textured medium phosphorus status soils of south-west Haryana.

Keywords: Sesame, yield, uptake, available soil p and economics

Introduction

Sesame (*Sesamum indicum* L.) commonly known as til, is also called as “queen of oilseeds” and has been known to be one of the earliest domesticated edible oilseed used by the mankind next to the groundnut and rapeseed and mustard. The oil seed crop is grown in wide range of environments extending from semi-arid tropics and sub tropics to temperate regions. Its oil and protein content generally varies from 46 to 52 per cent and from 20-26 per cent, respectively. About 70 per cent of the sesame produced in the country is used for oil extraction, 20 per cent for domestic uses including preparation of sweet candies as condiments, culinary and confectionary purposes, about 2-3 per cent for hydrogenations and 4.2 per cent for industrial purpose in manufacturing of paints, perfumed oils, pharmaceuticals and insecticides. The importance of sesame lies in its high content of oil, protein, calcium, iron and methionine (Gupta *et al*, 1998) [3]. Because of its excellent quality characters, sesame oil is also sometimes referred to as “poor man’s substitute for “ghee”. Sesame cake is also a valuable nutritious feed for cattle especially for milch animals and is ingredient of poultry feed because of its high methionine content. The cake contains 6.0-6.2 per cent N, 2.0-2.2 per cent P and 1.0-1.2 per cent K and can also be used as manure.

Globally, sesame is grown on 6.57 million hectares with production of 2.94 million tonnes and productivity of 448 kg ha^{-1}. India is largest producer and acreage holder (26%) of the sesame in the world. In India, it is cultivated on 1.56 million hectares with total production of 0.7 million tonnes. The average productivity of the crop is 478 kg ha^{-1} (Anonymous, 2018) [1]. Over the years along with its increasing demand, production of sesame seed is also increasing. Sesame seed has growing popularity due to its ability to facilitate digestion and reduce hypertension in several foods as a driving factor in the market. Furthermore, it has rising application as an antioxidant product in various pharmaceutical formulations which drives the growth of Indian sesame seeds market in the upcoming years.

Sesame, an indigenous oil producing crop has the history of cultivation in Haryana also. But the average productivity is very low in comparison to global as well as national level. Low and scanty rainfall, cultivation of crop on marginal and sub-marginal lands of poor fertility under very poor agronomic practices and inadequate or even no use of fertilizers are the major factors responsible for low productivity of the crop. Increasing global demand has opened up prospective market options for sesame. The use of mineral fertilizers and organic manures in balanced amount can ensure sustainable production at higher productivity and higher quality level of this oil seed crop. For optimum utilization of other essential inputs, fertilizer requirements need to be fine-tuned.

Phosphorus is very important macro plant nutrient which helps the growth and development of plant and increases crop yield. It is involved in many bio-chemical functions in the plant physiology systems and is essential part of skeleton of plasma membrane, nucleic acid, many coenzymes, organic molecules and phosphorylated compounds in plant system (Pandey and Sinha, 1986) [9]. Refinement of on-site nutrient management for sesame has led to the initiation of the present study, taken to determine the optimum dose of phosphorus for growth and yield performance of sesame in coarse textured soils of southern Haryana and to create awareness among the farming community about the judicious use of phosphorus fertilizer to get maximum production.

Materials and Methods

The experiment was conducted at Regional Research Station, CCS HAU, Bawal, Haryana during *kharif* season of 2015 to 2017 at three different locations. The site was situated at latitude 28.1º N, longitude 76.5º E having an altitude of 266 m above mean sea-level. The soil properties of the experimental site (mean of three years) are presented in table 1. The climate of the site is characterized by hot summers and cold winters with an average annual rainfall of 378.2, 575.5 and 565.10 mm during 2015, 2016 and 2017 of which is received during June–September.

Table 1: Physico-chemical properties of the experimental field at 0-15 cm depth (Mean of three years)

Soil properties	Mean Value
Soil texture	loamy sand
pH (1:2)	8.36
EC (dS m^{-1})	0.19
OC (g kg^{-1})	1.95
Available N (kg ha^{-1})	110.90
Available P (kg ha^{-1})	11.00
Available K (kg ha^{-1})	169.50

The experiment was laid out in randomized block design with three replications. There were five graded levels of phosphorus application *viz.*, 0, 10, 20, 30, and 40 kg P_2O_5 ha^{-1}. Recommended dose of nitrogen was applied @ 37.5 kg N ha^{-1} through urea. Irrigation and plant protection measures were taken as per recommended package of practices. Crop was harvested at physiological maturity and threshed and plot wise yield was also recorded. Seed, stalk and soil samples were taken and analyzed for P concentration (Jackson, 1967) in seed and stalk and available P in soil (Olsen *et al.*, 1954) [8]. The data was statistically analyzed and economics of P application was also worked out.

Result and Discussion

Effect of P fertilization on Crop yield

A perusal of data presented in table 2 revealed that there was a consistent increase in seed and stalk yield of sesame by increasing graded levels of phosphorus from 10 to 40 kg ha^{-1} in three *kharif* seasons. A significant increase in seed yield was found with the application of 20 kg P_2O_5 ha^{-1} whereas the seed yield of sesame crop was statistically at par with the application of 20, 30 and 40 kg P_2O_5 ha^{-1}. The mean seed and stalk yield was increased in the tune of 6.06, 13.17, 15.38 and 18.04 and 6.20, 14.28, 17.62 and 19.85 per cent respectively due to the application of 0, 10, 20, 30 and 40 kg P_2O_5 ha^{-1} the over control. The positive effect of phosphorus fertilization on seed and stalk yield of sesame might be attributed due to the medium available phosphorus content of the experimental soil. This necessitated the high demand of phosphorus by the crop as P is known to enhance the development of good root system (Russel, 1973) [12] which in turn increases efficiency of the roots in absorbing various nutrients. Marschner, 1986 [7] reported that the application of phosphorus stimulates photosynthesis, carbohydrate metabolism and synthesis of protein in turn increases the amount of metabolites synthesized by sesame plants. Also, it plays an important role in enhancing translocation of metabolites which might be the reason for the increasing seed and stalk yield. The improved growth and profuse branching due to P fertilization as discussed earlier coupled with increased photosynthates on one hand and greater mobilization of photosynthates toward reproductive parts of the plants on the other hand might have been responsible for significant improvement in yield attributes of sesame. These findings are in accordance with those reported by Singh *et al.* (1994) [15], Ravinder *et al*. (1996) [11] and Patra (2001) [10] in sesame crop.

Table 2: Effect of phosphorus on seed and stalk yield in sesame

P_2O_5 levels (kg ha^{-1})	Seed Yield (q ha^{-1})				Stalk Yield (q ha^{-1})			
	2015	2016	2017	Mean	2015	2016	2017	Mean
P_0	6.91	6.60	6.76	6.76	20.98	19.31	20.15	20.15
P_{10}	7.39	7.10	7.03	7.17	22.10	20.60	21.49	21.40
P_{20}	8.18	7.38	7.40	7.65	23.46	23.68	22.30	23.15
P_{30}	8.36	7.55	7.50	7.80	23.60	23.95	23.57	23.70
P_{40}	8.50	7.68	7.76	7.98	23.80	24.50	24.14	24.15
CD (P = 0.05)	0.62	0.60	0.56	0.59	1.64	1.79	1.81	1.75

Effect of P fertilization on Uptake, PUE and available P Content

The total P-uptake in sesame plant was also significantly influenced by each level of P application. The phosphorous uptake increased significantly with the increased levels upto 40 kg P_2O_5 ha^{-1}. The uptake was increased from 5.24 to 10.89 kg ha^{-1} with increasing levels of phosphorous from 0 to 40 kg P_2O_5 ha^{-1} (Table 3). The progressive increase in the supply of phosphorous to the crop resulted in higher availability of this nutrient, resulting in higher biomass yield. The impact of higher uptake of phosphorous under these treatments has been reflected in the growth and yield performance of the crop. Similarly, good supply of phosphorus is usually associated with increased root density and proliferation which aid in extensive exploration and supply of nutrients and water to the growing plant (Shehu *et al.*, 2010) [14].

The phosphorus use efficiency (PUE) ranged from 14.12 to 20.30%. It was increased with application of 10 and 20 kg P_2O_5 ha^{-1} to 16.30 and 20.30% and decreased to 16.80 and 14.12 percent at 30 and 40 P_2O_5 ha^{-1}, respectively. The highest PUE of 20.30% was recorded with the application of 20 kg P_2O_5 ha^{-1}. The increased supply of nutrients and good response by the plants resulted in enhanced translocation of nutrients and ultimately build-up the available P content in the soil and improve PUE as reported also by Ulukan, (2008) [16] and El-Ghamry *et al.* (2009) [2].

Increasing levels of phosphorous from 0 to 40 kg ha^{-1} significantly improved the available phosphorous in soil after harvesting of crop. The initial mean available P status was 11.00 kg P ha^{-1} whereas it was 9.90, 11.30, 12.68, 13.52 and 14.08 kg ha^{-1} with the application of 0, 10, 20, 30 and 40 kg P_2O_5 ha^{-1}, respectively (Table 3). The soil available P was significantly increased upto the application of 20 kg P_2O_5 ha^{-1}. Increasing levels of phosphorous from 30 and 40 kg ha^{-1} significantly improved available phosphorous in soil over control but at par with 20 kg P_2O_5 ha^{-1}. The highest available P content of 14.08 kg ha^{-1} was observed with the application of 40 kg P_2O_5 ha^{-1} which was significantly superior over control. Javia *et al.* (2010) [6] also observed improved post-harvest buildup of soil available P as compared without P application in sesame crop.

Table 3: Effect of phosphorus on total P uptake and available phosphorus in sesame

P_2O_5 levels (kg ha^{-1})	Total P uptake (kg ha^{-1})				PUE (%)	Available P (kg ha^{-1})			
	2015	2016	2017	Mean		2015	2016	2017	Mean
P_0	5.40	5.10	5.21	5.24	-	10.05	9.85	9.80	9.90
P_{10}	6.79	6.94	6.87	6.87	16.30	13.55	11.85	11.60	11.30
P_{20}	9.50	9.30	9.10	9.30	20.30	14.90	13.10	13.05	12.68
P_{30}	10.31	10.24	10.28	10.28	16.80	15.25	14.05	14.25	13.52
P_{40}	10.90	10.92	10.86	10.89	14.12	15.50	14.95	14.80	14.08
CD(P=0.05)	0.53	0.50	0.51	0.51	-	1.51	1.48	1.50	1.50

*PUE- Phosphorus use efficiency

Effect of P fertilization on crop economics

It is evident from the data presented in table 4 that gross returns and net returns of sesame increased with increasing levels of phosphorous at 10, 20, 30 and 40 kg P_2O_5 ha^{-1}, respectively which might be due to the increasing seed and stalk yield with increasing phosphorous levels. The minimum and maximum gross return of Rs. 37840 and Rs. 44699 were recorded with control and application of 40 kg P_2O_5 ha^{-1}, respectively. The results also indicated that the total cost of cultivation followed the same trend. The highest net return (Rs. 7241) was recorded from the phosphorous application of 40 kg P_2O_5 ha^{-1}, while minimum net return obtained with 0 kg P_2O_5 ha^{-1} (Rs 2181). The mean economic data analysis revealed that benefit cost ratio was also increased with the application of increasing levels of phosphorous. Whereas, the additional returns per rupee invested on P at 10, 20, 30 and 40 kg P_2O_5 ha^{-1} levels of phosphorous were Rs. 5.05, 5.51, 4.35 and 4.02, respectively. The highest additional returns per rupee (5.51) invested on P was obtained with application of 20 kg P_2O_5 ha^{-1}, owing to higher seed and stalk yield (Table 3). These findings are in agreement with Sharma (2005) [13], Hanumanthappa *et al.* (2008) [4] and Javia *et al.* (2010) [6].

Table 4: Effect of phosphorus application on economics in sesame

P_2O_5 levels (kg ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C	Additional returns per Rs. Invested on P
P_0	35658	37840	2182	1.06	-
P_{10}	36108	40111	4003	1.11	5.05
P_{20}	36558	42800	6242	1.17	5.51
P_{30}	37008	43722	6714	1.18	4.35
P_{40}	37458	44699	7241	1.19	4.02

Conclusions

Based on the results of research trial carried for three years, it can be concluded that application of phosphorous at 20 kg P_2O_5 ha^{-1} results significantly higher yield, uptake, phosphorous use efficiency and additional returns of sesame.

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