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Research Paper

Better growth and yield performance of lentil under different level of phosphorus, sulphur and zinc in sub-humid Southern plain of Rajasthan

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2020–21 and 2021–22 at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan) to assess the impact of different levels of phosphorus, sulphur and zinc on growth parameters and yield of lentil. The experiment was laid out in randomized complete block design (RCBD) with three replications and 18 treatment combinations. Phosphorus factor comprised of 3 levels, viz. 30, 40 and 50 kg P_2O_5/ha along with sulphur that comprised of 3 levels, viz. 15, 20 and 25 kg/ha; and zinc factor with 2 levels, viz. control and 0.5 % $ZnSO_4$ foliar spray at 55 Days after sowing (DAS). Results revealed that the higher plant height, dry matter accumulation (DMA) and primary branches/plant were recorded with application of 40 kg P_2O_5/ha in combination of 25 kg/ha sulphur and foliar spray of 0.5% $ZnSO_4$ at 55 DAS. The dry matter accumulation (0.838**) and plant height (0.871**) had a significant and positive correlation with the seed yield. The crop growth rate (CGR) enlaced by 10.49% and root-shoot ratio by 7.21% with application of 40 kg P_2O_5/ha over 30 kg P_2O_5/ha. Similarly, the CGR and root-shoot ratio of lentil were significantly enhanced by 11.95 and 5.19%, respectively with 25 kg/ha over 15 kg/ha sulphur application at 60-90 DAS. Likewise, the significantly increased CGR by 5.09% and root-shoot ratio by 3.72% with application of 0.5% $ZnSO_4$ as foliar spray over control. Moreover, the effective nodules increased by 22.68% and fresh and dry weight by 20.9 and 8.0% respectively with 50 kg P_2O_5/ha during both the years. The effective nodules and fresh and dry weight of nodules/plant increased by 13.59, 12.68 and 6.52% respectively with 25 kg/ha over 15 kg/ha suphur application while it was increased by. 6.71%, the by 6.39 and 4.08% respectively with 0.5% foliar spray of $ZnSO_4$ over control. Furthermore, significantly higher seed, haulm and biological yields increased by 9.34, 12.90 and 11.75%, respectively with 40 kg P_2O_5/ha followed by 50 kg P_2O_5/ha over 30 kg P_2O_5/ha. Similarly, the application of 25 kg/ha sulphur significantly enhanced seed yield, haulm and biological yields of lentil but it has no significant effect on the harvest index. The foliar spray of 0.5% $ZnSO_4$ increased the seed yield by 4.71 per cent, haulm yield by 7.30 per cent and biological yield by 6.45% over control. The plant growth parameters, yield attributes and yield of lentil were significantly enhanced with the application of P_2O_5 (40 kg/ha) and sulphur (25 kg/ha) along with $ZnSO_4$ (0.5%) as foliar spray at 55 days after sowing as compared to other treatment combinations. These treatment combinations could be adopted to achieve better growth performances and bridging yield gap of lentil in sub-humid agro ecologies.

Key words: Growth, Lentil, Phosphorus, Sulphur, Yield, Zinc

INTRODUCTION

Lentil is an annual crop recognized for its lens-shaped seeds having substantial dietary compositions, macro and micro nutrients including fiber, potassium, vitamins, iron and vitamin-A and prominent source of vegetable protein (Ganesan and Xu, 2017). Besides providing rich proteins and amino acids, it also acts as mini-nitrogen factory to reduce the necessity of chemical fertilizers and sustain the environment. One such example is the promotion of sustainable cereal-based production systems, which have the ability to fix free nitrogen at a rate of up to 107 kg/ha (Chand *et al*., 2015).

In India, pulses occupy 31.03 million hectares (M ha)

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area and records 27.69 million tonnes (m t) production. The area of pulses under cultivation in Rajasthan is about 6.15 m ha with the production of 4.41 m t. Around 5.01 m ha of land are used globally for cultivating lentils, that produce 40 lakh tonnes seeds with the productivity of 1038 kg/ha (FAOSTAT 2022). Lentil covers 1.42 m ha area in India which produces 1.28 mt seeds with the productivity 904 kg/ha. The predicted global consumption of lentils in 2030 is 5.50 MT, which corresponds to a 2.0 MT increase in output (Government of India 2021).

Pulses are the cheapest source of good quality protein, makes the diet more nutritive for vegetarian. Therefore, there is need to increase the pulse production in our country with adoption of better nutrients management practice. Thus, the nutrients nitrogen (N), phosphorus (P), sulphur (S) and zinc (Zn) pay vital role for crop growth, yield attributes, seed yield and nutritional value in pulses. Apart from nitrogen, other nutrients like P, S and Zn are the major limiting factors for lentil productivity. Pulses that have been fertilized with phosphate not only increase the production but also have a positive impact on the soil nitrogen content, lowering the amount of nitrogen that must be applied to successive non-legume crops (Mukherjee *et al.,* 2023). Phosphorus plays major role in growth and development of plant and it fasten the biological activities, nitrogen fixation, formation of root hairs and uptake of nutrients, the number of root nodules and their growth etc. (Miguez-Montero *et al.,* 2020, Khaleeq *et al.,* 2023). Sulphur is most important nutrient after N, P, K specially for legume crop. Sulphur plays major role in plant metabolism, formation of chlorophyll, cell development, drought hardiness etc. (Reddy *et al*., 2022). Sulphur is evolved in many amino acids such as cysteine, cystine, methionine and vitamins such as biotin and thiamine (Singh *et al*., 2016). Zinc involved in the synthesis of growth hormones, proteins, chlorophyll etc. and also an important component of numerous enzymes in plants. Moreover, it encourages seed development and maturity (Hidoto *et al*., 2017). Zinc is crucial for reproductive processes like fertilization and the generation of pollen grains. It has been observed that the zinc application influences the yield and nutritional status of crop (Hidoto *et al*., 2017).

The peculiarity of this research lies in its endeavor to identify the best nutrients management practices that can optimize lentil productivity with bridging nutrients limited yield gap of lentil in the southern region of Rajasthan. It was hypothesis that the plant growth parameters, yield attributes and yield of lentil were significantly enhanced with the application of P_2O_5 (40 kg/ha) and sulphur (25 kg/ha) along with $ZnSO_4$ (0.5%) as foliar spray at 55 days after sowing as compared to other treatment combinations. These treatment combinations could be adopted to achieve better growth performances and bridging yield gap of lentil in sub-humid agro ecologies.

MATERIALS AND METHODS

Experimental details: The field experiment was conducted during *rabi* 2020–21 and 2021–22 at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan), which is situated at 24°35'N latitude, 74°42'E longitude and at an altitude of 581.13 meters above mean sea level. The soil of the field was clay loam in texture with slightly alkaline in reaction (*p*H 8.2 and 8.1). The mean maximum temperature was 24.5-–33.7°C and 23.8–31.4°C, mean minimum temperature was 6.9–16.3°C and 3.3–12.4°C and relative humidity ranged between 56.6–94 and 65.7-–94.2 per cent during 2020–21 and 2021–22, respectively. The experiment was laid out in factorial randomized complete block design (FRBD) with 3 replications and 18 treatment combinations. Phosphorus factor comprised 3 levels, viz. 30, 40 and 50 kg/ha + sulphur level also comprised 3 levels, viz. 15, 20 and 25 kg/ha; while zinc factor comprised of 2 level, viz. control and 0.5% $ZnSO_4$ at 55 DAS.

Crop management: Lentil variety, Kota masoor-2 was grown in the experiment with 60 kg/ha of seed rate and 30 cm row spacing was kept during both the years of experimentation. Seeds were inoculated with the *Rhizobium leguminosarum* before sowing. The entire dose of N, P (in the form of DAP) and sulphur (in form of gypsum) was applied in the field before sowing of the crop. Zinc (in form of $ZnSO_4$ neutralized with lime) was applied through 0.5% zinc sulphate as foliar spray at 55 DAS. Other agronomic practices were followed as per the standard protocol for the region.

Data collection and statistical analysis: The growth parameters *viz*., plant height, dry matter accumulation, number of primary branches; root-shoot ratio, effective nodules/plant, pods/plant, seeds/pod, 1,000-seed weight and yields/plot were measured using standard procedures. Crop growth indices like CGR (crop growth rate) was calculated using standard formulas (Watson, 1952). Experimental data was statistically analyzed by the standard techniques and significance was tested by F-test at 5% level of significance (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Growth parameters: Our two-years study revealed that growth parameters of lentil *viz*; plant height, primary branches/plant and dry matter accumulation were significantly influenced by different level of phosphorus, sulphur and zinc application (Table. 1). Application of 40 kg P_2O_5/ha recorded significantly higher plant height (47.50 cm), dry matter accumulation (9.77 g/plant) and number

Table 1. Effect of phosphorus, sulphur and zinc levels on growth parameters of lentil (2-year mean basis).

Treatments	Plant Height (cm)	Dry matter accumulation (g /plant)	Primary branches/ plant	effective nodules	Fresh weight of effective nodules (mg/plant)	Dry weight of effective nodules (mg/plant)	Crop Growth Rate (g/m/day)	Root-shoot ratio
Phosphorus level (kg/ha)								
30	45.17	8.81	3.00	21.03	26.08	5.00	5.24	2.08
40	47.5	9.77	3.25	23.37	29.46	5.34	5.79	2.23
50	48.44	9.90	3.42	25.80	31.55	5.40	5.87	2.26
SEm±	0.40	0.099	0.030	0.120	0.168	0.032	0.091	0.011
CD (P=0.05)	1.12	0.281	0.085	0.339	0.474	0.089	0.256	0.031
Sulphur level (kg/ha)								
15	45.83	8.96	3.08	21.78	27.2	5.06	5.27	2.12
20	47.73	9.64	3.29	23.68	29.23	5.3	5.74	2.22
25	47.55	9.88	3.31	24.74	30.65	5.39	5.9	2.23
SEm±	0.40	0.099	0.030	0.120	0.168	0.032	0.091	0.011
CD (P=0.05)	1.12	0.281	0.085	0.339	0.474	0.089	0.256	0.031
Zinc level								
Control	46.27	9.27	3.12	22.64	28.13	5.14	5.5	2.15
0.5 % $ZnSO_4$	47.8	9.72	3.32	24.16	29.93	5.35	5.78	2.23
SEm±	0.33	0.081	0.025	0.098	0.137	0.026	0.074	0.009
CD (P=0.05)	0.92	0.229	0.070	0.276	0.387	0.073	0.209	0.025

of primary branches/plant (3.25) at harvest as compared to 30 kg P_2O_5/ha but these were statistically at par with 50 kg P_2O_5/ha on the two-year mean basis. Among sulphur application, 10.26 % increase in dry matter accumulation with 25 kg/ha over 15 kg/ha. Similar study was reported by Reddy *et al*. (2022) revealed that the plant height and DMA in lentil increased with the application of 50 kg P_2O_5/ ha and 25 kg sulphur (S)/ha. The supply of phosphorus and sulphur may have aided in quick cell division and higher chlorophyll content, which in turn speed up photosynthesis and eventually led to an increase in the amount of assimilates available to plants, which in turn enhanced the canopy, plant height and accumulation of dry matter at the various growth stages. A balanced supply of phosphorus may stimulate biological activity, leading to an increase in plant height. Increase in the dry weight of the plant as a result of different metabolites improved the capacity of photosynthesis of the plant, which ultimately led to an increase in the growth of the shoots. According to Arunraj *et al.,* (2018) and Patel *et al*., (2018), sulphur application in addition to the appropriate fertilizer dose resulted in noticeably increment in plant heights, leaf counts, branch counts and total dry matter production in green gram. Zinc spray showed significant improvement in plant height, DMA and number of primary branches/plant in the range of 3.31, 4.85 and 6.41 per cent higher respectively, over the control. Beneficial effects of zinc as growth regulator may affect the plant metabolism, photosynthetic pigments and enzyme activity contributing to an increase in vegetative growth, increased dry matter buildup and improved growth of plant.

Crop growth indices: The application of 40 kg P_2O_5/ha recorded CGR of 5.79 g/m^2/day that was 10.49 % higher to 30 kg P_2O_5/ha that and statistically *at par* with 50 kg P_2O_5/ha. On mean data basis root-shoot ratio was 7.21 % higher with application of 40 kg P_2O_5/ha in comparison to 30 kg P_2O_5/ha (Table 1). An increment of 11.95 % in CGR was observed with 25 kg S/ha over 15 kg S/ha at 60-90 DAS. Treatment with 25 kg S/ha recorded 5.19 % higher root-shoot ratio in comparison to 15 kg S/ha at harvest during the study. Application of 0.5% $ZnSO_4$ as foliar spray recorded significantly higher CGR by 5.09% over the control. Data indicated that Zn spray @ 0.5% enhanced the root-shoot ratio of lentil by 3.72% at 60 DAS over control. Patel *et al.* (2019) reported significant increase in LAI, CGR and RGR with increased fertility levels in lentil. The results of the current study are in close agreement with the research conducted by Parashar and Tripathi (2020) and Shiny *et al*., (2023).

Rhizospheric characteristics: The measured root parameters were significantly influenced by the application of phosphorus, sulphur, and zinc fertilization, as well as their interaction. Consequently, there was a significant increase in the number of active root nodules per plant and

the fresh and dry weight of these nodules (Table 1). Maximum number of effective nodules and higher fresh and dry weight of nodules was recorded under the effect of 50 kg P_2O_5/ha which was significantly higher than the 30 and 40 kg P_2O_5/ha during both the years. Number of effective nodules/plant was 22.68% and their fresh and dry weight was 20.97 and 8.0% higher, respectively with 50 kg P_2O_5/ha in comparison to 30 kg P_2O_5/ha, followed by 40 kg P_2O_5/ha. The improvement in the growth characteristics brought on the addition of nutrients resulted in to the establishment of lateral fibrous and healthy roots and root multiplication due to more cell differentiation. Gahoonia *et al*., (2006) revealed that the number of nodules reached to its maximum during the middle of flowering phase in lentil and application of phosphorus helped earlier nodule formation and enhanced the nitrogen fixation in the crop. An increase in root nodule was observed for every unit of phosphorus added up to 60 kg P_2O_5/ha in lentil (Yumnam *et al*., 2018). Phosphorus is essential for root growth and cell division as well as nodulation and nitrogen fixation and several metabolic processes are controlled by derivatives of phosphates. The higher number of effective nodules (24.74) and their fresh and dry weight (30.65 and 5.39 mg/plant) was observed with 25 kg S/ha over 15 and 20 kg S/ha. Application of 25 kg S/ha resulted increase in the quantity of effective nodules/plant and fresh & dry weight of nodules/plant of 13.59, 12.68 and 6.52 per cent, respectively compared to 15 kg S/ha on mean data basis at 60 DAS. Compared to control, 0.5% $ZnSO_4$ as foliar spray enhanced the number of effective nodules/plant by 6.71%, the fresh and dry weight of effective nodules/plant by 6.39 and 4.08% respectively. The increased nutrient absorption may have enhanced the photosynthetic capacity and the metabolites' translocation that has improved the root and shoot growth of the crop under this study.

Yield and yield attributes: The quantity of pods per plant, number of seeds per pod, weight of 1000 seeds, and lentil yield were significantly influenced by varying levels of phosphorus, sulphur and zinc. The increasing rate of phosphorus up to 40 kg/ha enhanced amount of pods/plant by 11.27%, number of seeds/pod by 4.0% and weight of 1,000-seeds by 13.28% in comparison to 30 kg P_2O_5/ha, which was statistically at par with 50 kg P_2O_5/ha (Fig. 1 and 2). Phosphorus promotes fruit and flowering and encouraged the plants to yield more of pods and higher seed-to-pod ratio. Significantly higher seed, haulm and biological yields were observed with 40 kg P_2O_5/ha followed by 50 kg P_2O_5/ha; the percent increase in seed, haulm and biological yields ranged from 9.34, 12.90 and 11.75 % over 30 kg P_2O_5/ha. Increased and balanced availability of nutrients and higher uptake of phosphorus might have enhanced the yield attributes by diverting photosynthates efficiently from source to sink and thus yield of lentil crop under present study. According to Singh *et al.,* (2017) and Datta *et al*., (2013), significant differences in the amount of pods/plant in lentil were recorded with the varying levels of phosphorus. Sulphur application significantly enhanced the number of pods/plant, number of seeds/pod and 1,000-seed weight as well as seed yield, haulm and biological yields of lentil over its lower level however, it has no significant effect on the harvest index. Maximum seed yield (1,790 kg/ha), haulm yield (3795 kg/ha) and biological yield (5,585 kg/ha) were achieved with 25 kg S/ha, which was substantially greater than 15 kg S/ha (1,635 kg ha) and 20 kg S/ha (1,725 kg/ha). Reddy *et al.,* (2022) reported that application of phosphorus and sulphur increased the number of seeds per pod, which leads to transformation of photosynthates and improved

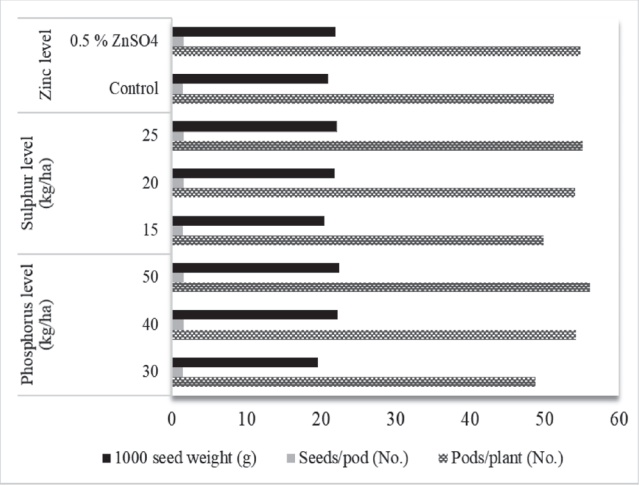

Fig. 1. Effect of phosphorus, sulphur and zinc levels on yield attributes of lentil

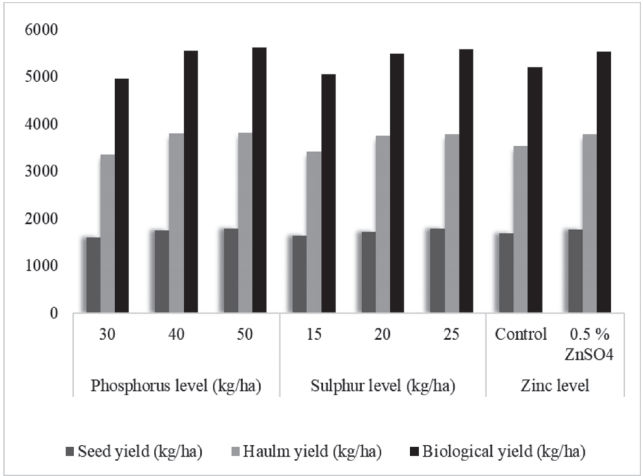

Fig. 2. Effect of phosphorus, sulphur and zinc levels on seed, haulm and biological yields of lentil

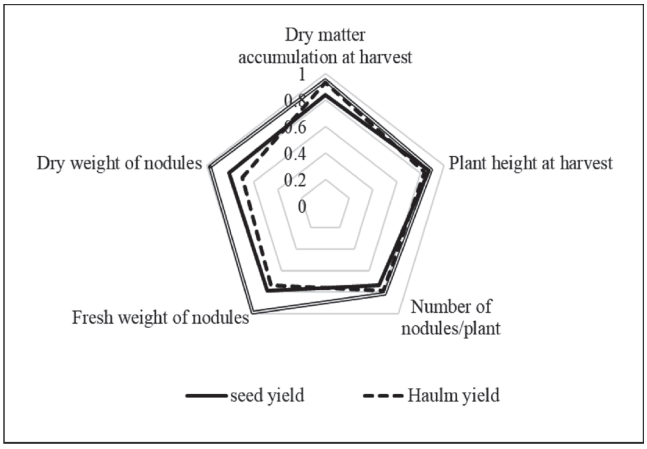

Fig. 3. Correlation between growth parameters and yields of lentil

the size and weight of the seeds in lentil. The increased sulphur availability and a favorable nutritional environment may have aided the plants during their peak growth and flowering stages, leading to an increase in test weight, the number of pods per plant and the number of seeds per pod (Teja *et al*., 2021; Patel *et al.,* 2019).

It was observed that Zn application affected the number of pods/plant, number of seeds/pod and 1,000-seed weight to the degree of 6.90, 2.61 and 4.57% higher, respectively as compared to control (Fig. 1 and 2). The foliar spray of 0.5% $ZnSO_4$ increased the seed yield by 4.71% , haulm yield by 7.30% and biological yield by 6.45% in comparison to the control. Increase in number of pods/plant may be due to the availability of additional nutrients that increased metabolism of carbohydrates and their translocation to the reproductive organs of the plant. The improved growth characteristics led to improved sink size and source-sink relationship while bolder seeds may be due to the increased dry-matter accumulation and better growth brought by the zinc application under this study. Balanced nutrition and healthy vegetative growth are believed to play a significant role in determining the seed yield of lentil crops, as suggested by Anchra *et al.,* (2024) and Gangwar and Singh (2023).

Correlation study: The growth parameters had positive association with the seed, haulm and biological yields in lentil. Plant height (0.888**) and dry matter accumulation (0.955**) had highly significant and positive correlation with biological yield while both the parameters had positive relation i.e., 0.871, 0.834 and 0.838, 0.933 with seed and haulm yields, respectively with the crop (Fig. 3). The study suggests that the plants having higher height and dry-matter content may culminate in to higher seed, haulm and biological yields. Aghili *et al*., (2012) observed that plant height had significant and positive association with yield and yield attributes viz*.,* pod fill, number of seeds/100 pods and 100 seed weight. The findings of the current study were consistent with Mahmood *et al*., (2019) who reported that highly positive association between seed yield/plant was seen to have a number of primary branches on each plant, plant height and number of pods/plant.

The study evaluated that the application of 40 kg P_2O_5/ha coupled with 25 kg S/ha along with 0.5% $ZnSO_4$ as foliar spray at 55 days after sowing resulted in to significant enhancement in growth performance and yield of lentil. Thus, the application of P_2O_5 (40 kg/ha) and sulphur (25 kg/ha) along with $ZnSO_4$ (0.5%) as foliar spray at 55 days after sowing was found superior as compared to other treatment combinations. These treatment combinations could be adopted to achieve better growth performances and bridging yield gap of lentil in sub-humid agro ecologies.

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