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Influence of Different Soil Types and Sulphur Fertilizer Rates on Performance of Pea (*Pisum sativum* L.)

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ABSTRACT

Sulphur is considered a neglected plant nutrient. However, soil scientists and plant nutritionists are increasingly investigating the nutritional value of sulphur due to its significant role in crop production. A green-house experiment was carried out at North-West University Research Farm to investigate the effect of soil types and sulphur fertilizer rates on the performance of pea. The experiment design was 4 × 2 factorial fitted in a randomized complete block design with four replications. The treatment factors included two soil types and four sulphur fertilizer rates. Plant performance was evaluated by examining parameters such as plant height, numbers of leaves, branches, flowers, pods/plants, pod length, pod mass and seed mass. The pea planted on sandy soil at 56 and 70 DAP achieved heights of 13.82 and 20.7 cm, respectively. The pea supplied with 60 kgS/ha had highest number of leaves (25.10 and 42.20) at 56 and 70 DAP. The highest number of pods/plants (1.00) was recorded in pea cultivated on sandy loam. Pea fertilized with 90 kgS/ha had the highest number of pods/plants (4.04) and seed mass (0.82 g). Notably, soil types were positively and significantly associated with yield parameters (R^2 = 0.5630 and 0.5214). Sulphur fertilizer rates were positively but not significantly associated with growth and yield parameters of pea. This showed that sandy loam was suitable for the performance of pea. The sulphur rate at 60 kg S/ha enhanced the growth of pea while 90 kg S/ha improved yield production of pea.

Keywords: sulphur fertilizer rates, soil types, seed mass, pod length, pea

INTRODUCTION

Pea is recognized as one of the most important cool season vegetable crops grown worldwide (Uddin et al., 2023). Pea is commonly consumed worldwide in its fresh and processed forms (Uddin et al., 2023). Its edible parts are green leaves, green pods and seeds (AbdulRab et al., 2018). The green pea or pods or immature seed is a popular vegetable. Green pea is a good source of food, mostly due to the high amount of protein and fibre (Haq and Ahmed., 2021).

Sulphur is a secondary plant nutrient and is becoming increasingly important in drylands as it is “the Master Nutrient” for all oil seed and pulses crops (Movalia and Saualia., 2020). Sulphur belongs to the “Four Major Plant Nutrients” along with nitrogen, phosphorus, and potassium (Movalia and Saualia., 2020). Peas like other legumes, require sulphur and thus form a symbiotic relationship with nitrogen-fixing bacteria in their root nodules. Adequate sulphur supply ensures the synthesis of essential proteins, promoting healthy plant growth (Zuber et al., 2013). Sulphur deficiency on pea plants cause symptoms such as chlorosis, reduced yield (limited flowering and pod production), thin and weak stems, rendering the plants more susceptible to lodging and damage from wind or rain (Ravanel et al., 2008). Excessive sulphur application can lead to imbalance in soil chemistry, potentially causing negative environmental effects (Henriet et al., 2019). Singh (2008) suggested that mostly 20–40 of sulphur/ha is sufficient to meet the nutrient requirement of most of the crop (Tandon 1991, Singh 2008).

Zenda et al. (2021) revealed that the most arable soil in the world has been deficient of sulphur over three decades. However, the negative effects of sulphur on crop production have just been recognized (Sahota, 2012; Rasool et al., 2013). Pea are widely adaptable legume crops for soils of different types, from sandy to clayey types (Velykis and Satkus., 2012). The total sulphur in mineral soil varied from <20 ppm in sandy soil to >600 ppm in heavy textured soil. The productivity of pea is always lower on soil with a hard setting surface with a clayey, poorly drained soil (AbdulRab et al., 2018). Hence, there is a need to investigate the response of peas to different sulphur fertilizer rates under different soil types.

MATERIAL AND METHODS

Description of the Study

The experiment was conducted in a greenhouse at North-West University farm (Molelwane) near Mafikeng with geographical coordinates of 25°48′04.3″ S and 25°38′20.8″ E. Temperatures range from 17–38 °C in summer and from 3–23 °C in winter (Sebetha and Islam, 2021). The annual rainfall during the summer range is 571 mm (Kasirivu et al., 2011). According to the South African soil classification system, the soils in Mafikeng belong to Hutton series and are classified as Ferric Luvisol and North-West University Garden as known as Chromic Luvisol (WRB, 2016).

Soil Sample Collection

The soil samples were collected at the North-West University Mafikeng campus research farm (Molelwane) and North-West University Campus Garden at a depth of 0–15 cm. The soil samples were analyzed for physical properties (sand, clay, and silt percentage) and chemical properties ($N\text{-}NO_3$, $N\text{-}NH_4$, P, K, SO_4) using the standard procedure (Table 1).

Table 1. Physical and chemical properties of experimental soil.

Chemical Properties	Molelwane Soil (mg/kg)	NWU Garden Soil (mg/kg)
$N\text{-}NO_3$	6.25	6.55
$N\text{-}NH_4$	5.50	3.95
P (Bray 1)	6	9
K	230	225
$S\text{-}(SO_4)$	16	14
pH (KCL) 1:2:5	6.44	6.99
Physical Properties	**Molelwane Soil (%)**	**NWU Garden Soil (%)**
Sand	87	80
Silt	3	5
Clay	10	15
Texture	Sandy soil	Sandy loam
Soil classification	Ferric Luvisol	Chromic Luvisol

NWU = North-West University.

Experimental Design

The experiment design was 4 × 2 factorial fitted in a randomized complete block design with four replications. The study had eight treatments with thirty-two experimental planting pots. The first treatment factor was two soil types, and the second treatment factor was sulphur fertilizer rates.

Agronomic Practices

Each planting pot was filled with 7 kg of two different soil types. Three seeds were planted per pot. Sulphur and single superphosphate fertilizers at different rates of 0 kg, 30 kg, 60 kg and 90 kg rates were applied after planting. The sulphur fertilizer used was green sulphur (35%) which contained 26% nitrogen (ammonium sulphate), calcium5% and sulphur 4%. Single superphosphate applied was 11%. Different rates of sulphur calculated were equal to 30 kg = 0.042 gS/pot, 60 kg = 0.0084 gS/pot and 90 kg = 1.26 gS/pot. Single superphosphate was 30 kg = 0.012 gS/pot, 60 kg = 0.023 gS/pot and 90 kg = 0.035 gS/pot. The fertilizer was applied by the ring method.

Data Collection

The growth parameters were collected at 42, 56 and 70 days after sowing. The growth parameters collected were plant height, number of leaves, flowers/plant, of pods/plants, pod length and seed mass. The plant height was determined using a measuring tape and the number of leaves and branches per plant was physically counted. The yield parameters collected included the number of flowers/plants and number of pods/plants. The pod length was determined using a measuring tape and seed mass was recorded with a weighing scale. The data collected were analyzed using variance (ANOVA) in the GenStat software. Means were separated at 5% significance using the LSD method.

RESULT

The Effect of Soil Types and Sulphur Fertilizer Rates on Plant Height

The soil type had no significant effect ($p \geq 0.05$) on the plant height (Table 2). Even though no significant effect was observed, pea sown in sandy loamy soil achieved a height of 12.67 cm at 42 DAP. Similarly, peas grown on sandy soil at 56 and 70 DAP, had a height of 13.82 cm and 20.7 cm, respectively. The sulphur fertilizer rates significantly ($p \leq 0.05$) influenced the plant height of pea. The pea fertilized with 60 kgS/ha had the tallest plant height (15.91 cm) at 42 DAP. During 56 DAPS, the pea treated with 30 kgS/ha showed tallest plant height (15.12 cm). However, unfertilized pea had the highest height (22.70 cm) compared to others at 70 DAP. The interaction between soil types and sulphur rates affected the height of the peas.

Table 2. The effect of soil types and sulphur fertilizer rates on plant height.

Treatment Factors	42 DAP	56 DAP	70 DAP
Soil types			
Sandy loam	12.67	13.82	20.7

Sandy soil	11.99	13.56	20.6
LSD ($p \leq 0.05$)	**3.38**	**4.62**	**4.79**
S-rate(kg/ha)			
0	9.61	11.8	22.70
30	12.62	15.12	19.10
60	15.91	15.04	20.4
90	11.15	13.53	20.5
LSD ($p \leq 0.05$)	**4.78**	**3.26**	**6.77**
Grand Mean	12.33	13.69	20.70
Soil types x sulphur rates	xx	xx	xx

DAP: Day After Planting.

The Effect of Soil Types and Sulphur Fertilizer Rates on Number of Leaves

The soil types showed no significant effect ($p \geq 0.05$) on number of leaves as indicated in Table 3. The pea grown on sandy loam had more leaves (14.25) at 42 DAP, but not significantly higher. Similarly, more leaves (25.50 and 40.80) were formed at 56 and 70 DAP, respectively. The sulphur fertilizer rates had no significant effect ($p \geq 0.05$) on number of leaves. The untreated pea produced non-significant and highest number of leaves (14.25) at 42 DAPS. The pea supplied with 60 kgS/ha had highest number of leaves (25.10 and 42.20) at 56 and 70 DAP. The number of leaves responded significantly to the interaction between soil types and sulphur fertilizer rates.

Table 3. The effect of soil types and sulphur fertilizer rates on number of leaves.

Treatment factors	42 DAP	56 DAP	70 DAP
Soil types			
Sandy loam	14.25	25.50	40.80
Sandy soil	13.00	18.40	29.10
LSD ($p \leq 0.05$)	**4.47**	**7.59**	**13.39**
S-rate(kg/ha)			
0	14.25	23.10	36.20
30	14.00	17.80	31.10
60	13.75	25.10	43.20
90	12.50	21.80	29.20
LSD ($p \leq 0.05$)	**3.16**	**10.73**	**18.94**
Grand Mean	**13.62**	**21.90**	**35.00**
Soil type x sulphur rates	xx	xx	xx

DAP: Day After Planting.

The Effect of Soil Types and Sulphur Fertilizer Rates on Number of Branches and Flowers

The soil type and fertilizer rates had no significant effect ($p \geq 0.05$) on number of branches and flowers of pea (Figure 1). Moreover, peas planted on sandy loam produced higher number of branches (1.56) and flowers/plants (3.38). although this effect was not significant. The 60 kgS/ha yielded the highest number of branches (1.76) than other application rates. However, untreated pea produced the highest number of flowers/plant (3.88). Notably, the number of branches increased following the application of 60 kgS/ha rate. The numbers of branches and flowers were significantly influenced by the interaction between soil types and sulphur rates.

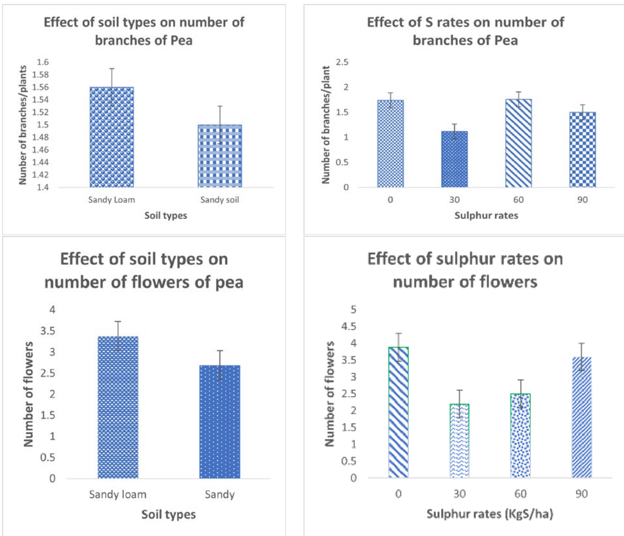

Fig. 1. Effect of soil types and sulphur rates on number of branches and flowers of pea.

The Effect of Soil Types and Sulphur Fertilizer Rates on Yield Parameters

The soil types had no significant effect ($p \geq 0.05$) on yield parameters (Table 4). The higher the number of pod/plant (1.00) was observed among the peas planted on sandy loam. The application of 90 kgS/ha produced the highest number of pods/plants (1.38). However, sand soil showed longer pod length (3.46 cm). The pots supplied 90 kg S/ha showed longest pod length (4.04 cm). Similarly, highest pod mass (0.96 g) and seed mass (0.57 g) were recorded in plants grown in sandy soil. The pea planted on sandy soil had a higher pod length 3.16 cm) pod mass (0.92) and seed mass (0.57). The yield parameters were significantly influenced by sulphur rates. Pea fertilized with 90 kgS/ha had the highest number of pod/plant (4.04). The application of 60 kgS/ha produced the highest pod mass/plant (1.38 g) whereas seed mass (0.82 g) was produced pea supplied with 90 kgS/ha rate of fertilizer. The application of 60 kg S/ha had the highest pod mass (1.38 g). The pea treated 90 kg S/ha had the highest seed mass (0.82 g). The interaction between soil types and sulphur rates affected the yield and its parameters.

Table 4. The effect of soil types and Sulphur fertilizer rates on number of pods/plants, pod length/plant, mass of pods/plant and mass of seeds

Treatment Factor	No of Pod/Plant	Pod Length (cm)	Pod Mass (g)	Seed Mass (g)
Soil types				
Sandy loam	1.00	3.16	0.86	0.40
Sandy soil	0.94	3.46	0.96	0.57
LSD ($p \leq 0.05$)	**0.40**	**1.38**	**0.62**	**0.40**
S-rates (kg S/ha)				
0	1.13	3,46	1.09	0.70
30	0.50	2.00	1.17	0.07
60	0.88	3.73	1.38	0.36
90	1.38	4.04	0.93	0.82
LSD ($p \leq 0.05$)	**0.50**	**1.96**	**0.88**	**0.56**

Grand Mean	**0.97**	**3.31**	**0.89**	**0.49**
Soil type x sulphur rates	xx	xx	xx	xx

DAP: Day After Planting.

Relationship between Soil Types, Growth and Yield Parameters of Pea

A positive but non-significant relationship was observed between soil types and growth and reproductive parameters (R^2 = 0.2907 and 0.3023). However, the association between soil types and yield parameters was positive and significant (R^2 = 0.5630 and 0.5214) as indicated in Figure 2.

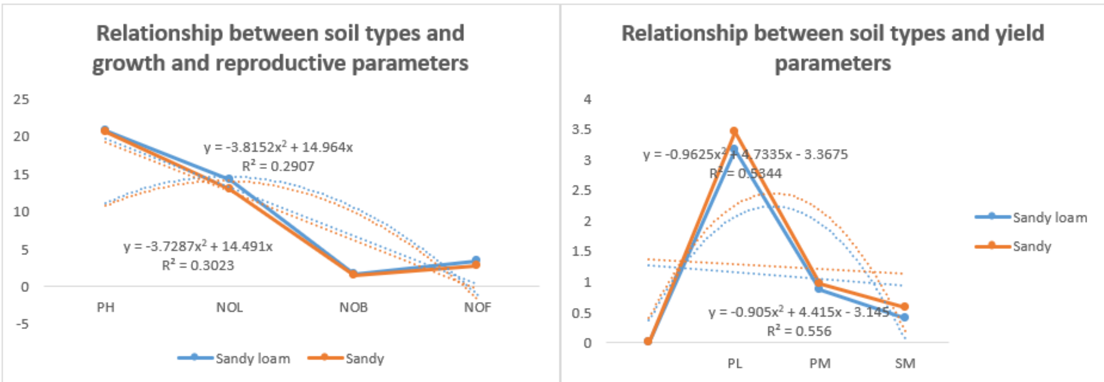

Fig. 2. Relationship between soil types, growth and yield parameters of peas. PH = Plant height; NOL = Number of leaves; NOB = Number of branches/plants; NOF = Number of flowers; PL = Pod length; NOP =Number of pods/plants; SM = Seed mass.

Relationship between Sulphur Rates, Growth and Yield Parameters of Pea

The correlation matrix demonstrated that sulphur fertilizer rates were positively but non-significantly associated with the growth and yield parameters of pea (Table 5). The number of flowers was positively and significantly related to the number of pods, seed mass, plant height and pod mass. The correlation between seed mass exhibited a positive and significant relationship between plant height, number of pods, number of flowers and pod mass.

Table 5. Correlation analysis.

Treatments	S rates	PL	NOP	SM	NOF	PH	NOB	NOL	PM
S rates	**1**	0.274	0.151	0.061	0.000	0.135	0.003	0.034	0.035
PL	0.274	**1**	0.774	0.677	0.393	0.341	0.609	0.068	0.036
NOP	0.151	**0.774**	**1**	0.976	0.812	0.445	0.341	0.024	0.379
SM	0.061	0.677	**0.976**	**1**	0.912	0.560	0.352	0.029	0.420
NOF	0.000	0.393	0.812	**0.912**	**1**	0.632	0.232	0.087	0.552
PH	0.135	0.341	0.445	0.560	**0.632**	**1**	0.679	0.081	0.045
NOB	0.003	0.609	0.341	0.352	0.232	**0.679**	**1**	0.472	0.046
NOL	0.034	0.068	0.024	0.029	0.087	0.081	0.472	**1**	0.734
PM	0.035	0.036	0.379	0.420	0.552	0.045	0.046	**0.734**	**1**

The bold value indicated significant values at $p \leq 0.05$. S rates: Sulphur rates, PL = Pod length, NOP = Number of pod/plants, SM = Seed mass, NOF = Number of flowers, PH = Plant height, NOB = Number of branches/plants, NOL = Number of leaves; PM = Pod mass.

DISCUSSION

Sandy loam soil was effective in enhancing the performance of pea, achieving good physical and chemical properties that supported the growth and yield of pea. This indicated that pea is less productive on sandy soil. Mile et al. (1999) reported that the best soil types for peas are silt loam, sandy loam or clay loam and soil pH of 6.0 to 7.0. In this study, soil pH of the experimental soil was 6.44 and 6.99, which promoted the growth and development of pea plants. Sharma et al. (2024) found that sandy soils are deficient in sulphur due to low organic carbon contents.

Sulphur is a major player in the intricate web of plant metabolic processes. The result revealed that peas performed better at 60 and 90 kg S/ha. Sulphur improved the metabolic activities, promoted chlorophyll formation, photosynthesis and root development by enhancing nutrient absorption (Kushwaha et al., 2019). It also supported the legume rhizobium symbiotic nitrogen fixation (Movalia and Sovalia., 2020). The soybean grown using 60 kg S/ha produced the tallest plant height (73.93 cm), primary branches/plant (6.02), secondary branches/plant (41.80), number of leaves (5.12), number of capsule/plant (1.4), seed/capsule (9.75) and yield (7.93) as reported by (Kushwaha et al., 2019). Rao et al., (2001) reported similar results about application rate and yield production and Scherer (2006) reveals that leguminous plant species require a large quantity of sulphur rate due to high protein content. Also, the soil types had low soil sulphur contents as revealed by (ArunRaj et al., 2018), suggesting that the soil types required the supplementation of sulphur fertilizers.

The relationship between soil types and growth of pea showed that pea required a fertile land to achieve optimal performance. The association between soil types and yield and parameters of pea revealed that yield parameters needed marginal land of optimum yield productivity as result that can fixed nitrogen as legumes crops. The correlation analysis revealed that little significant on growth, reproductive and yield parameters of pea.

CONCLUSION

This study showed that pea performed better on sandy loam soil than sandy soil. Moreover, application of 60 kg S/ha was conducive to the growth of pea and seed mass was improved following 9 kg S/ha application. This indicated that pea can grow on sandy loam soil. These findings indicate that 60–90 kg S/ha is suitable for optimal growth of pea.

CONFLICTS of INTEREST

Regarding the publication of this manuscript, the author declares no conflicts of interest.

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