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Effect of sulphur levels on growth and yield of different radish varieties in semi-arid region of Rajasthan

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Abstract
A field experiment was conducted at Crop Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan during *Rabi*, 2024-25 on sandy loamy soil. The experiment was laid out in Factorial Randomized Block Design, replicated thrice, consisting of twelve treatments four levels of sulphur (Control, 20, 40, and 60 kg/ha) and three radish varieties (Japanese White, Pusa Himani, and White Icicle). Results revealed that application of 60 kg/ha sulphur significantly enhanced growth and yield attributes including maximum fresh weight (294.48 g), dry weight (19.98 g), root length (26.93 cm), maximum root diameter (3.77 cm), maximum fresh root weight (151.52 g) and maximum root yield (460.27 q/ha). Among varieties, Japanese White produced the maximum fresh weight (277.30 g), dry weight (20.05 g), root length (29.83 cm), root diameter (3.64 cm), fresh root weight (151.46 g) and maximum root yield (505.77 q/ha). Research findings suggest that 60 kg/ha sulphur supplementation and selection of Japanese White are most suitable for optimizing yield (520.34 q/ha) of radish in semi-arid regions.

Keywords: Radish, sulphur, varieties, yield attributes, growth, yield, *Rabi*

1. Introduction
Radish (*Raphanus sativus* L.) is most popular and widely grown cool season vegetables among the root crops. It is a member of the Brassicaceae family native to Europe or Asia. The most commonly eaten portion of the radish is fusiform taproot, although the entire plant is edible and the tops can be used as a leaf vegetable. The root of Radish is usually eaten raw, although together specimens can be steamed. The raw flesh has a crisp texture and a pungent, peppery flavour caused by glucosinolates (4 methyl thio- 3- Trans butenyl iso-thiocynate) and the enzyme myrosinase, which combine when cewed to from allyl isothiocynate also present in mustard (Bahadur and Bala, 2017) [2].

It is a good source of vitamins C and minerals like calcium, potassium and phosphorus. The chemical composition per 100g of radish is energy-16 kcal, carbohydrates-3.4 g, sugar-1.86 g, dietary fiber-1.6 g, Fat-0.1 g, protein-0.68 g, thiamine-0.012 mg, riboflavin-0.039 mg, niacin-0.254 mg, pantothenic acid-0.165 mg, vitamin B6-0.071 mg, folate-25 ug vitamin C-14.8 mg, calcium-25 mg, iron-0.34 mg, magnesium-10 mg, manganese-0.069 mg, phosphorus- 20 mg, potassium-233 mg, zinc-0.28 mg (Tripathi *et al.*, 2017) [16].

Sulphur (S) is an essential plant nutrient and plays a vital role in the growth and development of crop plants. It is a component of amino acids cysteine and methionine, which act as precursor for the synthesis of all other compounds containing reduced sulphur. It also helps in chlorophyll synthesis, enhances the vegetative and reproductive growth in plants (Khalid *et al.*, 2012) [8]. Sulphur is directly or indirectly involved in various plant metabolic processes. Application of S as sulphate increases crop yield and quality. Sulphur deficiency is reported in many crops including vegetables grown in coarse textured soil due to leaching losses. Radish root yield is reported to increase with S application. Sulphur application affects crop yield through the effect on S use efficiency and its components (uptake efficiency and utilization efficiency). This experiment was designed to gain a deeper insight into radish S nutrition and its relationship to economic yield (Shakila and Srirama, 2020) [13].

There are several factors like variety, season of planting, nutrition and irrigation which plays a dominant role in yield contribution and quality production. Among these factors variety is predominant. Several varieties of radish are available in the market having varying length, size, colour, taste, yield potential and quality parameters. Higher yield, long sized roots and earliness are some of the characters which might be responsible for increase in the profit of radish growing farmers. The consumers as well as growers are demanding for the varieties having good qualities (Dongarwar *et al.*, 2018) [5].

2. Materials and Methods: The experiment was conducted at the experimental farm of the Department of Horticulture, Jaipur National University, from November 2024 to January 2025. The farm is geographically located at 75°85'99" E longitude and 26°84'79" N latitude, at an altitude of 431 meters above mean sea level, approximately 17 km from Jaipur city. The soil at the experimental site was sandy loam in texture. The area falls under a subtropical climatic zone. Weeding and hoeing operations were carried out as and when required throughout the crop cycle. Irrigation was applied five times on monthly bases from November to January. The observation recorded were fresh weight (gm), dry weight (gm), root length (cm), root diameter (cm), root weight (gm) and root yield (q/ha). The dry weight of plant has been recorded after taking fresh weight of plants then kept in hot air oven at 65+2°C temperature till constant weight. This observation recorded at harvest. The root diameter has been recorded by selecting five roots from each plot was measured by using vernier calliper at harvesting stage and the means were worked out and expressed in centimetre. The diameter was taken from middle portion of the root. Data on various growth parameters were recorded using standard agronomic procedures at harvest. Similarly, observations related to yield and quality was also collected on the harvest day. All collected data were subjected to statistical analysis using the analysis of variance (ANOVA) technique, following the method described by Gomez and Gomez (1984) [6].

3. Result and Disscussion

3.1 Fresh weight (gm): The perusal of data (Table 1) shows that fresh weight of radish significantly differs by different treatments of varieties and sulphur levels over control as well as other treatments. Maximum fresh weight (294.48 gm) was reported with application of Sulphur (60 kg ha^{-1}) which was significantly superior over all other treatments. However, Japanese white (277.30 gm) recorded maximum fresh weight in varieties. Similar results were reported by Ola *et al.*, (2018) and Singh *et al.*, (2022) [15, 11] in radish. This might be the reason of adequate supply of sulphur that resulted in increase the rate of photosynthesis and their translocation to sink, which ultimately results in the increment in fresh yield of radish (Sharma *et al.*, 2022). The results agree with those of Singh *et al.*, (2022) and Bairwa *et al.*, (2017) in radish [3, 15, 14].

3.2 Dry weight (gm)

The perusal of data (Table 1) shows that dry weight of radish significantly differs by different treatments of varieties and sulphur levels over control as well as other treatments. Maximum dry weight (19.98 gm) was reported with application of Sulphur (60 kg ha^{-1}) which was significantly superior over all other treatments. However, Japanese white (20.05 gm) recorded maximum dry weight in varieties. Variation for dry weight plant among varieties was also found by Singh *et al.*, (2022) in radish [15].

3.3 Root length (cm)

Result pertaining to the root length is presented in Table 2shows the effect of plant varieties and sulphur levels significantly increase root length at harvest. The root length varied from 23.29 cm to 29.83cm among all the treatments. Maximum root length (29.83 cm) was reported with variety Japanese White which was significantly superior over all other treatments. However, application of Sulphur (60 kg ha^{-1}) (26.93 cm) recorded maximum root length in Sulphur levels. Sulphur fertilization stimulates cell division and elongation, enhancing root development in radish. Latest studies report that optimal sulphur rates promote metabolite synthesis and meristematic activity, with genotype-specific responses resulting in the best root length when high sulphur levels (50-60 kg ha^{-1}) are combined with high-yielding varieties such as Japanese White. (Augilar *et al.*, 2024) [1].

3.4 Root diameter (cm)

Data presented in Table 2 shows the effect of plant varieties and sulphur levels significantly increase root diameter. The root diameter varied from 3.20 cm to 3.77cm among all the treatments. Maximum root diameter (3.77 cm) was reported with application of Sulphur (60 kg ha^{-1}) which was significantly superior over all other treatments. However, Japanese white (3.64 cm) recorded maximum root diameter in varieties. This is due to, genetic variability, heritability and genetic advance. With these the root diameter among the studied varieties dependent on genetic variability, heritability, genetic advance and also favourable environmental conditions (Semba *et al.*, 2019) [12]. The difference in root diameter among varieties was also reported by Singh *et al.* (2022) [15]. The increase in root diameter of radish in sulphur applied plots might be due to the higher production of metabolites and increase in meristematic activity (Singh *et al.*, 2022) [15]. These results are in agreement with those of Shakila and Sriram Chandrasekharan (2020) and Bahadur and Bala (2017) in radish [2, 13].

3.5 Root weight (gm)

Result pertaining to the root weight is presented in Table 2 shows the effect of plant varieties and sulphur levels significantly increase root weight at harvest. The root weight varied from 139.94 gm to 151.52 gm among all the treatments. Maximum root weight (151.52 gm) was reported with application of Sulphur (60 kg ha^{-1}) which was significantly superior over all other treatments. However, Japanese White (151.46gm) recorded maximum root weight in varieties. The differences for root weight among the cultivars may be due to genetic factors and their interaction to the environmental conditions (Ola *et al.*, 2018) [11]. These findings agree with Singh *et al.*, (2022) [15] in radish. The increase in yield attributes might be due to the important role of sulphur in lowering the pH of saline-alkaline soil resulting in increased availability of many nutrients or might be the activation of several enzymes and in carbohydrate metabolism. These finding corroborates with the findings of Shakila and Sriram Chandrasekharan (2020), Singh *et al.*, (2016) in radish [13].

3.6 Root yield (gm)

Data presented inTable2 shows the effect of plant varieties and sulphur levels significantly increase root yield. The root yield varied from 431.75 q/ha to 505.77 q/ha among all the treatments. Maximum root yield (460.27 q/ha) was reported with application of Sulphur (60 kg ha^{-1}) which was significantly superior over all other treatments. However, Japanese white (505.77 q/ha) recorded maximum root yield in varieties. Thus, the combination of Sulphur (60 kg ha^{-1}) + Japanese white found to be the best among all treatments. The genetic variability, heritability in superior gene characters and genetic advance plays a great role in determination on the radish root yield (Semba *et al.*, 2019) [12]. As the varieties which have shown superior performance in yield have significantly a greater number of vigorous leaves on it and more plant height, which could have synthesized more food material and supplied to the roots, that might have resulted in increasing the root weight and diameter and ultimately resulted in producing higher root yield in these varieties. The variations in yield among the cultivars were also found by Nargave *et al.*, (2018), Dahal *et al.*, (2021) in radish [4, 10].

3.7 Interaction Effect on Root Yield

The results revealed that the root yield of radish (q/ha) increased with increasing sulphur application across all varieties, with values for Japanese White being 491.82 (control), 499.99 (20 kg/ha), 510.93 (40 kg/ha), and 520.34 (60 kg/ha); for Pusa Himani, yields were 437.04, 445.21, 456.15, and 465.56 q/ha respectively; and for White Icicle, yields were 366.4, 374.57, 385.51, and 394.92 q/ha for the same respective sulphur levels. The overall yield ranged from a minimum of 366.4 q/ha (White Icicle, control) to a maximum of 520.34 q/ha (Japanese White, 60 kg/ha sulphur), showing the highest yield in Japanese White with 60 kg/ha sulphur and the lowest in White Icicle without sulphur application. Sulphur nutrition significantly enhances radish root yield by promoting enzyme activity and nutrient utilization, with marked variety differences attributed to genetic potential and efficiency in nutrient uptake. Current research recommends application rates up to 60 kg/ha for significant yield benefits, and the observed yield increment across sulphur levels agrees with contemporary findings on optimizing sulphur use for maximum productivity in radish. (Jankowski and Szatkowski, 2025) and (Augilar *et al.*, 2024) [1, 7].

Table 1: Effect of different sulphur levels and varieties on growth parameters of radish.

	Fresh Weight (gm)	Dry Weight (gm)
Sulphur Levels		
Control	252.69	15.27
20Kg/ha	269.29	17.18
40Kg/ha	277.42	18.21
60Kg/ha	294.48	19.98
SEm±	1.98	0.33
CD (0.05%)	5.96	1.01
Varieties		
Japanese White	277.30	20.05
Pusa Himani	273.51	17.23
White Icicle	269.60	15.70
SEm±	1.16	0.13
CD (0.05%)	3.45	0.40

Table 2: Effect of different sulphur levels and varieties on yield parameters of radish

	Root Length (cm)	Root Diameter (cm)	Root Weight (gm)	Root Yield (q/ha)
Sulphur Levels				
Control	23.29	3.20	139.94	431.75
20Kg/ha	24.73	3.38	142.76	439.92
40Kg/ha	25.69	3.57	145.66	450.86
60Kg/ha	26.93	3.77	151.52	460.27
SEm±	0.41	0.06	0.87	2.40
CD (0.05%)	1.24	0.18	2.62	7.22
Varieties				
Japanese White	29.83	3.64	151.46	505.77
Pusa Himani	25.13	3.49	144.68	450.99
White Icicle	20.53	3.31	138.78	380.35
SEm±	0.22	0.05	0.333	0.74
CD (0.05%)	0.64	0.15	1.01	2.24

Table 3: InteractionEffect of different sulphur levels and varieties on root yield of radish

Sulphur levels	Varieties		
	Japanese White	Pusa Himani	White Icicle
Control	491.82	437.04	366.4
20 kg/ha	499.99	445.21	374.57
40 kg/ha	510.93	456.15	385.51
60 kg/ha	520.34	465.56	394.92
SEm±	1.33		
LSD 0.05	3.99		

Conclusion

On the basis of findings of the present experiment, the following conclusion may be drawn: The experiment comprised 12 treatments, combining four levels of sulphur (Control, 20, 40, and 60 kg/ha) and three radish varieties (Japanese White, Pusa Himani, and White Icicle), conducted at Crop Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan during *Rabi*, 2024-25 on sandy loamy soil. Due to the low sulphur content present in the soil, the 60 kg/ha sulphur level treatment showed better results in growth and yield. The findings demonstrated that application of 60 kg/ha sulphur resulted in significant improvements in growth and yield attributes, including the maximum fresh weight (294.48 g), maximum dry weight (19.09 g), maximum root length (26.93 cm), maximum root diameter (3.77 cm), maximum fresh root weight (151.52 g), and maximum root yield (460.27 q/ha). Japanese White emerged as the best performing variety with maximum fresh weight (277.30 g), maximum dry weight (20.05 cm), maximum root length (29.83 cm), maximum root diameter (3.64 cm), maximum fresh root weight (151.46 g) and maximum root yield (505.77 q/ha). Therefore, supplementation of 60 kg/ha sulphur together with cultivation of Japanese White is recommended for optimizing yield (520.34 q/ha) of radish under semi-arid conditions of Rajasthan.

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