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Performance of radish (*Raphanus sativus* L.) under different irrigation and sulphur levels

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Abstract
The present experiment was conducted to study the effect of irrigation and sulphur levels on growth and quality of Radish (*Raphanus sativus* L.) during *rabi* season of 2020-21. The irrigation was applied as drip at different levels (60 %PE, 80 % PE, 100 %PE and 120 % PE) with four sulphur levels such as control, 15, 30 and 45 kg S ha^{-1}. Result revealed that irrigation through drip system at 100% PE was at par with 120% PE showed significantly higher plant height (58.07 cm, 69.16 cm) at 45 DAS & at harvest, number of leaves (9.47), fresh weight of leaves per plant (80.59) and total chlorophyll content in leaves (2.02 mg g^{-1}) as compared to rest of irrigation levels. In case of TSS of root (6.84º) and pungency level (378.97) was highest record at 60 percent PE. Among sulphur levels, application of 30 kg S ha^{-1} recorded significantly higher plant height (56.83 cm, 67.91 cm) at 45 DAS & at harvest, number of leaves (9.42), fresh weight of leaves per plant (79.12), TSS of root (6.99 º), pungency level (383.10) and total chlorophyll content (2.02 mg g^{-1}) over control and 45 kg S ha^{-1} but it was at par with sulphur level 45 kg S ha^{-1}.

Keywords: Radish, drip irrigation, sulphur, chlorophyll, TSS, pungency level

Introduction
Radish (*Raphanus sativus* L.) is one of the popular *rabi* season root crops and widely cultivated for its excellent nutritive and medicinal values. It belongs to family Cruciferae. Being a cool season crop, radish is sown in winter from September to January in northern plains. This is the vegetable of both tropical and temperate regions of the world, widely cultivated for its root, tender leaves and green shoots (Alam *et al.* 2010) [2]. Its consumption prevent from constipation, increase appetite and utile for jaundice, liver disorders etc. (Brintha and Seran, 2009) [6]. The leaves of radish are also cooked as vegetable. Radish is rich in glucosinolate contents and diverse amino acids (Xie *et al.* 2018) [18].

In India, radish is cultivated in an area of about 202 thousand hectare and annual production of 3.145 million tonnes (Anonymous, 2019a) [3]. Radish is grown round the year and throughout the country. However, West Bengal, Bihar, Uttar Pradesh, Karnataka, Haryana and Rajasthan are the major growing states. In Rajasthan, it occupies an area of 523 hectare and production is 6755 tonnes (Anonymous, 2019b) [4].

In the drip irrigation method, the water is carried to the plant under low pressure through small diameter plastic pipes and delivered at the root zone drop by drop through an emitting device. This method is primarily introduced to increase water use efficiency. Drip irrigation management is based on the frequent replenishment of water loss by evapo transpiration (ET). There is different agreement over the erect of irrigation frequency on crop water use. Goldberg *et al.* (1971) [10] indicated that the increase in irrigation frequency can reduce evaporation and deep percolation and established a favorable soil moisture and oxygen condition in the root zone throughout the crop period for better growth of the plant.

Sulphur is ranked as the fourth element after N, P and K in balanced fertilization. Sulphur is directly or indirectly involved in various plant metabolic processes. Application of S as sulfate increases crop yield and quality (Oh, 1998). Sulphur deficiency is reported in many crops including vegetables grown in coarse textured soil due to leaching losses. Glucosinolates provide a sulphur storage pool which is used in maintaining normal metabolism of plant under conditions of sulphur deficiency and their accumulation and the supply of sulphur are closely related (Schonhof *et al.* 2007) [16]. Under the agroclimatic condition of arid region where the scarcity of water is more and synergistic effect of sulphur has been reported on supply of glucosinate concentration.

As both are the important factors which influence yield and quality of radish crop, a proper balance of irrigation and sulphur is required for better production and quality.

Materials and Methods

The layout of experiment was laid out at Instructional Farm, College of Agriculture, Bikaner (Raj.). The soil of the experimental field was loamy sand in texture and slightly alkaline in reaction (pH 8.5), poor in organic carbon (0.12 per cent), low in available nitrogen (116 kg ha^{-1}) but medium in available phosphorus (15.3 kg ha^{-1}) and potassium (171.2 kg ha^{-1}) The experiment was laid out in split plot design and replicated thrice with combination of sixteen treatments. The treatments have four levels of irrigation (60% PE, 80% PE, 100% PE and 120% PE) and four sulphur levels (Control, 15, 30 and 45 kg S ha^{-1}) were randomly allotted to main plots and sub plots using random number tables of Fisher (1950) [9].

The experiment field was ploughed after pre-sowing irrigation by tractor drawn disc plough and disc harrow. Recommended dose of N, P_2O_5 and K_2O i.e. 30:58:87 kg ha^{-1} was applied through urea, DAP and MOP, respectively. Seeds were treated with 0.02 per cent thiram to check the infection of damping off. Seeds of variety Pusa Rashmi were sown on 5thNovember, 2020 in shallow furrows of line sowing by dropping the seeds at 1-2 cm depth. The distance between row to row and plant to plant was kept as 30 x 10 cm^2. The seed rate of radish was taken 12 kg ha^{-1}. Under drip system immediately after sowing 40 mm water was applied to ensure proper germination thereafter irrigation was applied at alternate days as per treatment. Five plants were randomly selected from each plot and tagged permanently. Height of each tagged plant was measured at 45 days and harvest from base of the plant to tip of the main shoot by meter scale and average height of five plants was recorded as mean plant height (cm). The number of leaves of five tagged plants was counted from each plot at harvest. The average number of leaves per plant was calculated. Fresh weight of leaves per plant of five tagged plants was recorded at the time of harvesting. Total chlorophyll content in leaves (mg $g^{-1)}$ at 45 days after sowing was estimated by the method of Hiscox and Israelstam, 1979 [11]. Total soluble solids content was determined with the help of 'Zeiss hand Refractometer and values obtained were corrected at 20 C^o (A.O.A.C., 1960) [1] at time of harvesting of roots. Isothiocyanate content (ug 100^{-1} root) of radish was determined by the method of extraction (Carlson *et al.*, 1985) [7] for obtaining pungency level.

Result and Discussion

Plant height

Results (Table 1) revealed that that height of radish plant influenced significantly due to irrigation and sulphur levels. Irrigation at 100% PE was at par with 120% PE showed higher plant height (58.07 cm and 69.16 cm) at 45 DAS and harvest, respectively, which was more than irrigation levels of 60% PE and 80% PE. With the enhancement of the irrigation levels from 60% PE to 120% PE increase the plant height. The increase in the plant height is due to 100% and 120% PE irrigation levels apply through the drip irrigation might be due to proper management of soil moisture content at field capacity. So, plants absorb proper amount of water and nutrient from the soil which in turn increased the cell elongation. The lowest (minimum) plant height at 60% and 80% PE irrigation levels was due to lack of soil moisture around root zone which results in decline of leaf water content as well as turgor pressure of plant cell. Highest plant height (57.58 cm and 68.99) was recorded with 45 kg S ha^{-1} as compared to control, 15 kg S ha^{-1}, but remained at par with 30 kg S ha^{-1} (56.83 cm and 67.91cm) at 45 DAS and harvest, respectively. 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. This result also related with the finding of Sriram Chandrasekharan (2012) [17], Kumar *et al.* (2016) [13] and Bala and Bahadur (2017) [5].

Number of leaves

Results (Table 1) revealed that that number of leaves per plant of radish influenced significantly due to irrigation and sulphur levels. Crop irrigate at 100% PE level of irrigation recorded higher number of leaves per plant (9.47) as compared to 60% PE and 80% PE irrigation levels but it was statistically at par with 120% PE level of irrigation. It is might due to proper availability of soil moisture in rhizosphere area and the continue increase in soil moisture in rhizosphere resulting in higher number of leaves per plant. The results were correlated with results of Isoda *et al*. (2007). Highest numbers of leaves per plant (9.97) produced with application of 45 kg S ha^{-1} as compared to control and 15 kg S ha^{-1}; it was at par with 30 kg S ha^{-1} (9.42). This might be the reason of adequate supply of sulphur that resulted in increased the rate of photosynthesis and their translocation to sink, which ultimately results in the increment in fresh yield of radish. This result also related with the finding of Sriramachandrasekharan (2012), Kumar *et al.* (2016) [13] and Bala and Bahadur (2017) [5].

Fresh weight of leaves

Results (Table 1) revealed that that fresh weight of leaves of radish influenced significantly due to irrigation and sulphur levels. Crop irrigate with 100% PE irrigation level produced higher fresh weight of leaves per plant (80.59 g) as compared to 60% and 80% PE, but it was at par with 120% PE. Minimum fresh weight of leaves per plant (66.69 g) was observed at 60% PE. The optimum soil moisture condition in the root zone was resulting increased of fresh weight of leaves in plants, while the moisture stress in rhizosphere results in adverse effects like decrease in crop growth, continue increase in respiration rate and reduced photosynthesis rate, which ultimate decrease fresh weight of leaves. Similar results were also recorded by Anupama, 2012. Among sulphur levels, higher fresh weight of leaves per plant (79.12g) produced with application of 30 kg S ha^{-1} as compared to control and 15 kg S ha^{-1}, but remain at par with 45 kg S ha^{-1}. 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. This result also related with the finding of Kumar *et al.* (2016) [13] and Bala and Bahadur (2017) [5].

Chlorophyll content

Data presented in table 2 indicated that chlorophyll content of leaves of radish influenced significantly due to irrigation and sulphur levels. Significantly higher chlorophyll content (2.02 mg g^{-1}) recorded with 100% PE level of irrigation over 60%

and 80% PE but noticed at par with 120% PE level of irrigation. The lowest chlorophyll content of leaves was observed under irrigation at 60% PE (Table 2). Among sulphur levels, application of 30 kg S ha^{-1} have significantly higher chlorophyll content (2.02 mg g^{-1}) as compared to the control and 15 kg S ha^{-1} but remained statistically as par with treatment 45 kg S ha^{-1} (2.13 mg g^{-1}). Similar findings had been seen by Jat *et al.* (2012) [12] and Bhat *et al.* (2017).

TSS content in roots of radish was significantly affected by levels of irrigation. Crop irrigated at 60% PE recorded higher TSS content (6.84^{0}Brix) over 80% PE (6.56^{0}Brix), 100% PE (6.24^{0}Brix) and 120% PE (6.13^{0}Brix) levels of irrigation. Maximum level of TSS content was recorded with 60% PE level of irrigation, which is more than the other higher irrigation level, this is possible due to the increase in the level of water content in radish, as level of water content increases in radish, the TSS content decreases because more dry matter content present in least irrigated area than the of highly irrigated area. In case of sulphur levels, maximum TSS content produced by 30 kg S ha^{-1} as (6.99^0 Brix) compared to control and15 kg S ha^{-1} but it was at par with 45 kg S ha^{-1}. Similar findings had been seen by Jat *et al.* (2012) [12] and Bhat *et al.* (2017).

Pungency level

Data presented in table 2 indicated that pungency level of leaves of radish influenced significantly due to irrigation and sulphur levels. Crop Irrigated with 60% PE (378.97 ug 100^{-1} root) recorded significantly highest pungency level as compared to 80% PE (376.92 ug 100^{-1} root), 100% PE (375.86 ug 100^{-1} root) and 120% PE (374.55 ug 100^{-1} root) level of irrigation. The level of pungency in radish decrease with increase in irrigation level this can be due to addition of water content in root of radish as water content in radish increases with increase the level of irrigation, which reduce the concentration of volatile sulphur when data taken on fresh weight basis. While less irrigated radish have slightly more dry matter or total soluble solids so pungency do not get much affected. Also there is high total GSL content in both root and leaves of radish in less irrigated area as compared to irrigated area. This result was also related with the finding of Macgillivray (1950) [14] and Chorol *et al.* (2021) [8]. In case of sulphur levels, application of 30 kg S ha^{-1} (383.10 ug 100^{-1} root) recorded significantly maximum pungency level over control and 15 kg S ha^{-1}, which was at par with 45 kg S ha^{-1} (384.15 ug 100^{-1} root). Similar findings had been seen by Jat *et al.* (2012) [12] and Bhat *et al.* (2017).

Table 1: Effect of irrigation and sulphur levels on growth parameters of radish

Treatments	Plant height (cm)		Number of leaves at harvest	Fresh weight of leaves at harvest (g)
	At 45 DAS	At harvest		
Irrigation Levels				
60% PE	39.13	53.13	7.73	66.69
80% PE	50.13	63.05	8.88	75.02
100% PE	58.07	69.16	9.47	80.59
120% PE	59.15	70.99	10.02	81.25
S.Em.±	0.42	0.76	0.23	0.80
CD at 5%	1.46	2.62	0.79	2.76
Sulphur Levels				
Control	41.29	56.38	7.96	68.03
15 Kg S ha^{-1}	50.37	63.04	8.75	75.48
30 Kg S ha^{-1}	56.83	67.91	9.42	79.12
45 Kg S ha^{-1}	57.98	68.99	9.97	80.92
S.Em.±	0.86	0.40	0.16	0.60
CD at 5%	2.51	1.16	0.46	1.76

Table 2: Effect of irrigation and sulphur levels on chlorophyll content, TSS and pungency level of radish roots

Treatments	Chlorophyll content in leaves (mg g^{-1}) at 45 days	TSS content in roots (^{0}Brix)	Pungency level (ug 100^{-1} root)
Irrigation Levels			
60% PE	1.37	6.84	378.97
80% PE	1.76	6.56	376.92
100% PE	2.02	6.24	375.86
120% PE	2.14	6.13	374.55
S.Em.±	0.08	0.07	0.28
CD at 5%	0.29	0.24	0.98
Sulphur Levels			
Control	1.40	4.96	362.03
15Kg S ha^{-1}	1.73	6.31	377.02
30Kg S ha^{-1}	2.02	6.99	383.10
45Kg S ha^{-1}	2.13	7.50	384.15
S.Em.±	0.07	0.19	0.48
CD at 5%	0.21	0.56	1.41

Conclusion

On the basis of present experimentation, it may be concluded that application of irrigation level at 100% PE and 30 kg S ha^{-1} proved superior in terms of growth and quality of radish root.

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