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Effect of nitrogen and sulphur levels on soil properties, nutrient content and uptake of radish under drip irrigation in western Rajasthan

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Abstract
An experiment was carried out at Research farm of Agricultural Research Station, SKRAU, Bikaner during *Rabi* season of 2019-20 on loamy sand soil. The experiment consisted of sixteen treatment combinations comprising of four levels of nitrogen (control, 40, 60 and 80 kg ha^{-1}) and four levels of sulphur (control, 15, 30 and 45 kg ha^{-1}). The experiment was laid out in factorial randomized block design with three replications. Results showed that application of 60 kg N ha^{-1}significantly increased the available nitrogen, sulphur, dehydrogenase enzyme activity, total bacteria and fungi population in soil and phosphorus, potassium, sulphur content and uptake in leaves which were statistically at par with 80 kg N ha^{-1}. However, nitrogen content and uptake in leaves significantly increased upto 80 kg N ha^{-1}. Total actinomycetes population in soil decreased significantly with increasing levels of nitrogen. However, soil pH, EC, organic carbon, available phosphorus and potassium in soil did not differ significantly due to different levels of nitrogen. Results further indicated that application of 30 kg S ha^{-1}significantly increased the available phosphorus, dehydrogenase enzyme activity, total bacteria and fungi population in soil and nitrogen, phosphorus, potassium content and uptake, sulphur uptake in leaves but it remained at par with 45 kg S ha^{-1}. However, sulphur content in leaves and available sulphur in soil increased significantly upto 45 kg S ha^{-1}. Soil pH and total actinomycetes population decreased significantly with increasing levels of sulphur from 0 to 45 kg S ha^{-1}. However, EC, organic carbon, available nitrogen and potassium in soil was found non-significant due to increasing levels of sulphur.

Keywords: Radish, N, P, K content and uptake, soil properties

Introduction
Radish (*Raphanus sativus* L.) is an open pollinated root and leafy vegetable belongs to family Brassicaceae with diploid species and chromosome number 2n = 2x =18 (Muminovie *et al*., 2005) [22]. It is an ancient crop indigene to the Eastern Middle East and Mediterranean. Radish is a widespread tropical and temperate crop. An areas of the world, broadly used as root vegetable, tender leaves and shoots as green (Alam *et al*., 2010) [2]. Radish is grown for its young tippy tuberous root which are used either raw or cooked. It is an excellent source of minerals such as calcium, potassium and phosphorus. It is a splendid source of carbohydrates, protein and vitamins A and C (Bakhsh *et al*., 2006) [4]. The leaves of radish are beneficial reservoir for extraction of protein on a commercial manner. Its consumption preclude constipation, increase appetite and utile for jaundice, liver disorders (Brintha and Seran 2009) [6]. Radish is an pabulum root vegetable with a pungent taste, due to glucosinolates (GLS).Which is a class of nitrogen and sulphur containing plant secondary metabolites with diverse effects on crop characteristics including flavour, nutrient content, resistance to herbivores and benefits to human health (Baik *et al*., 2003; Clay *et al*., 2009 and Lee *et al*., 2016) [3, 10, 21].

Nitrogen is the most deficient element especially in coarse texture sandy soil of Rajasthan. Nitrogen is abundantly available (70-80%) in the atmosphere yet the plants can’t hold it directly from the atmosphere. Nitrogen requirement of the plant is mostly met out with the use of chemical fertilizers. However, on the other hand, microorganisms are also available in soil, which can fix atmospheric nitrogen in plant roots. An excessive use of nitrogen fertilizers encourages vegetative growth and may negatively affect the crop’s nutritional value by limiting the synthesis of sugars, enhancing the nitrates accumulation and contributing to high nitrogen leaching from the soil (Rahn, 2000 and Neeteson and Carton, 2001) [25, 23].

Sulphur has been widely recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium for since last many years. Available suIphur in soil is often ranged between 5-10 ppm in light texture soils of Rajasthan. Application of sulphur helps in the availability of other nutrients resulting in better growth and increased uptake of all the nutrients at higher levels of sulphur (Nasreen *et al*., 2007) [37]. The favourable effect of sulphur on reducing soil pH and increasing soil particles flocculation, thereby improving soil structure and increasing the availability of certain plant nutrients in the soil. Therefore, keeping these points in consideration, the present investigation was planned to evaluate effect of nitrogen and sulphur on soil properties, nutrient content and uptake of radish under drip Irrigation in western Rajasthan.

Materials and Methods

The experiment was conducted at Research farm of Agricultural Research Station, SKRAU, Bikaner during *Rabi* season of 2019-20. Geographically, it is situated at 28˚ 10' N latitude and 73˚ 18' E longitude at an altitude of 223.88 m above mean sea level. The relative humidity of the locality fluctuates between 32.4 to 92.1 percent, total rainfall was 34 mm and average maximum and minimum temperature 2.3°C to 35.6°C respectively in *Rabi* season of 2019-20.

The experiment comprises of four levels of nitrogen (control, 40, 60 and 80 kg ha^{-1}) and four levels of sulphur (control, 15, 30 and 45 kg ha^{-1}) with three replication and making 16 treatment combinations. Observations were recorded at soil samples from each treatment plot taken with the help of an auger by boring randomly at four places after the harvest of the crop at 0-15 cm soil depths. Collected soil samples were air dried, ground in wooden pestle and mortar, passed through 2 mm sieve and preserved in cloth bags for the subsequent analysis for different chemical and biological properties. For determination of enzymatic activity in soil samples at 0-15 cm soil depth from each subplot were taken in a polythene bag. The soil samples from each replicate subplot were brought back to the laboratory, immediately sieved through a 2 mm sieve and stored at 4°C until used for the soil enzyme activity tests.20 gram of air dried soil stirred with 40 ml distilled water for half an hour and pH (1:2 soil: water suspension) determined using glass electrode in combination with calomel electrode. Electrical conductivity of (1:2 soil: water) supernatant solution measured by conductivity meter after keeping soil suspension over–night. Organic carbon was determined by following Walkley and Black (1934) [35] wet digestion method. Available nitrogen in soil was determined by Alkaline $KMnO_4$ method (Subhiah and Asija, 1956) [31]. Available phosphorus in soil was determined by 0.5 M $NaHCO_3$ (Olsen *et al*., 1954) [24]. Available potassium in soil was determined by 1 neutral normal ammonium acetate extractable K using flame photometer (Jackson, 1973) [16]. Available sulphur in soil was determined by Turbimetric method (Chesnin and Yien, 1950) [9]. Dehydrogenase activity was assayed by TTC method given by (Casida *et al*., 1964) [8]. Total actinomycetes, fungi and bacteria population were determined by serial dilution plate method (Dhingra and Sinclair, 1993) [11].

Representative leaves samples were taken from each plot at the time of harvesting for estimation of nutrients content. Further, samples were oven dried and grind separately in fine powder with grinder. Nitrogen content in plant sample was estimated by digesting with sulphuric acid and hydrogen peroxide. Estimation of nitrogen was done by colorimetric method using spectrophotometer after development of colours with Nessler's reagent (Snell and Snell, 1949) [30]. Phosphorus content was estimated by digesting plant samples with Di-acid mixture (Vanadomolybdete phosphoric yellow color method, Jackson, 1973) [16]. Potassium content was estimated by digesting plant samples with tri-acid mixture and was determined by suitable aliquot of digested material with the help of flame photometer (Richards, 1954) [26]. Sulphur content was estimated by digesting plant samples with Di-acid mixture (HNO_3 and $HClO_4$ in 3:1 ratio) and a suitable aliquot of digested material was taken to determine sulphur content by Turbimetric method (Tabatabai and Bremner, 1970) [33].

The uptake of N, P, K and S by leaves was estimated by using the following formula.

$$Nutrient\ uptake\ (kg\ ha^{-1}) = \frac{per\ cent\ nutrient\ content\ in\ leaves\ x\ dry\ matter\ yield\ (kg\ ha^{-1})}{100}$$

Experimental data recorded in various observations were statistically analysed with the help of Fisher's analysis of variance technique (Fisher, 1950) [12]. The critical difference (CD) for the treatment comparisons were worked out wherever the variance ratio (F test) was found significant at 5% level of significance.

Results and Discussion

Effect of nitrogen and sulphur levels on soil properties after harvest of radish

Results revealed that (Table 1) the soil pH, electrical conductivity and organic carbon have not significantly affected by different levels of nitrogen. The application of different level of nitrogen significantly influenced the available nitrogen in soil. Treatment N_{80} reported maximum (104.6 kg ha^{-1}) usable nitrogen in soil over the remainder of the study, but remained statistically equivalent to study N_{60} (103.7 kg ha^{-1}). The application of N_{60} treatment increased 3.59 and 10.20 per cent more available nitrogen over N_{40} treatment and control, respectively. There was no significantly effect of different levels of nitrogen application on available phosphorus and potassium in soil. Maximum sulphur in soil was recorded under treatment N_{80} over all applied treatment but remained statistically on par with treatment N_{60}.The effect of different levels of nitrogen application significantly influenced soil biological properties after harvest of radish (Table 2 and fig. 1)**.** The application of nitrogen fertilizer significantly increased the dehydrogenase enzyme activity of soil. Highest dehydrogenase enzyme activity*i.e.*60.06μg TPF g^{-1} soil was recorded under treatment N_{80}, which was statistically at par with N_{60}treatment.The application of N_{60}treatmentincreaseddehydrogenaseenzyme activity by 11.77 and 42.60 per cent over N_{40} treatment and control, respectively. Nitrogen fertilization in soil significantly enhanced to bacterial population after the harvest of radish up to N_{60}treatment, which was 7.91 and 27.81 per cent higher over N_{40}treatment and control, respectively. Highest bacterial population (4.17×10^6 c.f.u.g^{-1}) in soil was observed under treatment N_{80}but this level was at par with treatment N_{60}.Application of nitrogen up to N_{60}treatment decreased the actinomycetes population in soil significantly as compared to foregoing levels. Minimum actinomycetes population was recorded (3.59×10^4 c.f.u.g^{-1}) in treatmentN_{80} which was statistically at par with treatment N_{60}. Nitrogen application in soil significantly increased fungi population after the harvest of radish up to treatment N_{60}, which was 30.33 and 8.91 per cent more over treatment N_0 and N_{40}, individually. Application of nitrogen at treatment N_{80}recorded the highest fungi population in soil, which was found at par with treatment N_{60}.Higher available nitrogen and sulphur in soil may be due to with the application of higher nitrogen levels. Nitrogen, as nitrate and ammonium is highly soluble and moves rapidly in soil and thus increase in available nitrogen with increase in nitrogen levels. These results are in confirmation with the findings reported by Tagad *et al.* (2006) [34], Sharma *et al.* (2008) [28] and Cakmak *et al.* (2010) [7]. Soil pH, electrical conductivity, organic carbon, available phosphorus and potassium status of soil were not influenced by the nitrogen levels. Dehydrogenase enzyme activity, total bacteria, actinomycetes and fungi population in soil were significantly affected by nitrogen levels as well as environmental factors. Dehydrogenase activity in the soil is regarded as an indicator of the intensity of the respiratory metabolism of soil microbes. Similar results were found by Kaczmarek *et al*. (2008) [18] and Klikocka *et al*. (2012) [19].

The scrutiny of data presented in table 1 showed that the soil pH was significantly influenced by sulphur application. The maximum soil pH was observed under treatment S_0, which was significantly superior over treatmentS_{45} but remained statistically at par with treatment S_{15} and treatment S_{30}.Electrical conductivity, organic carbon, available nitrogen and available potassium have not significantly affected by different levels of sulphur application. Application of sulphur significantly influenced the available phosphorus in soil. Application of treatment $S_{4\ 5}$increased available phosphorus by 16.48, 8.01 and 1.28 per cent over treatment S_0, S_{15} and S_{30}, respectively. Sulphur application significantly influenced the available sulphur in soil. The maximum available sulphur in soil was recorded (36.21 kg ha^{-1}) under treatment S_{45} over rest of all applied treatment. The effect of different levels of sulphur application significantly influenced soil biological properties after harvest of radish (Table 2 and fig. 1). The dehydrogenase enzyme activity was significantly influenced by sulphur levels up to S_{30} treatment with per cent increase of 17.46 and 9.38 overS_0andS_{15}treatment, respectively but it was at par withS_{45} treatment. The bacterial population in soil enhanced significantly upto treatment $S_{30}$with per cent increase of 4.50 and 10.98 over S_{15} treatment and control, was statistically at par with treatment S_{45}. AppIication of sulphur up to S_{30}treatment decreased the actinomycetes population in soil significantly above foregoing levels. Minimum actinomycetes population was recorded (3.50×10^4 c.f.u.g^{-1}) in treatment S_{45}, which was statistically at par with treatment S_{30}. Maximum fungi population in soil was recorded (3.80×10^4 c.f.u.g^{-1}) in soil at treatment S_{45} and this level was at par with treatment S_{30}. Soil pH decreased might to be soil microbes convert the sulphur to sulfuric acid thus, lowering the soil pH. Phosphorus in soil increased might to be sulphur has also been reported to help in lowering the soil pH, which is the main reason for greater availability and mobility of nutrients especially phosphorus, iron, zinc and manganese (Hilal *et al*., 1992) [14]. The available sulphur status of the soil was significantly affected with the application of sulphur at increasing rate. This increase might be due to ameliorative effect of sulphur and improved chemical properties of soil. The higher amount of available sulphur may be attributed to a greater mineralization of organic sulphur and release of SO_4^{-2}ions on its gradual oxidation. Similar type of results has also been reported by Yang *et al.* (2007) [36], Skwierawska and Zawartka (2009) [29], Gajghane *et al.* (2015) [13] and Abhiram*et al*. (2016). The microbial population in soilwere significantly influenced might to be reported to help in decreasing the soil pH in presence of different sulphur levels. Dehydrogenase activity in the soil is regarded as an indicator of the intensity of the respiratory metabolism of the soil microbial population. The present findings are good accordance with the results of Yang *et al.* (2007) [36] and Shah *et al.* (2019) [27].

Effect of nitrogen and sulphur levels on nutrient content and uptake in leaves of radish

An appraisal of data presented in table 3 and fig. 2 indicated that nitrogen fertilization in radish significantly influenced the nutrient content and uptake in leaves. The nitrogen fertilization in radish significantly enhanced the nitrogen concentration in leaves up to treatment N_{80}, which was 38.21, 9.60 and 5.17 per cent higher N_0, N_{40} and N_{60} treatment, one by one. Application of nitrogen in radish significantly enhanced the phosphorus content in leaves up to treatment N_{60}, which was 13.92 and 5.26 per cent higher over treatment N_0 and N_{40}, individually. The increasing levels of nitrogen in radish raised significantly the potassium content in leaves up to treatment N_{60}, which was statistically at par with N_{80} treatment fertilization in leaves. Nitrogen application in radish raised the sulphur content in leaves up to treatment N_{80}, which was statistically at par with treatment N_{60}. The progressive increase in level of nitrogen significantly enhanced the nitrogen uptake by leaves up to treatment N_{80}. The highest nitrogen uptake (72.22 kg ha^{-1}) noted with treatment N_{80} that was significantly higher over treatment N_0, N_{40} and N_{60}, individually. Nitrogen fertilization in radish significantly raised the phosphorus uptake by leaves up to treatment N_{60}. This was 74.53 and 24.14 per cent more overtreatment N_0 and N_{40}, respectively. Nitrogen fertilization in radish significantly raised the potassium uptake by leaves up to treatment N_{60}, which was 76.15 and 23.33 per cent more overtreatment N_0 and N_{40}, respectively. Although, application of nitrogen at treatment N_{80} resulted the maximum potassium uptake by leaves, yet, it was statistically at par with treatment N_{60}. Application of nitrogen at treatment N_{80} maximized the sulphur uptake by leaves, yet, it was statistically at par with treatment N_{60}.The positive response of nitrogen fertilization on nitrogen, phosphorus, potassium and sulphur content of crop seems to be due to higher availability of soil nutrients which could be attributed for higher nutrient content in leaves and thus ultimately results in higher nutrient uptake by leaves. Increase in uptake of nitrogen, phosphorus, potassium and sulphur with increasing nitrogen levels might be due to the fact that nitrogen increases the cation exchange capacity of plant roots and these make them more efficient in absorbing nutrient ions. These findings corroborate the results of Nasreen *et al*. (2007) [37], Inam *et al*. (2011) [15], Kumar *et al*. (2011) [20] and Sukirtee *et al*. (2018) [32].

An examination of data presented in table 3 and fig. 2 indicated that sulphur application up to treatment S_{30} increased the nitrogen content significantly over foregoing levels. The increase in nitrogen content with this level was 27.41 and 9.13 per cent over treatment S_0 and S_{15}, individually. Maximum nitrogen content was recorded in treatment S_{45}, which was statistically at par with treatment S_{30}. The maximum phosphorus content in leaves was recorded

(0.183 per cent) at treatment S_{45} and this level was at par with treatment S_{30}.The potassium content of leaves was significantly influenced by sulphur application. The highest potassium content in leaves was recorded (1.82 per cent) under treatment S_{45}, which was significantly higher as compared to treatment S_0 and S_{15} but this level was at par with treatment S_{30}. Sulphur fertilization in radish significantly enhanced the sulphur content in leaves up to treatment S_{45}, which was 37.50, 17.58 and 6.56 per cent more in leaves over S_0, S_{15} and S_{30} treatment, respectively. Sulphur application in soil significantly enhanced the nitrogen uptake by leaves up to treatment S_{30}. The highest nitrogen uptake by leaves observed at treatment S_{45} (68.72 kg ha^{-1}), which was statistically at par with treatment S_{30}. Sulphur application in radish significantly enhanced the phosphorus uptake by leaves up to treatment S_{30}. However, highest phosphorus uptake by leaves recorded (4.87kg ha^{-1}) under treatment S_{45}, which was statistically at par with treatment S_{30}. Sulphur application in radish significantly increased the potassium uptake by leaves up to treatment S_{30}. However, highest potassium uptake by leaves at treatment S_{45} was statistically at par with treatment S_{30}. Sulphur application in radish significantly enhanced the sulphur uptake by leaves up to treatment S_{30} and this treatment was more over treatment S_0 and S_{15}, individually. But, sulphur uptake by leaves at treatment S_{45} which was statistically at par with treatment S_{30}. The positive response of sulphur fertilization on nitrogen, phosphorus, potassium and sulphur content of the radish leaves seems to be due to improved nutritional environment both in the rhizosphere and in the plant system. Thus, better availability of nutrients in the storage organs (root) coupled with increased metabolic activities at cellular level probably increased the nutrient uptake and their accumulation in vegetative plant parts. Thus, nitrogen, phosphorus, potassium and sulphur content in leaves increased significantly due to sulphur fertilization, which is in accordance with the findings of Bhat *et al*. (2017) [5], Jat *et al*. (2017) [17] and Sukirtee *et al*. (2018) [32].

Table 1: Effect of nitrogen and sulphur levels on soil chemical properties after harvest of radish

Treatments	pH	EC (dS m^{-1})	Organic carbon (%)	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})	Available sulphur (kg ha^{-1})
N_0	8.28	0.133	0.151	94.1	15.92	211.2	23.38
N_{40}	8.25	0.137	0.155	100.1	16.01	214.5	29.86
N_{60}	8.23	0.138	0.157	103.7	16.73	216.1	34.30
N_{80}	8.22	0.139	0.159	104.6	16.88	217.6	35.30
SEm±	0.03	0.006	0.007	1.16	0.35	4.06	0.61
CD at 5%	NS	NS	NS	3.34	NS	NS	1.76
S_0	8.30	0.131	0.152	98.8	14.92	212.7	22.44
S_{15}	8.26	0.136	0.155	99.7	16.09	214.8	29.95
S_{30}	8.22	0.139	0.157	101.8	17.16	215.8	34.23
S_{45}	8.19	0.140	0.158	102.1	17.38	216.2	36.21
SEm±	0.03	0.006	0.007	1.16	0.35	4.06	0.61
CD at 5%	0.08	NS	NS	NS	1.01	NS	1.76

Table 2: Effect of nitrogen and sulphur levels on soil biological properties after harvest of radish

Treatments	Dehydrogenase activity (µg TPF g^{-1}soil)	Bacteria population (c.f.u 10^6 g^{-1})	Actinomycetes population (c.f.u 10^4 g^{-1})	Fungi population (c.f.u 10^4 g^{-1})
N_0	40.02	3.20	3.89	3.00
N_{40}	51.06	3.79	3.77	3.59
N_{60}	57.07	4.09	3.61	3.91
N_{80}	60.06	4.17	3.59	4.00
SEm±	1.30	0.04	0.03	0.04
CD at 5%	3.75	0.12	0.10	0.12
S_0	43.06	3.55	3.99	3.37
S_{15}	50.81	3.77	3.80	3.58
S_{30}	55.58	3.94	3.59	3.76
S_{45}	58.75	3.98	3.50	3.80
SEm±	1.30	0.04	0.03	0.04
CD at 5%	3.75	0.12	0.10	0.12

Table 3: Effect of nitrogen and sulphur levels on nutrient content and uptake in leaves of radish

Treatments	Nutrient content (%)				Nutrient uptake (kg ha^{-1})			
	N	P	K	S	N	P	K	S
N_0	1.91	0.158	1.56	0.258	33.68	2.71	26.97	4.57
N_{40}	2.29	0.171	1.73	0.291	51.28	3.81	38.52	6.47
N_{60}	2.51	0.180	1.81	0.317	66.30	4.73	47.51	8.36
N_{80}	2.64	0.183	1.84	0.332	72.22	5.01	50.27	9.24
SEm±	0.04	0.002	0.02	0.006	2.00	0.16	1.59	0.33
CD at 5%	0.11	0.006	0.06	0.017	5.79	0.48	4.58	0.95
S_0	1.97	0.160	1.59	0.248	37.42	2.97	29.81	4.69
S_{15}	2.30	0.171	1.73	0.290	52.36	3.80	38.62	6.53
S_{30}	2.51	0.179	1.80	0.320	64.97	4.62	46.38	8.28

S_{45}	2.57	0.183	1.82	0.341	68.72	4.87	48.46	9.14
SEm±	0.04	0.002	0.02	0.006	2.00	0.16	1.59	0.33
CD at 5%	0.11	0.006	0.06	0.017	5.79	0.48	4.58	0.95

Conclusion

On the basis of one year experiment, results of this investigation it may be concluded that which gave significant higher nutrient content and uptake in leaves of radish and improves chemical and biological properties of soil by the application of nitrogen and sulphur. In regards to above mentioned parameters, the treatmentN_{60} and S_{30}gavesignificantly higher values as compared to other treatments.

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