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Effect of available S, N, P and soil characteristics on yield and S response in raya (Brassica juncea)

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Abstract

Drymatter yield and S uptake in control pots were significantly and positively correlated with soil available S, and negatively with available P and free $CaCO_3$ content. The per cent dry matter yield was negatively associated with clay content and CEC whereas per cent S uptake and maturity were significantly positively correlated with available S and N content but had negative association with available P, CEC and free $CaCO_3$ and sand fraction. Organic carbon had positive and pH had negative influence on advanced maturity. Available N also contributed significantly to S uptake and flowering period. Soils rich in available N, S and sand fraction did not respond to applied S.

Additional Key words : Maturity period, utilization of applied S, soil properties, available N

Introduction

Sulphur response in raya (*Brassica juncea var.* Varuna) has adequately been emphasised in soils of Kangra Valley (Jaggi 1994, 1998). Besides S, NPK also have their due contribution in affecting the crop yield. Soil properties bridge the gap between fertility and productivity by influencing the chemical, biological and physical environment of soil and as such have a direct or indirect bearing yield related parameters. Such studies on raya, known for high S requirement, in soils of Kangra Valley with distinctly different physical and chemical properties, have hardly been reported. The present study reports the relative contribution of the available N, P, K and S, organic carbon, pH, CEC, free $CaCO_3$, clay, silt and sand on yield and yield parameters in control and S treated representative soils of Kangra Valley of Himachal Pradesh under pot calture environment.

Materials and methods

Thirteen surface soil samples (0-22.5 cm) varying in available N, P, K and S, O,C, pH, CEC, free $CaCO_3$ and texture, representing raya growing areas, were collected in bulk from different places of Kangra district of Himachal Pradesh. Soils were analysed for available soil nutrients and physical and-chemical properties using standard laboratory procedures (Jackson 1973). The data (range and mean values) are presented in table 1.

Eight kg of each soil was filled in enamelled pots of 10 kg capacity having hole at the bottom. Six pots were prepared for each of the thirteen soils. To each soil S through gypsum ($CaSO_4$, $2H_2O$ with 18.6% S), was applied @ 30 and 60 mg/kg in two replications. Basal application of N, P_2O_5 and K_2O were made @ 60, 40 and 40 kg/ha. The sources of fertilizer used were urea, dihydrogen-orthophosphate and muriate of potash, respectively. Potassium, being applied through KH_2PO_4 was adjusted while using muriate of potash. All the fertilizers including full dose of N were applied at the sowing time by thoroughly mixing in the whole soil before filling the pots.

Fifteen healthy seeds of Raya (*Brassica juncea* Varuna) were sown in each pot but

Table 1. Properties of soils (range and mean values) used in the study (n=13)

Symbol	Soil properties	Range	Mean
x_1	Available S (kg/ha)	27.2 – 36.1	31.0
x_2	Available N (kg/ha)	240 – 360	323
x_3	Available P (kg/ha)	6.2 – 16.8	9.9
x_4	Available K (kg/ha)	146 – 370	184
x_5	O.C. (g/kg)	7.0 – 13.8	10.3
x_6	pH	6.3 – 7.1	6.2
x_7	CEC (cmol (p^+)/kg	6.9 – 11.4	8.5
x_8	Free $CaCO_3$ (g/kg)	8.4 – 17.8	11.8
x_9	Clay (%)	10.0 – 24.0	14.0
x_{10}	Silt (%)	23 – 42	32.5
x_{11}	Sand (%)	41 – 65	53.5

after germination only 7 plants were allowed to grow. The crop was raised up to flowering following recommended practices. To study the effect of applied S on flowering in soils of varying fertility status, an account of number of days taken for flower initiation was maintained for each pot. For this a fixed number of flowers *i.e.* five per pot were taken as a criteria to designate the onset of flower initiation process. The crop was harvested immediately after flowering (85 DAS). Sulphur content in the plant material were determined using procedure of Chesnin and Yien (1950).

Crop growth parameters without S treatments : These include drymatter yield, S uptake and number of days for flower initiation in control pots.

Sulphur response parameters :

$$\text{Per cent dry matter yield} = \frac{\text{Dry matter yield in control pots}}{\text{Maximum dry matter yield in S treated pots}} \times 100$$

$$\text{Per cent S uptake} = \frac{\text{S uptake in control pots}}{\text{Maximum uptake in S treated pots}} \times 100$$

S uptake (mg/kg) in S treated pots

$$\text{Per cent utilization of applied S} = \frac{-\text{S uptake (mg/kg) in control pots}}{\text{Amounts (mg/kg) of applied S}}$$

In 30 and 60 mg/kg S treatments, advanced flowering/maturity was computed by number of days by which flowering/ maturity was advanced (taking maximum out of the two S treatments) over the control pots of the same soil.

Simple correlations and step-wise regressions were calculated between crop yield and sulphur response parameters; and available S, N, P, K and other soil properties by using Cp statistics (Draper and Smith 1981).

Results and discussion

Table 2. Data on yield and related parameters (control pots); and sulphur rersponse parameters (Range and mean values)

Sr. No.	Parameters	Range	Mean
A. Yield and related parameters (control pots)			
	Dry matter yield (g/pot)	25.8 – 32.0	28.0
	Sulphur uptake (mg/pot)	31.0 – 83.2	83.4
	Days to flower	70 – 85	--
B. Sulphur response parameters			
	Per cent drymatter yield (%)	62.2 – 86.0	74.4
	Per cent sulphur uptake (%)	22.0 – 60.0	40.2
	Advanced flowering/maturity (days)	4.0 – 11.0	6.2
	Per cent utilization of applied S (%)		
	At 30 mg/kg dose	4.2 – 15.7	8.2
	At 60 mg/kg dose	5.8 – 11.6	8.3

The relevant characteristics of different soils used (loamy and to silty clay loam) in the study are presented in table 1. The data on yield and related parameters in control pots and sulphur response parameters have been given in table 2.

Yield and yield related parameters : Drymatter yield and S uptake in control pots were significantly and positively correlated with available S (r = 0.737** and r = 0.661**) and negatively with available P (r = – 0.485* and r = – 0.577**) and free CaCO3 (r = – 0.485* and r = – 0.457*) content. The positive correlation of soils' available S with drymatter yield and S uptake is because of high S requirement of this crop. Phosphate (PO_4^{-3}) is stronger than anion (SO_4^{-2}) and as such dominates in anionic competition on the root absorption sites (Pasricha and Aulakh 1991) and that resulted in negative correlation

Table 3. Correlations of drymatter yield and related parameters with soil properties.

Parameters	Available S (x1)	Available N (x2)	Available P (x3)	Available K (x4)	O.C. (x5)	pH (x6)	Sand (x7)	Silt (x8)	Clay (x9)	CEC (x10)	Free $CaCO_3$ (x11)
Drymatter yield (control pots)	0.737**	0.332	–0.485**	–0.232	0.299	–0.239	0.130	0.111	0.104	–0.194	–0.485**
S uptake (control pots)	0.667**	0.611**	–0.518**	–0.185	0.189	–0.262	–0.130	–0.044	–0.197	–0.463*	–0.457*
Days to flowering (control pots)	–0.821**	–0.501**	0.364	–0.008	–0.212	0.121	–0.069	–0.156	0.077	0.242	0.296
Per cent drymatter yield	0.299	0.369	–0.177	–0.076	–0.076	0.180	–0.300	–0.135	–0.406*	–0.432*	–0.001
Per cent S uptake	0.649**	0.662**	–0.512**	–0.260	0.235	–0.240	–0.127	–0.021	–0.221	–0.500**	–0.443*
Advanced maturity	0.629**	0.474*	–0.540**	–0.211	0.618**	–0.469*	0.448*	0.370	0.377	–0.405*	–0.458*
Percent utilization of applied S (30 mg/kg)	–0.298	–0.433*	0.242	0.164	0.257	–0.131	0.346	0.138	0.492**	0.551**	0.088
Per cent utilization of applied S (60 mg/kg)	–0.479**	–0.577**	0.325	0.308	–0.125	0.070	0.150	–0.009	0.309	0.475*	0.248

* = Significant at 5% level
** = Significant at 1% level

Table 4. Stepwise regression equation between drymatter, S-uptake, days to flower and selected soil properties

Parameters	Steps	Stepwise regression equations	Cumulative contribution (R^2 x 100)	Contribution of individual soil property (R^2 x 100)
Drymatter yield	1	$y = 11.44 + 0.53x_1$	54.30**	
	2	$y = 15.78 + 0.47x_1 - 0.19x_8$	59.36**	5.06
S uptake	1	$y = -34.78 + 2.84x_1$	44.46**	
	2	$y = -68.56 + 2.29x_1 + 0.16x_2$	64.07**	19.61
	3	$y = -56.74 + 2.30x_1 + 0.21x_2 - 0.85x_{10}$	74.26**	10.19
	4	$y = -43.58 + 2.16x_1 + 0.22x_2 - 0.98x_{10} - 0.04x_4$	77.35**	3.09
Days to flower	1	$y = 117.52 - 1.34x_1$	67.44**	
	2	$y = 125.79 - 1.20x_1 - 0.04x_2$	75.45**	8.01
	3	$y = 129.24 - 1.25x_1 - 0.04x_2 - 0.01x_4$	77.60**	2.15

Note : x_1 to x_{11} soil properties.

between soils' available P and drymatter yield and S uptake. The available N had positive (r=0.611) influence on suphate through increased dry matter. There was negative relationship (Table 3) of flowering period with available sulphur (r = – 0.821**) and nitrogen (r = – 0.501**).

S response parameters : A significant negative relationship was observed between per cent drymatter yield and clay content and CEC (r = – 0.406* and – 0.432*). Similarly advanced maturity was significantly and positively correlated with available S (r = 0.629*), N (r = 0.474*), O.C. (r = 0.618*) and sand fraction (r = 0.448*); and negatively with soil pH (r = – 0.469*). Negative relationship of available S with pH (Aulakh and Dev 1976; Sharma and Jaggi 2000) and negative relationship with organic carbon (Jaggi 1991; Sharma and Jaggi, 2001) were also reported.

Step-wise regression analysis : The data presented in table 4 show that available S accounted for maximum variation in drymatter yield (54.3%), S uptake (44.5%) and flowering period (67.4%). The inclusion of available N and K one after the other in steps in the regression model; the variation in flowering period was improved significantly. In an earlier study Jaggi (1998) found that maturity in raya significantly advanced due to S application @ 30 kg/ha.

Sulphur response parameters : Sulphur response is inversely related to per cent dry matter yield and per cent sulphur uptake; and directly to the advanced maturity.

Per cent drymatter yield : Data presented in table 5 indicated that cation exchange capacity influenced maximum variation of 18.7% in R^2 value of the regression model worked for per cent drymatter yield, followed by soil pH (18.6%), sand fraction (10.8%) and available sulphur (8.2%) and their collective contribution in the R^2 value was 77.3%.

Per cent sulphur uptake : The presence of available N alone contributed a variation of 43.9% in R^2 value of the regression equation on per cent S uptake (Table 5), an inclusion of sand fraction, soil available potassium and organic carbon in stepwise manner increased the total variation from 67.3 to 85.2%. The available nitrogen and sulphur, organic carbon and sand negatively affected the sulphur response.

Advanced maturity : In the regression model on advanced flowering, available S alone contributed 39.5% variation, and the inclusion of organic carbon and CEC in stepwise manner increased it to 60.4 and 71.6% respectively (Table 4). The available sulphur and organic carbon were positively related to maturity whereas CEC is negatively related.

Cation exchange capacity, clay and available phosphorus positively influenced the utilization of applied sulphur at 30 mg/kg dose. These factors in combination contributed 59.5% variation in regression equation. Similarly, at 60 mg/kg S dose, available N alone contributed 33.3% variation to the per cent utilization of applied S. With the inclusion of

Table 5. Soil properties predicting sulphur response

Parameters	Steps	Stepwise regression equations	Cumulative contribution (R^2 x 100)	Contribution of individual soil property (R^2 x 100)
Per cent dry	1	$y = 93.59 – 2.23x_7$	18.70**	
matter yield	2	$y = 78.97 – 2.35x_7 + 0.29x_{11}$	29.52**	10.82
	3	$y = 56.08 – 2.18x_7 + 0.32x_{11} – 0.64x_1$	37.69**	8.17
	4	$y = 46.29 – 2.20x_7 + 0.43x_{11} + 0.56x_1 + 0.63x_5$	39.25*	1.56
	5	$y = –58.57 – 3.18x_7 + 0.62x_{11} + 0.06x_1 + 4.50x5 + 12.82x_6$	57.84**	18.59
	6	$y = –72.57 – 3.54x_7 + 0.60x_{11} – 0.36x_1 + 5.04x_5 + 19.26x_6 – 1.20x_8$	63.15**	5.61
	7	$y = –88.89 – 3.28x_7 + 0.58x_{11} – 0.60x_1 + 5.56x_5 22.82x_6 – 0.85x_8$	65.34**	2.19
	8	$y = –108.20 – 3.56x_7 + 0.51x_{11} – 0.77x_1 + 6.11x_5 26.92x_6 – 0.86x_8 + 0.03x_4$	68.81**	3.47
	9	$y = –194.31 – 2.31x_7 + 1.27x_{11} – 1.05x_1 + 6.86x_5 + 27.78x_5 – 0.48x_8 + 0.03x_4 + 1.06x_{10}$	73.39**	4.58
	10	$y = –280.20 – 4.13x_7 + 2.85x_{11} – 1.23x_1 + 9.16x_5 + 27.12x_6 – 0.97x_8 + 0.05x_4 + 3.09x_{10} – 0.18x_2$	77.32**	3.93
Per cent	1	$y = –13.24 + 0.17x_2$	43.87**	
sulphur	2	$y = –50.68 + 0.13x_2 + 1.58x_2$	67.29**	23.42
uptake	3	$y = –80.40 + 0.15x_2 + 1.62x_1 + 0.41x_{11}$	77.64**	10.35
	4	$y = –74.52 + 0.16x_2 + 1.50x_1 + 0.48x_{11} – 0.04x_4$	83.24**	5.60
	5	$y = –87.21 + 0.14x_2 + 1.38x_2 + 0.67x_{11} – 0.04x_4 + 1.06x_5$	85.19**	1.95
Advanced	1	$y = –6.82 + 0.42x_1$	39.52**	
flowering	2	$y = –8.89 + 0.33x_1 + 0.48x_5$	60.38**	20.86
	3	$y = –3.73 + 0.30x_1 + 0.48x_5 – 0.51x_7$	71.06**	10.68

Parameters	Steps	Stepwise regression equations	Cumulative contribution (R^2 x 100)	Contribution of individual soil property (R^2 x 100)
Per cent utilization of applied sulphur				
At 30 mg/kg	1	$y = -3.41 + 1.37x_7$	45.38**	15.01
dose	2	$y = -6.30 + 1.17x_7 + 0.33x_9$	59.50**	14.12
	3	$y = -10.55 + 0.59x_7 + 0.58x_9 + 0.57x_3$		
At 60 mg/kg	1	$y = -16.40 - 0.03x_2$	33.27	
dose	2	$y = 20.85 - 0.02x_2 - 0.19x_1$	44.27	11.00
	3	$y = 25.95 - 0.02x_2 - 0.20x_1 - 0.07x_1$	54.28	10.01
	4	$y = 24.59 - 0.03x_2 - 0.17x_1 - 0.09x_{11} + 0.009x_4$	64.27	9.99

Note : x_1 to x_{11} soil properties.

available S, sand and available K in the regression model, the extent of variation increased to 67.3% (Table 5). Available sulphur, nitrogen and sand fraction adversely affected the utilization of applied sulphur at its higher dose. A significant increase in flower count in raya is due to individual applications of sulphur and phosphorus over their respective controls has been observed by Jaggi (1998). Organic carbon helps to moderate N:S ratio which has a significant correlation with the crop maturity (Jaggi and Sharma 2000). The negative contribution of CEC in advancing maturity period might be due to the release of cations from the exchange complex demanding matching amounts of anions like SO_4^{-2} and PO_4^{-3}, important for the advancement of crop maturity (Jaggi 1998).

It is concluded that available S had the highly significant and positive correlation with all the crop growth parameters including advanced maturity than the other nutrients and soil properties. It has also contributed maximum variation in crop growth (control pots) as well as S response parameters. Thus, major determinants of yield and advanced maturity in raya are available S followed by available N.

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