Indian J. Plant Physiol., Vol. 17, No. 1, (N.S.) pp. 65-70 (Jan.-Mar., 2012)

SHORT COMMUNICATION

SULPHUR ASSIMILATION AND PARTITIONING IN INDIAN MUSTARD (*BRASSICA JUNCEA* (L.) CZERN & COSS.)

J. NANJUNDAN*, N.K. THAKRAL, DHIRAJ SINGH AND K. MOHANRAJ**

Department of Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 001, Haryana

Received on 30th November, 2011; Revised and accepted on 24th February, 2012

Sulphur uptake and its partitioning in stem, root, leaf and siliqua was studied in 36 crosses of Indian mustard at three levels of sulphur viz. 0, 30 and 60 kg S ha^{-1}. The results show vast genetic variability for sulphur assimilation and partitioning across the genotypes. Sulphur concentration in siliqua was highest and followed by leaves, stem and root. The sulphur partitioning was influenced by increasing S levels from 0 to 60 kg S ha^{-1} resulting in more S diversion to the vegetative parts like stem, root and leaves than to the reproductive parts like siliqua. Three crosses {RH 30 x RH (OE) 103, RH 0270 x F_1 and RH 30 x HO 1} were found to mobilize highest amount of sulphur from source to sink, and can be exploited for partitioning more sulphur into the reproductive parts (siliqua) which, in turn, may result in better oil in terms of both quantity and quality.

***Key words*: Indian mustard, sulphur levels, sulphur partitioning, trip1e test cross**

Sulphur (S) plays an important role in the plant nutrition of oilseed crops. Now it is recognized as the fourth major nutrient in addition to N, P and K. The oilseed brassicas synthesizes a great variety of secondary metabolites containing sulfur viz., amino acids (cystein and methionine), chlorophyll, oil, certain vitamins, etc. The best characterized group of such compounds is the glucosinolates, important for plant defense against pathogens (Dubuis *et al*. 2005), and also of great nutritional value (Bones and Rossiter 1996). The sulphur is also essential for the synthesis of different fatty acids (Dimree and Dwivedi 1994). Thus, the information about S partitioning provides an opportunity for increasing seed yield and quality by exerting selection pressure towards better sulphur assimilation, breeding for '00' types (mustard cultivars having less than 2% erucic acid in the seed oil and less than 30 µ moles glucosinolates per gram of de-fatted meal). Zhao *et al.* (1993) from their study on *Brassica napus* reported that the distribution of sulphur between the different plant tissues changed with sulphur levels. But, very little is known about the sulphur uptake and its partitioning in Indian mustard (*Brassica juncea*). Therefore, the present investigation was conducted to study S assimilation and its partitioning in crosses of Indian mustard.

A set of 36 crosses were developed by crossing twelve varieties/genotypes (RH 30, RH 9304, RH 8812, RH 0270, UDN 69, JMM 937, RH 781, RC 5, RC 199, RC 1425, RH 0028, and RH 8701) as females with three male testers namely; HOI, RH (OE) 0103 and HOI x RH (OE) 0103 as per the Triple Test Cross (TTC) mating design. In the next crop season, a pot experiment was laid out by raising those 36 crosses in Completely Randomized Design (CRD) with two replications under green house condition at College of

*Corresponding author: agrinanju@gmail.com, Present address: DRMR (ICAR), Bharatpur, Rajasthan, ** SBI (ICAR), Coimbatore, TN

Agriculture, CCS Haryana Agricultural University, Hisar, India. The genotypes were raised in earthen pots filled with sandy loam sulphur deficient soil. The pots were lined with polythene bags to avoid loss of nutrients by leaching. The sulphur in the form of ammonium sulphate [$(NH_4)_2$ SO_4] was supplied at the rate of 0 (control), 30 and 60 kg S ha^{-1}(designated as 0S, 30S and 60S, respectively). The recommended doses of nitrogen (80 kg ha^{-1}) and phosphorus (40 kg ha^{-1}) were also given in the form of urea and potassium dihydrogen orthophosphate, respectively. Nitrogen supplied by $(NH_4)_2$ SO_4 was taken in account and remaining nitrogen was supplied through urea in order to keep the level of basal dose of nitrogen equal in all the treatments. All the nutrients were applied in the form of solution. After the emergence of seedlings two plants per pot were retained.

Plant samples were collected from all 36 crosses and sulphur treatments. The entire plant was uprooted from the pots and separated into stem, root, leaves and siliqua. The leaf samples were collected 5-10 days in advance as plants become leafless at harvest due to leaf fall. The plant parts were first sun dried and then oven dried at 60^0C for 48 hours to obtain dry weights. Grinding of samples was done and the samples were stored in polythene bags for the estimation of sulphur. The sulphur content of the plant parts (stem, root, leaves and siliqua) was estimated by method of Chesnin & Yien (1951). Sulphur partitioning coefficient was measured as the ratio of the S content of plant parts, to the S content of the biological yield. The data were analyzed using the SPSS software package.

The S concentration was significantly different among the genotypes, plant parts, S levels and their interaction in most of the comparisons indicating the presence of ample amount of genetic variability for S uptake and its partitioning (Table 1). Among the crosses, the variability for sulphur content was highest in stem (28.67% CV) followed by root (26.14% CV), leaf (11.79% CV) and siliqua (10.64% CV). Increasing the S application from 0S to 60S showed a corresponding significant increase in the S concentration of stem, root, leaf and siliqua (Fig. 1). The results also elicited the genotypic response for S uptake up to 60 kg ha^{-1} which might be due to poor S status of the soil used as pot mixture. Patel *et al.* (2009) reported that the successive increase in S application up to 40 kg ha^{-1} resulted in remarkable improvement in S uptake by groundnut crop. In the present study, among the plant parts the S concentration in siliqua was highest (22.75 mg g^{-1}) followed by leaves (17.25 mg g^{-1}), stem (4.62 mg g^{-1}) and roots (3.55 mg g^{-1}). Singh and Kumar (2007) while studying the response of eight *brassica* genotypes to three sulphur levels reported the highest sulphur concentration in seeds. Matula and Zukalova (2001) reported that in vegetative stages, levels of total S were higher in leaves. In the present study, at the harvest stage more S is mobilized from source to sink resulting in higher amount of S in siliqua than that in other plant parts.

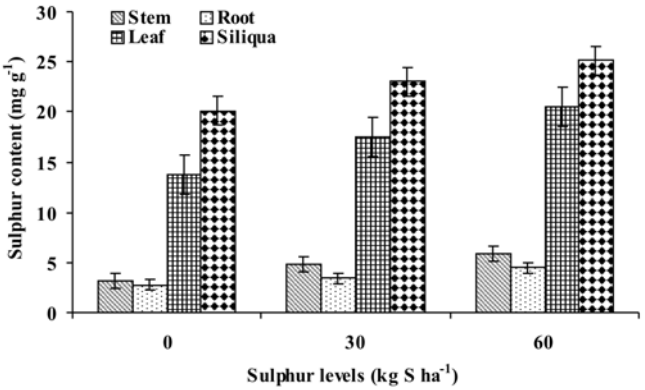

Fig. 1. Sulphur partitioning in Indian mustard under three sulphur levels.

In leaves, the sulphur content ranged from 10.74 mg g^{-1} (RH 30 x HO 1) to 17.6 mg g^{-1} (RC 1425 x F_1) in 0S. At 30S and 60S, the S content of the leaves increased with the ranges from 14.47 mg g^{-1} (RC 781 x RH (OE) 103) to 22.12 mg g^{-1} (RC 1425 x F_1) and 17.59 mg g^{-1} (RC 781 x RH (OE) 103) to 24.85 mg g^{-1} (RC 1425 x F_1), respectively. In the Sulphur treatments 0S, 30S and 60S, the crosses RC 199 x RH (OE) 0103, RC 781 x F_1 and RC 1425 x F_1 recorded the maximum leaf partitioning coefficient of 0.443, 0.411 and 0.416, respectively (table not shown). In these genotypes the glucosinolates concentration in leaves was expected to be high (offering resistance to foliar diseases) as the synthesis of glucosinolates directly depends on sulphur availability (Schnug 1993).

Table 1. Sulphur content (mg g^{-1}) in different plant parts of Indian mustard under three sulphur levels

Crosses	Stem			Root			Leaf			Siliqua		
	0S	30S	60S	0S	30S	60S	0S	30S	60S	0S	30S	60S
RH 30 x HO 1	1.52	1.83	2.11	1.88	2.40	2.75	10.74	14.70	18.23	17.95	19.25	23.38
RH 30 x RH (OE)103	1.96	4.85	5.30	1.89	2.31	3.55	12.46	15.57	18.11	22.24	23.11	26.45
RH 30 x F_1	2.25	3.64	4.90	1.58	3.99	5.25	14.23	17.79	21.01	23.32	24.25	25.71
RH 9304 x HO 1	2.51	5.27	5.94	3.13	3.80	4.33	11.89	16.39	19.61	18.94	26.30	28.06
RH 9304 x RH (OE)103	4.44	5.81	6.38	2.56	2.73	3.39	11.59	15.55	18.16	22.03	24.36	26.09
RH 9304 x F_1	2.66	5.78	6.21	4.38	5.40	5.52	14.74	17.80	20.97	19.26	20.61	21.45
RH 8812 x HO 1	2.70	3.60	5.32	1.33	3.11	5.48	11.86	15.39	18.59	19.05	23.89	26.96
RH 8812 x RH (OE)103	2.08	5.42	6.58	3.56	4.04	6.72	12.12	16.65	20.02	21.14	27.97	31.09
RH 8812 x F_1	3.78	4.77	5.23	3.74	3.78	6.89	14.17	17.07	20.23	19.98	23.32	24.57
RH 0270 x HO 1	3.75	4.48	6.50	2.48	2.62	3.79	13.26	16.86	19.39	21.51	22.01	23.00
RH 0270 x RH (OE)103	4.22	4.91	4.96	2.83	3.11	4.38	13.00	17.65	20.82	22.18	26.72	27.28
RH 0270 x F_1	3.49	4.90	6.77	2.20	2.69	3.81	11.20	15.05	18.24	20.01	24.99	26.13
UDN 69 x HO 1	4.71	4.96	5.23	2.10	3.84	3.92	14.31	17.21	19.96	18.58	20.40	21.48
UDN 69 x RH (OE)103	5.22	6.31	6.88	2.40	5.40	5.52	13.04	16.64	19.82	19.42	22.38	26.24
UDN 69 x F_1	1.86	5.60	5.85	1.44	1.89	4.84	10.85	15.51	18.63	18.43	21.34	25.30
JMM 937 x HO 1	2.80	5.10	5.53	2.60	2.69	3.82	13.19	16.72	19.53	18.93	24.16	26.93
JMM 937 x RH (OE)103	3.67	4.54	5.54	3.21	3.87	4.14	15.11	19.64	22.95	21.96	23.76	24.43
JMM 937 x F_1	4.48	5.79	6.54	2.31	2.60	5.08	16.32	20.14	23.22	22.02	22.96	25.54
RC 781 x HO 1	3.54	5.75	6.42	4.09	4.31	4.70	11.81	14.85	17.96	25.38	27.40	27.85
RC 781 x RH (OE)103	2.23	5.42	6.00	2.65	4.02	4.56	10.91	14.47	17.59	17.74	20.46	22.93
RC 781 x F_1	2.75	3.51	5.04	3.18	3.24	3.30	17.10	21.54	24.35	21.01	24.07	26.54
RC 5 x HO1	2.59	2.60	3.81	2.19	3.10	3.32	13.26	16.17	19.48	15.25	19.18	21.65
RC 5 x RH (OE)103	1.68	3.06	4.80	2.10	2.51	3.80	13.32	16.92	20.01	20.10	23.89	26.30
RC 5 x F_1	2.51	2.90	3.24	1.84	2.71	3.03	14.19	18.90	21.96	22.61	23.09	25.45
RC 199 x HO 1	4.00	4.36	5.74	2.28	3.13	4.02	16.84	20.76	23.49	21.68	25.14	27.78
RC 199 x RH (OE)103	1.70	3.01	4.34	2.20	2.87	3.56	14.32	17.16	20.48	14.13	19.40	21.87
RC 199 x F_1	2.36	3.06	6.20	2.95	3.35	4.41	13.22	16.69	19.82	17.32	20.92	23.39
RC 1425 x HO 1	4.39	5.26	6.87	3.69	4.71	5.53	16.98	21.61	24.80	24.94	24.22	26.99
RC 1425 x RH (OE)103	3.99	6.27	6.97	3.54	3.61	4.90	12.03	15.65	18.71	20.66	23.07	24.09
RC 1425 x F_1	6.64	7.66	8.51	5.27	5.55	5.62	17.60	22.12	24.85	18.07	20.43	20.72
RH 0028 x HO 1	5.02	6.43	9.43	3.30	4.02	4.85	15.13	18.96	22.27	25.19	25.96	27.66
RH 0028 x RH (OE)103	1.44	5.69	6.50	3.42	3.51	3.82	13.18	16.22	19.30	17.40	20.82	23.29
RH 0028 x F_1	3.95	5.79	7.01	2.87	2.33	3.36	15.97	19.64	22.18	20.29	24.33	26.80
RH 8701 x HO 1	2.18	5.58	6.52	3.13	3.50	5.50	14.24	18.84	22.06	18.16	20.46	22.61
RH 8701 x RH (OE)103	2.61	4.98	6.30	2.48	3.78	5.02	16.88	19.72	23.00	17.49	20.16	22.63
RH 8701 x F_1	2.06	5.14	6.09	2.07	3.11	5.20	13.58	17.05	19.79	19.05	23.72	26.19
Mean	3.16	4.83	5.87	2.74	3.43	4.49	13.74	17.49	20.54	20.09	23.01	25.13

CD at 5%

Plant parts	0.11
Sulphur	0.10
Genotypes	0.34
Plant parts x sulphur	0.198
Plant parts x genotypes	0.688
Sulphur x gentypes	0.595
Plant parts x Sulphur x Genotypes	1.19

The S content of stem ranged from 1.44 mg g^{-1} [RH 0028 x RH (OE) 103] to 6.64 mg g^{-1} [RC 1425 x F_1] in 0 S, 1.83 mg g^{-1} [RH 30 x HO 1] to 7.66 mg g^{-1} [RC 1425 x F_1] in 30 S and 2.11 mg g^{-1} [RH 30 x HO 1] to 9.43 mg g^{-1} [RH 0028 x HO 1] in 60 S. Similarly, in the root, the S content ranged from 1.33 mg g^{-1} [RH 8812 x HO 1] to 5.27 mg g^{-1} [RC 1425 x F_1], 1.89 mg g^{-1} [UDN 69 x F_1] to 5.55 mg g^{-1} [RC 1425 x F_1] and 2.75 mg g^{-1} [RH 30 x HO 1] to 6.89 mg g^{-1} [RH 8812 x F_1] in 0 S, 30S and 60 S, respectively.

Increase in the S level resulted in a corresponding increase in the S content of siliqua (Table 1). The mean S content of the siliqua was 20.1, 23.01 and 25.13 mg g^{-1} in the treatments 0S, 30S and 60S, respectively. The cross families RH 30 x RH (OE) 103, RH 0270 x F_1 and RH 30 x HO 1 recorded highest siliqua partitioning coefficients of 0.577, 0.525 and 0.503 in the treatments 0S, 30S and 60S respectively (table not shown). These crosses mobilized highest amount of sulphur from source to sink, are to be exploited for selecting the genotypes efficiently partitioning the sulphur more into the reproductive parts (siliqua) which, in turn, result in better oil in terms of both quantity and quality.

Sulphur application significantly increased the seed yield and biomass (Table 2). The seed yield per plant ranged from 0.68 g (RC 5 x F_1) to 2.18 g (RH 30 x HO 1) in 0S, 0.97 g (RC 5 x F_1) to 2.38 g (RH 0270 x HO 1) in 30S and 1.17 g (RC 5 x F_1) to 2.66 g (JMM 937 x RH (OE) 103) in 60S. More increment in the seed yield has been observed between the treatments 0S and 30S than between 30S and 60S. Whereas, in case of biomass, it was recorded more between 30S and 60S compared to that between 0S and 30S. The biomass yield per plant ranged from 3.47 g (RC 5 x F_1) to 10.30 g (RH 8812 x RH (OE) 103), 3.62 g (RC 5 x F_1) to 12.81 g (UDN 69 x RH (OE) 103) and 5.06 g (RC 781 x RH (OE) 103) to 19.94 g (RH 8812 x RH (OE) 103) in the treatments 0S, 30S and 60S, respectively.

It is clear from the results that the increasing S levels influenced the sulphur partitioning to different plant parts (Table 3). The combined partitioning coefficient of stem, leaf and root (vegetative tissue) was increasing significantly with the increase in sulphur levels (0.494 in

Table 2. Seed yield and biomass per plant of Indian mustard under three sulphur levels

Crosses	Seed yield (g plant^{-1})			Biomass (g plant^{-1})		
	0S	30S	60S	0S	30S	60S
RH 30 x HO 1	2.18	2.35	2.36	9.28	9.55	9.87
RH 30 x RH (OE)103	1.83	2.06	2.29	8.40	8.58	10.62
RH 30 x F_1	1.76	2.08	2.16	7.95	8.88	10.79
RH 9304 x HO 1	1.45	1.95	2.14	5.39	8.92	9.41
RH 9304 x RH (OE)103	1.63	2.00	2.22	7.69	8.81	10.04
RH 9304 x F_1	1.29	1.48	1.68	4.84	7.11	9.57
RH 8812 x HO 1	1.11	1.40	1.68	4.38	6.11	7.89
RH 8812 x RH (OE)103	1.72	2.20	2.54	10.30	11.77	19.94
RH 8812 x F_1	1.18	1.61	2.04	4.68	5.33	9.35
RH 0270 x HO 1	2.08	2.38	2.58	8.50	8.86	10.06
RH 0270 x RH (OE)103	1.75	2.05	2.26	9.25	9.72	11.96
RH 0270 x F_1	1.51	1.63	1.64	5.34	5.40	7.27
UDN 69 x HO 1	1.05	1.26	1.37	5.49	6.96	7.23
UDN 69 x RH (OE)103	1.63	1.77	1.90	6.76	12.81	14.16
UDN 69 x F_1	1.47	1.48	1.48	4.99	5.01	5.80
JMM 937 x HO 1	1.18	1.71	2.05	6.85	9.79	13.23
JMM 937 x RH (OE)103	1.54	2.10	2.66	6.89	7.16	10.00
JMM 937 x F_1	1.60	2.02	2.34	7.25	8.09	12.72
RC 781 x HO 1	1.13	1.46	1.64	4.91	6.38	8.44
RC 781 x RH (OE)103	0.98	1.24	1.50	3.51	4.08	5.06
RC 781 x F_1	1.21	1.41	1.61	4.18	4.32	6.18
RC 5 x HO1	1.48	1.55	1.62	5.27	5.59	6.76
RC 5 x RH (OE)103	1.36	1.69	2.01	7.05	7.23	9.78
RC 5 x F_1	0.68	0.97	1.17	3.47	3.62	6.05
RC 199 x HO 1	0.90	1.44	1.63	4.86	5.90	6.48
RC 199 x RH (OE)103	0.91	1.40	1.63	3.52	5.21	7.78
RC 199 x F_1	1.14	1.33	1.52	5.11	5.29	6.77
RC 1425 x HO 1	1.33	1.75	2.02	6.58	7.35	8.01
RC 1425 x RH (OE)103	1.58	1.74	1.90	5.55	6.69	6.96
RC 1425 x F_1	1.32	1.36	1.41	5.02	6.25	6.34
RH 0028 x HO 1	1.53	1.68	1.83	6.10	6.65	8.95
RH 0028 x RH (OE)103	0.91	1.43	1.65	4.07	4.87	5.65
RH 0028 x F_1	0.93	1.37	1.70	4.07	5.01	6.67
RH 8701 x HO 1	1.25	1.45	1.64	4.62	5.48	6.70
RH 8701 x RH (OE)103	1.29	1.49	1.68	5.57	6.68	7.15
RH 8701 x F_1	1.83	2.10	2.28	7.69	8.08	8.33
Mean	1.38	1.68	1.88	5.98	7.04	8.83
CD at 5%						
Genotypes		0.236			0.467	
Sulphur levels		0.068			0.135	
Genotypes x Sulphur levels		N/A			0.810	

Table 3. Sulphur partitioning coefficients in different plant parts of 36 crosses of Indian mustard at three sulphur levels

Plants parts	Sulphur levels (kg S ha^{-1})						Mean
	0		30		60		
Stem	0.078	0.494	0.099	0.528*	0.104	0.551*	0.094
Root	0.069		0.070		0.080		0.073
Leaf	0.347		0.359		0.367		0.357
Siliqua	0.507	0.507	0.473	0.473*	0.449	0.449*	0.476
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00

*Significant at 5% CD (0.011)

0S, 0.528 in 30S and 0.551 in 60S), whereas, the partitioning coefficient of siliqua (reproductive tissue) was decreasing with the increasing sulphur levels (0.507 in 0S, 0.473 in 30S and 0.449 in 60S). This indicates that the increase in the sulphur application from 0 kg S ha^{-1} to 60 kg S ha^{-1}, resulted in more sulphur diversion to the vegetative parts like stem, root and leaf than to the reproductive parts like siliqua. Similarly, Zhao *et al*. (1993) reported that the distribution of S between different plant tissues changed with S treatments. These findings emphasize that mere increase in external S application, and its consequent uptake, alone does not guarantee an economic utilization of sulphur i.e. accumulating more S in the reproductive parts. The sulphur partitioning has importance equal to that of its assimilation process. Shukla *et al*. (2005) emphasized the importance of sulphur partitioning in controlling the growth and yield of *Brassica napus* genotypes. Sources and sinks, their relative sizes and physiological activities and the path length between the sources and sink also influence the rate and amount of substrate movement (Herold 1980, Gifford and Evan 1981, Snyder and Carlson 1984 and Tyagi *et al*.1996).

The present study has revealed considerable genetic variability among the 36 crosses for sulphur assimilation and its distribution in different plant parts (stem, root, leaf and siliqua) which can be exploited for selecting the genotypes efficiently partitioning the sulphur more into the reproductive parts (siliqua) which, in turn, result in better seed yield and quality oil. Therefore, the use of some crosses, for example, RH 30 x RH (OE) 103, RH 0270 x F_1 and RH 30 x HO 1, with the judicious distribution of sulphur among plant parts and having better seed yield, in the breeding programme, would provide an opportunity for increasing seed yield and quality by exerting selection pressure for better sulphur assimilation, in early generation of a segregating population. Also, there is enough scope to modify the biosynthetic pathway of glucosinolates to check its synthesis in seeds, not in plant parts (to have the defense system of plant intact), by closely observing the pattern of S partitioning among the different plant parts.

ACKNOWLEDGEMENTS

The first author acknowledges the financial support provided by the CSIR in the form of JRF for conducting this study.

REFERENCES

Bones, A.M. and Rossiter, J.T. (1996). The myrosinase-glucosinolate system, its organization and biochemistry. *Physiol. Plant*. **97:** 194-208.

Chesnin, L. and Yien, C.H. (1951). Turbidometric determination of available sulphates. *Soil Soc. Am. Proc.* **15:** 149-151.

Dimree, S. and Dwivedi, K.N. (1994), Response of sulphur and phosphorus on groundnut. *J. Oilseeds Res.* **11:** 193-195.

Dubuis, P.H., Marazzi, C., Stadler, E. and Mauch, F. (2005). Sulphur deficiency causes a reduction in antimicrobial potential and leads to increased disease susceptibility of oilseed rape. *J. Phytopathol*. **153:** 27-36.

Gifford, R.M. (1974). Mechanisms of Regulation of plant growth. In: Bieleski, R.L., Ferguson, A.R. and Cresswell, M.M. (Eds.). *Bull. R.. Soc., N.Z.K*. **12:** 887-893.

Gifford, R.M. and Evan, L.T. (1981). Photosynthesis, carbon, partitioning and yield. *Annu. Rev. Pl. Physiol*. **32:** 485-509.

Herold, A. (1980). Regulation of photosynthesis by sink activity- The missing link. *New Phytol*. **86:** 131-144.

Matula, J. and Zukalova, H. (2001). Sulphur concentration and distribution in three varieties of oilseed rape in relation to sulphur fertilization at vegetative stages. *Rostlinna Vyroba*. **47:** 1-6.

Patel, G.N., Patel, P.T., Patel, P.H., Patel, D.M., Patel, D.K. and Patel, R.M. (2009). Yield attributes, yield, quality and uptake of nutrients by summer groundnut, *Arachis hypogaea* L. as influenced by sources and levels of sulphur under varying irrigation schedules. *J. Oilseeds Res*. **26:** 119-122.

Schnug, E. (1993). Physiological functions and environment relevance of sulphur containing secondary metabolites. In: Kola, D. *et al* (ed.) Sulphur nutrition and sulphur assimilation in higher plants, SPB Academic Publishers, The Hague. pp. 97-106.

Shukla, R.K., Arvind, K., Mahapatra, B.S. and Basanth, K. (2005). Response of sulphur and nitrogen fertilization on yield, quality and other metric traits of *Brassica napus*. *Brassica.* **7:** 47-51.

Singh, K. and Kumar, D. (2007). Differential susceptibility of *Brassica* genotypes to sulphur stress conditions. *J. Oilseeds Res*. **24:** 193-194.

Snyder, F.W. and Carlson, G.E. (1984). Selection of partitioning of photosynthetic products in crops. *Adv. Agron*. **37:** 47-71.

Tyagi, P.K., Singh, D. and Rao, V.V.M. (1996). Production and distribution of dry matter in plant components of *raya* varieties. *Ann. Agri. Bio. Res.* **1:** 125-131.

Zhao, F.J., Evans, E.J., Bilsborrow, P.E. and Syers, J.K. (1993). Sulphur uptake and distribution in double and single low varieties of oilseed rape (*Brassica napus* L.). *Plant Soil*. **150:** 69-76.