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Difference in dry matter accumulation with variable rates of sulphur and potassium application under calcareous soils in *Brassica napus vs. B. juncea*

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Abstract

Improper sulphur (S) and potassium (K) fertilizer management decrease dry mater (DM) accumulation and yield in *Brassica* under calcareous soils. A field experiment was conducted at The University of Agriculture, Peshawar, Pakistan. The main objective of this study was to evaluate the effect of S and K fertilization on DM accumulation of *Brassica* species under calcareous soil at the study area. The experiment was conducted in a randomized complete block design using three replications. Each replication consisted of 20 treatments having two *Brassica* species [rape (*B. napus*) and Indian mustard (*B. juncea*)], three rates of S (15, 30, and 45 kg ha^{-1}), three rates of K (30, 60, and 90 kg ha^{-1}) and one control (no S and K applied). The DM accumulation at various growth stages increased with K and S fertilization as compared to the zero-S/ zero-K control plots. Both species responded positively to K and S fertilization, but the magnitude of response varied with levels of S and K. It was concluded that a combination of 60 kg K + 30 kg S ha^{-1} could improve DM accumulation and yield in *Brassica* species.

Keywords: *Dry matter accumulation, growth stages, Brassica, potassium, sulphur*

Introduction

In Pakistan, there is a huge shortage of edible oil, because of lack of high yielding cultivars and lower production per unit area. Rapeseed-mustard are sensitive to sulphur (S) and potassium (K) supply, and poor yields and quality are obtained on S and K deficient soils (Govahi and Saffari, 2006; Damon et al., 2007; Malhi *et al*., 2007). Variations in seed yield of rape and mustard with K and S have been earlier reported by various researchers in different parts of the world (Misra, 2003; Ahmad *et al*., 2007). Information on the combined applications of S and K fertilization on the dry matter (DM) accumulation of rape and mustard is lacking. Keeping in view the importance of S and K fertilization, this experiment was therefore, carried out with objective to determine the most suitable K + S fertilizer combination for improvement in DM of rapeseed-mustard in the study area.

Materials and Methods

Experimental Site

A field experiment was conducted at the Agriculture Research Farm of the University of Agriculture Peshawar, Peshawar, Pakistan, during winter 2007–2008. The experimental farm is located at 34.01° N latitude, 71.35° E longitude at an altitude of 350 m above sea level in Peshawar valley. Peshawar is located about 1600 km north of the Indian Ocean and has continental type of climate. The research farm is irrigated by canal. Soil at the experimental site was clay loam, with 0.87% organic matter, 6.57mg extractable phosphorus (P) kg^{-1}, 121 mg exchangeable K kg^{-1}, and alkaline (pH 8.2) and calcareous in nature (Amanullah *et al*., 2009).

Experimentation

The field experiment was conducted in randomized complete block design using three replications. Twenty treatments per replication in a factorial combination were consisted of two oilseed rape (*B. napus* canola) and Indian mustard (*B. juncea*) species at three rates of sulphur (15, 30, and 45 kg S ha^{-1}) and potassium (30, 60, and 90 kg K ha^{-1}) plus one control (no S and K). A plot size of 10.8 m^2 having 6 rows, 3 m long and 60 cm apart, was used. A recommended dose of 75 kg nitrogen (N) ha^{-1} as urea and 50 kg P ha^{-1} as diammonium phosphate was applied. Half N and all P were applied at the time of seedbed preparation, while the remaining half N was applied at first irrigation. Sulphur as ammonium sulfate and K as potassium chloride were applied during seedbed preparation. Weeds were controlled manually and irrigation was applied according to the need of the crop. All other agronomic practices were kept normal and uniform for all the experimental units. Data were recorded on dry matter accumulation (kg ha^{-1}) at different growth stages i.e. at rosette, flowering and ripening. The increase in DM in from rosette to flowering, and flowering was also calculated.

Statistical Analysis

Data were subjected to analysis of variance according to the methods described by Steel and Torrie (1980), and means between treatments were compared by least significant difference (LSD) at P=0.05.

Results and Discussion

The fertilizer treated plots (rest) had signif-icantly higher dry matter (DM) accumulation at the three growth stages (rosette, flowering and ripening) than control (Table 1) in both *Brassica* species. The increase in DM the treated plots were attributed to increase in yield components and seed yield over control. Amanullah *et al*. (2011a) reported that the S + K applied treatments (rest) produced significantly higher number of siliqua plant"1 and seeds silqua"1, siliqua length, thousand seed weight (TSW), seed yield and harvest index over control. Misra (2003) suggested that seed yield in Indian mustard increased in the linear order up to 40 kg S + 60 kg K ha"1. The increase in DM from rosette

Table 1. Dry matter accumulation (kg ha^{-1}) response of control vs. rest (K and S treated plots) at various growth stages of *Brassica* to sulphur and potassium application under semiarid condition.

Treatments	DM at Rosette stage	DM at flowering stage	Increase in DM from rosette to flowering	DM at ripening stage	Increase in DM from flowering to ripening
Control	59.7	114.3	54.6	343.3	229.0
Rest	82.6	180.3	97.7	401.6	221.3
Significance	**	**	**	**	ns

**stands for significant a 1% level of probability & ns stands for non-significant.

to flowering was also significantly higher for the treated (rest) plots than control (Table 2). The specie *B. juncea* produced significantly higher DM than *B. napus* at the three growth stages (Table 2). However, the increase in DM accumulation from rosette to flowering, and flowering to ripening was statistically the same in both species. *B. juncea* produced significantly higher DM than *B. napus* at different growth stages. Differences in DM accumulation of both species were attributed to the differences in the genetic makeup, yield and yield components (Amanullah et al. (2011a). Tuncturk and Ciftci (2007) reported differences in number of pods plant^{-1}, seeds pod^{-1}, TSW and seed yield of rape cultivars. Rabjee *et al*. (2004) reported that different cultivars of the same species had different yield potential. Iqbal *et al*. (2008) reported that *Bjuncea* produced significantly higher yield than *B. napus.*

Effect of Sulphur

The DM accumulation was significantly higher with S application than control at the three growth stages (Table 3). At rosette and flowering stages, application of 30 and 45 kg S ha^{-1} produced statistically the same but significantly higher DM than application of 15 kg S ha^{-1}. At ripening stage, both of 15 and 45 kg S ha^{-1} produced statistically the same but significantly lower DM than

Table 2.Dry matter accumulation (kg ha^{-1}) response of *Brassica species (B. napus* vs. *B. juncea)* at various growth stages to sulphur and potassium fertilization under semiarid condition.

Species	DM at Rosette stage	DM at flowering stage	Increase in DM from rosette to flowering	DM at ripening stage	Increase in DM from flowering to ripening
B. napus	69.2	173.0	103.8	372.9	199.9
B. juncea	77.8	187.7	109.9	395.5	207.8
LSD	4.14	6.92	ns	12.29	ns

Table 3.Dry matter accumulation (kg ha^{-1}) in *Brassica* at various growth stages to sulphur and potassium fertilization under semiarid condition

Sulphur (kg ha^{-1})	DM at Rosette stage	DM at flowering stage	Increase in DM from rosette to flowering	DM at ripening stage	Increase in DM from flowering to ripening
0	59.7	114.4	54.7	343.3	228.9
15	75.2	172.0	96.8	395.4	223.4
30	85.6	183.9	98.4	413.9	230.0
45	87.0	185.1	98.1	395.5	210.4
$LSD_{0.05}$	5.34	8.93	ns	15.86	ns
Potassium (kg ha^{-1})					
0	59.7	114.4	54.7	343.3	228.9
30	78.5	150.3	71.8	378.8	228.5
60	90.0	190.8	100.8	400.0	209.2
90	79.3	199.9	120.6	425.9	226.0
$LSD_{0.05}$	5.34	8.93	26.79	15.86	ns

30 kg S ha^{-1}. The increase in DM from rosette to flowering, and flowering to ripening was statistically the same in control and S treated plots. However, the increase in DM from rosette to flowering with S application was almost doubled than control. The increase in DM in S treated plots were attributed to increase in yield components and seed yield over control. Amanullah *et al.* (2011a) reported that the S fertilization significantly increase number of siliqua plant^{-1} and seeds siliqua^{-1}, siliqua length, thousand seed weight (TSW), seed yield and harvest index over control. Malhi *et al*. (2007) through quadratic regression analysis found that seed yield increased sharply with first 10 kg S ha^{-1} increment, and moderately with second increment. The increase in seed yield was small with the third S increment, and beyond the 30 kg S ha^{-1} rate there was slight increase to slight decline in seed yield. Govahi and Saffari (2006) found that plant height, number of siliqua plant^{-1}, TSW, and seed yield of rapeseed increased significantly with S application as compared to control.

Effect of Potassium

Potassium levels had significant effects on DM accumulation at the three growth stages (Table 3). The DM accumulation was significantly higher with all three K levels than control at all growth stages. At rosette stage, application of 30 and 90 kg K ha^{-1} produced statistically the same but significantly lower DM than application of 60 kg K ha^{-1}. At the two later growth stages (flowering and ripening stages), the DM accumulation showed positive relationship with increase in K level. The increase in DM accumulation from rosette to flowering was statistically different among the treatments. The two higher K levels (60 and 90 kg ha^{-1}) significantly increased DM accumulation from rosette to flowering. The increase in DM from flowering to ripening was statistically the same in control and all K treated plots. The increase in DM in K treated plots was attributed to increase in yield components and seed yield over control. Amanullah *et al*. (2011a) reported that the K fertilization significantly increase number of siliqua plant^{-1} and seeds siliqua^{-1}, siliqua length, thousand seed weight (TSW), seed yield and harvest index over control. Application of K fertilizer increased number of siliqua plant^{-1} and seed weight (Khan, 2004) and seed yield (Damon *et al*., 2007). However, Govahi and Saffari (2006) reported that K application had no significant effects on plant height, number of siliqua plant^{-1}, TSW and seed yield.

K x S Interaction

Interaction of K × S had significant effect only on DM accumulation at rosette stage (Table 4). The three K x S combinations viz. 30 x 15, 60 x 30, and 60 x 45 significantly increased the DM at the rosette stage (Fig. 1). The K x S interaction only had significant effect on DM accumulation combinations at the rosette stage. The intermediate level of K (60 kg ha^{-1}) along with two higher levels of S (30 and 45 kg ha^{-1}) was found most beneficial in terms of higher DM accumulation at rosette stage (Fig.1). Govahi and Saffari (2006) noted significant effect of K × S on number of seeds siliqua^{-1} and siliqua plant^{-1}, 1000 seed weight and seed yield. Amanullah *et al*. (2011a) reported significant effect of K x S on number of seeds siliqua^{-1} and 1000 seed weight of *Brassica* sp. Amanullah *et al.* (2011b) also reported significant effect of K x S on seed oil and protein contents of *Brassica* species.

Table 4.Dry matter accumulation (kg ha^{-1}) response of *Brassica* at various growth stages to sulphur x potassium application to sulphur and potassium fertilization under semiarid condition.

K x S (kg ha^{-1})	DM at Rosette stage	DM at flowering stage	Increase in DM from rosette to flowering	DM at ripening stage	Increase in DM from flowering to ripening
0 x 0	59.7	114.4	54.7	343.3	228.9
30 x 15	84.7	143.6	58.9	371.3	227.7
60 x 15	77.4	183.0	105.7	403.7	220.7
90 x 15	63.5	189.3	125.8	411.1	221.8
30 x 30	75.4	152.7	77.4	396.4	243.7
60 x 30	97.3	202.2	104.9	407.7	205.5
90 x 30	84.0	196.9	112.9	437.6	240.7
30 x 45	75.3	154.5	79.2	368.8	214.3
60 x 45	95.4	187.2	91.8	388.7	201.5
90 x 45	90.3	213.5	123.2	429.1	215.6
LSD	9.26	ns	ns	ns	ns

G × S Interaction

Interaction effect of G × S was significant on DM accumulation at rosette stage (Table 5). Both species produced similar DM at 0, 30 and 45 kg S ha^{-1}; however, *B. napus* was most efficient in terms of DM accumulation at 15 kg S ha^{-1} (Fig. 2). *B. juncea* also had produced relatively higher DM at 45 kg S ha^{-1} but the differences were statistically the same. Interaction of G × S was also significant on DM increase from rosette to flowering (Table 5). The increase in DM from rosette to flowering was higher for *B. napus* than *B. juncea* at 15 kg S ha^{-1}; however, *B. juncea* had accumulated more DM than *B. napus* at 30 and 45 kg S ha^{-1} (Fig. 3). *B. napus* was most efficient in terms of DM accumulation at 15 kg S ha^{-1} (Fig. 2). Amanullah *et al.* (2011a) reported significant effect of G x S on TSW of *Brassica* species. They found that in *B. napus*, TSW increased with each increment in S level; in *B. juncea*, TSW increased when S level was increased up to 30 kg S ha^{-1}, but further

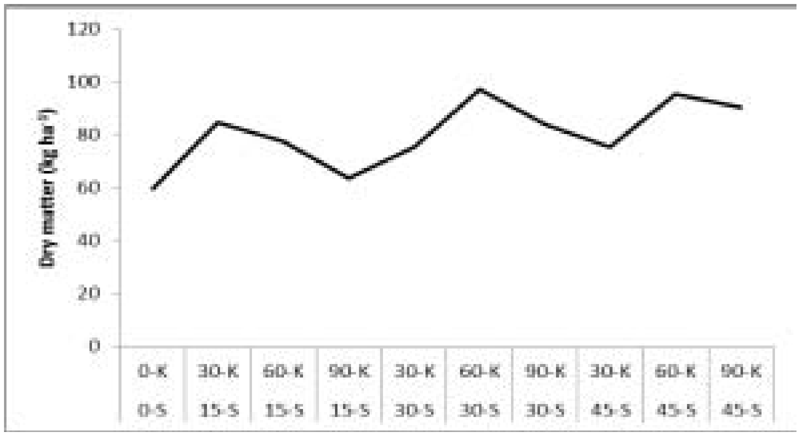

Fig. 1. Interactive effect of potassium (kg K ha^{-1}) into sulphure (kg S ha^{-1}) on DM accumulation (kg ha^{-1}) at rosette growth stage of *Brassica*.

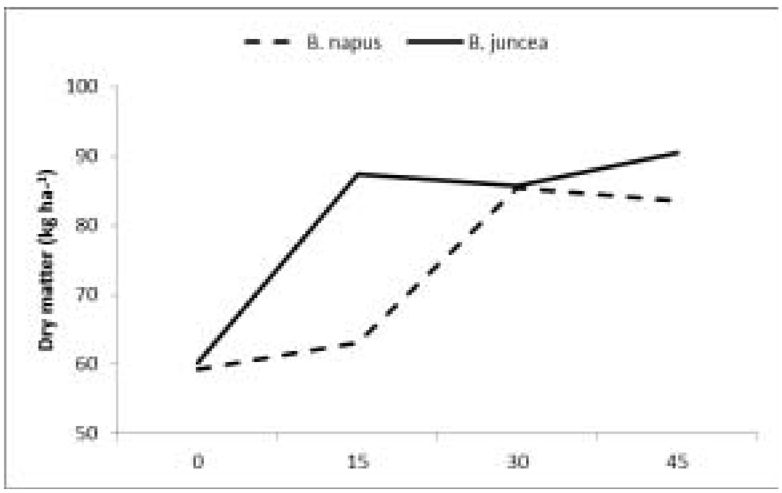

Fig. 2. Interactive effect of sulphure (kg S ha^{-1}) into *Brasica* species on DM accumulation (kg ha^{-1}) at rosette growth stage.

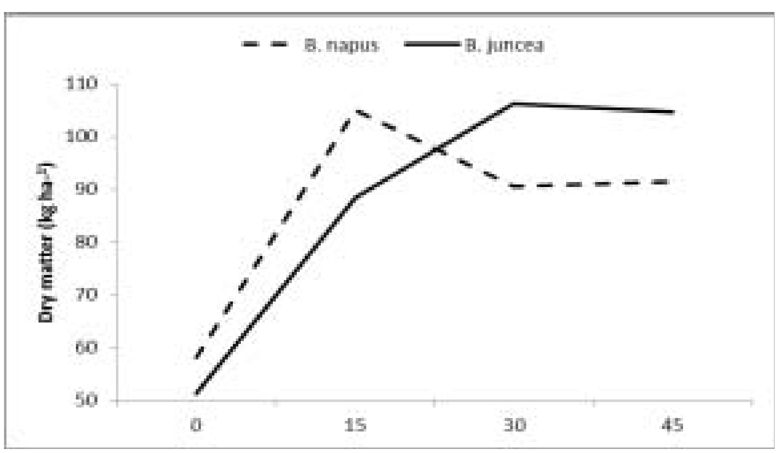

Fig. 3. Interactive effect of sulphure (kg S ha^{-1}) into *Brasica* species on DM accumulation (kg ha^{-1}) increase from rosette to flowering growth stages.

Table 5.Dry matter accumulation (kg ha^{-1}) response of *Brassica napus* vs. *Brassica juncea* at various growth stages to sulphur and potassium fertilization under semiarid condition.

Genotype	Rate of S(kg ha^{-1})	DM at Rosette stage	DM at flowering stage	Increase in DM from rosette to flowering	DM at ripening stage	Increase in DM from flowering to ripening
B. napus	0	59.2	117.3	58.1	320.3	203.0
	15	63.0	168.1	105.1	382.6	214.5
	30	85.4	175.9	90.5	415.7	239.8
	45	83.5	174.9	91.4	393.2	218.3
B. juncea	0	60.2	111.5	51.3	366.3	254.8
	15	87.4	175.9	88.5	408.1	232.2
	30	85.7	192.0	106.3	412.2	220.2
	45	90.5	195.2	104.7	397.8	202.6
	LSD	7.56	ns	15.47	ns	ns

increase in S level up to 45 kg S ha^{-1} decreased TSW. Ahmad *et al.* (2007) stated that S fertilization increased seed yield of *B. juncea* by 30% and *B. rapa* by 46% over control. Malhi *et al.* (2007) reported that seed yield response to S fertilization was different among *Brassica* species and varied with year. Amanullah *et al.* (20011b) also reported that G x S interaction influence days to flowering, seed fill duration, days to physiological maturity and seed protein content. Sharifi (2012) reported variances in dry matter accumulation of canola cultivars with various levels of sulphur fertilizer. They reported that in all of cultivars, DM accumulation increased during plant growth with increasing sulphur fertilizer and reached to a maximum level at 282-296 days after sowing (DAS), then showed a declining trend at maturity (296-310 DAS).

G × K Interaction

Interaction effect of G × K was significant on DM accumulation at flowering stage (Table 6). In *B. napus,* DM increased significantly when K was increased from 0 to 90 kg K ha^{-1}, in *B. juncea,* DM accumulation was increased when K was increased from 0 to 60 kg K ha^{-1}, but further increase in K up to 90 kg K ha^{-1} decreased DM accumulations (Fig. 4). Interaction effect of G × K was found significant for DM increase from rosette to flowering stage (Table 6). In both species the DM increase from rosette to flowering was the same at 0 and 60 kg K ha^{-1}; however, *B. juncea* performed better at 30 kg K ha^{-1}, and *B. napus* performed better at 90 kg K ha^{-1} in terms of DM increase from rosette to flowering stage (Fig. 5). *B. napus* increased DM when K was increased from 0 to 90 kg K ha^{-1}, in *B. juncea,* DM accumulation was increased when K was increased from 0 to 60 kg K ha^{-1}, but further increase in K up to 90 kg K ha^{-1} decreased DM accumulations resulting in significant G x K interaction (Fig. 4). Amanullah *et al.* (2011a) reported significant effect of G x K on number of seeds pod^{-1} and TSW. They reported that number of seeds pod^{-1} and TGW increased significantly when K level was increased up to 60 kg K ha^{-1} in plots sown with *B. napus,* while further increase in K level up to 90 kg K ha^{-1} decreased seeds pod^{-1}. On the other hand, in plots sown with *B. juncea* the number of seeds pod^{-1} increased significantly with each increment in K level. Amanullah *et al.* (20011b) also reported that G x S interaction influence days to flowering, days to pod formation and seed protein contents. Damon *et al.* (2007) also reported that *Brassica* genotypes responded differently to K availability. They reported that the potential mechanisms for genotypic variation to K fertilization depend on K uptake and utilization efficiencies. In the current study the DM accumulation increased from rosette to ripening stage. Papantoniou *et al.* (2013) reported that total DM accumulation increased sharply during the stage of main-stem development, reached a peak at the end of anthesis, and then remained constant until crop maturity.

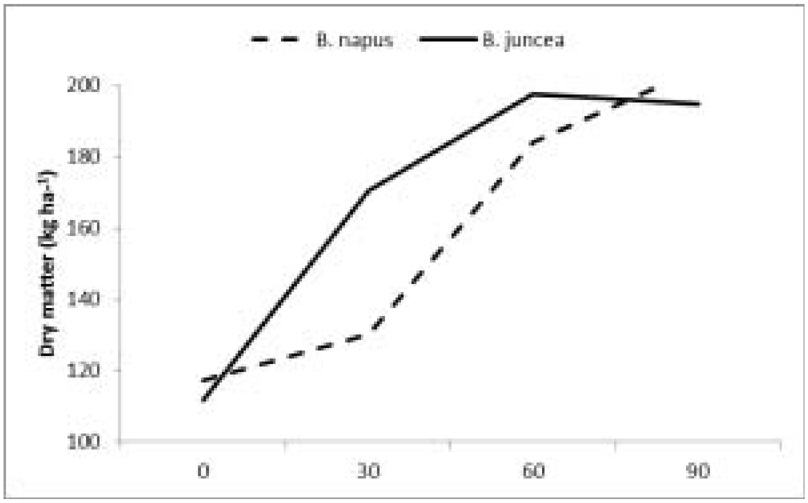

Fig. 4. Interactive effect of potassum (kg K ha^{-1}) into *Brasica* species on DM accumulation (kg ha^{-1}) at flowering stage.

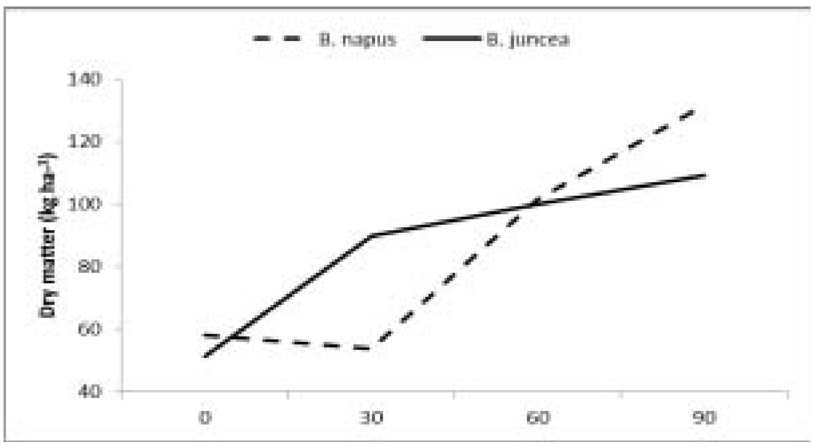

Fig 5. Interactive effect of potassium (kg K ha^{-1}) into *Brasica* species on DM accumulation (kg ha^{-1}) increase from rosette to flowering growth stages.

Table 6.Dry matter accumulation (kg ha^{-1}) response of *Brassica napus* vs. *Brassica juncea* at various growth stages to potassium application on calcareous soils

Genotype	Rate of K(kg ha^{-1})	DM at Rosette stage	DM at flowering stage	Increase in DM from rosette to flowering	DM at ripening stage	Increase in DM from flowering to ripening
B. napus	0	59.2	117.3	58.1	320.3	203.0
	30	76.5	130.2	53.7	373.4	243.3
	60	82.5	184.0	101.5	390.0	206.0
	90	72.9	204.8	131.9	428.0	223.2
B. juncea	0	60.2	111.5	51.3	366.3	254.8
	30	80.5	170.4	90.0	384.2	213.8
	60	97.5	197.6	100.1	410.1	212.4
	90	85.6	195.0	109.4	423.9	228.8
	LSD	ns	12.63	15.47	ns	ns

Dry matter accumulation in both *Brassica* species improved with K and S application as compared to the control. The findings suggest that combine application of 60 kg K + 30 kg S ha^{-1} could improve growth and yield of both rape and mustard in the study area. Farmers in the study area (North West Pakistan) generally do not apply S and K fertilizers to oilseed crops. The growers in the area are therefore required demonstration of S and K fertilization to oilseed crops.

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