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Sulphur Treatments Influence the Yield and its Components in *Brassica campestris* Linn. Cv. Pusa Gold

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Abstract

Sulphur dioxide is one of the critical phytotoxic air pollutant in some areas with low rainfall and irrigated agriculture. It is the most significant gaseous pollutant in some countries, based on its mass emissions, impact area and toxicity. Therefore, the present study as a field trial was conducted to assess the effect of sulphur (S) on the yield and its components of *Brassica campestris* Linn. cv. Pusa Gold. During the present study, five different treatments of sulphur (150, 300, 450, 600 and 750 µg mL^{-1}) were used and compared against the control (0 µg mL^{-1}) at three developmental stages of crop growth. The nutrient sulphur was provided in the form of sodium meta-bisulphite ($Na_2S_2O_5$). Three replications of each treatment were administered in a randomized block design for the treatments. The following variables were examined at various time intervals: the number of siliquae per plant, the number of seeds per siliquae, the seed yield, the biological yield, the harvest index, the N: S ratio in seeds, the oil content and the oil yield. The effect of the foliar-applied sulphur pollutant on the yield and its components of *B. campestris* Linn. cv. Pusa Gold revealed that lower concentrations of foliar-applied sulphur were conducive for the growth and yield of the crops, as rapeseed is a crop species with high sulphur demand. Still, with the increase in the concentration of sulphur, a reduction in the number of siliquae per plant, the number of seeds per siliquae, the seed yield, the biological yield, the harvest index, the N: S ratio in seeds, the oil content and the oil yield was noticed.

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Introduction

Air pollution that causes a serious setback to the normal form and function of the green members is increasing on a routine basis. Sulphur dioxide is a pre-eminent air pollutant produced from burning coal, home heating in the coal-fired furnace and

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electric power-generating plants. The sensitivity of plants to sulphur pollutants depends on the morphological, anatomical and physiological responses of the plant. In the leaves, sulphur dioxide is absorbed primarily by the chloroplasts due to its entry through the stomata, affecting their structure and function.[1,2] Although many mechanisms by which sulphur dioxide could interfere with plant functioning are resolved, the role of these in the interspecific and intraspecific variation in sulphur dioxide phytotoxicity is still unclear. The sulphate/ bisulphate formed when sulphur dioxide dissolves might interfere with several metabolic processes

Brassica campestris Linn. cv. Pusa Gold (Rapeseed) belongs to the family Cruciferae (now Brassicaceae) and is the most significant oilseed crop in India. In addition to being grown for its oil, it is used for a variety of industrial and nutritional purposes as well. A sulphur-containing metabolite group called glucosinolates limits the usefulness of protein rapeseed meals as a protein source after oil extraction.[3] Oil seed crops are important worldwide and rapeseed is one of the most extensively studied crops for sulphur responsiveness.[4] Sulphur is involved in oil synthesis and is a constituent of glucosinolates present in mustard oils.[5] It is known to increase the yield of mustard which varies from 12 to 48% in irrigated areas and 25 to 124% in rainfed areas. As a result of sulphur fertilization, mustard, groundnuts and soybeans have a higher oil content[6,7] Generally, a 10 to 20% increase in crop yield is obtained with the application of 20 to 40 kg of S/ha. In the pot-culture experiments, a significant effect on the yield, uptake and utilization of soil and fertilizer sulphur with different levels of its application has been observed.[8,9] Many studies on the sulphur requirement of this crop relating to nitrogen have been reported.[10-13] It has been shown that the growth and yield of rapeseed mustard can be optimized only when both sulphur and nitrogen are supplied together in balanced doses and split application.[14,15] Sulphur plays an important role in the formation of glucosinolates, which on hydrolysis generate higher amounts of allyl-isothiocyanate, which causes oil to have a pungent odour.[16]

The present investigation was conducted to study the effect of sodium meta-bisulphite on yield and its components in rapeseed. For the development of yield components, such as the number of siliquae per plant, the number of seeds per siliquae and the weight of 1000 seeds, the growth qualities are the main prerequisite.

Materials and Methods

Experimental Material

High-yielding variety of *B. campestris* Linn. cv. Pusa Gold was used during the present study. The experiments were conducted in the experimental field of Jamia Hamdard University, Hamdard Nagar, New Delhi (240amsl).

Experimental Design

Each experimental plot included 12 rows of 4 meters in length, with inter and intra-row spacing of 30 and 10 cm, respectively. During the rabi season, the experiment was set up using an entirely randomized block design with three replications.

Treatments and Cultural Practices

The source of sulphur used was sodium meta-bisulphite ($Na_2S_2O_5$). *B. campestris* Linn. cv. Pusa Gold was exposed to six different concentrations of sodium meta-bisulphite (foliar application) i.e., 0 μg mL^{-1} (T_0), 150 μg mL^{-1} (T_1), 300 μg mL^{-1} (T_2), 450 μg mL^{-1} (T_3), 600 μg mL^{-1} (T_4) and 750 μg mL^{-1} (T_5) at three developmental stages of crop growth viz., 30 days after sowing (DAS), at flowering and pod formation stages.

The field was properly ploughed and levelled before sowing seeds of rapeseed. The recommended doses of nitrogen, phosphorous and potassium fertilizers were applied as 100 kg N ha^{-1}, 40 kg P ha^{-1} and 40 kg K ha^{-1}. Urea, single super phosphate and muriate of potash were the sources of nitrogen, phosphorous and potassium, respectively. All plots received base treatments containing potassium and phosphorus. The nitrogen was administered in three separate doses: the first was administered at the time of planting together with the phosphorus and potassium; the second was administered 35 days later and the third was administered 50 days later. Irrigation was done as and when required. The crop was kept free of weeds by routine weeding procedures.

Sampling

From each plot and replication, 10 competitive plants were chosen at random for data collection by analyzing eight parameters, including the number of siliquae per plant, the number of seeds per siliquae, the seed yield, the biological yield, the harvest index, the N: S ratio in the seeds, the oil content and the oil yield.

Estimation of Yield Attributes

The siliquae from the three plant samples collected from each plot were separated and counted. Results were expressed as the number of siliquae per plant. The number of seeds in 25 siliquae from each treatment was counted and expressed on a per siliqua basis. A sample of 1000 seeds was randomly drawn from each treatment and the weight was recorded. Results were expressed as one thousand (1000) seeds weighing in grams. The total weight of seeds obtained from three plant samples of each plot was divided by the number of plants to get the seed weight per plant. The total grain produced from the one-meter square (1 m^2) area was cleared and weighed to compute the seed yield in g m^{-2}.

Estimation of Oil Content of the Seeds

The oil in the seed was extracted as described by Horwitz.[17] Briefly, weigh 10 grams of seeds and grind them with the anhydrous sodium sulphate using a mortar and pestle. (Add the sodium sulphate till it looks white). Make the paste of it by adding hexane. Pour the solution into the condenser of the fractional distillation plant. Plug the bottom of the condenser with the wet cotton. Collect the oil after two cycles of rotation.

Data Analysis

Data were collected at nine intervals viz., 30 DAS (days after sowing), 42 DAS, 50 DAS, 72 DAS, 80 DAS, 95 DAS, 102 DAS and 110 DAS. Data collected were subjected to statistical analysis as per the standard procedure of Cochran and Cox.[18]

Results and Discussion

Yield Components

The yield components of *B. campestris* Linn. cv. Pusa Gold observation revealed that the number of siliquae per plant and number of seeds per siliquae exhibits non-significant difference up to the concentration of 450 µg mL^{-1} of sodium meta-bisulphite, but showed a significant decrease at 600 µg mL^{-1} $Na_2S_2O_5$ and 750 µg mL^{-1} $Na_2S_2O_5$ as data shown in table 1. The maximum reduction in the number of siliquae per plant and the number of seeds per siliquae was observed at 750 µg mL^{-1} $Na_2S_2O_5$ and a decrease of 2.4% and 2.5% respectively as compared to the control. The effects of sodium meta-bisulphite ($Na_2S_2O_5$) are very similar to those of gaseous SO_2 since it contains excess SO_2, which can be liberated by bubbling air through the solution.[19] It has been observed that sodium meta-bisulphite (sulphur pollutant) applied foliarly reduced leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), chlorophyll content, soluble protein content, nitrate reductase enzyme activity, assimilate formation and transfer from the leaves and stems into pods are reduced at concentrations of 150 µg mL^{-1} during the present study. Hence, crops fumigated with high concentrations of foliar-applied sulphur pollutants in the form of sodium meta-bisulphite would decrease the number of siliquae per plant. As a result of the high concentration of foliar sulphur pollution in the form of sodium meta-bisulphite, they would also appear smaller and shorter due to the lack of enough photoassimilates. As we observed in our experiment if the supply of photoassimilates decreased to pods, seed growth would be allowed to occur, however, we would observe a noticeable decline in the weight of 1000 seeds. In addition to reducing the photosynthetic leaf area and duration, a greater concentration of foliar sulphur pollutant also reduced the photosynthetic rate. As a result, the growth of floral buds, the production of siliquae, and the growth of newly formed pods and seeds in them were all inhibited by the lack of photosynthates.[20] A higher concentration of foliar applied sulphur pollutant in the form of sodium meta-bisulphite further resulted in reduced seed filling and more flower and pod shedding. Further, it might cause abortion of the ovules, which could have possibly resulted due to impaired photosynthetic activity.

Seed Yield, Biological Yield and Harvest Index

The seed yield (g $plant^{-1}$) of the genotype was significantly reduced when treated with sodium meta-bisulphite compared to the control. The treatment resulted in a 22.1 to 68.8% reduction in the seed yield of the genotype when compared to the control (Table 2).

Table 1: Influence of foliar-applied sulphur pollutant on yield components of *B. campestris* Linn. cv. Pusa Gold.

Treatments (T)	No. of Siliquae (Plant^{-1})	No. of Seeds (Siliqua^{-1})	1000 Seed Weight (g)
T_0	314	31.4	4.04
T_1	317.3	31.7	1.83
T_2	312.3	31.3	1.63
T_3	309	30.9	1.45
T_4	307.7	30.8	1.35
T_5	306.3	30.6	1.27
Mean	**311.1**	**31.12**	**1.93**
L.S.D. at 5% P	13.85	2.4	1.05

The biological yield (g plant^{-1}) of the genotype was also significantly reduced when treated with sodium meta-bisulphite compared to the control. The treatments resulted in a 20.9 to 62.4% reduction in the biological yield of the genotype when compared to the control. Our data also suggest a significant reduction in harvest index percentage. The harvest index was reduced from 50.9% in the control to 39.9% in the plants treated with 750 g mL^{-1} $Na_2S_2O_5$. A positive correlation was observed by several investigators in various crop plants.[21-23] The yield components of the genotype were found to be affected by SO_2 exposures. This ultimately leads to a reduction in the yield of rapeseed.

Table 2: Influence of foliar-applied sulphur pollutant on seed yield, biological yield and harvest index of *Brassica campestris* Linn.cv. Pusa Gold.

Treatments (T)	Seed Yield (g Plant^{-1})	Biological Yield (g Plant^{-1})	Harvest Index (%)
T0	52.90	104.30	50.90
T1	41.20	82.40	50.30
T2	30.50	73.50	43.30
T3	24.40	56.20	42.10
T4	18.50	46.40	41.50
T5	16.50	39.20	39.90
Mean	**30.67**	**67.00**	**44.67**
L.S.D. at 5% P	5.10	12.55	4.86

An individual plant's yield is determined by the number of siliquae per plant, the number of seeds per siliqua and the weight of 1000 seeds, whereas biological yield is an expression of the overall growth of the plant. As well as the photosynthetic system's size, efficiency and duration, it also depends on how dry matter is translocated in an economic sink for the plant to produce an economic yield. The final built-up is the cumulative function of yield components. An important aspect of yield measurement is the harvest index. It represents an increase in physiological capacity (e.g. sink power or sink capacity) for mobilizing photosynthates and translocating them to economically significant organs. The application of sodium meta-bisulphite on the foliar surface affected seed yield, biological yield and harvest index. In addition, comparable results were also found from previous studies that used different exposure techniques or regimes to induce sulphur-induced reductions in seed yield, biological yield and harvest index.[24] The maximum reductions were noticed at 750 µg mL^{-1} $Na_2S_2O_5$ (Table 2). A decrease in biological yield of up to 39% was observed, which was mainly attributed to a decrease in the number of siliqua per plant and 1000 seed weight. Significant differences were observed in the seed yield, biological yield and harvest index with the application of foliar applied sulphur in the form of sodium meta-bisulphite at different concentrations. The reduction in growth and yield attributes by foliar-applied sulphur pollutants in the form of sodium meta-bisulphite finally led to less biomass production (biological yield) and decreased seed yield. Application of foliar applied sulphur pollutant in the form of sodium meta-bisulphite resulted in a proportionally more reduction in the seed yield compared with a biological yield, which ultimately led to a lesser harvest index.

Table 3: Influence of foliar-applied sulphur pollutant on oil content, oil yield and N: S ratio in the seed of *B. campestris* Linn. cv. Pusa Gold

Treatments (T)	Oil Content (%)	Oil yield (g Plant-¹)	N:S ratio in seed
T_0	45.40	24.00	12.20
T_1	42.00	17.30	15.90
T_2	35.00	10.70	9.40
T_3	33.80	8.20	9.40
T_4	32.80	7.10	8.30
T_5	19.60	3.60	7.30
Mean	**34.77**	**11.82**	**10.42**
L.S.D. at 5% P	1.55	2.42	0.97

Oil Content, Oil Yield and N: S Ratio

The oil content percentage was significantly reduced by the foliar application of $Na_2S_2O_5$ (Table 3). It continued to decrease and the reduction started at a concentration of 150 µg mL^{-1} $Na_2S_2O_5$. Oil content, which was 45.40% in the control plants, decreased to 19.60% in plants treated with 750 µg mL^{-1} $Na_2S_2O_5$. Foliar application of sodium meta-bisulphite decreases the percent oil content in seeds when compared to the control. Accumulation of oil is a consequence of the transformation of carbohydrates and is likely to be affected by foliar-applied sulphur pollutants. The magnitude of reduction of percentage oil content was higher in the genotype when foliar applied sulphur pollutant was given at a concentration of 750 µg mL^{-1} $Na_2S_2O_5$. Oil yield depends upon both the seed yield and the percent oil content in seeds, and hence it followed the same pattern as that of seed yield obtained under different treatments. The foliar-applied sulphur pollutant in the form of sodium meta-bisulphite in rapeseed deserves due attention because a very close association of this pollutant exists in plants with nitrogen. Protein synthesis relies heavily on sulphur as its availability or deficiency affects the formation of methionine, an amino acid that initiates the synthesis of protein.[25]

A significant effect of the foliar-applied sulphur pollutant was also noticed in the N: S ratio of seeds (Table 3). At a concentration of 150 µg mL^{-1} $Na_2S_2O_5$, the N: S ratio in seeds was increased as compared to the control, however, when the concentration of $Na_2S_2O_5$ was increased from 300 µg mL^{-1} to 750 µg mL^{-1} $Na_2S_2O_5$, a decline was observed. An observed reduction in the N: S ratio with an increase in the concentration of foliar applied sulphur pollutant in the form of sodium meta-bisulphite in the seeds is accounted by increased translocation of the same from the leaves to the seeds and hence its greater accumulation and resulting in lower N: S ratio. Our results are in confirmation with the preceding work carried out by various workers.[10,26]

Conclusions

The present investigation concluded that the number of siliquae per plant was higher in control as compared to those, which were exposed to 750 µg mL^{-1} $Na_2S_2O_5$. The number of seeds per siliqua was, however, almost the same with lesser seed weight as compared to the control. The number of siliquae and the 1000-seed weight were affected by foliar-applied sodium meta-bisulphite at 750 µg mL^{-1}. The maximum reduction in the seed yield, the biological yield and the harvest index was noticed at 750 µg mL^{-1} $Na_2S_2O_5$. The percent oil content was also reduced by foliar applied sulphur pollutant in the form of sodium meta-bisulphite achieving maximum reduction at 750 µg mL^{-1} $Na_2S_2O_5$. Oil yield followed the same trend as that of seed yield obtained under various treatments. In general, it can be suggested that a higher concentration of $Na_2S_2O_5$ may bring an overall decrease in certain parameters like the number of siliquae, the 1000-seed weight, the seed yield, the biological yield and the harvest index in *B. campestris* plants when exposed to the higher concentrations of sulphur pollutant.

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Conflict of interest

The authors declare that they have no conflict of interest.

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