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RESEARCH ARTICLE

Effect of phosphorus and sulphur nutrients on *Brassica campestris* L. variety toria under dry land condition

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ABSTRACT : The experiment was laid out in a Factorial Randomized Block Design with twelve treatments and replicated thrice. Results indicate that the effect of phosphorus and sulphur nutrient with different treatments. Significant effects were observed in plants growth attributes due to presence of phosphorus and uptake of phosphorous increased due to presence of sulphur ultimately resulting in good yield. However, plant heights (165.00 cm), number of branches plant^{-1} (7.33), plant dry weight (g) (21.27), crop growth rate (g m^{-2} day^{-1}) (19.90), relative growth rate (g g^{-1}day^{-1}) (0.055), number of siliqua plant^{-1}, (329.13), number of seeds siliqua^{-1} (18.73), test weight (g) (3.83), seed yield (t ha^{-1}) (1.96), harvest index (%), (19.89) and oil content (%)(1.22) were found significantly affected by the application of phosphorus and sulphur and cost benefit ratio was also found (2.24) on higher side.

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Rapeseed, RBD, Phosphorus, Sulphur, Plant parameter

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Oil seed crops occupy an important place in agriculture and are important components of India economy. They constitute the second major group of agriculture crops in the country, next only to food grain crops. After food grains and that play an important role in Indian agriculture and industries. Besides having immense value in our diet, oils and fats are used in cosmetics, soaps, lubricant, paints and varnish industries and their medicinal and therapeutic value. India is endowed with a wealth of vegetable oil resources in the form of cultivated annuals and perennial tree species. Among the cultivated annuls, sesamum, rapeseed, mustard, niger, castor and safflower are supposed to be the most ancient ones. Rapeseed (*Brassica campestris* L.) is an important oilseed crop of family cruciferace and occupies a prominent place among oilseed crops being next to groundnut in importance. The technology mission in oilseeds initiated in 1986 paved the way to meet different challenges and complexities in the oilseed sector. There was five times increase in oilseed production during the period between 1950-2016 under predominantly rainfed agro-ecological conditions. This was higher than even the corresponding production increase in total food grains during 2015-2017. Even with a record oilseed production of 70.1 million tones, India imported 51 lakh tones of vegetable oils costing more than Rs.11, 000 crores. The country's demand for vegetable oils is expected to increase from the current level of 13 million tones to, 18.3 and 21.8 million tons by, 2015 and 2020, respectively (Hedge, 2007). Toria (*Brassica campestris* L.) is important oil seed crop of family *cruciferae* and occupies a prominent place among oilseed crops being next to groundnut in important.The present production of oilseed is around 70.7 million tonnes and rapeseed mustard sown area in India is 10.1 million hectare which has a production of 8.1 million tonnes. The average productivity of oil seed in India is 100 kg ha^{-1} and for rapeseed and mustard, it is 1115 kg ha^{-1}. India accounts for 12-13 per cent of world oilseed production and in Rajasthan mustard occupies an ares of 48 per cent with a production of 35.6 million tonnes. (Anonymous, 2016). The country shares about 23 per cent of the world production of rapeseed and mustard. These crops are of particular significance of Rajasthan and Uttar Pradesh, which shares about 80 per cent of area and production of entire country. Nearly 76 per cent oil seeds area is rainfed which is often subjected to erratic monsoon. The oil content of the seeds ranges from 35-37 per cent and 20-40 per cent protein. The oil obtained is the main cooking medium and cannot be easily replaced by any other edible oil. The seed and oil are used as a condiment in the preparation of pickles and for flavouring curries and vegetables. The oil cake is mostly used as a cattle feed and the leaves of young plants are used as green vegetables. The use of mustard oil for industrial purposes is rather limited on account of its high cost. Apart from this rapeseed and mustard cake is also used as organic manure for the soil. The nutrient elements of major significance for yield and quality of rapeseed and mustard are nitrogen, phosphorus and sulphur. Nitrogen is the most important nutrient which determines the growth of mustard and rapeseed that increases the amount of protein, methionine, dry matter and yield. Phosphorus and potash are known to be efficiently utilized in the presence of nitrogen to promote flowering, setting of siliqua and increase the size of siliqua and yield. It is well known that sulphur is only next to nitrogen in the nutrition of *Brassica* crops. Sulphur requirement is higher than any other crops because the synthesis of thioglucosides and other related compounds present to the extent of about 3 per cent of plant dry weight. Sulphur plays a significant role in increasing production especially in oilseeds. Sulphur is essential for synthesis of sulphur containing amino acid *viz.,* methionine, cystine and chlorophyll. It is also responsible for synthesis of certain vitamins (Thiamine, biotin), lipoid acid and glutathiones It is essential for metabolism of carbohydrate, proteins, oils and in synthesis of coenzyme-A. Sulphur deficiencies are occurring with greater magnitude at various locations in India. The recent study conducted in India revealed that 85 districts are deficient in sulphur. Enhanced removal of sulphur under exploitative agriculture seems to be the principal cause for occurrence of progressive incidence of sulphur deficiency. Leaching losses and depletion of soil sulphur due to maximum cultivation of pulses and oilseed crops in cropping sequences created a gap between supply and removal of sulphur. Use of sulphur free fertilizer in intensively cropped areas and depletion of organic matter in soil, which is supposed to be a reservoir of sulphur, is also an important cause for sulphur deficiency (Kumar *et al.*, 2006). The decline soil fertile Plants need phosphorus for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division, fat and albumen formation. Phosphorus compounds are involved in the transfer and storage of energy within plants. Energy from photosynthesis and the metabolism of carbohydrates is stored in phosphate compounds for later use in growth and reproduction. Phosphorus is readily translocated within the plants, moving from older to younger tissues as the plant forms cells and develops roots, stems and leaves. Adequate P results in rapid growth and earlier maturity, which is important in areas where frost is a concern. Frequently, the quality of vegetative growth is improved. A good supply of P has been associated with increased root growth, which means the plant can explore more soil for nutrients and moisture. Phosphorus occurs in most plants in concentrations between 0.1 and 0.4 per cent. Phosphorus plays on important role in increasing oil content and also influences the initial growth of plants. Phosphorus stimulates pod setting help in improving the seed weight and peroxides and on extensive and vigorous root system. It also helps in better partitioning of reproductive parts which increase the seed and stover ratio (Singh, 2005). Therefore, keeping these facts in view of field experiment entiteled “Effect of phosphorus and sulphur nutrients on rapeseed (*Brassica campestris* L.) variety toria” is planned to be conducted during *Rabi* season of 2016 at Agronomy Research Farm, Department of Agriculture Bhagwnat University Ajmer Rajasthan with the following objective :- To find out the effect of phosphorus on rapeseed. To find out the effect of sulphur on rapeseed. To study the economics of different treatment combinations.

Experimental Methodology

The detailed account of the treatments, observations recorded procedures of chemical and statistical analysis adopted during the course of investigation, are presented in this chapter.

Soil:

The soil of the experimental field constituting a part of central Gangetic alluvium is neutral and deep. Pre-sowing soil samples were taken from a depth of 15cm with the help of an auger and mixed thoroughly to prepare a composite sample, during the years of experimentation, 2011. The composite samples were used for the chemical and mechanical analysis. The soil was sandy loam in texture, low in organic carbon and medium in available nitrogen, phosphorus and low in potassium. The mechanical, chemical and physico-chemical properties of the soil of experimental field and the methods used, are presented in Table A.

Experimental details :

The experiment was laid out in 4 x 4 Factorial Randomized Block Randomized comprising of sixteen treatment combinations each replicated thrice. Treatments were randomly arranged in each replication, divided into for forty eight plots. The treatments tested, specifications of the layout, etc. are given below:

Details of treatment :

Factor 1:

Different levels of phosphorus: (i) 0kg ha^{-1} (ii) 35kg ha^{-1} (iii) 60kg ha^{-1} (iv) 85kg ha^{-1}.

Factor- 2 :

Different levels of sulphur : (i) 0kg ha^{-1} (ii) 35kg ha^{-1} (iii) 60kg ha^{-1} (iv) 85kg ha^{-1}.

Treatment combination:

(i) 0kg P_2O_5 + 0kg S (ii) 0kg P_2O_5 + 35kg S (iii) 0kg P_2O_5 + 60kg S (iv) 35kg P_2O_5 + 0kg S (v) 35kg P_2O_5 + 35kg S (vi) 35kg P_2O_5 + 60kg S (vii) 35kg P_2O_5 + 85kg S (viii) 60kg P_2O_5 + 0kg S (ix) 60kg P_2O_5 +35kg S (x) 60kg P_2O_5 +60kg S (xi) 85kg P_2O_5 + 0kg S (xii) 85kg P_2O_5 + 35kg S (xiii) 85kg P_2O_5 + 60kg S (xiv) N 60, K_2O 35 blanket application.

Agronomic characters of the variety PT-353:

The plants are dwarf in height, moderately branched, leaves are small in size, dark green in colour, 80 days of maturity, siliqua are open type and medium in size, seed medium in size and brown in colour, having 42 per cent oil content. Resistant to Alternaria disease and fog and recommended for extra early sown situation and suited to multiple cropping in U.P.

Details of fields operations:

Fertilizer application :

Nitrogen was applied through urea, phosphorus through SSP, potash through MOP and sulphur was applied through gypsum. half dose of nitrogen (40 kg ha^{-1}) and full dose of potash (40kg ha^{-1}), sulphur (four levels 0, 35, 60 and 85kg ha^{-1}) and phosphorus (four levels 0, 35, 60 and 85kg ha^{-1}) was given as basal application at

Table A : Mechanical, chemical and physico-chemical field characteristics of the experimental field (0 -15cm)

Particulars	Experimental year 2016-17	Methods of determination	Reference
Mechanical analysis			
Sand (%)	62.25	International Pipette Method	Piper, 1966
Silt (%)	24.17		
Clay (%)	14.58		
Textural class	Sandy Loam	USDA Triangle	Soil Survey, 1975
Chemical analysis			
Organic carbon (%)	0.29	Walkley and Black Method	Jackson, 1973
Available Nitrogen (kg ha^{-1})	317.50	Alkaline Permanganate Method	Subbaiah and Asija, 1956
Available P (kg ha^{-1})	19.00	Olsen's Colorimetric Method	Olsen *et al*., 1954
Available K (kg ha^{-1})	110.00	NH_4OAc- leaching	Jackson, 1973
Physico-chemical properties			
Soil pH	7.7	Glass electrode pH meter	Jackson, 1973

the time of sowing and remaining was top dressed at 35 DAS for each nitrogen levels.

Sowing of seeds:

Sowing was done on 3rd Oct. 2016. Spacing was maintained at 35cm between rows and10 cm between plants. 2-3 seeds were dibbled in each hole and there after seeds were covered with soil and gently pressed.

Thinning:

Thinning was done at 14 DAS. This operation was done for maintaining a proper plant to plant distance and standard plant population.

Weeding:

Hand weeding was done at 25 DAS to maintain a proper weed free environment during the initial crop growth stages.

Irrigation :

The crop was irrigated two times; first irrigation was given at 35 DAS.

Harvesting :

The crop was harvested plot-wise at maturity stage, when plants turned yellow and grains became hard at 80 DAS. Harvesting was done manually with sickles.

Observations recorded:

During the course of experiment a number of observations were taken to study the growth and yield of crop. It was divided mainly into two groups (A) pre-harvest observations and (B) post-harvest observations. A brief description of the method of taking each observation is given below:

Pre-harvest observations:

Plant height (*cm*):

Three plants were selected randomly from each plot and tagged. The heights of these plants were measured from the ground level upto the tip of the plant. First observation was taken 15 DAS and subsequent observations were taken at 15 days interval *i.e.* 35, 45 and 60 DAS. The average height (cm) was then calculated for each observation recorded.

Number of branches per plant:

From the five tagged plants of each plot, number of branches at different growth stages were recorded at 15, 35, 45 and 60 DAS and the average number of branches per plant was calculated for each observation.

Plant dry weight (*g*):

Dry weight of plants was recorded at 15, 35, 45 and 60 DAS. For this observation three plants were uprooted randomly from each plot. These plants were air dried by keeping in air-dry oven for 24 hrs at 70^{0}C and their dry weight was recorded. The average dry weight per plant was calculated for each observation.

Crop growth rate:

It represents dry weight gained by a unit area of crop in a unit time expressed as g plant^{-1} and is given as (Fisher, 1921):

$$\text{Crop growth rate} = \frac{W_2 - W_1}{t_2 - t_1} (\text{g plant}^{-1})$$

where, W_1= Initial dry weight of plant (g), W_2 = Final dry weight of plant (g), t_1 = Initial time period, t_2= Final time period.

Relative growth rate :

This parameter indicates the rate of growth per unit of dry matter. It is expressed as 'g' of dry matter production by a 'g' existing dry matter in a day. The incorporation of dry matter in to the substance of a plant was measured by relative growth rate (R.G.R.) and is expressed mathematically as per equation given by (Fisher, 1921).

$$\text{Relative growth rate} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1} (\text{g g}^{-1} \text{ day}^{-1})$$

where, W_1= Initial dry weight of plant (g), W_2= Final dry weight of plant (g), t_1= Initial time period, t_2= Final time period.

Post-harvest observations :

Different observations regarding the yield were taken after harvesting the crop, which is listed below in brief.

Number of siliqua per plant:

From the tagged plants of each plot, the number of siliqua per plant was recorded and the average number of siliqua per plant was calculated.

Number of seed per siliqua:

From the tagged plants of each plot, the number of seed per siliqua was recorded and the average number of seed per siliqua was calculated.

Test weight:

Weight of 1000-seeds from each plot was taken and the average test weight of each plot was recorded.

Grain yield:

The total yield obtained after harvesting 1 m^2 area was recorded for each treatment, it was converted on per ha basis to obtain the total yield in quintals per hectare and the average yield for each treatment was calculated.

Harvest index:

Harvest index was calculated by using the following formula (Singh Staskopt, 1917):

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Oil content (%) :

Oil content in seeds was estimated through 'Soxhlet' apparatus using petroleum ether as organic solvent (40-60^0 C) as per the methodology of Perry and Green, 1988. The extractor and extraction flask was cleaned and dried. The extraction flask was weighed in a chemical balance upto 3 decimal places. Seeds were first oven dried, cooled in a dessicator and then weighed in a chemical balance. Three gram oven dried seeds were taken after removing the seed coat. The kernels were kept on 2 filter papers (Whatmann's No. 42), which were folded and the kernels were crushed or tapped with a rubber pestle. Care was taken that the oil did not come out of the filter paper. The filter paper was shaped into a thimble and then the thimble was placed inside the extractor. Two hundred and fifty ml of ether solvent was added in the extraction flask. Direct heating was avoided and the extractor condenser on the top. The inlet and outlet aided. In the control of the flow of water in the condenser. Whole assembly was fixed on a clamp stand. Heating was done gently, and then 200 ml of ether solvent was added. Four cycles of siphoning were needed for complete removal of the oil from the kernel sample. When four cycle processes of oil extraction was completed, and then spirit lamp turned off and kept away from the Soxhlet's apparatus. After that fifteen minutes continuous flow of water was maintained in four Soxhlet's apparatus. After fifteen minutes the flask was separated from Soxhlet's apparatus. Thereafter water was boiled in the copper bowl. In this boiling bowl, flask was kept. After a while, flask was taken out and shaken well and kept again in boiling water in the bowl. This process was continued for two hour's duration, in order to separate the ether from oil in the flask. When the smell of ether stopped, *i.e.*, complete excape of ether from the oil flask, the flask was weighed in an electronic balance. Thereafter calculation was done by substracting weight of flask from oil contained in the flask.

$$\text{Oil content in kernels (\%)} = \frac{W_2 - W_1}{W_3} \times 100$$

where, W_1 = Weight of flask (g), W_2 = Weight of flask + oil (g), W_3 = Weight of sample (g).

Economics:

The economics regarding the cultivation of crop was calculated separately for all the treatment combinations on per hectare basis.

Cost of cultivation:

Cost of cultivation (Rs. ha^{-1}) for each treatment combination was calculated separately taking into consideration all cultural practices followed in the cultivation.

Gross return:

The gross return (Rs. ha^{-1}) for each treatment combination was calculated taking into consideration the yield and market price of produce.

Net return:

The net return (Rs. ha^{-1}) was calculated for each treatment combination separately by using the following expression:

Net return (Rs. ha^{-1}) = Gross return (Rs. ha^{-1}) – Cost of cultivation (Rs. ha^{-1}).

Benefit cost ratio:

The benefit cost ratio for each treatment combination was calculated separately using the following expression:

$$\text{B : C} = \frac{\text{Net return (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

EXPERIMENTAL FINDINGS AND DISCUSSION

The findings of the present experiment entitled, "effect of phosphorus and sulphur nutrients on *Brassica campestris* L. variety toria under dry land condition" are being presented and discussed in the following pages under appropriate headings. Data on pre-harvest and post harvest observations were analyzed and discussion on experimental findings in the light of scientific reasoning has been stated.

Pre-harvest observations (At 20, 40, 60 and 80DAS):-Plant height (cm):

The data on plant height (cm) at 20, 40, 60 and 80DAS as influenced by Phosphorus and Sulphur are presented in Table 1. Significant difference was observed due to effect of hosphorus and Sulphur nutrients in plant height at different stages at 20, 40, 60 and 80 DAS. All the treatments showed significantly maximum plant height at 80 DAS over untreated control (135.15cm). Among the other treatments, the seeds treated with T_{13} (85 kg P_2O_5 + 60kg S) recorded highest plant height (55.67cm), (95.12cm) and (165.33cm) at 40, 60 and 80 DAS, respectively. However, T_8 (60 kg P_2O_5+ 0 kg S) treatment recorded plant height (53.55cm), (92.91cm) and (160.43cm), at 40, 60 and 80 DAS, respectively. Followed by T_7 (35 kg P_2O_5 + 85kg S) (51.07cm), (91.64cm), (158.71cm), at 40, 60 and 80 DAS, respectively. This was found statistically at par to T_{13} (0kg P_2O_5 + 0kg S). Lowest plant height was recorded with T_1 (0kg P_2O_5 + 0kg) treatment (35.22cm), (68.13cm), (135.15cm) at 40, 60 and 80 DAS, respectively. Experimental finding show that positive effect of sulphur along with phosphorus. The maximum plant height was found due to better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication, elongation and cell expression in the plant body which ultimately increased the plant height.

Number of branches plant^{-1}:

The data on number of branches plant^{-1} at 40, 60 and 80 DAS as influenced by phosphorus and sulphur are presented in Table 2. Significant difference was observed due to treatment in number of branches plant^{-1} at different stages at 40, 60 and 80 DAS. All the treatment showed significantly maximum number of branches plant^{-1} at 80 DAS over untreated control (4.93). Among the other treatments, the seeds treated with T_{13} (85kg P_2O_5+60kg S) recorded highest number of branches plant^{-1} (2.80), (5.73) and (7.33) at 40, 60 and 80 DAS, respectively. However, T_8 (60kg P_2O_5 + 0kg S) treatment recorded number of branches plant^{-1} (5.33) and (7.13), at 60 and 80 DAS, respectively followed by

Table 1 : Effect of phosphorus and sulphur nutrients on of plant height (cm) of rapeseed different intervals

Treatments	Plant height			
	20 DAS	40 DAS	60 DAS	80 DAS
T_1 0 kg P_2O_5 + 0 kg S	1.92	35.22	68.13	135.15
T_2 0 kg P_2O_5 + 35 kg S	1.31	38.26	71.84	142.65
T_3 0 kg P_2O_5 + 60 kg S	1.49	40.28	73.71	143.89
T_4 35 kg P_2O_5 + 0 kg S	1.23	39.60	75.28	144.75
T_5 35 kg P_2O_5 + 35 kg S	1.45	36.94	83.38	148.34
T_6 35 kg P_2O_5 + 60 kg S	1.00	40.61	85.41	150.21
T_7 35 kg P_2O_5 + 85 kg S	1.11	51.07	91.64	158.71
T_8 60 kg P_2O_5 + 0 kg S	1.82	53.55	92.91	160.43
T_9 60 kg P_2O_5 +35 kg S	1.06	40.11	81.81	152.91
T_{10} 60 kg P_2O_5 +60 kg S	1.59	44.07	88.42	157.10
T_{11} 85 kg P_2O_5 + 0 kg S	1.25	45.72	83.48	154.12
T_{12} 85 kg P_2O_5 + 35 kg S	1.21	45.41	85.26	150.45
T_{13} 85 kg P_2O_5 + 60 kg S	1.49	55.67	95.12	165.33
F- test	S	S	S	S
S.E.±	0.231	3.109	2.466	4.627
C.D. (P = 0.05)	0.477	6.418	5.091	9.551

S= Significant

T_7 (35kg P_2O_5 + 85kg S) recorded number of branches plant^{-1} (5.13) and (7.00), at 60 and 80 DAS, respectively followed by T_9 (60 kg P_2O_5 +35kg S) recorded number of branches plant^{-1} (7.13) at 80 DAS that was found statistically at par to T_{13} (85kg P_2O_5 + 60kg S). Lowest number of branches plant^{-1} was recorded with T_1 (0kg P_2O_5 + 0kg S) treatment (1.20), (2.87), (4.93) at 40, 60 and 80 DAS, respectively. Experimental finding show that positive effect of sulphur along with phosphorus. The maximum branches per plant was found due to better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication, elongation and cell expression in the plant body which ultimately increased the maximum branches per plant.

Table 2 : Effect of phosphorus and sulphur nutrients on of number of branches plant^{-1} of rapeseed different intervals

Treatments	Number of branches plant^{-1}		
	40 DAS	60 DAS	80 DAS
(T_1)-0kg P_2O_5 + 0kg S	1.20	2.87	4.93
(T_2)-0kg P_2O_5 + 35kg S	1.17	3.47	5.53
(T_3)-0kg P_2O_5 + 60kg S	1.53	3.67	5.87
(T_4)-35kg P_2O_5 + 0kg S	1.46	4.00	6.13
(T_5)-35kg P_2O_5 + 35kg S	1.66	4.33	6.53
(T_6)-35kg P_2O_5 + 60kg S	1.86	4.33	6.11
(T_7)-35kg P_2O_5 + 85kg S	2.33	5.13	7.00
(T_8)-60kg P_2O_5 + 0kg S	2.53	5.33	7.13
(T_9)-60kg P_2O_5 +35kg S	1.60	4.67	6.80
(T_{10})-60kg P_2O_5 +60kg S	1.86	3.80	6.40
(T_{11})-85kg P_2O_5 + 0kg S	1.33	4.27	6.67
(T_{12})-85kg P_2O_5 + 35kg S	1.53	4.13	6.67
(T_{13})-85kg P_2O_5 + 60kg S	2.80	5.73	7.33
F- test	S	S	S
S.E.±	0.02	0.401	0.278
C.D. (P = 0.05)	0.05	0.828	0.573

S= Signfificant

Plant dry weight (g):

The data on plant dry weight (g) at 20, 40, 60 and

Table 3 : Effect of phosphorus and sulphur nutrients on of dry weight (g) of rapeseed different intervals

Treatments	dry weight (g)			
	20 DAS	40 DAS	60 DAS	80 DAS
(T_1)-0kg P_2O_5 + 0kg S	0.02	0.85	5.44	13.50
(T_2)-0kg P_2O_5 + 35kg S	0.05	1.34	6.14	16.27
(T_3)-0kg P_2O_5 + 60kg S	0.08	1.71	6.28	14.49
(T_4)-35kg P_2O_5 + 0kg S	0.16	1.91	7.00	18.94
(T_5)-35kg P_2O_5 + 35kg S	0.05	2.02	6.61	19.89
(T_6)-35kg P_2O_5 + 60kg S	0.03	1.68	7.05	17.11
(T_7)-35kg P_2O_5 + 85kg S	0.02	2.24	9.16	20.66
(T_8)-60kg P_2O_5 + 0kg S	0.05	2.62	9.83	21.00
(T_9)-60kg P_2O_5 +35kg S	0.02	2.32	8.27	18.83
(T_{10})-60kg P_2O_5 +60kg S	0.09	2.03	6.60	19.22
(T_{11})-85kg P_2O_5 + 0kg S	0.10	2.06	7.27	18.16
(T_{12})-85kg P_2O_5 + 35kg S	0.03	2.10	6.61	18.79
(T_{13})-85kg P_2O_5 + 60kg S	0.05	2.80	11.05	21.27
F- test	NS	S	S	S
S.E.±	0.052	0.243	0.618	0.871
C.D. (P = 0.05)	-	0.502	1.275	1.798

NS= Non-significant S= Singnificant

80 DAS as influenced by phosphorus and sulphur nutrients are presented in Table 3. Significant difference was observed due to treatment in plant dry weight (g) at different stages at 20, 40, 60 and 80DAS. 20 DAS treatment showed none significantly and 40, 60 and 80 DAS the treatment showed significantly maximum plant dry weight (g) at 80 DAS over control (13.50g). Among the other treatments, the treatment T_{13} (85kg P_2O_5 + 60kg S) recorded highest plant dry weight (g) (2.80g), (11.5g) and (21.27g) at 40, 60 and 80DAS, respectively. However, T_8 (60kg P_2O_5 + 0kg S) treatment recorded plant dry weight (g) (2.62g), (9.83g) and (21.00g), at 40, 60 and 80 DAS, respectively. Followed by T_7 (35kg P_2O_5 + 85kg S) recorded plant dry weight (g) (20.66g), at 80 DAS. Followed by T_9 KCl (60kg P_2O_5 +35kg S) recorded plant dry weight (g) (2.32g) at 40 DAS. Followed by T_5 (35kg P_2O_5 + 35kg S) recorded plant dry weight (g) (19.89) at 80 DAS. That was found statistically at par to T_{13} (85kg P_2O_5 + 60kg S). Lowest plant dry weight (g) was recorded with no soaking treatment (0.85g), (5.44g), (13.50g) at 40, 60 and 80 DAS, respectively. Experimental finding show that positive effect of sulphur along with phosphorus. The maximum branches per plant was found due to better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication, elongation and cell expression in the plant body which ultimately increased the maximum branches per plant.

Crop growth rate (g $m^{-2}day^{-1}$):

The data on crop growth rate (g $m^{-2}day^{-1}$) at 0 to 20, 20 to 40,40 to 60 and 60 to 80DAS as influenced by phosphorus and sulphur treatment are presented in Table 4. Significant difference was observed due to treatment in crop growth rate (g $m^{-2}day^{-1}$) at different stages at 0 to 20, 20 to 40,40 to 60 and 60 to 80 DAS . 0 to 20 DAS treatment showed non significantly at 20 to 40, 40 to 60 and 60 to 80 DAS the treatment showed significantly maximum crop growth rate (g m^{-2} day^{-1}) at 60 to 80 DAS over control (13.426. g). Among the other treatments, the T_{13} (85 kg P_2O_5 + 60 kg S) recorded highest crop growth rate (g $m^{-2}day^{-1}$) (4.585g $m^{-2}day^{-1}$) (13.754g m^{-2} day^{-1}) at 20 to 40, 40 to 60 DAS, respectively. However, (60kg P_2O_5 + 0kg S) treatment recorded crop growth rate (g m^{-2} day^{-1}) (4.283 g m^{-2} day^{-1}) and (12.021 g m^{-2} day^{-1}) at 20 to 40 and 40 to 60 DAS, respectively. Followed by T_7 (35kg P_2O_5 + 85kg S) was (11.538g m^{-2} day^{-1}), 40 to 60 DAS, respectively. This was found statistically at par to T_{13} (85kg P_2O_5 + 60kg S). Lowest crop growth rate (g $m^{-2}day^{-1}$) was recorded with T_1 (0kg P_2O_5 + 0kg S) treatment (1.385g m^{-2} day^{-1}) and (13.426g $m^{-2}day^{-1}$) at 20 to 40 and 60 to 80 DAS, respectively.

Table 4 : Effect of phosphorus and sulphur nutrients on crop growth rate (g m^{-2} day^{-1}) of rapeseed different intervals

Treatments	Crop growth rate (g $m^{-2}day^{-1}$)			
	0-20 DAS	20-40 DAS	40-60 DAS	60-80 DAS
(T_1)-0kg P_2O_5 + 0kg S	0.037	1.385	7.644	13.426
(T_2)-0kg P_2O_5 + 35kg S	0.088	2.145	8.005	16.882
(T_3)-0kg P_2O_5 + 60kg S	0.133	2.711	7.616	13.693
(T_4)-35kg P_2O_5 + 0kg S	0.267	2.916	8.477	19.909
(T_5)-35kg P_2O_5 + 35kg S	0.091	3.270	7.649	22.131
(T_6)-35kg P_2O_5 + 60kg S	0.046	2.748	8.955	16.759
(T_7)-35kg P_2O_5 + 85kg S	0.039	3.694	11.538	19.165
(T_8)-60kg P_2O_5 + 0kg S	0.077	4.283	12.021	18.615
(T_9)-60kg P_2O_5 +35kg S	0.031	3.835	9.921	17.593
(T_{10})-60kg P_2O_5 +60kg S	0.145	3.238	7.616	21.026
(T_{11})-85kg P_2O_5 + 0kg S	0.165	3.274	8.682	18.148
(T_{12})-85kg P_2O_5 + 35kg S	0.057	3.443	7.510	20.298
(T_{13})-85kg P_2O_5 + 60kg S	0.076	4.585	13.754	17.037
F- test	NS	S	S	S
S.E.±	0.086	0.387	1.199	1.634
C.D. (P = 0.05)	-	0.799	2.475	3.372

NS= Non-significant S=Significant

Table 5 : Effect of phosphorus and sulphur nutrients relative growth rate (g $g^{-1}day^{-1}$) of rapeseed different intervals

Treatments	Relative growth rate (g $g^{-1}day^{-1}$)		
	20-40 DAS	40-60 DAS	60-80 DAS
(T_1)-0kg P_2O_5 + 0kg S	0.196	0.094	0.045
(T_2)-0kg P_2O_5 + 35kg S	0.166	0.077	0.048
(T_3)-0kg P_2O_5 + 60kg S	0.152	0.066	0.042
(T_4)-35kg P_2O_5 + 0kg S	0.158	0.066	0.050
(T_5)-35kg P_2O_5 + 35kg S	0.239	0.059	0.055
(T_6)-35kg P_2O_5 + 60kg S	0.216	0.073	0.045
(T_7)-35kg P_2O_5 + 85kg S	0.266	0.070	0.041
(T_8)-60kg P_2O_5 + 0kg S	0.237	0.066	0.038
(T_9)-60kg P_2O_5 +35kg S	0.248	0.063	0.042
(T_{10})-60kg P_2O_5 +60kg S	0.250	0.059	0.053
(T_{11})-85kg P_2O_5 + 0kg S	0.162	0.063	0.046
(T_{12})-85kg P_2O_5 + 35kg S	0.243	0.057	0.052
(T_{13})-85kg P_2O_5 + 60kg S	0.247	0.069	0.033
F- test	NS	NS	S
S.E.±	0.053	0.009	0.004
C.D. (P = 0.05)	-	-	0.009

NS= Non-significant S= Significant

Relative growth rate (g $g^{-1}day^{-1}$) :

The data on relative growth rate (g m^{-2} day^{-1}) at 0 to 20, 20 to 40, 40 to 60 and 60 to 80 DAS as influenced by phosphorus and sulphur are presented in Table 5. significant difference was observed due to treatment relative growth rate (g $g^{-1}day^{-1}$) at different stages at 60 to 80 DAS treatment showed non-significantly 20 to 40 and 40 to 60 DAS the treatment showed significantly maximum crop growth rate (g $g^{-1}day^{-1}$) at 60 to 80 DAS over control (0.045g g^{-1} day^{-1}). Among the other treatments, the treatment with T_7 (35 kg P_2O_5 + 85 kg S) recorded highest crop growth rate (g $g^{-1}day^{-1}$) (0.266g g^{-1} day^{-1}) at 0 to 20 DAS. Followed by No soaking recorded highest crop growth rate (g $g^{-1}day^{-1}$) (0.095g g^{-1} day^{-1}) 40 to 60 DAS followed by T_6 (35kg P_2O_5 + 60 kg S) recorded highest crop growth rate (g $g^{-1}day^{-1}$) (0.055g g^{-1} day^{-1}) however, T_{12} (85kg P_2O_5 + 35kg S) treatment recorded relative growth rate (0.052g g^{-1} day^{-1}) 60 to 80 DAS. Followed by T_{10} (85kg P_2O_5+35kg S) treatment recorded relative growth rate (g g^{-1} day^{-1}) (0.053g $g^{-1}day^{-1}$) at 60 to 80 DAS. That was found statistically at par to T_6 (35kg P_2O_5 + 60kg S). Lowest relative growth rate recorded with 35kg P_2O_5 + 60kg S treatment recorded relative growth rate (g $g^{-1}day^{-1}$) (0.033g $g^{-1}day^{-1}$), 60 to 80 DAS, respectively.

Post-harvest observations:

Number of siliqua plant^{-1}:

The data on number of siliqua plant^{-1} as influenced by seed treatment are presented in Table 6. Significant difference was observed due to seed treatment in number

Table 6 : Effect of phosphorus and sulphur nutrients on number of siliqua plant^{-1} of rapeseed different intervals

Treatments	Number of siliqua plant^{-1}
(T_1)-0kg P_2O_5 + 0kg S	169.47
(T_2)-0kg P_2O_5 + 35kg S	193.40
(T_3)-0kg P_2O_5 + 60kg S	133.28
(T_4)-35kg P_2O_5 + 0kg S	226.33
(T_5)-35kg P_2O_5 + 35kg S	247.47
(T_6)-35kg P_2O_5 + 60kg S	250.07
(T_7)-35kg P_2O_5 + 85kg S	295.00
(T_8)-60kg P_2O_5 + 0kg S	303.27
(T_9)-60kg P_2O_5 +35kg S	261.72
(T_{10})-60kg P_2O_5 +60kg S	250.87
(T_{11})-85kg P_2O_5 + 0kg S	272.60
(T_{12})-85kg P_2O_5 + 35kg S	264.93
(T_{13})-85kg P_2O_5 + 60kg S	329.13
F- test	S
S.E. ±	10.122
C.D. (P = 0.05)	20.891

S= Significant

of siliqua plant^{-1} at different stages. The seed treatment showed significantly. Among the other treatments, the seeds treated with T_{13} (85kg P_2O_5 + 60kg S) recorded highest number of siliqua plant^{-1} (329.13). Lowest Number of siliqua plant^{-1} was recorded with T_1 treatment (169.47). Experimental finding show that positive effect of sulphur along with phosphorus. The maximum number of siliqua plant was found due to large amount of phosphorus found in the seed and siliqua which is considered essential for seed formation and boldness of seed.Sulphur presences of phosphorus stimulate flowering and seed formation in siliqua.

Number of seeds siliqua^{-1}:

The data on number of seeds siliqua^{-1} as influenced by phosphorus and sulphur are presented in Table 7. Significant difference was observed due to treatment in number of seeds siliqua^{-1} at different stages, the treatment showed significantly. Among the other treatments, the Treatment with T_{13} (85kg P_2O_5+60kg S) recorded highest seeds siliqua^{-1} (18.73). However, T_8 (60kg P_2O_5+ 0kg S) treatment recorded seeds siliqua^{-1} (18.42). Followed by T_7 (35kg P_2O_5+ 85kg S) treatment recorded seeds siliqua^{-1} (18.13) was found statistically at par to T_{13} (85kg P_2O_5 + 60kg S). Lowest number of siliqua plant^{-1} was recorded with T_1 treatment (13.80). Experimental finding show that positive effect of sulphur along with phosphorus. The maximum number of seed siliqua^{-1} was found due to large amount of phosphorus found in the seed and siliqua which is considered essential for seed formation and boldness of seed. Sulphur presences of phosphorus stimulate flowering and seed formation in siliqua.

Table 7: Effect of phosphorus and sulphur nutrients on number of seed siliqua^{-1} of rapeseed different intervals

Treatments	Number of seed siliqua^{-1}
(T_1)-0kg P_2O_5 + 0kg S	13.80
(T_2)-0kg P_2O_5 + 35kg S	14.33
(T_3)-0kg P_2O_5 + 60kg S	14.60
(T_4)-35kg P_2O_5 + 0kg S	15.60
(T_5)-35kg P_2O_5 + 35kg S	16.00
(T_6)-35kg P_2O_5 + 60kg S	16.13
(T_7)-35kg P_2O_5 + 85kg S	18.13
(T_8)-60kg P_2O_5 + 0kg S	18.42
(T_9)-60kg P_2O_5 +35kg S	17.46
(T_{10})-60kg P_2O_5 +60kg S	17.20
(T_{11})-85kg P_2O_5 + 0kg S	17.47
(T_{12})-85kg P_2O_5 + 35kg S	17.60
(T_{13})-85kg P_2O_5 + 60kg S	18.73
F- test	S
S.E.±	0.503
C.D. (P = 0.05)	1.038

S= Significant

Test weight (g):

The data on test weight (g) as influenced by phosphorus and sulphur are presented in Table 8. Significant difference was observed due to treatment in test weight (g) at different stages. All the seed treatment showed significantly. Among the other treatments, with T_{13} (85kg P_2O_5 + 60kg S) recorded highest test weight (g) (3.83g). However, T_8 (60kg P_2O_5 + 0kg S) treatment recorded seed yield (t ha^{-1}) (3.69g). Followed by T_7 (35 kg P_2O_5 + 85 kg S) was (3.68g) was found statistically at par to T_{13} (85kg P_2O_5 + 60kg S). Lowest test weight (g) was recorded with T_1 treatment (2.73g).

Table 8: Effect of phosphorus and sulphur nutrients on test weight of seed (g ha^{-1}) of rapeseed different intervals

Treatments	Test weight of seed (g ha^{-1})
(T_1)-0kg P_2O_5 + 0kg S	2.73
(T_2)-0kg P_2O_5 + 35kg S	2.95
(T_3)-0kg P_2O_5 + 60kg S	3.03
(T_4)-35kg P_2O_5 + 0kg S	3.42
(T_5)-35kg P_2O_5 + 35kg S	3.20
(T_6)-35kg P_2O_5 + 60kg S	3.30
(T_7)-35kg P_2O_5 + 85kg S	3.68
(T_8)-60kg P_2O_5 + 0kg S	3.69
(T_9)-60kg P_2O_5 +35kg S	3.42
(T_{10})-60kg P_2O_5 +60kg S	3.43
(T_{11})-85kg P_2O_5 + 0kg S	3.62
(T_{12})-85kg P_2O_5 + 35kg S	3.44
(T_{13})-85kg P_2O_5 + 60kg S	3.83
F- test	S
S.E.±	0.18
C.D. (P = 0.05)	0.37

S= Significant

Seed yield (t ha^{-1}):

The data on seed yield (t ha^{-1}) as influenced by phosphorus and sulphur are presented in Table 9. Significant difference was observed due to treatment in

Seed yield (t ha^{-1}) at different stages. All the treatment showed significantly. Among the other treatments, the treated with T_{13} (85kg P_2O_5 + 60kg S) recorded highest seed yield (t ha^{-1}) (3.83 t ha^{-1}). However, T_8 ((85kg P_2O_5 + 60kg S) treatment recorded seed yield (t ha^{-1}) (1.85 t ha^{-1}). Followed by T_7 (35kg P_2O_5 + 85kg S) was (1.80 t ha^{-1}) was found statistically at par to T_{13} (85kg P_2O_5 + 60kg S) Lowest seed yield (t ha^{-1}) was recorded with T_1 treatment (1.40 t ha^{-1}). Experimental finding show that positive effect of sulphur along with phosphorus on yield of rapeseed. Application of phosphorus and sulphur, which were directly involved in better adsorption of applied nutrients and cell multiplication as well as expansion of deep green colour of leaves due to chlorophyll synthesis in comparison with plants deficient in phosphorus and sulphur. It also helps in better partitioning of photosynthative parts which increase the seed straw ratio.

Table 9 : Effect of phosphorus and sulphur nutrients on test weight of seed yield (t ha^{-1}) of rapeseed different intervals

Treatments	Seed yield (t ha^{-1})
(T_1)-0kg P_2O_5 + 0kg S	1.40
(T_2)-0kg P_2O_5 + 35kg S	1.01
(T_3)-0kg P_2O_5 + 60kg S	1.33
(T_4)-35kg P_2O_5 + 0kg S	1.43
(T_5)-35kg P_2O_5 + 35kg S	1.40
(T_6)-35kg P_2O_5 + 60kg S	1.42
(T_7)-35kg P_2O_5 + 85kg S	1.80
(T_8)-60kg P_2O_5 + 0kg S	1.85
(T_9)-60kg P_2O_5 +35kg S	1.60
(T_{10})-60kg P_2O_5 +60kg S	1.59
(T_{11})-85kg P_2O_5 + 0kg S	1.44
(T_{12})-85kg P_2O_5 + 35kg S	1.52
(T_{13})-85kg P_2O_5 + 60kg S	1.96
F- test	S
S.E.±	0.16
C.D. (P = 0.05)	0.33

S=Signficant

Harvest index (%):

The data on harvest index (%) as influenced by phosphorus and sulphur are presented in Table 10. Significant difference was observed due to treatment in harvest index (%) at different stages. the treatment showed non-significantly. Among the other treatments, the treatment with T_2 (0kg P_2O_5 + 35kg S) recorded highest number of harvest index (%) (19.89%). Lowest harvest index (%) was recorded with T_{11} (85kg P_2O_5 + 0kg S) treatment (14.54%). Experimental finding show that positive effect of sulphur along with phosphorus on yield of rapeseed. Application of phosphorus and sulphur, which were directly involved in better adsorption of applied nutrients and cell multiplication as well as expansion of deep green colour of leaves due to chlorophyll synthesis in comparison with plants deficient in phosphorus and sulphur. It also helps in better partitioning of photosynthative parts which increase the seed straw ratio.

Table 10 : Effect of phosphorus and sulphur nutrients on harvest index (%) of rapeseed different intervals

Treatments	Harvest index (%)
(T_1)-0kg P_2O_5 + 0kg S	18.52
(T_2)-0kg P_2O_5 + 35kg S	19.89
(T_3)-0kg P_2O_5 + 60kg S	17.52
(T_4)-35kg P_2O_5 + 0kg S	17.06
(T_5)-35kg P_2O_5 + 35kg S	17.97
(T_6)-35kg P_2O_5 + 60kg S	17.08
(T_7)-35kg P_2O_5 + 85kg S	16.54
(T_8)-60kg P_2O_5 + 0kg S	16.60
(T_9)-60kg P_2O_5 +35kg S	15.77
(T_{10})-60kg P_2O_5 +60kg S	16.13
(T_{11})-85kg P_2O_5 + 0kg S	14.54
(T_{12})-85kg P_2O_5 + 35kg S	15.53
(T_{13})-85kg P_2O_5 + 60kg S	16.64
F- test	NS
S.E.±	8.356
C.D. (P = 0.05)	-

NS= Non-significant

Oil content (%):

The data on oil content (%) as influenced by treatment are presented in Table 11. Significant difference was observed due to treatment oil content (%) at different stages. Among the other treatments, the treatment with T_6 (35kg P_2O_5 + 60kg S) recorded highest oil content (%) (1.220 %). Lowest oil content (%) was recorded

Table 11 : Effect of phosphorus and sulphur nutrients on oil content (%) of rapeseed different intervals

Treatments	Oil content (%)
(T_1)-0kg P_2O_5 + 0kg S	1.002
(T_2)-0kg P_2O_5 + 35kg S	1.034
(T_3)-0kg P_2O_5 + 60kg S	1.194
(T_4)-35kg P_2O_5 + 0kg S	1.181
(T_5)-35kg P_2O_5 + 35kg S	1.220
(T_6)-35kg P_2O_5 + 60kg S	1.192
(T_7)-35kg P_2O_5 + 85kg S	1.189
(T_8)-60kg P_2O_5 + 0kg S	1.048
(T_9)-60kg P_2O_5 +35kg S	1.182
(T_{10})-60kg P_2O_5 +60kg S	1.200
(T_{11})-85kg P_2O_5 + 0kg S	1.189
(T_{12})-85kg P_2O_5 + 35kg S	1.150
(T_{13})-85kg P_2O_5 + 60kg S	1.134
F- test	S
S.E. ±	0.030
C.D. (P = 0.05)	0.062

S=Significant

with T_1 treatment (1.002 %).

Economics:

Observations regarding the economics are given in the Table 12. Highest gross return (Rs.78430.00), net return (Rs. 43439) and benefit-cost ratio (2.24) were observed in treatment T_{13} 85kg P_2O_5 + 60kg S compared with other treatment combinations. The economic analysis shows the potential promise of mustard cultivation.

Conclusion :

The required quantity of phosphorus and sulphur nutrients and then dried in shade. Indian Rapeseed variety toria was grown with 80 kg N, 60 kg P and 40 kg K/ha basal. The total rainfall received during the growth season was 6.22 mm in 2016-2017. Crop-growth rate was recorded at different growth stages of plant growth. It may be concluded that amongst the treatments T_{13} (85 kg P_2O_5 + 60 kg S) in combination with seed treatment, was found to be the best for obtaining highest seed yield 1.96 (t ha^{-1}) and benefit cost ratio 2.24 in Rapeseed. Since the findings are based on the research done in one season it may be

Table 12: Cost of different agronomic practices done in mustard during the spring season 2016-17

Particulars	Unit	Qty.	Rate/unit (Rs. ha^{-1})	Cost (Rs. ha^{-1})
Land preparation				
Ploughing	Hours	3	500	1,500
Disc harrowing and leveling	Hours	3	500	1,500
Layout of the field and sowing of seeds	Labour	15	165	2,475
Seed sowing				
Seed	kg	7	160	1,120
Inter-culture				
Hand weeding	Labour	18	165	2,970
Nutrients				
Urea	kg	173.91	15	2,608.65
SSP	kg	375.00	30	11,250.00
MOP	kg	66.66	20	1,333.20
Harvesting				
Harvesting	Labour	25	165	4,125
Plant protection				
Monocrotophos	Litre	0.75	600	450
Rental value of land	Months	4	600	2,400
Supervision charges	Months	4	800	3,200
Total cost of cultivation (Rs.ha^{-1})				34,931

Table 13 : Economics of different treatments combinations of seed treatment and its effect of mustard sale price of mustard 35000 ha^{-1} sale price of straw 1000 ha^{-1}

Treatments	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})	Sale rate		Gross return (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C
			Seed (Rs. h^{-1})	Straw (Rs. h^{-1})				
(T_1)-0kg P_2O_5 + 0kg S	1.40	6.21	49000	6210	55210	34931	20279	1.58
(T_2)-0kg P_2O_5 + 35kg S	1.01	5.72	35350	5720	59270	34931	24339	1.69
(T_3)-0kg P_2O_5 + 60kg S	1.33	6.28	46550	6280	52830	34951	17879	1.51
(T_4)-35kg P_2O_5 + 0kg S	1.43	7.00	50050	7000	53830	34951	18879	1.54
(T_5)-35kg P_2O_5 + 35kg S	1.40	6.48	49000	6480	55480	34971	20509	1.58
(T_6)-35kg P_2O_5 + 60kg S	1.42	6.90	49700	6900	56600	34945	21655	1.61
(T_7)-35kg P_2O_5 + 85kg S	1.80	9.10	63000	9100	72100	34961	37139	2.06
(T_8)-60kg P_2O_5 + 0kg S	1.85	9.33	64750	9330	74080	34961	39119	2.11
(T_9)-60kg P_2O_5 +35kg S	1.60	8.53	56000	8530	64530	34981	29549	1.84
(T_{10})-60kg P_2O_5 +60kg S	1.59	8.36	55650	8360	64010	34981	29029	1.82
(T_{11})-85kg P_2O_5 + 0kg S	1.44	8.60	50400	8600	59000	35001	23999	1.68
(T_{12})-85kg P_2O_5 + 35kg S	1.52	8.23	53200	8230	61430	34975	26455	1.75
(T_{13})-85kg P_2O_5 + 60kg S	1.96	9.83	68600	9830	78430	34991	43439	2.24

repeated for confirmation (Table 13).

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