International Journal of Environment and Climate Change

Volume 13, Issue 11, Page 560-567, 2023; Article no.IJECC.107818
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Phenological and Metabolic Study of Mustard (*Brassica juncea* L. Czern. & Coss.) as Affected by Sulphur and Zinc Levels

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i113200

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/107818

Original Research Article

Received: 01/08/2023
Accepted: 06/10/2023
Published: 11/10/2023

ABSTRACT

The Field experiment was carried out during rabi season of 2021-22 and 2022-23 at Students Instructional Farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. The experiment consist of 14 treatments combinations in factorial randomized block design with three

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replications consisted of 7 fertility levels (including sulphur and zinc) and two varietal factors (i.e. Rohini & Maya). Mustard varieties Rohini & Maya were grown with the recommended agronomic practices. On the basis of results emanated from investigation it can be concluded that among the metabolic studies the maximum chlorophyll content at pre and post anthesis are 46.70 and 48.88 SPAD were recorded in the treatment T_{14} [Var. Maya with Sulphur @900 ppm] during the first year (2021-22). Maximum rate of photosynthesis at pre and post anthesis are 25.97 and 33.29 µmole m^{-2}/ s^{-1} respectively, during 1st years of experimentation were associated with the treatment T_{14} [Var. Maya with Sulphur @900 ppm]. Similarly during 2nd year of experimentation the maximum pre and post anthesis chlorophyll content (47.27 and 49.45 SPAD) and pre and post anthesis rate of photosynthesis (26.32 and 34.50 µmole m^{-2}/ s^{-1}) was found in the treatment T_{14} [Var. Maya with Sulphur @900 ppm]. Along with this, among the phenological studies minimum number of days taken to anthesis, number of days taken to 50 % flowering and number of days taken to maturity, was also found in the treatment T_{14} [Var. Maya with Sulphur @900 ppm].

Keywords: Mustard; zinc; sulphur; metabolic; yield.

1. INTRODUCTION

Rapeseed and mustard is one of the most important edible oil seed crops of India next to groundnut and soybean. India has 12-15 % of the world's area under oilseed but account for less than 6-7 % of world's production to meet the need of about 16 % of world population (FAO, 2011). India ranked third, both in terms of production and area under rapeseed and mustard in the world with 9.34 mt production and 6.23 m ha of area and having average productivity 1499 kg ha^{-1} [1]. Rajasthan having first position in terms of area and production accounting for 2.37 m ha & 4.08 mt followed by Uttar Pradesh with around 0.75 m ha & 1.12 mt out of the total rapeseed mustard area and production respectively. In UP Mathura district has the highest area, production and productivity which is 0.053 mha, 0.077 mt and 1453 kg ha^{-1} respectively [1].

The plant species *Brassica juncea,* also referred to as Indian mustard or brown mustard, is a member of the *Brassicaceae* family. It is a significant crop that is widely grown around the world for its seeds, leaves, and oil. Annual plants like *Brassica juncea* often reach heights of 1 to 2 metres (3 to 6 feet). It features upright stems with large, lobbed leaves with green to purplish undertones. India and Bangladesh are the two countries in South Asia where Brassica juncea is indigenous. Other places with favourable weather conditions, including as portions of Africa, Europe, North America, and Australia, are also where it is grown [2].

Rapeseed-mustard oil is regarded as a crucial component of the Indian diet and is used to make soap, flavour curries, cook vegetables, add flavour to hair oils, and preserve pickles. According to Panday et al. [3], mustard seed typically contains 33-39% oil, 17–25% proteins, 8-10% fibres, and 10-12% extractable compounds. The most common uses for green stem, leaves, and cake are as manure and animal feed. Young plant leaves are consumed as green vegetables because they provide enough sulphur and minerals for a vegetarian diet. Mustard oil is used in the tanning industry to soften leather (Singh et al., 2015).

The soils in Uttar Pradesh have been found to be deficient in micronutrients. The advent of high yielding crop varieties and intensive cropping systems has made the problem worse. Micronutrient deficits are predicted to worsen as nutrient demands for higher yields rise and plant needs for main nutrients are only partially satisfied. Farmers, extension agents, and researchers have all noted nutritional deficiencies in the soil of Uttar Pradesh. Poor vegetative development, flower and fruit drop, a low harvest index, and low seed production are all associated with a lack of the aforementioned micronutrients. The most important nutrients for the growth and development of oil seeds are sulphur and zinc [4].

After nitrogen, phosphorus, and potassium, sulphur is regarded as the fourth most crucial necessary ingredient for plant growth. Numerous physiological processes involving sulphur include the creation of cysteine, methionine, chlorophyll, and oil in oil seed crops. Sulphur helps legumes nodulation by fixing nitrogen from the atmosphere. It is crucial for the synthesis of chlorophyll. In the chain of fatty acids, it functions as a biological agent [5].

Sulphur is an essential secondary plant nutrient and fourth most important nutrient in crop production to increase quality and productivity of mustard next to N, P and K. It is an essential constituent of S-containing amino acids and helps in synthesis of cystine (27% S), cysteine (26% S) and methionine (21% S), as about 90% of sulphur is present in these amino acids [6]. Sulphur is an essential component in the formation of chlorophyll, a constituent of vitamins biotine and thiamine (B_1) and iron sulphur proteins called ferredoxins. It also plays a role in activation of various vitamins and enzymes, sulphydryl (SH) linkages, synthesis of oil and protein (Rathore et al. 2015).

2. METHODS AND MATERIALS

2.1 Experimental Site

The experiment was conducted during *rabi* season of 2021 and 2022 at student's Instructional farm, C.S.A. University of Agriculture and Technology, Kanpur Nagar (U.P.). The field was well leveled and irrigated by tube well. The farm is situated at main campus of the university, in the west northern part of Kanpur city under sub-tropical zone in v^{th} agroclimatic zone (central plain zone).

2.2 Edaphic Condition

The soil was moist, well drained with uniform plane topography. The soil of the experimental field was alluvial in origin, sandy loam in texture and slightly alkaline in reaction having pH 7.97 and 7.92 (1:2.5 soil: water suspension method given by Jackson, [7]), electrical conductivity 0.36 and 0.35 dSm^{-1}(1:2.5 soil: water suspension method given by Jackson, [7]), Organic carbon percentage in soil is 0.35 and 0.35 per cent (Walkley and Black's rapid titration method given by Walkley and Black, [8]), with available nitrogen 197.25 and 198.42 kg ha^{-1}(Alkaline permanganate method given by Subbiah and Asija, [9]), available phosphorus as sodium bicarbonate-extractable P was 12.14 and 12.21 kg ha^{-1}(Olsen's calorimetrically method**,** Olsen et al. [10]), available potassium was 265.15 and 266.68 kg ha^{-1} (Flame photometer method given by Hanwey and Heidel, [11], available sulphur was 7.8 and 8.0 kg ha^{-1} (Turbidimetric method given by Chesnin and Yein, 1950) and available zinc 0.542 and 0.546 ppm ha^{-1} (DTPA extraction method given by Lindsay and Norvell, 1978).

2.3 Detail of treatments and design

The 14 treatments combination of nutrient management practices having three each Zinc levels (500, 1000 and 1500 ppm) and Sulphur levels (300, 600, 900 ppm) along with two mustard varieties Rohini & Maya. Experiment was laid out in Factorial Randomized Block Design with three replications.

2.4 Crop Husbandry

A pre-sowing irrigation (Paleva) was done in the experimental field with an object to get optimum moisture conditions for attaining good germination. At proper tilth, one ploughing with tractor drawn mould bold plough was done followed by two ploughings by cultivator. Nitrogen @ 120 kg ha^{-1}, Phosphorous @ 60 kg ha^{-1} and potash @ 40 kg ha^{-1} applied uniformly through urea DAP and muriate of potash respectively. Zinc and Sulphur were sprayed before flowering as per treatment. The sowing of mustard crop was done using a seed rate of 5 kg ha^{-1} with spacing 45×15 cm spacing and 3-4 cm depth.

Table 1. Detail of the treatment combinations

S. No.	Treatment Details	Symbol
1.	Rohini + Control	V_1T_0
2.	Rohini + ZnSO4@ 500 ppm	V_1T_1
3.	Rohini + ZnSO4@ 1000 ppm	V_1T_2
4.	Rohini + ZnSO4@ 1500 ppm	V_1T_3
5.	Rohini + Sulphur@ 300 ppm	V_1T_4
6.	Rohini + Sulphur@ 600 ppm	V_1T_5
7.	Rohini + Sulphur@ 900 ppm	V_1T_6
8.	Maya + Control	V_2T_0
9.	Maya + ZnSO4@ 500 ppm	V_2T_1
10.	Maya + ZnSO4@ 1000 ppm	V_2T_2
11.	Maya + ZnSO4@ 1500 ppm	V_2T_3
12.	Maya + Sulphur@ 300 ppm	V_2T_4
13.	Maya + Sulphur@ 600 ppm	V_2T_5
14.	Maya + Sulphur@ 900 ppm	V_2T_6

Harvesting and threshing: The crop was harvested at maturity and was allowed to dry in sun. Separate bundles were made for each plot and weighted. The after drying harvest was threshed manually.

2.5 Chlorophyll Study (SPAD Value)

It was recorded by a hand-held device chlorophyll meter model: SPAD-502 PLUS (company Mantola) and taken at 30-35 (pre-flowering) and 90-95 (post- flowering) stages.

2.6 Photosynthetic Rate (µmole m^{-2}/ s^{-1})

Photosynthetic rate was measured at 30-35 (pre-flowering) and 90-95 (post- flowering) stages. The photosynthetic rate was measured using C1-301 CO_2. Gas analyzer CID, Inc.

2.7 Anthesis

Anthesis date was recorded from the date of sowing to first flower blooming.

2.8 Days to 50 % Flowering

Days to 50 % flowering date was recorded from the date of sowing to 50 % flowers originate in field.

2.9 Physiological Maturity

Physiological maturity date was recorded from the date of sowing to crop gets mature.

Statistical analysis: The growth parameters and yields were recorded and analyzed as per Gomez and Gomez (1984) the tested at 5% level of significance to interpret the significant differences.

3. RESULTS AND DISCUSSION

3.1 Metabolic Studies

A critical perusal of the data given in Table 2 clearly shows that among the metabolic study of mustard such as chlorophyll content and rate of photosynthesis significantly increase due to the application of Sulphur and Zinc. Chlorophyll content at pre anthesis varied from 42.58-46.99 SPAD and rate of photosynthesis at pre anthesis varied from 22.23-26.15 µmole m^{-2}/ s^{-1}, on pooled basis. Chlorophyll content at post anthesis varied from 42.62-49.17 SPAD and rate of photosynthesis at post anthesis varied from 24.54-33.90 µmole m^{-2}/ s^{-1}, on pooled basis. Maximum chlorophyll content at pre anthesis (47.27 SPAD) and post anthesis (49.45 SPAD) were associated with the treatment T_{14} [Maya with Sulphur @900 ppm] followed by T_{11} [Var. Maya with $ZnSO_4$ @1500] and T_7 [Var. Rohini with Sulphur @1500] during the second year (2022-23) of experimentation. Similarly maximum rate of photosynthesis at pre anthesis (26.32 µmole m^{-2}/ s^{-1}) and post anthesis (34.50 µmole m^{-2}/ s^{-1}) were associated with the treatment T_{14} [Maya with Sulphur @900 ppm] followed by T_{11} [Var. Maya with $ZnSo_4$ @1500] and T_7 [Var. Rohini with Sulphur @1500] during the second year (2022-23) of experimentation. Minimum chlorophyll content at pre anthesis (42.31 SPAD) and post anthesis (42.51 SPAD) were associated with the treatment T_1 [Rohini + Control] during the first year (2021-22) of experimentation. Similarly minimum rate of photosynthesis at pre anthesis (22.12 µmole m^{-2}/ s^{-1}) and post anthesis (24.22 µmole m^{-2}/ s^{-1}) were associated with the treatment T_1 [Rohini + Control] during the first year (2021-22) of experimentation. The interaction between sulphur and zinc levels on metabolic studies were not statistically significant. The consequences of the current investigation are additionally in concurrence with the investigation of Jahan et al. (2021), Lallawmzuali et al. [12] and Kaundal et al. [13].

3.2 Phenological Studies

At a glance over the data given in the Table 3 clearly shows that among the phenological studies of mustard such as no. of days to anthesis and no. of days at 50% flowering significantly increase due to the application of sulphur and zinc levels except no. of days to physiological maturity. The no. of days to anthesis, no. of days at 50 % flowering and no. of days to physiological maturity decreased to the magnitude of 50.2 to 41.3, 58.8 to 50.0 and 136.0 to 125.6 respectively, on pooled basis. Minimum no. of days to anthesis (41.1 days), no. of days at 50% flowering (49.8 days) and no. of days to physiological maturity (125.4 days) were associated with the treatment T_{14} [Maya with Sulphur @900 ppm] during the first year (2021-22) of experimentation. Maximum no. of days to anthesis (50.3 days), no. of days at 50 % flowering (59.0 days) and no. of days to physiological maturity (136.5 days) were found under the treatment T_1 [Rohini + Control] during the second year (2022-23) of experimentation. The interaction between sulphur and zinc levels on phenological studies were statistically significant except no. of days to physiological maturity. The results of the present investigation are also in agreement with the findings of Anjum et al. [14], Kumar et al. [15] and Geremew et al. [16,17,18,19,20].

Table 2. Effect of different treatment combinations on productivity parameters of mustard

Treatments	Chlorophyll content (SPAD value)					
	Pre anthesis			Post anthesis		
	2021-22	**2022-23**	**Pooled**	**2021-22**	**2022-23**	**Pooled**
T_1	42.31	42.85	42.58	42.51	42.73	42.62
T_2	43.01	43.62	43.32	43.22	43.54	43.38
T_3	43.85	44.36	44.11	45.12	45.61	45.37
T_4	45.43	45.98	45.71	47.23	47.82	47.53
T_5	43.05	43.61	43.33	43.75	44.35	44.05
T_6	44.25	44.78	44.52	45.55	45.96	45.76
T_7	45.76	46.42	46.09	47.91	48.4	48.16
T_8	42.45	42.91	42.68	42.63	43.21	42.92
T_9	43.21	43.88	43.55	44.2	44.68	44.44
T_{10}	44.63	45.27	44.95	45.96	46.49	46.23
T_{11}	46.52	47.16	46.84	48.49	48.85	48.67
T_{12}	43.54	44.1	43.82	44.63	45.12	44.88
T_{13}	44.9	45.52	45.21	46.65	47.21	46.93
T_{14}	46.7	47.27	46.99	48.88	49.45	49.17
S.Ed±	**0.964**	**1.207**	**0.983**	**1.098**	**1.014**	**1.021**
C.D. at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Where,

[T_1 = Rohini + control, T_2 = Rohini + $ZnSO_4$@ 500 ppm, T_3 = Rohini + $ZnSO_4$@ 1000 ppm, T_4 = Rohini + $ZnSO_4$@ 1500 ppm, T_5 = Rohini + Sulphur@ 300 ppm, T_6 = Rohini + Sulphur@ 600 ppm, T_7 = Rohini + Sulphur@ 900 ppm, T_8 = Maya + control, T_9 = Maya + $ZnSO_4$@ 500 ppm,T_{10} = Maya + $ZnSO_4$@ 1000 ppm, T_{11} = Maya + $ZnSO_4$@ 1500 ppm, T_{12} = Maya + Sulphur@ 300 ppm, T_{13} = Maya + Sulphur@ 600 ppm, T_{14} = Maya + Sulphur@ 900 ppm.]

Table 3. Effect of different treatment combinations on metabolic parameters of mustard

Treatments	Rate of photosynthesis (µmole m^{-2}/ s^{-1})					
	Pre anthesis			Post anthesis		
	2021-22	**2022-23**	**Pooled**	**2021-22**	**2022-23**	**pooled**
T_1	22.12	22.34	22.23	24.22	24.86	24.54
T_2	22.61	22.97	22.79	25.45	25.92	25.69
T_3	23.72	24.05	23.89	29.87	30.17	30.02
T_4	24.86	25.14	25.00	32.24	32.8	32.52
T_5	22.92	23.21	23.07	26.99	27.45	27.22
T_6	23.95	24.23	24.09	30.11	30.75	30.43
T_7	25.14	25.55	25.35	32.67	32.98	32.83
T_8	22.17	22.63	22.40	24.35	24.83	24.59
T_9	23.11	23.45	23.28	28.56	28.79	28.68
T_{10}	24.31	24.68	24.50	31.2	31.67	31.44
T_{11}	25.63	25.99	25.81	33.15	34.48	33.82
T_{12}	23.54	23.84	23.69	29.34	29.95	29.65
T_{13}	24.45	24.76	24.61	31.56	31.86	31.71
T_{14}	25.97	26.32	26.15	33.29	34.50	33.90
S.Ed±	**0.516**	**0.606**	**0.597**	**0.689**	**0.721**	**0.693**
C.D. at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Where,

[T_1 = Rohini + control, T_2 = Rohini + $ZnSO_4$@ 500 ppm, T_3 = Rohini + $ZnSO_4$@ 1000 ppm, T_4 = Rohini + $ZnSO_4$@ 1500 ppm, T_5 = Rohini + Sulphur@ 300 ppm, T_6 = Rohini + Sulphur@ 600 ppm, T_7 = Rohini + Sulphur@ 900 ppm, T_8 = Maya + control, T_9 = Maya + $ZnSO_4$@ 500 ppm,T_{10} = Maya + $ZnSO_4$@ 1000 ppm, T_{11} = Maya + $ZnSO_4$@ 1500 ppm, T_{12} = Maya + Sulphur@ 300 ppm, T_{13} = Maya + Sulphur@ 600 ppm, T_{14} = Maya + Sulphur@ 900 ppm.]

Table 4. Effect of different treatment combinations on phenological studies of mustard

Treatments	Number of days taken to anthesis			Number of days taken to 50 % flowering			Number of days taken to maturity		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	50.1	50.3	50.2	58.5	59.0	58.8	135.4	136.5	136.0
T_2	45.4	45.9	45.7	53.3	53.8	53.6	128.4	128.8	128.6
T_3	41.5	41.8	41.7	50.1	50.5	50.3	125.5	130.2	127.9
T_4	48.5	49.1	48.8	56.7	57.4	57.1	133.5	134.2	133.9
T_5	49.8	50.3	50.1	58.2	58.7	58.5	135.1	135.9	135.5
T_6	49.2	49.7	49.5	57.5	57.8	57.7	134.6	135.2	134.9
T_7	46.1	46.6	46.4	53.9	54.3	54.1	130.6	131.3	131.0
T_8	47.7	48.2	48.0	56.1	56.6	56.4	132.2	132.7	132.5
T_9	47.3	47.9	47.6	55.4	56.1	55.8	131.9	132.4	132.2
T_{10}	46.6	47.2	46.9	54.3	54.9	54.6	131.3	131.6	131.5
T_{11}	42.5	42.9	42.7	51.2	51.5	51.4	126.8	127.1	127.0
T_{12}	44.8	45.3	45.1	52.6	52.5	52.6	127.6	128.3	128.0
T_{13}	43.4	43.8	43.6	51.8	52.1	52.0	127.2	127.9	127.6
T_{14}	41.1	41.5	41.3	49.8	50.2	50.0	125.4	125.8	125.6
S.Ed±	0.726	0.694	0.793	1.019	1.134	1.222	2.874	3.195	2.842
C.D. at 5 %	2.123	2.029	2.319	2.980	3.315	3.572	NS	NS	NS

Where,

[T_1 = Rohini + control, T_2 = Rohini + $ZnSO_4$@ 500 ppm, T_3 = Rohini + $ZnSO_4$@ 1000 ppm, T_4 = Rohini + $ZnSO_4$@ 1500 ppm, T_5 = Rohini + Sulphur@ 300 ppm, T_6 = Rohini + Sulphur@ 600 ppm, T_7 = Rohini + Sulphur@ 900 ppm, T_8 = Maya + control, T_9 = Maya + $ZnSO_4$@ 500 ppm,T_{10} = Maya + $ZnSO_4$@ 1000 ppm, T_{11} = Maya + $ZnSO_4$@ 1500 ppm, T_{12} = Maya + Sulphur@ 300 ppm, T_{13} = Maya + Sulphur@ 600 ppm, T_{14} = Maya + Sulphur@ 900 ppm.]

4. CONCLUSION

The current study demonstrate the benefit of Zinc and Sulphur with recommended N, P and K for achieving higher chlorophyll content and rate of photosynthesis by mustard crop. Application of Zinc and Sulphur decreased no. of days to anthesis, 50 % flowering and physiological maturity of mustard crop. Finally it can be concluded application of sulphur and zinc improves chlorophyll content and rate of photosynthesis and reduces no. of days to anthesis, 50 % flowering and physiological maturity of mustard crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/107818