Phenological and Metabolic study of mustard (*Brassica juncea* L. Czern.& Coss.) as affected by sulphur and zinc levels

Abstract

Field experiments were conductedduring rabi season of 2021 and 2022 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 replications consisted of ~~consisted of~~7 fertility levels (including sulphur and zinc) and two varietal factors (i.e. Rohini & Maya). Mustard varietiesRohini & 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 is 46.70 and 48.88days were recorded in the treatment T_{14} [Var. Maya with Sulphur @900 ppm] during the first year (2021-22). Maximum rate of photosynthesis is 25.97 and 33.29µmole m^{-2}/ s^{-1}during1st years of experimentation are associated with the treatment T_{14}[Var. Maya with Sulphur @900 ppm].Similarly during 2nd year of experimentation the maximum chlorophyll content (47.27 and 49.45)and rate of photosynthesis (26.32 and 34.50µmole 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].

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Key Words: Mustard, Zinc, Sulphur, Metabolic and Yield.

Introduction

Oilseed crops are the second most significant factor affecting the agricultural economy, only after cereals. Oilseed self-sufficiency achieved during the "Yellow Revolution" in the early 1990s could only lasted for a little time. India is currently one of the biggest importers of vegetable oils while producing the fifth-largest amount of oilseed crops worldwide. Vegetable oil utilisation has increased significantly in recent years for both industrial and consumable purposes. Due to a severe supply-demand imbalance for edible oils, 60 % of the nation's needs were met by massive imports in 2016–17 (14.01 million tonnes at a cost of Rs. 73,048 crore). **(NFSM, 2018)**

Although domestic oilseed production of the nine annual crops performed admirably (Compound Annual Growth Rate of 3.89 %), it was unable to keep up with the 6 % growth in per capita demand because of increased per capita consumption of oil (18 kg per year), which was fuelled by population growth and rising per capita income. Soybean, groundnut, rapeseed-mustard, sesame, sunflower, castor, safflower, linseed, and Nigeria are some of the most cultivated oil seed crops worldwide. The average contribution of the nine oilseed crops grown in India to total oilseed output is dominated by the soybean (38 %), followed by rapeseed-mustard (27 %), and groundnut (27%). Similar to how soybeans make up the largest average percentage of the total oilseed area, it is followed by rapeseed-mustard (24 %) and groundnut (20 %). On average, the proportion of all Kharif oilseed crops to total production is roughly 67 % and the remaining 33 % is of Rabi/Summer oil seed crops.

India's population is constantly growing by 2025, and 2030, it is predicted to reach 1.42 and 1.48 billion. Similar to this, the level of living is rising, leading to increase per capita use of edible oil. Between 2011 and 2030, the demand for edible oil would increase by 3.54 % year. Accordingly, it is predicted that from its current level of 16.38 kg per year, the per capita consumption of edible oil would increase to 23.1 kg per year per person by the year 2030. Therefore, 34.10 mt of edible oil, or roughly mt of oilseeds, would be needed to achieve self-sufficiency in edible oil **(DRMR, 2011)**.

During the 2018–19 growing season, the estimated global rapeseed-mustard area, production, and yield were 36.59 million hectares (mha), 72.37 million tonnes (mt), and 1980 kg ha^{-1}, respectively. In terms of overall area and production worldwide, India accounts for 19.8 % and 9.8 %, respectively (USDA). The productivity has improved significantly over the past eight years, going from 1840 kg ha^{-1} in 2010-11 to 1980 kg ha^{-1} in 2018–19, and the production has gone up as well, going from 61.64 mt in 2010-11 to 72.42 mt in 2018-19. In India, rapeseed-mustard crops are cultivated in a variety of agroclimatic conditions, including irrigated/rainfed, timely/late sown, saline soils, and mixed cropping. These conditions range from north-eastern/north-western hills to down south. Around 75-80 % of the 6.23 million acres of these crops were planted with Indian mustard during the 2018-19 growing season **(DRMR, Bharatpur)**.

With 9.34 mt of production, 6.23 m ha of area, and an average productivity of 1499 kg ha^{-1}, India came in third place overall for rapeseed and mustard production and area **(Directorate of Economics and Statistics, 2020-21 (DAC&FW))**. In terms of area and production, Rajasthan ranks top with 2.37 million hectares and 4.08 million tonnes, respectively, followed by Uttar Pradesh with about 0.75 million hectares and 1.12 million tonnes. The maximum acreage, production, and productivity in UP are found in the Mathura district, with respective values of 0.053 mha, 0.077 mt, and 1453 kg ha^{-1}. **(DAC&FW, 2020-21) (Directorate of Economics and Statistics)**.

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 **(Rai *et al.*, 2022).**

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.* (2013),** 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**(Shukla *et al.*, 2018).**

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 **(Patil, 2011)**.

Sulphur is an essential secondary plant nutrient and fourth most importantnutrient 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 **(Havlin *et al*., 2013).** 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).**It is also a component of glucosinolate and glycosidase enzyme, which are the source of aroma and pungency in mustard oil. Compared to other crops mustard is more responsive to sulphur. Therefore, adequate sulphur availability is very crucial for its productivity. Studies have confirmed that sulphur fertilizer increases the growth, yield and quality of Indian mustard **(Singh *et al*., 2015; Piri *et al*., 2011).** Application of sulphur has a significant effect on oil, fatty acids and glucosinate content in mustard seeds **(Falk *et al*., 2007).** Sulphur application also has marked effect on soil properties and is used as soil amendment to improve the availability of other nutrients in soil.

Method and Materials

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).

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, 1973**), electrical conductivity 0.36 and 0.35 dSm^{-1}(1:2.5 soil: water suspension method given by **Jackson, 1973**), 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, 1934**), with available nitrogen 197.25 and 198.42 kg ha^{-1}(Alkaline permanganate method given by **Subbiah and Asija, 1956**), available phosphorus as sodium bicarbonate-extractable P was 12.14 and 12.21 kg ha^{-1}(Olsen's calorimetrically method**, Olsen *et al.*, 1954**), available potassium was 265.15 and 266.68 kg ha^{-1} (Flame photometer method given by **Hanwey and Heidel, 1952**), 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).

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.

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

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} withspacing45×15 cm spacing and 3-4 cm depth.

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.

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.

Photosynthetic rate

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.

Anthesis

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

Days to 50 % flowering

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

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.

Result and Discussion

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 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 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) andpost anthesis (49.45) 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 (26.32µmole m^{-2}/ s^{-1}) andpost anthesis (34.50µmole 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. Minimumchlorophyll content at pre anthesis (42.31) andpost anthesis (42.51) 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 (22.12µmole m^{-2}/ s^{-1}) andpost anthesis (24.22µmole 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 zinclevels 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.*, (2022)andKaundal *et al.*, (2023)**

Table-2: Effect of different treatment combinations on productivity parameters of mustard

Treatments	Chlorophyll content					
	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**

Table-3: Effect of different treatment combinations on metabolic parameters of mustard

Treatments	Rate of photosynthesis					
	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**

Phenological studies

At a glance over the data given in the Table-3 and depicted in Fig.-1 clearly shows that among the phenological studies of mustard such as no. of days to anthesisand 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 maturitydecreased 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) werefound under the treatment T_1 [Rohini + Control] during the second year (2022-23) of experimentation. The interaction between sulphur and zinclevels 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.*, (2017)**, **Kumar *et al.*, (2021)andGeremew *et al.*, (2023)**

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

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 maturityof 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 maturityof mustard crop.

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