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Effect of Elevated Temperatures on Growth and Yield of Mustard Cultivars at Varied Crop Geometry

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Authors' contributions

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

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ABSTRACT

A field experiment was conducted in sandy clay loam soil of Agriculture College, RVSKVV, Gwalior during rabi season 2021-22. The experiment was conducted in a two way factor anova comprising of five elevated/ambient temperature viz., ambient in OTC, ambient+1ºC, ambient+1.5ºC, ambient+2ºC, Open field (control) and two mustard cultivars at varied crop geometry i.e., RVM2 (45x10cm & 25x20cm) and Giriraj (45x10cm & 25x20cm). The experiment was replicated three times. Results revealed that significantly higher plant height (cm), no. of leaves per plant, root length (cm), no. of branches, no. of siliqua per plant, no. of seed per siliqua, length of siliqua (cm), 1000 seed weight (g), total biomass (q/ha), seed yield (q/ha) and harvest index (%) was obtained at ambient +1ºC which were significantly superior over rest of the ambient temperature and open field control conditions. Maximum number of plant height (cm), no. of branches, no. of siliqua per plant, no. of seed per siliqua, length of siliqua (cm), 1000 seed weight (g), total biomass (q/ha) and seed

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yield (q/ha) was recorded with Giriraj (45x10 cm) mustard cultivar except no. of leaves per plant, root length (cm) and harvest index (%), respectively.

Keywords: Sandy clay loam; ambient temperature; RVM2; Giriraj; Open Field Top Chamber (OTC).

1. INTRODUCTION

The Brassicaceae, contains about 3500 species and 350 genera, is one of the 10 most economically important plant families. It is distinguished on the basis of the presence of Conduplicate cotyledons (i.e. the cotyledons are longitudinally folded around the radical) and/ or two-segmented fruits (siliquae), which contain seeds in one or both segments, and only simple hairs, if present. Crop brassicas include a wide variety of plants that are grown as vegetables, fodder, or as a source of oil and spices. There has been a huge expansion in the area of oilseeds in Rajasthan, Madhya Pradesh and Chhattisgarh. Rapeseed & Mustard contributed maximum in increasing oilseeds area during this *Rabi* season. Mustard area increased by 6.77 lakh hectares from 91.25 lakh hectares in 2021-22 to 98.02 lakh hectares in 2022-23. Thus, out of 7.49 lakh hectares increase in area under oilseeds, rapeseed & mustard alone accounted for 6.44 lakh hectares. The area brought under rapeseed and mustard cultivation is 54.51% more than the normal sown area of 63.46 lakh hectares. Mustard area in Madhya Pradesh is 1.23 million ha which is about 5.5% of the total net sown area. The production is 1.69 million tones with yield of 1376 kg/ha [1]. In India consumption of mustard seed and oil is generally high in northern mustardoil. The seed and oil both are used as a condiment in the preparation of various pickles and flavoring the curries and vegetables. The oilcake is mostly used as a cattle feed and manure. The leaves of the mustard plants are used vegetable food. Furthermore both the seeds and leaves traditionally have been used for medicinal purpose. Mustard crops are important for the Indian economy, since India imports large quantities of edible oil despite having the largest area of cultivated oil seeds in the world. In recent past the country has grown to become one of the major vegetable oil importers and due to a decline in oil seeds production and a study fall in international prices. China, India and Japan are considered as net importers in the international mustard oil trade [2].

Annual mean temperature in India has increased by about 1.2°C since the beginning of the 20th century and the year 2016 registered the highest annual mean temperature at 25.1°C in the winter of 2016- 17, the mean temperature was 2.95°C higher than the baselines likely to directly impact food production across the globe. Increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce final yield. In areas where temperatures are already close to the physiological maxima for crops, warming will impact yields [3]. Indian mustard (*Brassica juncea* L.) accounts for nearly 80% of the area under these crops in the country. This crop grows under diverse agro ecological situations such as timely / late sown, rainfed / irrigated, sole & mixed crop with cereals (wheat, barley etc.) and *rabi* (October-April) pulses (chickpea, lentil etc.). Hall [4] reported that flowering is the most sensitive stage for temperature stress damage probably due to vulnerability during pollen development, anthesis and fertilization leading to reduce crop yield. High temperature in Brassica enhanced plant development and caused flower abortion with appreciable loss in seed yield [5]. Flowering duration had a strong influence on seed yield and a rise of 30ºC in maximum daily temperature (21-24ºC) during flowering caused a decline of 430 kg/ha in canola seed yield [6]. Due to its hardy nature and capacity to thrive well under poor conditions of fertility and moisture, it is generally raised as rainfed crop due to which its average yield is low. Mustard is the crop of tropical as well as temperate zone. The temperature requirement varies from 0.5-3.0ºC (min.) to 35-40ºC (max.) with an optimum of temperature regime of 20-35ºC. Cool temperature, dry weather with good amount of bright sunshine increases the oil yield. Cool temperature, dry weather with good amount of bright sunshine increases the oil yield. Mustard needs high temperature for vegetative growth (20ºC-32ºC) and cool temperature with clear sky during reproductive growth and maturity.

Optimum planting geometry and selection of improved cultivars play an important role in crop production. Optimum plant stand leads to proper growth and development and hence better productivity. Dense population/ narrow spacing leads to poor plant stand and greater competition for available growth resources like light, space, nutrient. Suboptimal plant stand/wider spacing lead to better performance of individual plant, while yield per unit area decreased. Different cultivars respond variability under different weather condition.

Production potentiality of Indian mustard can be fully exploited under these conditions with suitable agronomic practices and varieties. The major mustard growing district in Madhya Pradesh is Bhind, Morena, Shivpuri, Gwalior, Neemuch and Mandla. In Bhind district the mustard crop covers ofaverage 180546 thousand hectare area and 175.5 thousand tones production and it shares 24 percent area and 27 percent production of mustard in Madhya Pradesh [2]. Since Madhya Pradesh has large area under mustard so the present investigation is an attempt to analyze the effects of high temperature on seed yield, and growth parameters of mustard cultivars under elevated temperature.

2. MATERIALS AND METHODS

The experiment was carried out in open top chambers established in the department of environmental sciences at College of Agriculture, Gwalior during *rabi* season of 2021-22 having uniform topography and adequate drainage conditions. The Open top chambers (OTCs) were setup in order to examine the effect of elevated temperature on growth and yield of mustard cultivars, where the basic metal frame fitted in the field are covered by PVC (polyvinyl chloride) sheet to allow maximum natural light was open at the top. Gwalior is situated in Gird zone at the latitude of 26’13’ North and longitude 76’14’ East with an altitude of 211.52 meters from above mean sea level, in the Madhya Pradesh, India. The region comes under semi-arid sub-tropical climate with extreme weather conditions with hot and dry summer and cold winter which is also affected due to undergoing climate change pattern. Generally, monsoon sets in during the last week of June to the first week of July. Annual rainfall ranges from 700 to 800 mm, most of which falls during last June to the first fortnight of September. The maximum temperature goes up to 45-46°C during summer and minimum as low at3.8°C during winter.

Open top chambers (OTC) are built with high quality multilayered UV protected 90% light transparent polycarbonate sheet 4-5 mm thickness and galvanized iron and hi-grade aluminum channel, circular type structure with top side of the chamber partially open for the experimental purpose. These chambers are designed for carbon di-oxide (CO_2), ozone (O_3) and the temperature elevation facilities. It is also integrated with meteorological parameter, soil sensors, wireless communication and web based (GPRS) SCADA technology.

OTC Diameter: Top height: 3.5 mtr, diameter 4.5 mtr, cylindrical shape, area: 15 m^2. Height adjustable IR heater, Sensor box, Agitating Fans 4 nos integration.

Environmental control inside the experimental chambers: The elevated temperature inside the chamber was maintained during experimental period.

Temperature control and monitoring: The equipment for monitoring and controlling the levels of temperature in OTC’s was fully automated and desired levels of ambient temperature, ambient +1°C, ambient+1.5°C, ambient+2°C was maintained throughout the experiment period in the OTC with the help of infrared heaters.

Relative humidity control: The RH inside the chambers was calculated through thermos-hygrometer. The maximum achievable relative humidity was 99 per cent.

The present experiment four open top chambers and one control plot were selected having the diameter of 4.7 m at the research farm of Department of Environmental sciences, Climate change project unit, College of Agriculture, Gwalior. The two mustard cultivars at varied crop geometry i.e., RVM2 (45x10cm & 25x20cm) and Giriraj (45x10cm & 25x20cm) were grown in the chambers as well as in the natural conditions. First open top chamber was maintained with ambient temperature, 2nd with ambient + 1ºC, 3rd with ambient + 1.5ºC, 4th with ambient + 2ºC for the present study. Temperature was maintained in all the chambers with the help of infrared heaters having automation system in order to maintain the level of temperature under the research work. Two plots in each OTC of 2 m2 areas were laid out and in each 2 m^2 area there were 3 replications having 8 plants of Brassica cultivars in each. The plants were tagged for sampling from each plot and each chamber. The plant growth observations were recorded at harvest stages. Plants were marked and tagged for data. The yield was measured at harvesting stage and all plants from each plot of 2 m^2 area were harvested to record yield. The data were statistically analyzed using two way factor analysis with replication to test the significance of elevated temperature at 1% and 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Growth & Yield Parameters at Harvest

Data pertaining to plant height, no. of leaves per plant (cm), root length (cm), no. of branches, no. of siliqua/plant, no. of seed / siliqua, length of siliqua (cm), 1000 seed weight (g), total biomass (q/ha), seed yield (q/ha) and harvest index (%) as affected by ambient/elevated temperature and mustard cultivars have been presented in Table 1.

The elevated temperature level with ambient+1ºC (189.93 cm) attained significantly higher values of plant height at harvest stage. The ambient+2ºC recorded the significant reduction in the values of plant height of mustard cultivars compared to ambient/elevated temperature and control plot conditions. The elevated temperature level with ambient+1ºC (15.10) attained significantly maximum values of no. of leaves per plant at harvest stage. The ambient+2ºC recorded the significant reduction in the values of no. of leaves per plant of mustard cultivars compared to ambient/elevated temperature and control plot conditions. The elevated temperature level with ambient+1ºC (18.38 cm) attained significantly highest values of root length at harvest stage. The ambient+2ºC recorded the significant reduction in the values of root length of mustard cultivars compared to ambient/elevated temperature and control plot conditions. The elevated temperature level with ambient+1ºC (23.53) attained significantly higher values of no. of branches. The ambient + 2ºC recorded the significant reduction in the values of no. of branches of mustard cultivars compared to ambient/elevated temperature and control plot conditions. The elevated temperature level with ambient+1ºC (160.88 siliqua/plant) attained significantly higher values of no. of siliqua per plant. The ambient+2ºC recorded (150.68 siliqua/plant) the significant reduction in the values of no. of siliqua per plant of mustard cultivars compared to ambient/elevated temperature conditions and control plot. The elevated temperature level with ambient + 1ºC (5.53 cm) attained significantly higher values of length of siliqua. The ambient+2ºC recorded (4.25 cm) thesignificant reduction in the values of length of siliqua of mustard cultivars compared to ambient/elevated temperature conditions and control plot. The elevated temperature level with ambient+1ºC (5.74 g) attained significantly higher values of 1000 seed weight. The ambient+2ºC recorded (4.25 g) the significant reduction in the values of 1000 seed weight of mustard cultivars compared to ambient/elevated temperature conditions and control plot. The elevated temperature level with ambient+1ºC (212.20 q/ha) attained significantly higher values of total biomass. The ambient+2ºC recorded (193.35 q/ha) the significant reduction in the values of total biomass of mustard cultivars compared to ambient/elevated temperature conditions and control plot. The elevated temperature level with ambient+1ºC (23.47 q/ha) attained significantly higher values of seed yield. The ambient+2ºC recorded (20.45 q/ha) the significant reduction in the values of seed yield of mustard cultivars compared to ambient/elevated temperature conditions and control plot. The elevated temperature level with ambient+1ºC (11.05%) attained significantly higher values of harvest index at harvest stage. The ambient+2ºC recorded (10.58%) the significant reduction in the values of harvest index of mustard cultivars compared to ambient/elevated temperature conditions and control plot. These results are also in conformity with the findings of Angadi *et al.* [7],Srinivasa *et al.* [8] and Dhanuja *et al.* [9].

The mustard cultivars at varied crop geometry (RVM2 and Giriraj) also exhibited significant differences on the growth and yield attributes at harvest stages. The mustard cultivars Giriraj (45x10 cm) performed best and highest values (190.18 cm) of plant height under all mustard cultivars at varied crop geometry at harvest stage. A perusal of data showed that no. of leaves per plant and root length was non-significant due to the mustard cultivars at varied crop geometry under harvest stages. The mustard cultivars Giriraj (45x10 cm) performed best and highest values (23.22) of no. of branches under all mustard cultivars at varied crop geometry. The mustard cultivars Giriraj (45x10 cm) performed best and highest values (155.88 siliqua/plant) of no. of siliqua per plant under all mustard cultivars at varied crop geometry. The mustard cultivars Giriraj (45x10 cm) performed best and highest values (5.08 cm) of length of siliqua under all mustard cultivars at varied crop geometry. The mustard cultivars Giriraj (45x10 cm) performed best and highest values (5.19 g) of 1000 seed weight under all mustard cultivars at varied crop geometry. The mustard cultivars Giriraj (45x10 cm) performed best and highest values (201.82 q/ha) of total biomass under all mustardcultivars at varied crop geometry. The mustard cultivars Giriraj (45x10 cm) performed best and highest values (22.12 q/ha) of seed yield under all mustard cultivars at varied crop geometry. A perusal of data showed that harvest index percentage was non-significant due to the mustard cultivars at varied crop geometry. Similar results were also observed by Saini et al. [10], Angadi et al. [7], Srinivasa et al. [8] and Dhanuja et al. [9].

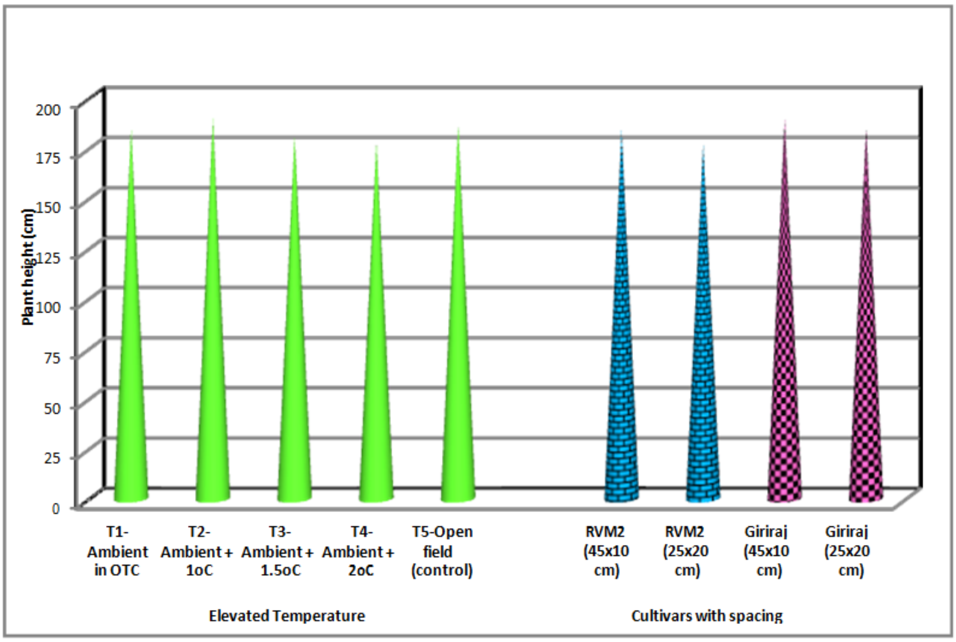

Fig. 1. Plant height (cm) of mustard cultivars varied crop geometry as influenced by elevated temperature at harvest stages

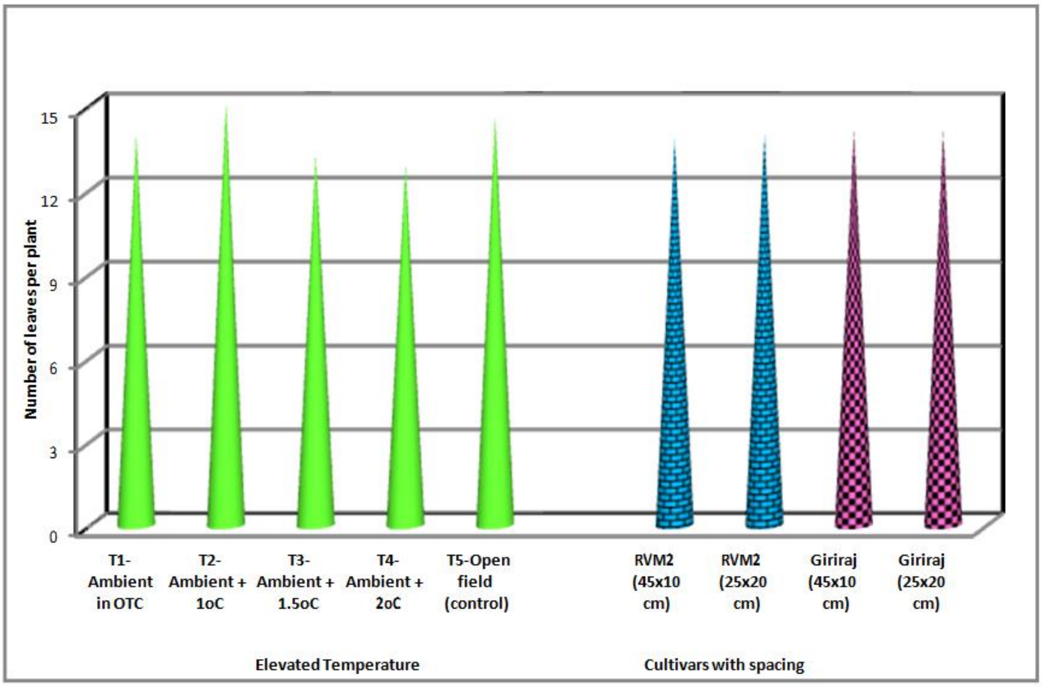

Fig. 2. Number of leaves per plant of mustard cultivars varied crop geometry as influenced by elevated temperature at harvest stages

Table 1. Growth parameters and yield attributes and seed yield of mustard cultivars varied crop geometry as influenced by elevatedtemperature (at harvest stages)

Elevated Temperature	Plant height (cm)	No. of leaves / plant	Root length (cm)	No. of branches	No. siliqua /plant	No. of seed/ siliqua	Length of siliqua (cm)	1000 seed weight (g)	Total biomass (q/ha)	Seed yield (q/ha)	Harvest index (%)
T1-Ambient in OTC	185.09	13.98	17.25	21.90	154.33	16.10	4.58	4.99	197.45	21.58	10.94
T2-Ambient + 1ºC	189.93	15.10	18.38	23.53	160.88	18.58	5.53	5.74	212.20	23.47	11.05
T3-Ambient + 1.5ºC	181.11	13.23	16.98	20.63	152.30	16.05	4.45	4.94	194.05	21.19	10.92
T4-Ambient + 2ºC	178.22	12.90	16.25	20.58	150.88	15.68	4.25	4.92	193.35	20.45	10.58
T5-Open field (control)	186.72	14.58	17.63	22.53	154.33	17.63	5.40	4.99	198.23	22.01	11.10
S.E.(m)+	**1.142**	**0.109**	**0.155**	**0.145**	**0.322**	**0.166**	**0.063**	**0.018**	**1.150**	**0.207**	**0.114**
CD (at 0.05%)	**3.270**	**0.312**	**0.443**	**0.414**	**0.921**	**0.475**	**0.181**	**0.052**	**3.292**	**0.593**	**0.326**
Cultivars with spacing											
RVM2 (45x10 cm)	184.28	13.76	17.28	21.02	153.84	16.46	4.82	5.07	196.02	21.44	10.93
RVM2 (25x20 cm)	177.01	13.96	17.18	22.40	153.32	16.38	4.56	5.09	197.08	21.47	10.89
Giriraj (45x10 cm)	190.18	14.06	17.46	23.22	155.88	17.74	5.08	5.19	201.82	22.12	10.96
Giriraj (25x20 cm)	185.38	14.04	17.26	20.68	155.12	16.64	4.90	5.11	201.30	21.92	10.89
S.E.(m)+	**1.022**	**0.097**	**0.138**	**0.129**	**0.288**	**0.148**	**0.057**	**0.016**	**1.028**	**0.185**	**0.102**
CD (at 0.05%)	**2.925**	**NS**	**NS**	**0.370**	**0.823**	**0.425**	**0.162**	**0.046**	**2.945**	**0.530**	**NS**

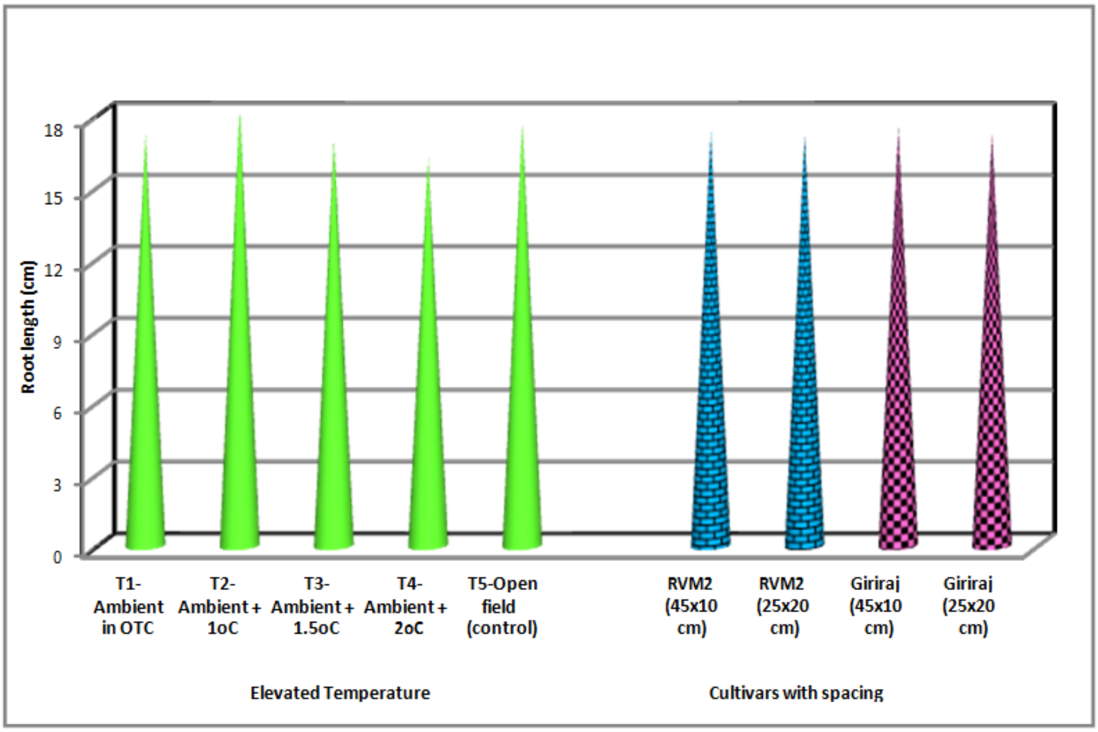

Fig. 3. Root length (cm) of mustard cultivars varied crop geometry as influenced by elevated temperature at harvest stages

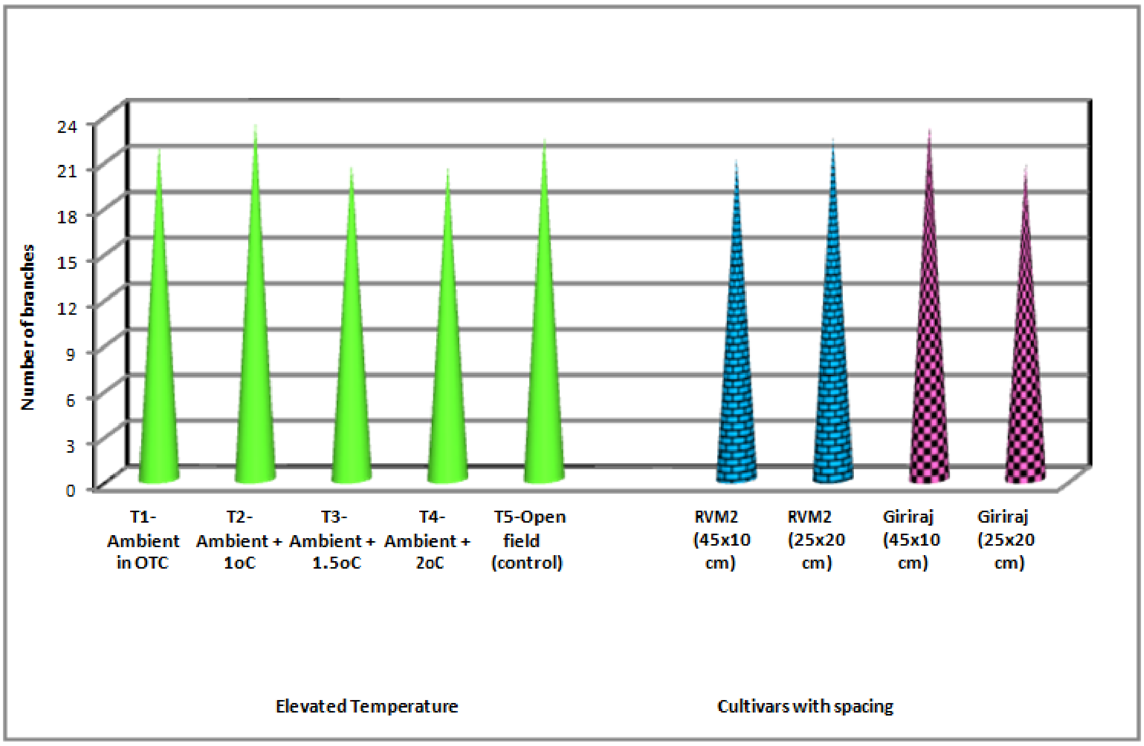

Fig. 4. Number of branches of mustard cultivars varied crop geometry as influenced by elevated temperature at harvest stages

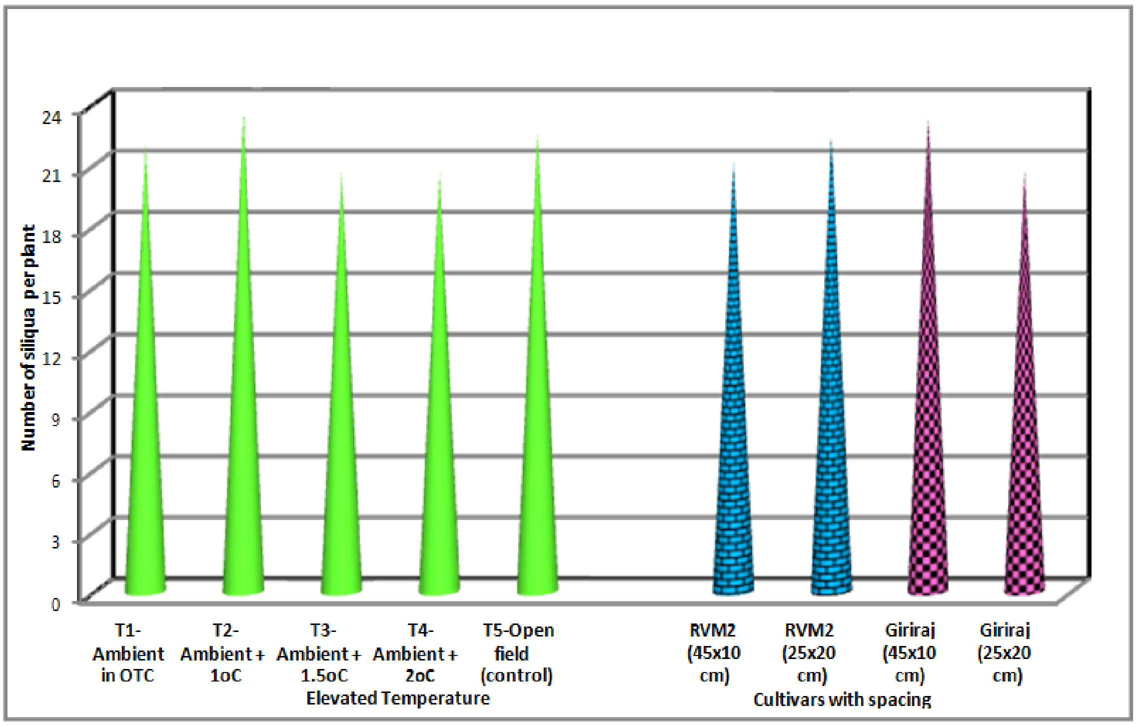

Fig. 5. Number of siliqua per plant of mustard cultivars varied crop geometry as influenced by elevated temperature at harvest stages

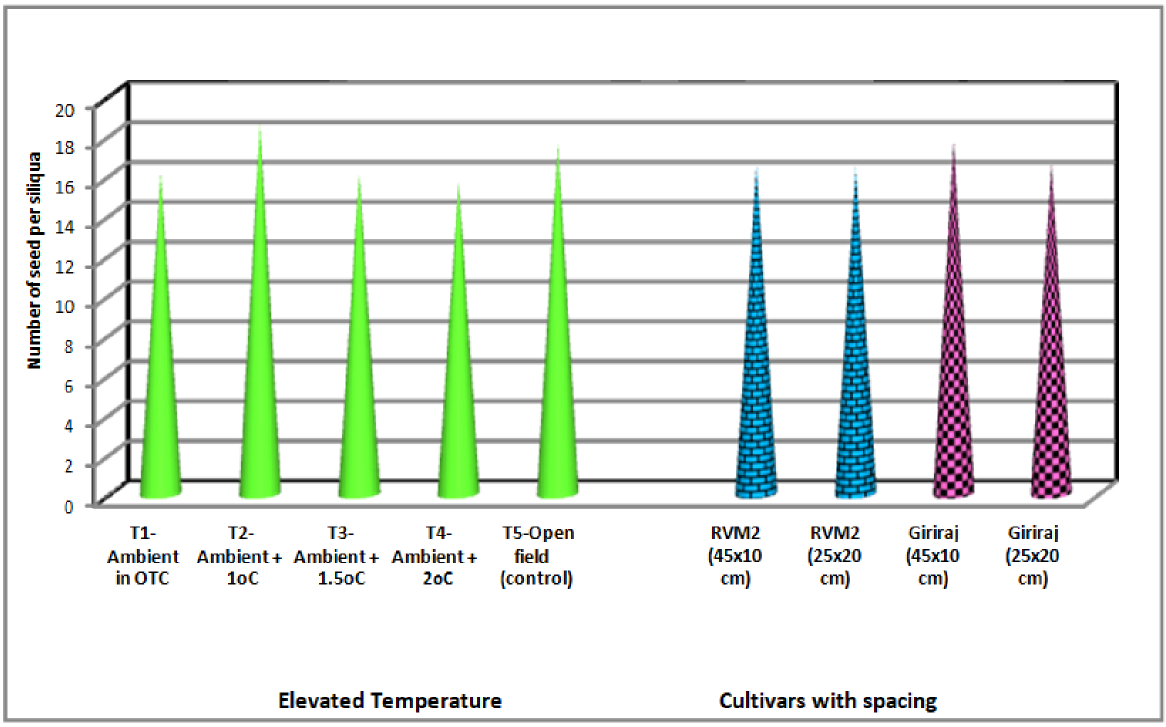

Fig. 6. Number of seed per siliqua of mustard cultivars varied crop geometry as influenced by elevated temperature at harvest stages

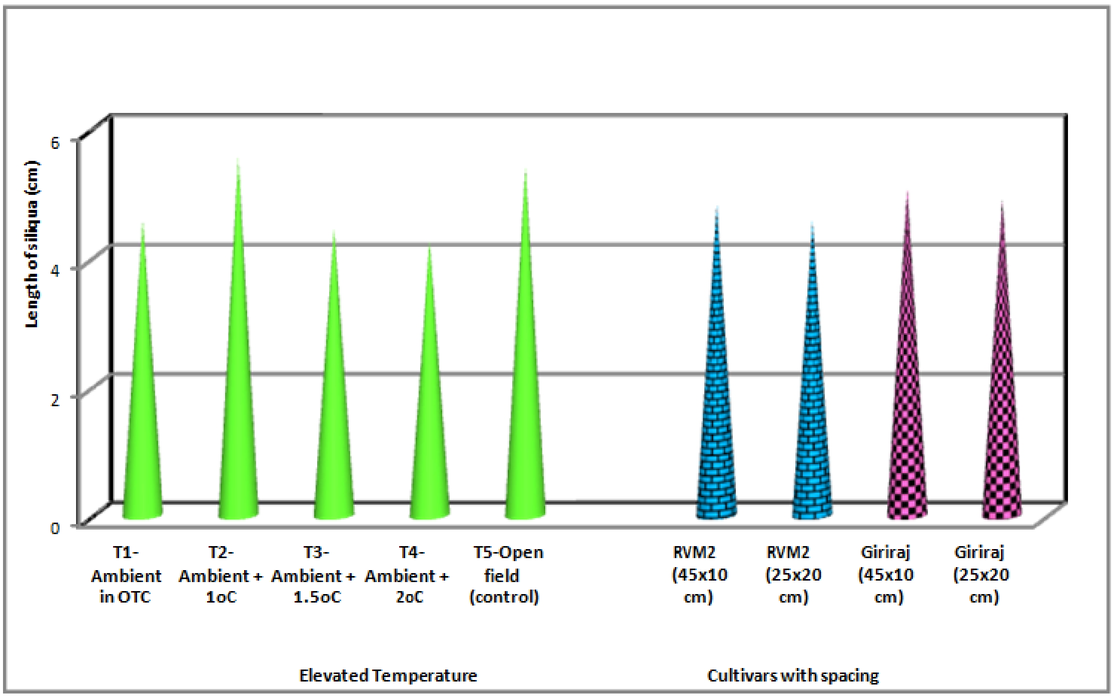

Fig. 7. Length of siliqua (cm) of mustard cultivars varied crop geometry as influenced by elevated temperature at harvest stages

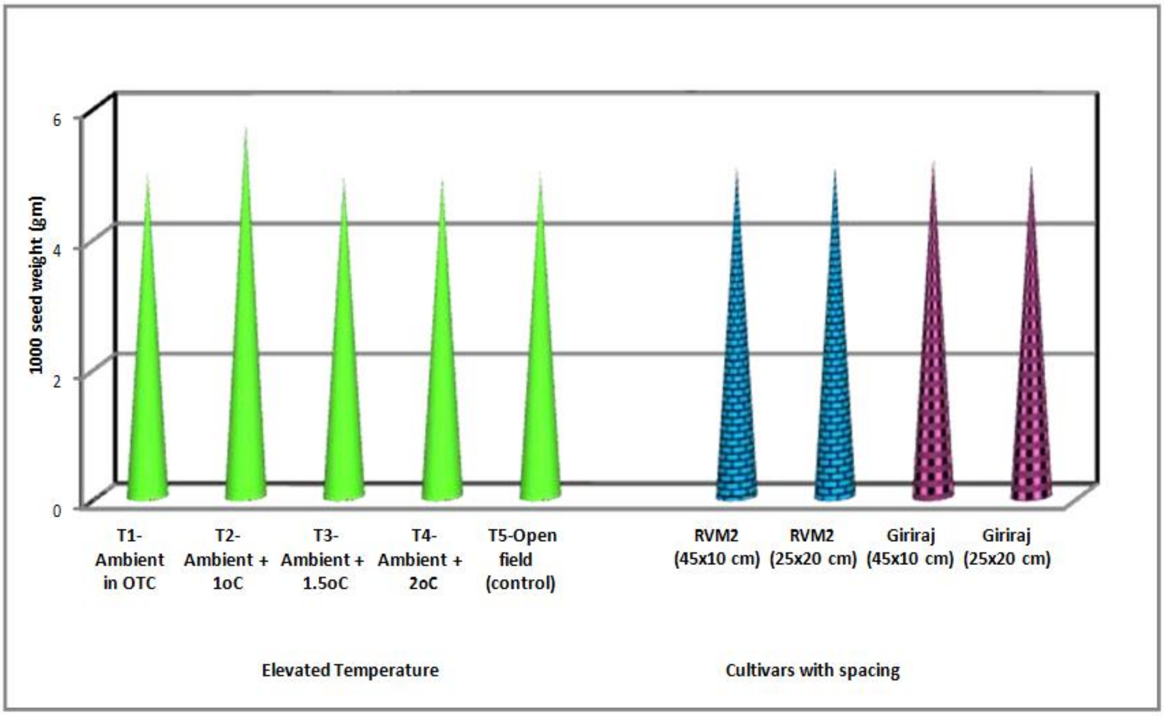

Fig. 8. 1000 seed weight (gm) of mustard cultivars varied crop geometry as influenced by elevated temperature (at harvest stages)

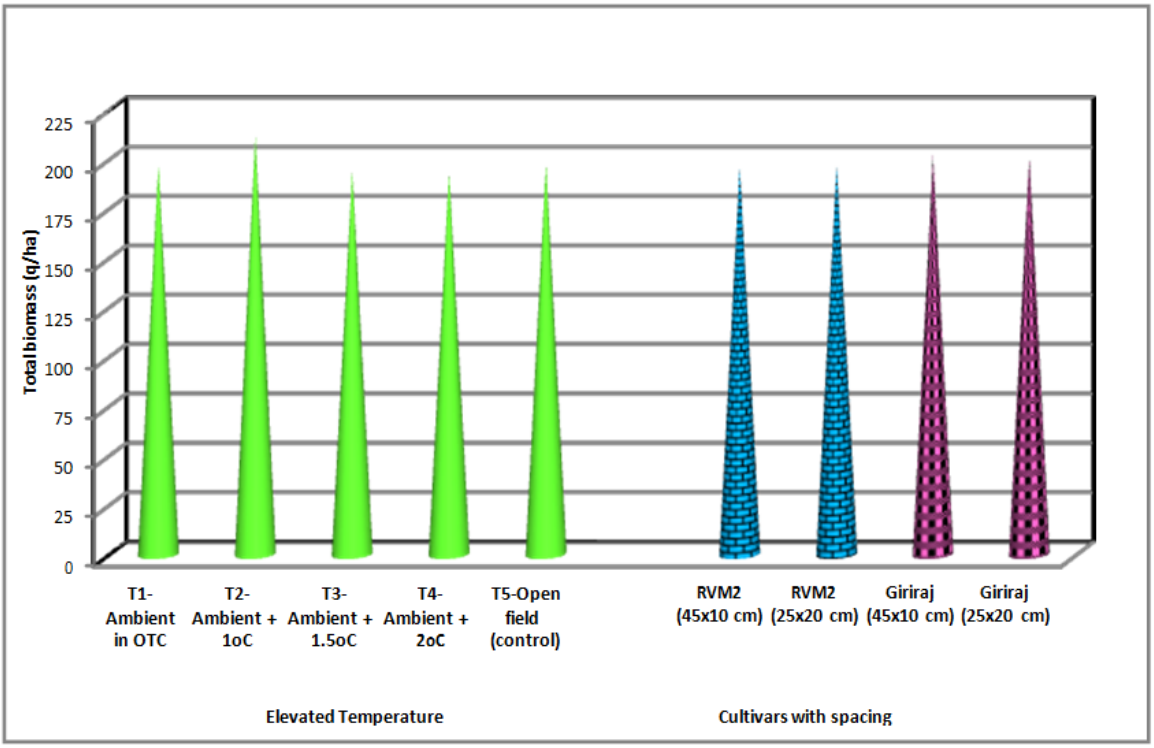

Fig. 9. Total biomass (q/ha) of mustard cultivars varied crop geometry as influenced by elevated temperature (at harvest stages)

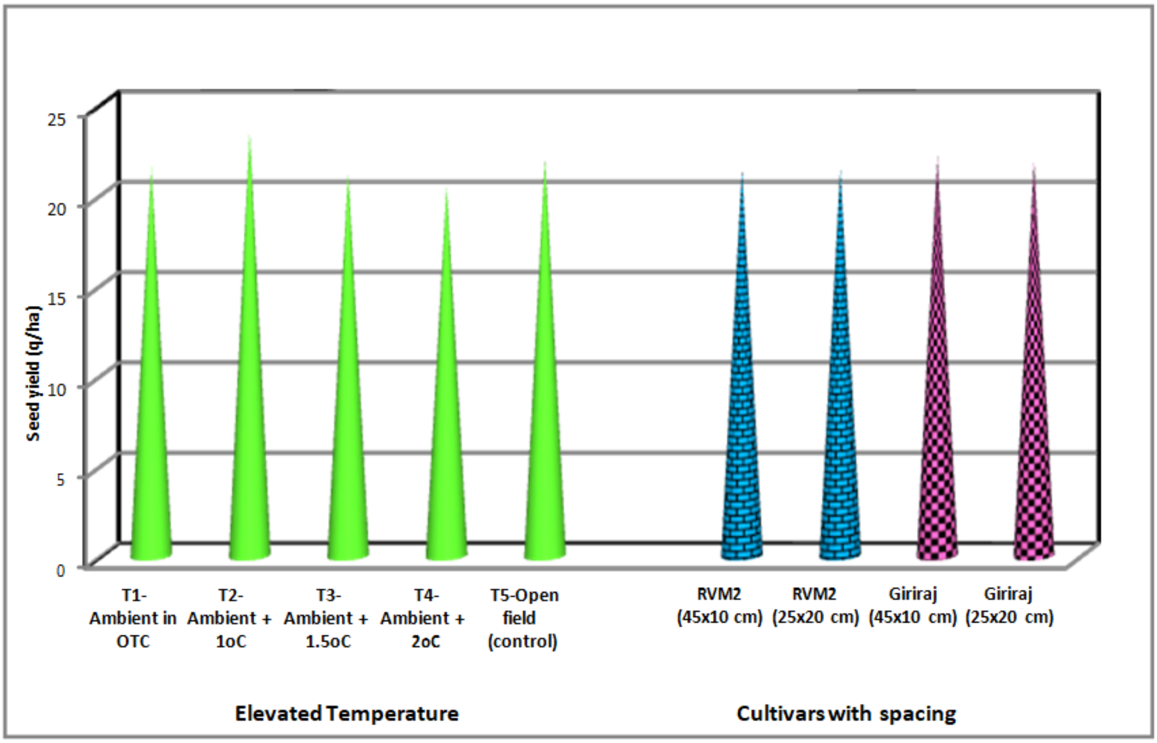

Fig. 10. Seed yield (q/ha) of mustard cultivars varied crop geometry as influenced by elevated temperature at harvest stages

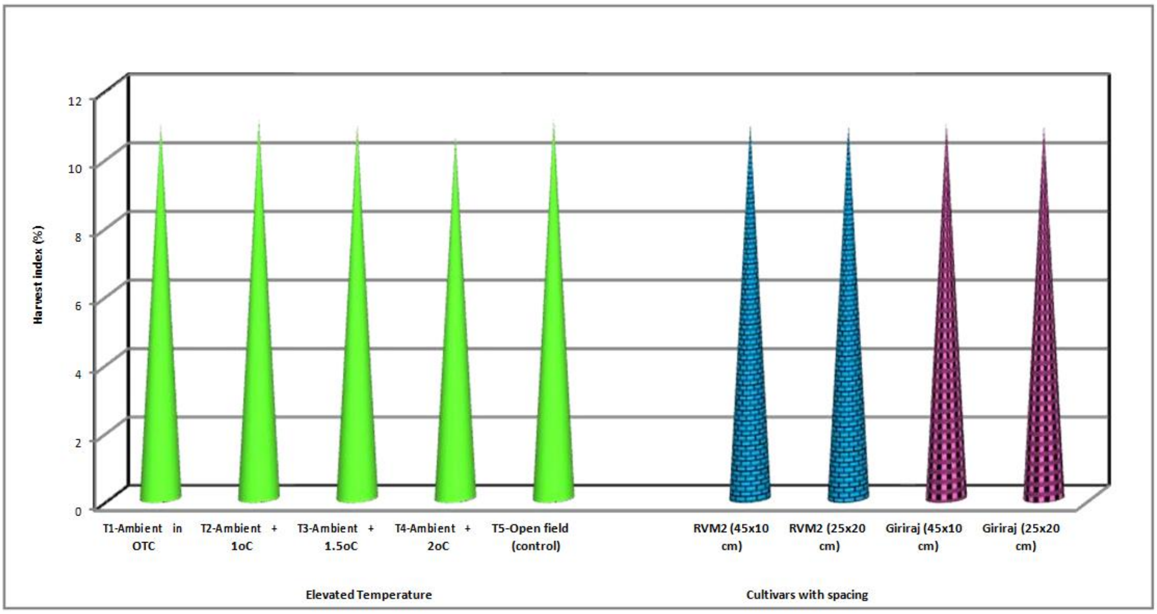

Fig. 11. Harvest index (%) of mustard cultivars varied crop geometry as influenced by elevated temperature (at harvest stages)

4. CONCLUSION

The revealed that among mustard cultivars (RVM-2 and Giriraj) varied geometry differential response was seen under changing climate scenario. Mustard cultivars have depicted significant variation with respect to growth and yield aspects under *Rabi* season 2021 elevated temperature conditions and Giriraj performed well as compared to RVM-2. However, elevated temperature (ambient + 1^{0}C) lead to increased growth and development. It can be concluded from the research work that if there is an increase in the mean temperature of the earth in future by 1^{o}C there will not be a significant effect on the growth of mustard cultivars RVM-2 and Giriraj.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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