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***Short Communication***

# Impact of high temperature stress on growth and yield of cauliflower

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Cauliflower is a very healthy crop for human consumption as it is low in fat, high in dietary fibers, also a good source of vitamin C and B-6. Its curd contains tocopherol, carotenoid and glucosinolates which have anti-cancerous properties. It is used as cereal supplement because of it's high nutritive value. Phenology of cauliflower from planting to harvesting can be separated mainly into three phases: juvenile phase, curd initiation phase and curd growth phase. For the transformation from vegetative to curd induction phase and for the development of curd, it requires specific climatic conditions (Ray and Mishra, 2017). For temperate cultivars, the optimum temperature for curd induction is around 15°C (Wiebe, 1981). Curd induction is delayed or inhibited at temperatures above 20°C, causing uneven development. Wide harvest window and multiple selective harvests lead to a high cost of harvests (Wiebe, 1981).

Consumption of cauliflower in India has increased over a period of time due to its nutritional and food values supported by year-round availability. In India, cauliflower is classified into four maturity groups *viz*., i) early season crop (mid-May to mid-November), ii) mid-early (July end to mid-December), iii) mid-late (August end to mid-January) and iv) late snowball types, based on temperature requirement for curd initiation and curd development (Singh and Sharma, 2015).

India is the third largest producer of cauliflower with a productivity of 19.52 Mg ha$^{-1}$. Cauliflower area is expanding in India from a mare 75,000 ha in 1987-88 to 463,000 ha with production of 9038 Mt during 2020-2021(DAC&FW, 2021). Despite this significant increase in productivity from 6.04 Mg ha$^{-1}$ to 19.52 Mg ha$^{-1}$, the spread of cauliflower across seasons in India is still mainly limited to Bihar, Uttar Pradesh, Orissa, Assam, Madhya Pradesh, Gujrat and Haryana. Cauliflower is very sensitive to temperature regimes. Temperature is known to cause physiological disorders in cauliflower resulting in quality and yield deterioration, affecting the profitability. It is more likely that crops will be exposed to both heat and water stress simultaneously (Vanaja *et al*., 2017, Kimani *et al*., 2022) in changing climates. For instance, crop grown in regions in parts of southern states of India with high temperatures yield small and loose curd, causing economic loss to the farmers. Keeping this in view, a field experiment was conducted with an objective to delineate the effect of growing season temperature on growth, development and yield of cauliflower.

A field experiment was conducted by transplanting 30 days old seedlings of three cultivars viz., Pusa Sharad, Pusa Hybrid 2 and Pusa Ashwini of cauliflower during the winter season of 2018-19 in the Research Farm, Indian Agricultural Research Institute, New Delhi. The soil of experimental site is slightly alkaline (pH >8) with low electrical conductivity and is sandy loam in texture. Seedlings were transplanted on 10$^{th}$ October, 2018 at a plant to plant and row to row spacing of 45x45 cm. Two weeks before this, all plots received the farm yard manure @ 6 Mg ha$^{-1}$. At the time of transplantation nitrogen @40 kg ha$^{-1}$, phosphorous @60 kg ha$^{-1}$ and potassium @ 60 kg ha$^{-1}$were added in the form of urea, DAP and MOP, respectively. Rest of nitrogen (40 kg ha$^{-1}$) was applied at the time curd initiation.

***Temperature treatments***

Three cultivars of cauliflower were subjected to six treatments *viz*.,

i) ambient temperature (26.9/10.1$^{o}$C), denoted as AT,

ii) high temperature (~2 $^{o}$C above ambient) from planting to curd initiation, T(J)

iii) high temperature (~2 $^{o}$C above ambient) during curd development phase, T(CD)

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**Table 1:** Total dry matter (TDM) and yield per hectare and harvest index (HI) at curd harvest

| Cultivar | Temperature treatment | Marketable curd (g plant$^{-1}$) | TDM (kg ha$^{-1}$) | Net curd dry weight (kg ha$^{-1}$) | Net curd fresh weight (Mg ha$^{-1}$) | Market-able curd yield (Mg ha$^{-1}$) | HI for net curd (dry weight basis) | HI for marketable curd (on fresh weight basis) |
|---|---|---|---|---|---|---|---|---|
| Pusa Sharad | Ambient | 720 | 3148 | 1103 | 21.5 | 31.97 | 35.0 | 65.16 |
| | T (J) | 725 | 3038 | 1057 | 19.3 | 32.19 | 34.8 | 57.09 |
| | T(CD) | 475 | 2388 | 1009 | 13.1 | 21.09 | 42.3 | 66.90 |
| | T(H) | 635 | 2807 | 678 | 14.2 | 28.19 | 24.2 | 58.53 |
| | T(M) | 465 | 1940 | 672 | 15.1 | 20.65 | 34.7 | 66.43 |
| | T(L) | 580 | 2886 | 1079 | 16.2 | 25.75 | 37.4 | 56.86 |
| Pusa Hybrid 2 | Ambient | 905 | 4026 | 1295 | 24.6 | 40.18 | 32.2 | 62.20 |
| | T (J) | 610 | 4325 | 1894 | 19.3 | 27.08 | 43.8 | 61.21 |
| | T(CD) | 720 | 3893 | 1551 | 18.6 | 31.97 | 39.8 | 59.26 |
| | T(H) | 770 | 4924 | 1572 | 20.0 | 34.19 | 31.9 | 52.20 |
| | T(M) | 655 | 3648 | 1204 | 15.8 | 29.08 | 33.0 | 56.22 |
| | T(L) | 498 | 3063 | 823 | 12.1 | 22.09 | 26.9 | 62.19 |
| Pusa Ashwini | Ambient | 565 | 3163 | 871 | 14.7 | 25.09 | 27.5 | 59.47 |
| | T (J) | 510 | 2999 | 679 | 11.5 | 22.64 | 22.6 | 54.26 |
| | T(CD) | 325 | 2122 | 495 | 8.0 | 14.43 | 23.3 | 55.08 |
| | T(H) | 605 | 3235 | 863 | 15.3 | 26.86 | 26.7 | 55.76 |
| | T(M) | 595 | 2642 | 900 | 15.5 | 26.42 | 34.1 | 59.80 |
| | T(L) | 450 | 2208 | 648 | 11.8 | 19.98 | 29.3 | 62.07 |
| CD at p=0.05 | | | | | | | | |
| Cultivars (C) | | 62 | 494 | 225 | 1.94 | 2.77 | 2.87 | 1.47 |
| Temperature (T) | | 60 | 288 | 85 | 1.75 | 2.67 | 1.8 | 1.71 |
| C x T | | 68 | 258 | 188 | 1.94 | 3.02 | 3.9 | 2.67 |

* Days after transplantation

iv) plants grown in temperature tunnels from transplanting to harvest at ~1.5°C, T(L)

v) ~2.0°C, T(M) and

vi) ~3.0°C, T(H) higher than ambient.

Three cultivars with six treatments in three replications in a total of 54 plots that were maintained in open field, temperature chambers as well as in temperature gradient tunnels. In treatments 2 and 3, only during the designated growth phase for that treatment, temperatures were raised by placing the chambers covered with UV-stabilized transparent polythene sheets, provided with enough ventilation. The temperature tunnel grown seedlings, however, were subjected to temperature stress from the day of transplantation. Daily values of maximum and minimum temperature and humidity were recorded from each treatment. Apart from these, the daily weather data were collected from the IARI weather observatory.

***Observations on crop:*** Observations on growth, physiological and yield parameters such as phenological events, leaf area index (LAI), dry matter production and partitioning and curd yield were taken on three plants in each plot. The date, on which 50% of the plants attained curd initiation stage, is designated as 50% curd initiation (50% CI) date for that plot. Similarly, dates of harvest of curd were recorded in each plot. In order to get the marketable curd fresh weight, plants were harvested from field and the excess leaves and stem part were chopped as is done for marketable curd and fresh weight was taken to get the marketable curd weight.

***Statistical analysis:*** The data on various observations recorded was statistically analyzed using general linear model for univariate ANOVA using SPSS software for Factorial Randomized Block Design (RBD) as suggested by Gomez and Gomez (1984). The critical difference (C.D.) was calculated at 5% level of significance for comparing the means.

Results indicate that the LAI, phenological events and yield of cauliflower cultivars were significantly influenced by the temperature treatments.

***Leaf area index***: The temperature regimes significantly influenced the LAI at 41, 48 DAT and at curd harvest. Cultivars significantly differed for their response to temperature regimes at all stages except at 50% curd initiation. In general, plants exposed high temperatures during juvenile phase or during entire growth period had lower LAI as compared to those grown in ambient temperature.

***Phenological response:*** Among the cultivars, plants of Pusa Sharad grown under high temperature for whole growth period completed juvenile phase earlier and had early curd initiation while it was delayed in the case of Pusa Hybrid 2 and Pusa Ashwini, as compared to their respective ambient grown plants. The plants treated with high temperature during juvenile phase took maximum days to initiate curd (Fig 2). Curd harvest time also differed significantly

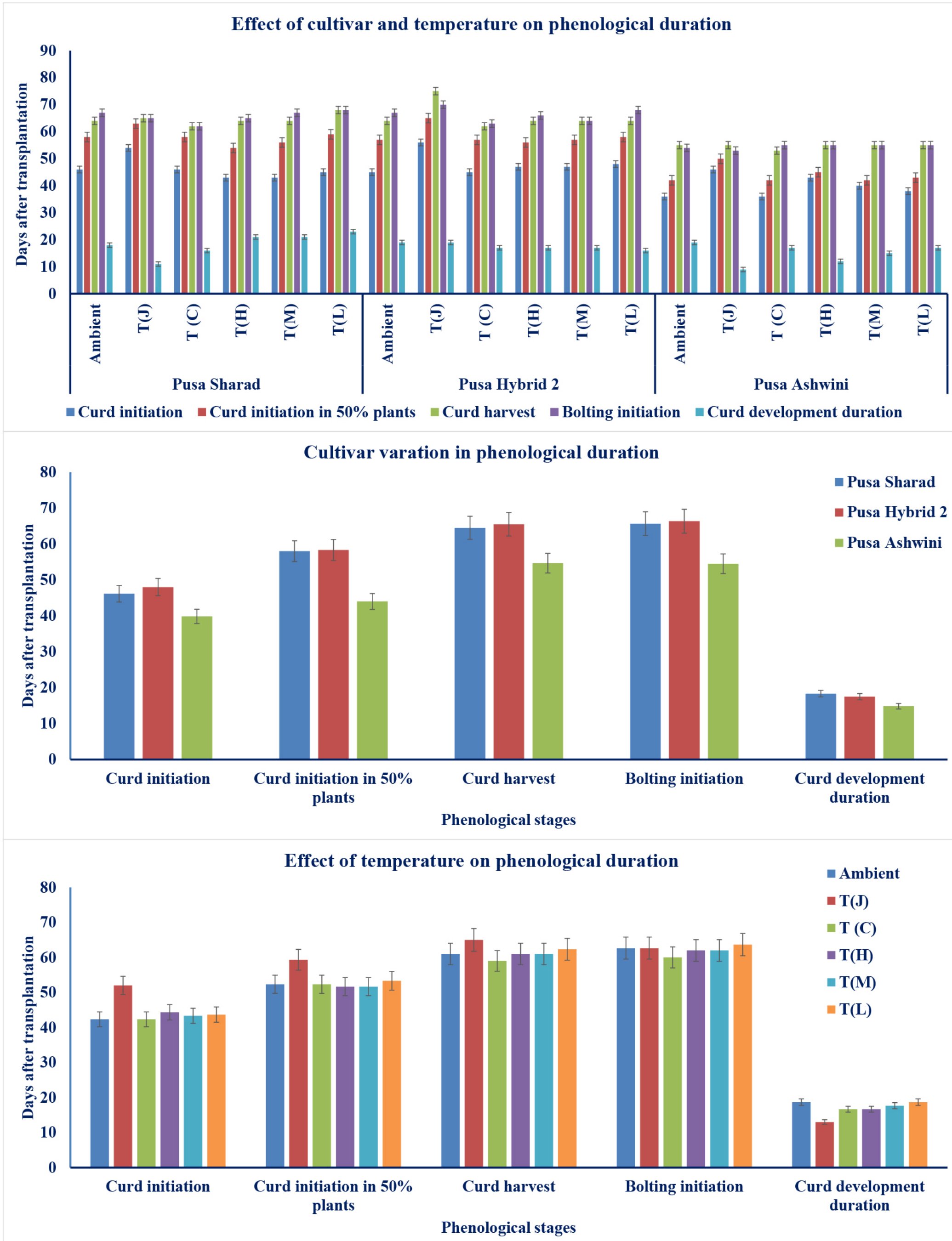


**Fig 1**: Effect of cultivar, temperature and their interaction on duration of different phenological events in cauliflower

among cultivars but didn't differ significantly among temperature treatments. Plants of Pusa Ashwini took minimum days for curd development followed by Pusa Sharad and Pusa Hybrid 2.High temperature during juvenile phase did not affect the further development of curd, but high temperature during curd development resulted in early harvestable curd and premature bolting.

***Yield and harvest index:*** At curd harvest, the TDM (kg $ha^{-1}$) was maximum in plants grown in T(H) while minimum was in plants grown under T(L) condition, irrespective of cultivars (Table 1). The plants of Pusa Hybrid 2 had the highest TDM (kg $ha^{-1}$) followed by plants of Pusa Sharad and Pusa Ashwini. Net curd fresh weight and marketable curd yield was highest in plants grown in ambient condition. Among the cultivars, Pusa Hybrid 2 had highest net curd fresh weight and marketable curd yield followed by Pusa Sharad and Pusa Ashwini.

Harvest index (HI) for net curd on dry weight basis was maximum in plants grown under high temperature during curd development. Irrespective of the temperature regimes, HI for both net curd and marketable curd was maximum in plants of Pusa Sharad followed by Pusa Hybrid 2 and Pusa Ashwini. Irrespective of cultivars, the plants grown under ambient condition had maximum net curd and marketable curd yield while the plants grown under

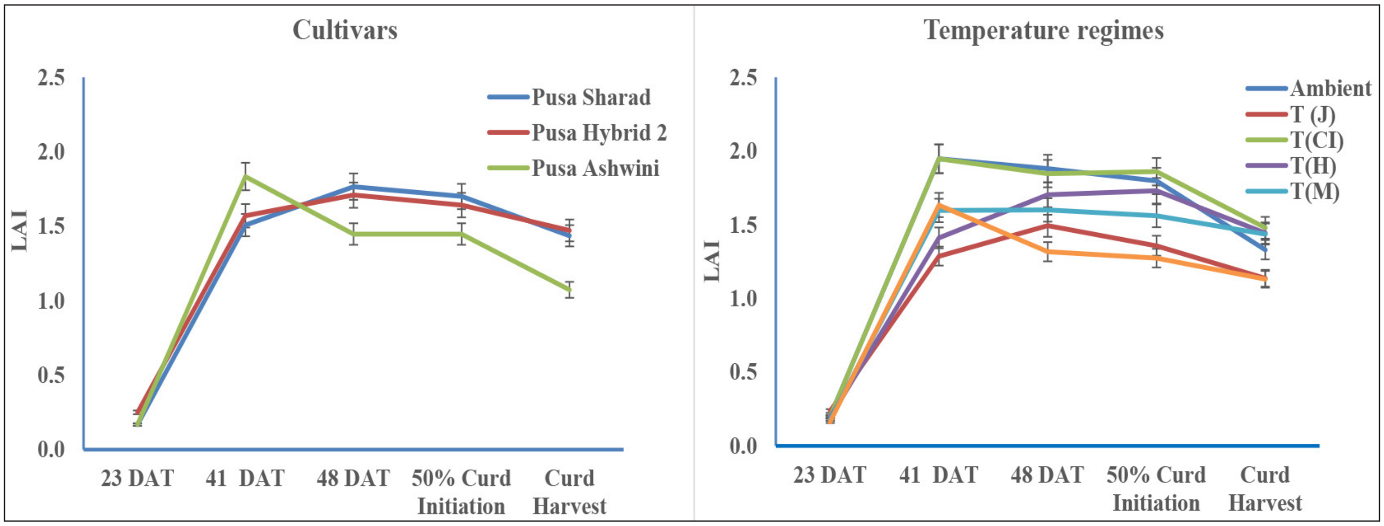


**Fig 2:** Variation in leaf area index (LAI) among cultivars and temperature regimes

high temperature during curd development phase had the lowest yield.

Experimental study indicated that the phenology, LAI, biomass production and partitioning, and curd yield responded differentially in three cultivars with the different temperature regimes. Temperatures of 28.7/12°C coinciding juvenile phase of cauliflower seems to have no significant influence on curd yield but the curd initiation is delayed. However, crop exposed to high temperature stress (28.4-30/12.1-14.1°C) for entire growth period has less yield as compared to that grown in ambient condition. The curd initiation is delayed due to lack of sufficient growing time during which the temperature is below or above a critical value (Liptay, 1981).

The high temperature stress during curd development phase resulted in lower curd yield, caused early bolting and had higher leaf area index. In these plants reduced total dry matter and increase in harvest index was also noted. Earlier reports indicated that increase in temperature for entire growth period results in a reduction of leaf area expansion rate and dry matter production rate (Olesen and Grevsen, 1997). However, this experiment has revealed that the temperatures of 25.9/9.8°C during curd development in fact enhance the leaf area and significantly affect the dry matter and curd yield.

Out of these three cultivars, Pusa Ashwini is an early variety and requires high temperatures (20-27°C) for curd initiation (Singh and Sharma, 2015). Therefore, these plants had early curd initiation. On the other hand, other two cultivars belong to mid-early group that require temperatures between 16-20°C. Hence the curd initiation in these plants occurred only when the temperatures reached this level and thus have taken a greater number of days to curd initiation. Since the number days for curd development is also less in Pusa Ashwini, they had lowest dry matter and yield. Decreasing temperatures below optimum with the progression of winter seems to have played major role in reducing the LAI and curd yield. Based on the overall performance under each temperature treatment, Pusa Hybrid 2 had performed better in terms of maximum dry matter at harvest, net and marketable curd yield followed by Pusa Sharad and Pusa Ashwini. Pusa Hybrid 2, a F1 hybrid, could perform better in terms of dry matter production and yield even at temperatures of 30°C, indicating that this hybrid is capable of withstanding higher temperatures as compared to Pusa Sharad, the other cultivar in mid-early group. Hence, Pusa Hybrid 2 is found to be more suitable cultivar for withstanding increase in temperature. This can also be planted in early season.

From the results it can be concluded that i) yield in plants exposed to high temperature stress during curd development phase is affected more than in those exposed during vegetative phase (pre-curd initiation), ii) high temperature stress (28.7/12°C) during vegetative phase of cauliflower seems to have no significant influence on curd yield but the curd initiation is delayed. However, crop exposed to high temperature stress (28.4-30/12.1-14.1°C) for entire growth period has less yield as compared to that grown in ambient (26.9/10.1°C) conditions and iii) Pusa Hybrid 2 is more suitable for changing climatic conditions as it out performed other two cultivars when exposed to high temperature stress (28-30/11-14 °C). Pusa Sharad can withstand the high temperature stress during juvenile phase.


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