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EFFECT OF MILD TEMPERATURE STRESS ON REPRODUCTION DYNAMICS AND YIELD OF CHICKPEA (*CICER ARIETINUM* L.)

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SUMMARY

A field study was conducted to examine the effect of mild temperature stress (MTS) on reproduction dynamics and yield components of two prominent chickpea genotypes viz. Pusa 1103 (*desi*) and Pusa 1105 (*kabuli*). Exposure to MTS was given by raising the plants in a polytunnel where the average air temperature was moderately higher (~5°C) than ambient. The rate of both flower and pod production was higher under ambient temperature. Days to initiation of flowering and podding was advanced by 12 and 10 days, respectively and this duration of flower and pod production increased significantly under MTS. No significant effect of MTS occurred on number of flowers produced per plant but number of pods per plant decreased considerably due to higher flower abortion and reduced pod set. Slower pod growth rate under MTS affected seed size in Pusa 1105 and thus, resulted in higher yield loss per plant. With higher impairment of reproductive development, Pusa 1105 was found to be more sensitive to MTS as compared to Pusa 1103. Overall, MTS showed significant impact on reproductive dynamics followed by reduced yield. Thus, predicted moderate increase in air temperature under future climate change scenario might be critical for the cool-season chickpea crop.

***Keywords: Cicer arietinum*, mild temperature stress, flower/pod production rate, flower abortion, yield**

INTRODUCTION

The climatic variability and predicted climatic changes are of major concern in agriculture because of their potential threat to crop productivity (Khan *et al.* 2009). Among the various climatic factors affecting crop production, the increasing average surface temperature may have a major impact (Mall *et al.* 2006). In spite of projected enhancement in photosynthesis due to more availability of CO_2 (Aggarwal 2003), increased temperature in future environment may result in reduced crop productivity (Wassmann *et al.* 2009, Turner and Meyer 2011). Temperature is an important factor controlling plant growth and development (Zinn *et al.* 2010). Daily or seasonal temperatures above optimum become a limiting factor for crop production when they coincide with critical stages of development (Thuzar 2010). IPCC (2007) has projected 1.6 to 3.8°C increase in global average air temperature by 2100 and it is reported that 1°C rise in temperature at the critical stage may cause considerable yield losses (Lobell and Field 2007). Moreover, the rise in temperature is reported to be greater during the *rabi* season and thus, crops grown in the *rabi* season are more vulnerable (Aggarwal and Mall 2002).

Pulses are sensitive to change in temperature and particularly cool-season pulse crops are more sensitive

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to high temperature (Wang *et al.* 2006). High temperature may affect the productivity of pulse crops as both duration and rate of grain filling are sensitive to changes in temperature (Wheeler *et al.* 2000). Chickpea (*Cicer arietinum* L.) is the most important *rabi* season pulse crop in India grown on an area of 6.6 million hectares with production of 5.3 million tonnes (Suhasini *et al.* 2009). With its high nutritional value, chickpea is primarily a major source of protein, essential amino acids, valuable source of energy and essential nutrients such as calcium, zinc and iron for the vegetarian populations (Khetarpal *et al.* 2009). The chickpea crop often experiences abnormally high temperature (>35^{o}C) during the reproductive phase that adversely affects its productivity due to poor fertilization and development of reproductive organs (Wang *et al.* 2006). However, low temperatures (0 to 10^{o}C) at early flowering stage may also lead to excessive floral abortion causing low pod and seed set in chickpea (Srinivasan *et al.* 1998). Studies on the effect of late sowing (Krishnamurthy *et al.* 2011) and high temperature exposure in controlled environments (Wang *et al.* 2006) have shown that high temperature induced potential loss in yield with decreased flower and pod production and poor seed set in chickpea. Egli and Bruening (2005) reported that duration of flowering and pod setting is important determinant of yield under stress condition. No reports to date are available on the dynamics of flower and pod production and pod growth rate in chickpea in context with variation in duration of reproductive phase under moderate high temperature in the field conditions. Thus, the present study was conducted to examine the (i) effect of mild temperature stress (~5^{o}C higher than ambient) on the period and pattern of flower and pod production along with the kinetics of pod growth rate and yield in two promising high yielding chickpea genotypes viz. Pusa 1103 (*desi* type) and Pusa 1105 (*kabuli* type), and (ii) the sensitivity of above genotypes to mild temperature stress.

MATERIALS AND METHODS

Plant material and experimental details: A field experiment was conducted from November 2009 to March 2010 in the Division of Plant Physiology, Indian Agricultural Research Institute (IARI), Pusa, New Delhi (Latitude: 28^{o} 38'23"N, Longitude: 77^{o} 09'27"E) to examine the effect of mild temperature stress (MTS) on reproductive development and yield of two chickpea (*Cicer arietinum* L.) genotypes, viz. Pusa 1103 and Pusa 1105. Seeds of both genotypes were obtained from the Division of Genetics, IARI, Pusa, New Delhi. All seeds were treated with 0.1% $HgCl_2$ (w/v) for 60 s followed by 1% bavistin (w/v) for 300 s to remove any surface contamination, thereafter seeds were washed five times with double distilled water and moisture was removed with sterilized blotting paper. The field was divided in 2x2 m blocks representing one individual replication and each treatment in a genotype comprised of three replications. For MTS treatment, blocks were prepared in a poly tunnel (aluminium frame covered with polythene sheet with >80% transmittance and 800 to 1000 μmol m^{-2} s^{-1} photosynthetically active radiation (PAR) where the average day temperature was 4 to 6^{o}C above ambient (Fig. 1). The soil of the experimental site belongs to the major group of Indo-Gangetic alluvium (Holambi series), which is a member of non-acidic mixed hyperthermic family of typic Haplustept. The soil was non-calcareous, slightly alkaline in reaction, and sandy loam in texture with medium to weak angular blocky structure having bulk density 1.56 Mg m^{-3}, saturated hydraulic conductivity 1.05 cm h^{-1}, pH (1: 2.5 soil/water suspension) 7.3, EC 0.49 dS m^{-1}, organic C, 0.3 g kg^{-1}, total N 0.031%, and available P and K, 6.9 and 279.0 kg ha^{-1}, respectively. Seeds were sown on 11 November 2009 in 6 rows 0.30 m apart in each block with 0.10 m plant to plant spacing in a row. Temperature and humidity sensors (TRH-511, Ambetronics Engg. Pvt. Ltd. India) were fixed at 1 m above plant canopy level at both the environments and the temperature and humidity data was monitored on daily basis using data loggers (TC800, Ambetronics Engg. Pvt. Ltd. India) through micro processor based Program Logic Control (PLC) and Supervisory Control and Data Acquisition (SCADA) winlog software (M/s Genesis Technologies).

Growth and yield measurements: Observations on the number of flowers produced/unit time, number of pods produced/unit time, total number of flowers/plant, total number of pods/plant, flower abortion (%) and pod growth rate were recorded during the period from flower initiation (80 days after sowing, DAS) to physiological maturity (123 DAS) of both the genotypes under ambient

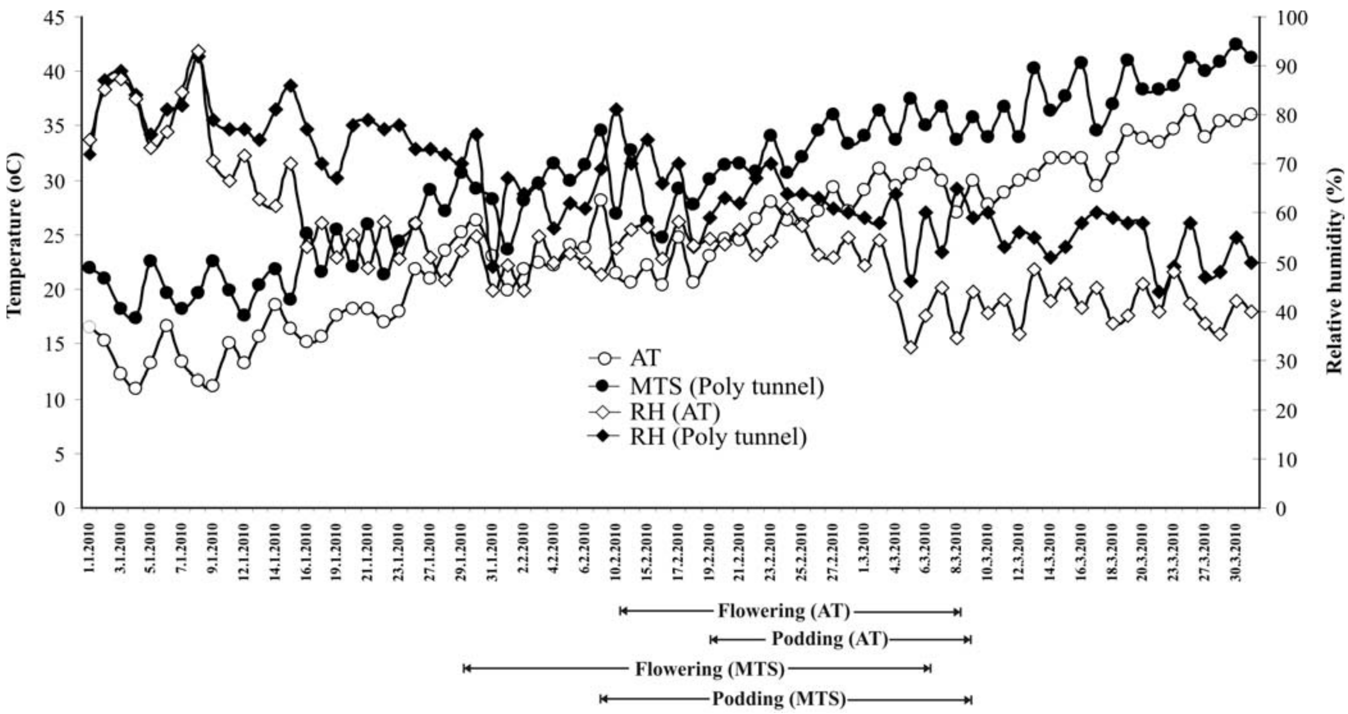

Fig. 1. Mean temperature and relative humidity (RH) from January to March 2010 under ambient temperature (AT) and mild temperature stress (MTS) treatments. Each value shown in the graph represents mean of total observations taken between 08.00 and18.00 h daily at every half an hour interval.

and MTS treatments. For all observations, three plants in each row were selected randomly from each replication of both the genotypes. All the newly produced flowers were counted every second day and marked with an acrylic colour on the pedicel, while the flowers developed into pods were again marked with a different colour and counted. The percentage flower abortion was calculated as follows:

$$\text{Flower abortion (\%)} = \frac{[\text{Total No. of flowers - Total No. of pods}]}{\text{Total number of flowers}} \times 100$$

For the measurement of pod growth rate, ten separate plants were randomly selected from each replication and a total of eighty pods of same growth stage were tagged with acrylic colour at the pod initiation stage (90 DAS). Three pods were removed at every 3-days interval and oven dried at 65°C to measure dry weight and same procedure was repeated till physiological maturity stage. Harvesting from each 2 m x 2 m block (~108 plants) was done at crop maturity. Yield attributes viz. total biomass/plant, number of pods/plant, number of seeds/plant, pod weight/plant, seed weight/plant and 100 seed weight were recorded in harvested and sun dried plant samples.

Statistical analysis: The experiment was arranged in Complete Randomized Blocks Design (CRBD) with three replications. All data were subjected to two way factorial ANOVA carried out using SPSS computer package (SPSS Inc. USA).

RESULTS AND DISCUSSION

Flower and pod initiation: Flower initiation was observed at 92 days after sowing (DAS) in both the genotypes under AT while it was noted 12 days earlier under MTS (Fig. 2). Paton (1968) reported that flowering initiation is sensitive to temperature change and can be delayed by prolonged low temperature exposure or high temperature. Cold temperature is known to delay flowering (Zinn *et al.* 2010), while high temperature can induce early flower initiation (Balasubramanian *et al.*

2006, Hedhly *et al.* 2008) and similar pattern was observed in this study under MTS. Pod initiation was also observed 10 days earlier under MTS (Fig. 2). Genotypic differences in time to flower and pod initiation were not seen in both the genotypes and started flowering and podding simultaneously (Fig. 2 and 3).

Flower and pod production: Flower production per plant increased to reach a maximum rate in about 15 days after first flower formed and was higher under ambient temperature than at MTS in both genotypes. Besides, higher flower production in Pusa 1105 at the beginning, Pusa 1103 produced more number of flowers/plant /unit time under both AT and MTS (Fig. 2). Previous studies reported that flower production rate is adversely affected by high temperature possibly due to the sensitivity of flowering stimulus to temperature change (Erickson and Markhart 2002, Hedhly *et al.* 2008, Zinn *et al.* 2010) and shedding of flowers under high temperature (Khattak *et al.* 2009). Pod production rate reduced significantly under MTS in both the genotypes. However, Pusa 1103 showed higher pod production rate under both the temperature environments (Fig. 3). Both pod initiation and production rate are reported to be more sensitive to stress (Fang *et al.* 2010), including high temperature stress (Vara Prasad *et al.* 2000), thereby affecting yield (Leport *et al.* 2006). We observed that total flowering and podding period extended under MTS by 10 (Fig. 2) and 8 days, respectively (Fig. 3). Craufurd and Wheeler (2009) reported that warmer temperatures resulted in shortening the duration of the vegetative phase and thus, comparatively early initiation of reproductive phase. However, effect of MTS in our study was associated with the longer duration of flowering and podding as compared to AT.

Low variability was noted in total number of flowers produced and the difference was less evident at both treatment and genotypic levels (Fig. 4). Unlike flower production, MTS treatment significantly ($P < 0.05$) decreased the total number of pods produced/plant by 29 and 34% in both Pusa 1103 and Pusa 1105, respectively, and it might be due to higher shedding (Khattak *et al.* 2009) and abortion rate of flowers (Young *et al.* 2004, Hedhly *et al.* 2008) and low pod set (Wang *et al.* 2006) as compared to AT.

MTS enhanced the flower abortion in both genotypes. At AT, the *kabuli* genotype showed significantly higher ($P<0.05$) flower abortion (44%) than the *desi* genotype (31%). Flower abortion increased further in the MTS 64% in *kabuli* genotype and 48% in *desi* genotype (Fig. 5). Various factors like slow pollen tube growth, low pollen viability, and hydration, stigma receptivity, ovary viability are crucial to determine flower fertilization and pod set under temperature stress (Zinn *et al.* 2010), and a negative influence of higher temperature on these factors will increase flower abortion and later decrease the pod set (Erickson and Markhart 2002, Wang *et al.* 2006, Thuzar 2010).

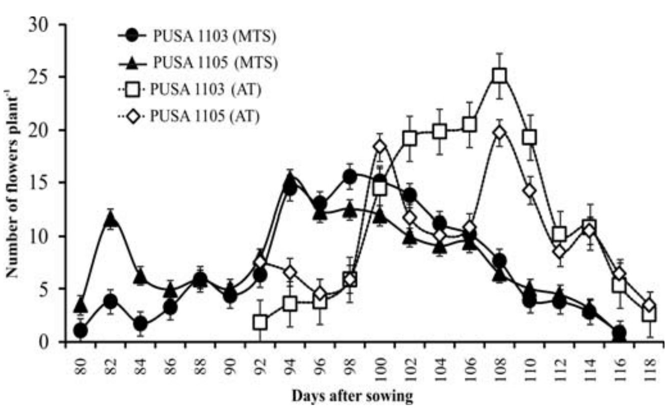

Fig. 2. Effect of mild temperature stress (MTS) on the number of flowers produced per plant per unit time in chickpea genotypes. Data represents mean of three replications ± S.E.

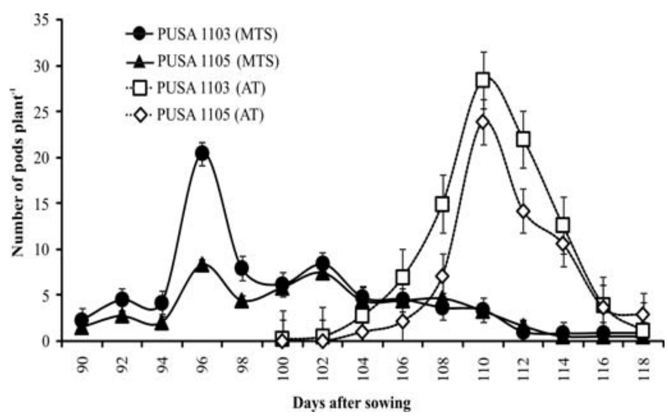

Fig. 3. Effect of mild temperature stress (MTS) on the number of pods produced per plant per unit time in chickpea genotypes. Data represents mean of three replications ± S.E.

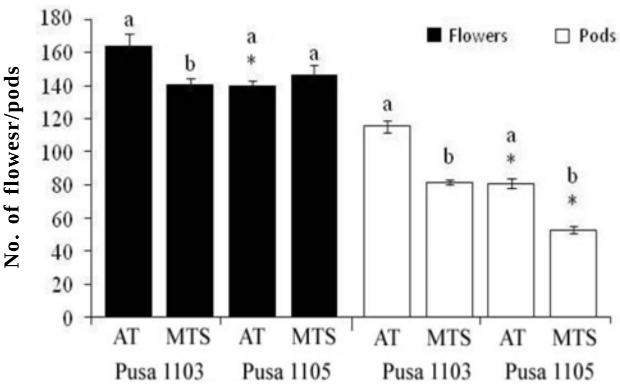

Fig. 4. Effect of mild temperature stress (MTS) on the total number of flower and pods produced per plant in chickpea genotypes. Data represents mean of three replications ± S.E. Bars in a genotype indicated with common letters are not significantly different by Duncan's test while *shows significant difference between the genotypes (p<0.05).

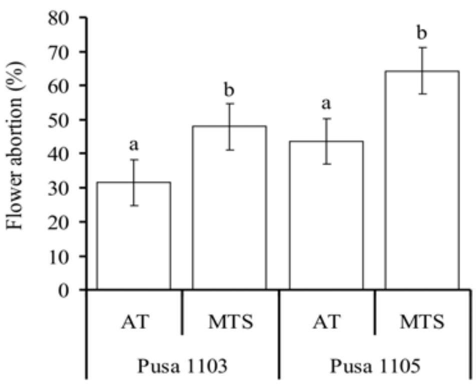

Fig. 5. Effect of mild temperature stress (MTS) on flower abortion in chickpea genotypes. Data represents mean of three replications ± S.E. Bars in a genotype indicated with common letters are not significantly different by Duncan's test.

Pod growth rate: Gain in dry weight of pods in unit time was slower in both genotypes under MTS. However, this effect was not significant ($P < 0.05$) for Pusa 1103 (Fig. 6). Conversely, Pusa 1105 showed significant reduction in pod growth rate under MTS which might be attributed to poor seeds filling (Table 1). Wang *et al.* (2006) reported that high temperature stress during pod development affects the remobilization of photosynthates to grain and prevents the seeds from filling to their full potential size. This might affect both seed size and weight along with the number of seeds/plant and thus crucial for the final yield.

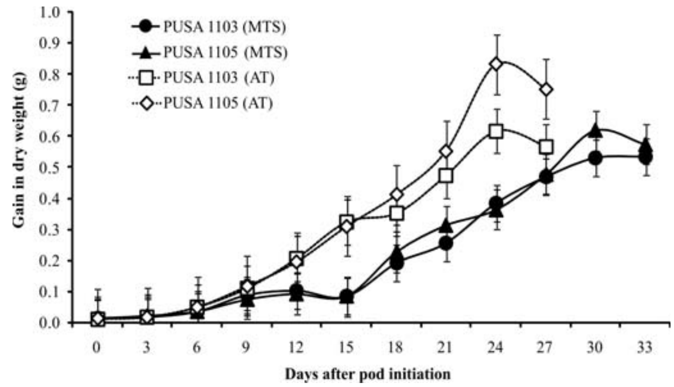

Fig. 6. Pod growth rate (g/plant/unit time) of chickpea genotypes under mild temperature stress (MTS). Data represents mean of three replications ± S.E.

Yield attributes: Under the MTS treatment, plant biomass/plant, pod number/plant, pod weight (g/plant), seed number/plant, and seed weight (g/plant) decreased compared to the AT in both chickpea genotypes (Table 1). Pusa 1103 showed a smaller reduction in comparison to Pusa 1105 under MTS. However, the percentage reduction in seed number/plant was higher for Pusa 1103 (28%) compared to Pusa 1105 (21%). By contrast, total biomass in Pusa 1105 was not affected. Khetarpal *et al.* (2010) also reported increase in total biomass in *kabuli* type even under temperature 3^{o}C higher than ambient. Seed yield/plant was lower under MTS in both genotypes and the reductions were higher in Pusa 1105 (39%) compared to Pusa 1103 (22%). Moreover, reduced seed size under MTS in Pusa 1105 caused 19.51 per cent reduction in 100-seed weight. However, reduction was not significant in Pusa 1103. The findings indicate that the *kabuli* genotype is more sensitive to MTS compared to the *desi* genotype. Similarly, Gan *et al.* (2004), Leport *et al.* (2006) and Wang *et al.* (2006) have reported that *desi* genotypes were more efficient than *kabuli* under both normal and stress conditions and produced more pods, and the difference was far greater under stress conditions.

Correlation matrix of number of flowers/plant, number of pods/plant, number of seeds/plant, total biomass (g/plant) and seed yield (g/plant) revealed a significant positive correlation between seed yield and number of pods (r^2= 0.911), number of seeds (r^2= 0.888), total biomass (r^2= 0.723), respectively. Conversely,

Table 1. Effect of mild temperature stress on total biomass and yield attributes of chickpea genotypes. Data represents mean of three replications ± S.E. Means of each treatment that do not have common letters are significantly different by Duncan's test. Values shown in parentheses show per cent change under MTS compared with AT.

Genotype	Temperature treatment	Total biomass (g plant^{-1})	Number of pods plant^{-1}	Pod weight (g plant^{-1})	Number of seeds plant^{-1}	Seed weight (g plant^{-1})	100-seed weight
Pusa 1103	AT	50.31±1.79^{a}	111.83±4.17^{a}	27.72±1.53^{a}	123.17±4.42^{a}	24.26±0.95^{a}	19.7±0.97^{a}
	MTS	37.05±1.13^{b}	79.33±2.36^{b}	20.97±0.68^{b}	88.33±2.75^{b}	19.02±0.65^{b}	21.5±0.82^{a}
		(-26.36)	(-29.06)	(-24.36)	(-28.28)	(-21.60)	(+9.14)
Pusa 1105	AT	34.04±1.17^{a}	75.50±3.13^{a}	21.98±1.84^{a}	81.67±1.80^{a}	16.75±0.71^{a}	20.5±0.19^{a}
	MTS	34.21±1.05^{a}	51.17±3.01^{b}	13.91±0.64^{b}	64.83±1.96^{b}	10.21±0.35^{b}	16.5±0.77^{b}
		(+0.51)	(-32.23)	(-36.69)	(-20.61)	(-39.04)	(-19.51)

AT = Ambient Temperature; MTS = Mild Temperature Stress

number of flowers showed least correlation with other traits (Table 2). The results showed that number of pods were crucial to determine final yield while number of flowers have no effect in this study. It is concluded that the time to first flower and first pod were significantly shortened under MTS in both the chickpea genotypes, while pod set and pod growth rate decreased and flower abortion increased. Moreover, the high flower abortion percentage and slow pod growth rate in the MTS treatment decreased seed number, seed size (in Pusa 1105) and seed weight/plant. Overall, *desi* type had a smaller yield loss under MTS compared to *kabuli* type, similar to the smaller effect of drought stress in *desi* compared to *kabuli* chickpea (Leport *et al.* 2006). Compared with previous studies on the adverse effect of high temperature on overall growth, development of reproductive organs and yield, this study showed that a moderate increase in temperature, as predicted by IPCC, will be detrimental for the reproductive development and critical for the yield of cool-season chickpea crop.

Table 2. Correlation matrix of yield and yield component in chickpea genotypes Pusa 1103 and Pusa 1105.

Characters	Seed yield	No. of flowers	No. of pods	No. of seeds	Total biomass
Seed yield	1.000				
No. of flowers	0.177	1.000			
No. of pods	0.911**	0.093	1.000		
No. of seeds	0.888**	0.008	0.903**	1.000	
Total biomass	0.723**	-0.091	0.816**	0.916**	1.000

** Correlation significant at ($p \leq 0.01$)

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