Indian J. Plant Physiol., Vol. 14, No. 4, (N.S.) pp. 377-383 (Oct.-Dec., 2009)

EFFECT OF ELEVATED TEMPERATURE ON GROWTH AND PHYSIOLOGICAL CHARACTERISTICS IN CHICKPEA CULTIVARS

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Received on 24 Dec., 2008, Revised on 15 Dec., 2009

SUMMARY

A study was conducted to investigate the effect of rising temperature on growth and physiological characteristics in chickpea genotypes. Plants of Pusa 1108 and Pusa 1053 (both *kabuli* type) were raised in earthenware pots under natural environment. One set of plants was raised in a polycover and exposed to high temperature (3.1°C above ambient) through out the growth period. Similarly, two sets of plants were exposed to high temperature at flowering and podding for short duration of ten days only. Plants of both the cultivars grown at high temperature through out the growth period exhibited enhanced vegetative growth in terms of increased shoot length, production of more number of branches, leaf area and dry weight accumulation per plant. Rate of photosynthesis increased, stomatal conductance decreased but membrane stability and proline concentration was higher in plants of both cultivars under high temperature but no significant changes were observed in relative water content and total sugars. Yield attributes like pod and seed weight and plant biomass of these plants was less than the plants exposed to high temperature for short duration only at flowering and podding stages. These findings suggest that 3.1°C increase in growth temperature may enhance vegetative growth and photosynthesis in chickpea but may not influence the plant yield. On the other hand, short terms exposure of higher temperature at flowering or podding may have positive influence on yield of chickpea cultivars in timely sown crop under Delhi conditions.

***Key words*: Chickpea, growth, photosynthesis, temperature, yield**

INTRODUCTION

The rising atmospheric CO_2 and temperature are important factors of climate change which are likely to impact agriculture and food security across the globe. Despite some projected increase in photosynthesis caused by higher atmospheric CO_2, increased temperature may result in reduced productivity (Wassmann *et al.* 2009). IPCC (2007) has projected that the global average air temperature would rise by 1.8 to 4.0°C by the end of this century. Relatively, *rabi* season temperature is expected to increase more than *kharif* (Aggarwal and Mall 2002). In India, large number of studies have been conducted on response of crops to climate change but they primarily have been focused on cereal crops like rice and wheat and less attention has been given to pulses. Pulse production is low world over and more so in the developing countries. In our country, pulses are grown both as *rabi* and *kharif* crops and may be vulnerable to climate change like other crops. Nutritionally pulses are important primarily being main source of protein, essential amino acids, valuable source of energy and essential nutrients such as calcium, zinc and iron. It is presumed that climate change mediated

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effects on yield and nutritional quality of pulse crops may have long-term effect on our nutritional food security (Porter and Semenov 2005). Therefore, it is important to evaluate the influence of climate change on growth and yield of important pulse crops and to identify genotypes best suited for future climate scenario.

The rise in atmospheric temperature may affect productivity of pulses as both duration and rate of grain filling are sensitive to changes in temperature. Increased rate of grain growth and shortening of grain filling period has been reported in various crops (Wheeler *et al.* 2000). Chickpea is one of the most important pulse crop in India and has been suggested sensitive to low as well as high temperature (Nayyar *et al.* 2007). Among various phenological stages in chickpea, reproductive stage has been reported to be more sensitive to high temperature stress (Wang *et al.* 2006). Most of the studies in chickpea have been planned either under low or high temperature stress and the information on the effect of moderate increase in ambient temperature as projected by IPCC (2007), on the growth and yield of chickpea is scanty. Hence, the present study was planned to investigate the effect of elevated temperature (3.1 ^{0}C higher than ambient) on growth and physiological characteristics of two chickpea genotypes.

MATERIAL AND METHODS

Seeds of two cultivars of chickpea, viz. Pusa 1108 and Pusa 1053 (both *kabuli* type) were obtained from the Division of Genetics, Indian Agricultural Research Institute (IARI), New Delhi, and were inoculated with *Mesorhizobium ciceri* SPG strain before sowing. Eight seeds of each cultivar were sown in earthenware pots (diameter 12") containing sandy loam soil (3:1) and mixed with farm yard manure and fertilizers under natural environment. The inorganic fertilizers, potassium and phosphorous were applied at the rate of 60 and 40 kg/ha and nitrogen was applied at the rate of 20 kg/ha as starter dose. Seedlings were thinned to four plants per pot after one week of emergence.

To expose the chickpea plants to high temperature, a wooden structure of size 3 x 2 x 2 metre was erected and covered with PVC (polyvinyl chloride) film (Caprihans, Sunflex 0.15 mm thickness and 85% transmittance). There was 15 cm open space at the bottom of the chamber. Thermo-hygrometer was placed inside the poly cover and the levels of temperature and humidity were recorded regularly. The mean day temperature inside the polycover was recorded 3.1^{o}C higher than normal environment. Twenty pots of each genotype were selected randomly and transferred inside the polycover for high temperature exposure throughout the growth period. Similarly, another two sets of 10 pots for each cultivar were exposed to high temperature only for short duration of 10 days during flowering and podding stage and thereafter were raised under normal environment. One set of 20 pots for each cultivar was raised under normal environment only and served as control.

Observations on shoot length, leaf area, leaf, stem and shoot dry weight and physiological parameters, viz rate of photosynthesis, stomatal conductance, membrane stability index, relative water content, proline concentration, total sugars were recorded at three growth stages viz. vegetative, 50% flowering and 50% podding in control and the plants exposed to high temperature throughout the growth period. Yield parameters were recorded at the harvest of the crop from each treatment. Leaf area was measured using a leaf area meter (Model LI-3100, LICOR Inc. Nebaraska, USA) and expressed as cm^2 $plant^{-1}$. For determination of dry weight, all the plant parts like stem, leaves and branches were dried to constant weight in a hot-air oven at 70^{o}C and weighed.

The rate of photosynthesis was measured using portable photosynthesis system (Model LI-6400, LICOR Inc. Nebaraska, USA) between 10.00 AM to 11.30 AM. The photosynthetically active radiation (PAR) during gas exchange measurement was saturating (> 1200 μmol m^{-2} s^{-1} upon the leaf surface). Top most fully developed leaflets were used. Simultaneously stomatal conductance was also measured using the above photosynthesis system and expressed as cm s^{-1}. Membrane stability index (MSI) was estimated by the method given by Onwueme (1979). Relative water content (RWC) was determined following the method described by Barrs and Weatherley (1962). Free proline concentration in the leaves was determined following the method of Bates *et al.* (1973). For estimation of sugars, 1.0 g leaf sample was boiled in 95% ethanol for extraction of sugars following the method of McCready *et al.* (1950). Total sugar content was determined following Nelson's arsenomolybdate method (Nelson 1944). Improved copper reagent of Somogyi (1952) was used.

Yield parameters were recorded at the maturity of the crop. Twenty plants from each cultivar and treatment were separated into different plant parts like leaves, stem and pods and were dried for yield analysis. Analysis of variance (ANOVA) was performed on the data following Panse and Sukhatme (1967) and critical difference (CD) was calculated at 5% probability level.

RESULTS AND DISCUSSION

Temperature is an important factor which affects growth and development of plants. All plants require a certain amount of heat units during growth period and the duration to achieve heat units depends upon the climatic conditions. If the temperature is warmer plant may achieve this requirement earlier. On the other hand, in the temperate environment the duration of heat units is longer and as a result the growth and development of plants is delayed. In the present study, chickpea plants of both the cultivars grown under high temperature throughout the growth period exhibited enhanced vegetative growth in terms of increased shoot length, production of more number of branches and number of leaves, higher leaf surface area and dry weight accumulation per plant (Table 1 and 2). The response however, differed in both the cultivars. Highest increase in shoot length (51%) and leaf area (66%) was observed in Pusa 1108 in high temperature grown plants, while number of branches increased more in Pusa 1053 (74.6%) under high temperature (Table 1). Growth

Table 1. Effect of high temperature exposure on shoot length, number of branches and leaf area of two chickpea cultivars at different growth stages

Varieties	Growth stages	Shoot length (cm plant^{-1})		Number of branches (plant^{-1})		Leaf area (cm^2 plant^{-1})	
		Ambient temp.	High temp.	Ambient temp.	High temp.	Ambient temp.	High temp.
Pusa-1053	Vegetative	17.48	23.32* (33.41)	10.67	10.00 (-6.28)	80.50	111.32 (38.29)
	Flowering	31.90	40.93 (28.31)	21.67	27.00* (24.60)	281.15	401.41* (42.77)
	Podding	47.50	52.50* (10.53)	21.00	36.67* (74.62)	724.91	766.67 (5.76)
Pusa-1108	Vegetative	20.29	26.43* (30.26)	11.00	15.00* (36.36)	95.02	157.62* (65.88)
	Flowering	27.23	33.00* (21.19)	18.33	15.33 (-16.37)	172.54	187.37 (8.60)
	Podding	46.93	71.00* (51.29)	39.33	45.00 (14.42)	788.11	1305.86* (65.70)

Values in parentheses indicate per cent change. * Indicate significant difference at $P < 0.05$

Table 2. Effect of high temperature exposure on stem, leaf and shoot dry weight of two chickpea cultivars at different growth stages

Varieties	Growth stages	Stem dry weight (g plant^{-1})		Leaf dry weight (g plant^{-1})		Shoot dry weight (g plant^{-1})	
		Ambient temp.	High temp.	Ambient temp.	High temp.	Ambient temp.	High temp.
Pusa-1053	Vegetative	0.27	0.39 (43.44)	0.49	0.70 (43.25)	0.76	1.09 (43.31)
	Flowering	1.35	1.85* (37.04)	1.89	2.20* (16.61)	3.24	4.05 (25.13)
	Podding	3.66	4.75* (29.87)	3.53	4.02 (13.80)	7.19	8.77 (21.92)
Pusa-1108	Vegetative	0.37	0.54 (48.05)	0.56	0.80* (41.68)	0.93	1.34* (44.19)
	Flowering	0.83	0.99 (19.57)	1.12	1.30 (15.73)	1.95	2.29 (17.36)
	Podding	4.68	6.02* (28.61)	5.24	6.54 (24.81)	9.93	12.56 (26.50)

Values in parentheses indicate per cent change. * Indicate significant difference at $P < 0.05$

enhancement at high temperature in both the chickpea cultivars suggests that chickpea growth was sensitive to low temperature and enhancing the level of temperature by 3.1°C exhibited positive response. Croser *et al.* (2003) have reported reductions in germination and vegetative growth in chickpea when growth temperature was 15°C or less.

Leaf, stem and shoot dry weight also increased in high temperature grown plants of both the cultivars and magnitude of increase was more or less similar (Table 2). The mean temperature below 15°C has been known to affect development and function of reproductive structures in chickpea which may lead to flower abortion (Clark 2001). Similar effects of low temperature on plant height, leaf shape and size and floral initiation has been reported in chickpea by Christiansen and St. John (1984). Nayyar *et al.* (2007) have reported similar increase in growth and plant dry weight in chickpea cultivars grown at higher temperature (28/17°C) compared to lower temperature (17/2.3°C) in Northern part of India. In tropical climate, when the temperature exceeds the optimum growth requirement, it becomes limiting factor for plant growth and yield. In the present study, no inhibitory effect of the elevated temperature (3.1°C higher than ambient) was observed on plant growth and it suggests that such a moderate increase in temperature under climate change scenario may not have harmful effects on growth of chickpea during winter season in Delhi region of India.

In most plants, changes in photosynthetic rate in response to temperature are significant over a range of 10°C to 35°C, but exposure to temperatures below or above this range may cause injury to the photosynthetic system. In the present study, significant increase in rate of photosynthesis and reduction in stomatal conductance was observed in both the chickpea cultivars grown at high temperature. Pusa 1053 showed significant increase (64 %) in rate of photosynthesis during flowering stage. Similarly, Pusa 1108 plants showed 15.5 and 24.3% increase in rate of photosynthesis during vegetative and podding stages (Fig. 1). Stomatal conductance decreased in both the cultivars under elevated temperature significantly at all the growth stages. Among two cultivars, Pusa 1053 showed higher reductions (43%) in stomatal conductance during vegetative stage (Fig. 1). The response of crop species to temperature depends upon the temperature optima of photosynthesis, growth and yield (Conroy *et al.* 1994). When the level of temperature is below the optimum for photosynthesis, a small increase in temperature can greatly increase the rate of photosynthesis and crop growth and the reverse is true when the level of temperature is near the maximum for growth and photosynthesis (Polley 2002). The enhancement in photosynthesis rate under elevated temperature in this study indicates that ambient temperature during the crop growth period was below optimum for photosynthesis. As a result, exposure of the plants to high temperature increased rate of photosynthesis. Farquhar and von Caemmerer (1982) have reported a similar response of shift in optimum temperature for photosynthesis with changes in growth temperature.

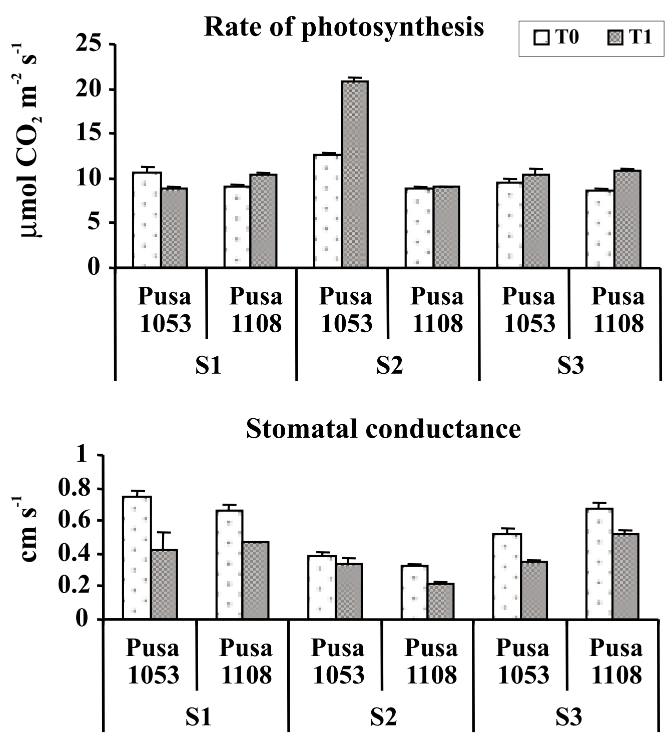

Fig. 1. Effect of high temperature on rate of photosynthesis and stomatal conductance at different growth stages in two chickpea cultivars (T0 = normal temperature; T1 = high temperature exposure throughout growth period; S1 = vegetative stage; S2 = flowering stage; S3 = podding stage)

The function of cellular membranes under stress is critical for the processes such as photosynthesis and respiration (Blum 1988). Heat stress makes the lipid bilayer of biological membrane more fluid by either denaturation of protein or an increase in unsaturated fatty acids (Savchenko *et al.* 2002). Such alterations enhance permeability of membranes and result in loss of electrolytes. In our study, significant increase in MSI was observed in both chickpea cultivars during flowering stage due to exposure to elevated temperature (Fig. 2). But no significant changes were observed in relative water content (RWC) of both the chickpea cultivars (Fig. 2). This suggests that elevated temperature exposure was not injurious to decrease the cellular membrane fluidity. On the other hand reduction in cell membrane stability under high temperature stress has been reported in cowpea (Ismail and Hall 1999).

Accumulation of osmolytes like proline and sugars, is one of the key adaptive mechanisms in many plants grown under abiotic stresses, including temperature, salinity, water deficit, etc. In this study we observed increased concentration of proline and carbohydrate sugars in elevated temperature grown chickpea plants. Pusa 1108 plants showed significant increase in proline concentration at all growth stages, while in Pusa 1053 it increased significantly only during podding stage (Fig. 3). No significant changes were observed in total sugar concentration of Pusa 1053 but Pusa 1108 plants showed significant reductions at podding stage under high temperature (Fig. 3). Similar increase in soluble sugars under elevated temperature stress has been reported in various other crop species by Wahid and Close (2007). Accumulation of more proline in Pusa 1108 under high temperature may be considered as its characteristic for temperature tolerance.

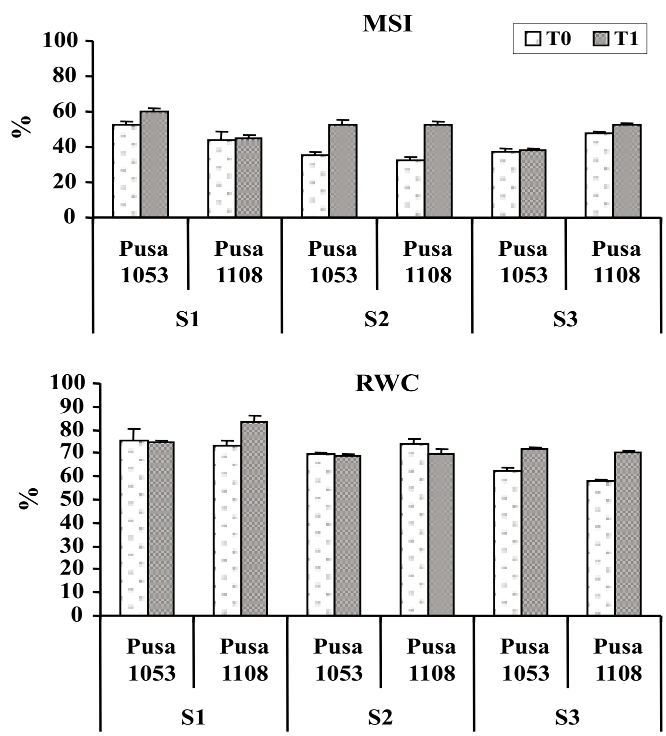

Fig. 2. Effect of high temperature on membrane stability index (MSI) and relative water content (RWC) at different growth stages in two chickpea cultivars (T0 = normal temperature; T1 = high temperature exposure throughout growth period; S1 = vegetative stage; S2 = flowering stage; S3 = podding stage)

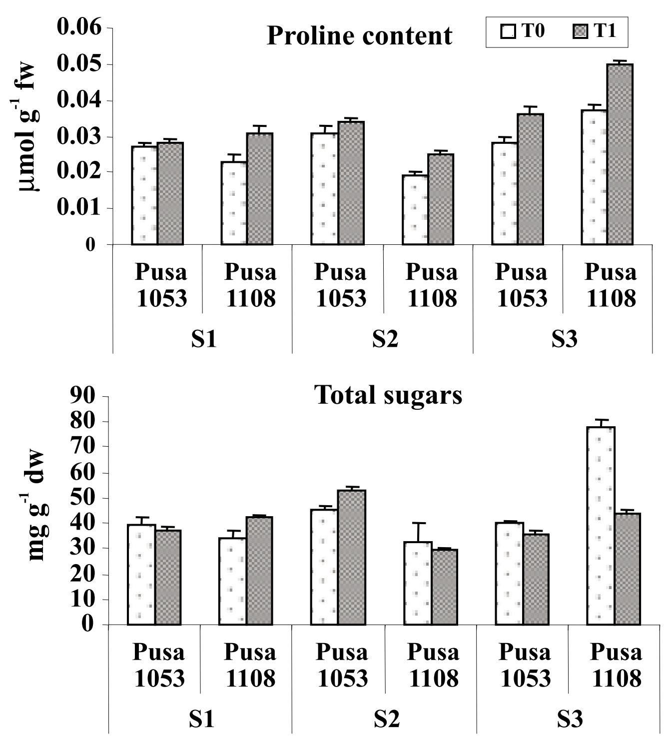

Fig. 3. Effect of high temperature on proline content and total sugars at different growth stages in two chickpea cultivars (T0 = normal temperature; T1 = high temperature exposure throughout growth period; S1 = vegetative stage; S2 = flowering stage; S3 = podding stage)

Despite of enhanced growth and rate of photosynthesis in the chickpea plants grown under high temperature throughout the growth period, their yield was less compared to plants exposed to higher temperature only for 10 days durations during flowering and podding stages. Pusa 1053 plants grown under elevated temperature throughout the growth period (T1), showed no significant changes in their number of pods per plants, pod and seed weight per plant and for other yield attributes, while the plants of same cultivar exposed to elevated temperature for short duration of ten days during flowering or podding stage (T2 and T3) showed significant increase in pod number (54.4%), seed weight (51.5%) and plant biomass (24.3%) (Fig. 4). On the other hand, no significant changes were observed in plants of cultivar Pusa 1108, in respect to above parameters under similar temperature treatments. These findings suggest that enhanced growth during vegetative stage is not desirable for higher yield in chickpea. Wang *et al.* (2006) have suggested exposure of chickpea to abiotic stress (either temperature or drought) to suppress vegetative growth and enhance plant yield.

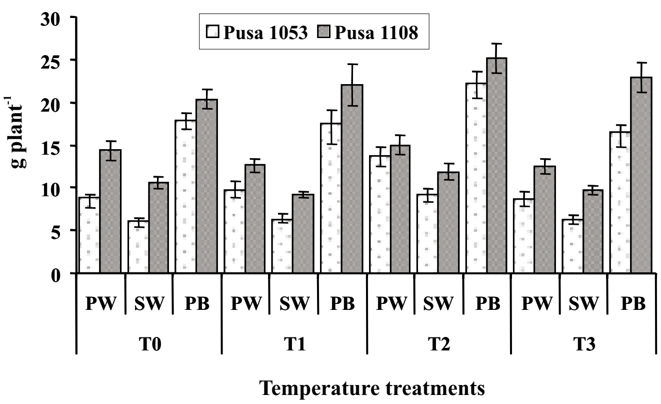

Fig. 4. Effect of high temperature on yield attributes in two chickpea cultivars (T0 = normal temperature; T1 = high temperature exposure throughout growth period; T2 = high temperature exposure at flowering; T3 = high temperature exposure at podding; PW = pod weight plant^{-1}; SW = seed weight plant^{-1}; PB = plant biomass plant^{-1})

Nayyar *et al.* (2007) reported that during winter season low temperature suppresses the growth and seed yield of chickpea in Northern India. Similar reductions in growth and yield of chickpea and other legumes have been reported under low temperatures (Singh *et al.* 1993, Spears *et al.* 1997). Nayyar *et al.* (2007) also reported increase in pod numbers and weight in chickpea at higher temperature compared to low temperature. In our study increased seed yield in Pusa 1053 in plants exposed to high temperature during flowering and podding is consistent to above reports. This study suggests that 3.1°C increase in growth temperature may enhance vegetative growth and photosynthesis in chickpea but may not affect the seed yield. On the other hand short terms exposure of higher temperature during flowering or podding may have positive influence on yield of chickpea cultivar in timely sown crop under Delhi conditions. Finally, it is concluded that moderate increase in temperature under future climate change scenario may not be detrimental for chickpea in northern region of India.

ACKNOWLEDGEMENTS

The authors thank Head, Division of Plant Physiology and Principal and Head, Botany Department, M.M.H. College, Ghaziabad for providing encouragement and necessary facilities.

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