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Heat sensitivity on physiological and biochemical traits in chickpea (*Cicer arietinum*)

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Abstract. Four chickpea cultivars viz. kabuli (Pusa 1088 and Pusa 1053) and desi (Pusa 1103 and Pusa 547) differing in sensitivity to high temperature conditions were analyzed in earthern pot (30 cm) at different stages of growth and development in the year of 2010 and 2011. Pusa-1053 (kabuli type) showed maximum photosynthetic rate and least by Pusa-547 (desi type), whereas maximum cell membrane thermostability were recorded in Pusa-1103 and minimum in Pusa-1088. Among the treatments, the plants grown under elevated temperature conditions had produced 13.01% more significant data in comparison to plants grown under continuous natural conditions. Stomatal conductance were reduced 44.25% under elevated temperature conditions than natural conditions, whereas 35.56%, when plants grown under initially natural conditions upto 30DAS, then 30-60DAS elevated temperature and finally shifted to natural conditions till harvest. In case of Pusa-1103, stomatal conductance was maximum as compared to rest of 2.7% from Pusa-1053, 8.9% from Pusa-1088, and 10.3% in Pusa-547 throughout the study. Plants grown under continuous elevated temperature conditions had produced 15.30% and 15.32% more significant membrane thermostability index in comparison to continuous natural conditions at vegetative stage and 19.40% and 18.44% at flowering stage, while the better response was recorded at pod formation stage. Pusa-1053 had given 2.8% more membrane thermostability index than Pusa-1088 and Pusa-1103 had given 1.6% more membrane thermostability index than Pusa-547 in the present study. The membrane disruption caused by high temperature may alter water ion and inorganic solutes movement, photosynthesis and respiration. Thus, thermostability of the cell membrane depends on the degree of the electrolyte leakage.

Keywords: chickpea; photosynthetic rate; stomatal conductance and cell membrane thermostability index

1. Introduction

Gobal warming and changes in cropping systems are driving chickpea production to relatively warmer growing conditions. By the end of the 21st century, the earth's climate is predicted to warm by an average of 2-4°C (IPCC 2007), due to both anthropogenic and natural factors (Eitzinger *et al*. 2010). Emission of green houses gases and nitrous oxide from agricultural systems is one of the major sources contributing to this global increase of temperature (Maraseni *et al*. 2009, Smith and Olesen 2010). The impact of high temperature at night is more devasting than day

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time or means daily temperatures. The effects of heat stress during the vegetative, poding and reproductive stages using agronomic, phonological and morphological and physiological assessment has been studied in various crops such as wheat (Sharma *et al*. 2005), cotton (Cottee *et al*. 2010) and rice (Weerakoon *et al*. 2008). Chickpea is grown in semiarid regions of the world for hundred so years, primarily in India, Pakistan and the Middle East (Kumar and Abbo 2001). Chickpea is sensitive to high temperature at the full bloom stage. Major reductions in the seed yields after brief episodes of high temperature (30-35°C) during seed filling can diminish seed set, seed weight and accelerate senescence and reduce yield (Siddique and Loss 1999), while only limited research has been conducted on screening of heat tolerance in chickpea (Wang *et al*. 2006, Krishnamurthy *et al*. 2011, Upadhyaya *et al*. 2011, Chakrabarti *et al*. 2013).

2. Materials and methods

The experiment was laid out in earthern pots (30 cm) under following treatments as: (a) Natural conditions throughout growing period as control; (b) Poly covered hut conditions throughout growing period as ± 5°C elevated temperature conditions; and (c) One set of pots were shifted to hut conditions to exposed under high temperature conditions after 30 days intervals viz. 30DAS, 60DAS, 90DAS and 120DAS till maturity of the crop at different stages of growth on 10th November 2009 and 2010 at Agricultural Research Farm, Janta Vedic College, Baraut (Baghpat). Seeds of selected four cultivars of chickpea viz. kabuli (Pusa 1088 and Pusa 1053) and desi (Pusa 1103 and Pusa 547) were obtained from the Pulses Laboratory, IARI, Pusa, New Delhi. To expose chickpea plants to elevated temperature, a wooden structure of size 10 × 5 × 2 meter were erected on the pots with PVC (Polyvinyl chloride) film (Caprihans, Sunflex 0.15 mm thickness and transmittance 85%) and 4 inches space above the ground was uncovered for air circulation for control the humidity level inside the poly cover. Thermo-hygrometer was placed inside the polycover and the levels of temperature and humidity were recorded regularly. The uniform basal dosage of nitrogen in the form of urea (20 kg/ha) and potassium in the form of potash (40 kg/ha) were applied in the soil before filling in to the pots and the desired plant population (3 plants in each pots), gap filling and thinning operation were carried out after twenty days of sowing in the pots of all the cultivars of chickpea to avoid the competition for the light, space and nutrients. Endosulphan was sprayed @ 2 ml/litre to protect against pod borer attack at the pre-flowering and at the beginning of pod formation stage. Photosynthetic Rate (μ mole $CO_2m^{-2}s^{-1}$), Stomatal conductance ($cm^{-1}s^{-1}$) were measured by LI-6200 Portable System containing LI-6250 Analyzer, whereas cell membrane thermostability (%) was determined by the method of Sullivan (1972) from all the representative plants in each treatment of all cultivars in all conditions at different stages of growth in three replications. Statistical analysis was done by adopting appropriate method of “Analysis of Variance” as described by Panse and Sukhatme (1967).

3. Result and discussion

3.1 Photosynthetic Rate (μ *mole* $CO_2m^{-2}\ s^{-1}$)

Photosynthesis is one of the most heat sensitive physiological processes in plants (Crafts-Brander and Salvucci 2002). High temperature has a greater influence on the photosynthetic

Table 1 Photosynthetic rate (μmol $CO_2 m^{-2} s^{-1}$) as influenced by natural and elevated temperature conditions at different stages of growth and development in kabuli and desi cultivars of chickpea (both years)

Trt.	2009-10			2010-11		
	Stages					
	Vegetative	Flowering	Pod formation	Vegetative	Flowering	Pod formation
V_1T_0	10.40	9.67	9.61	10.10	11.91	10.18
V_1T_1	8.66	19.73	11.45	8.56	19.18	11.17
V_1T_2	8.04	11.53	8.44	8.12	11.45	8.47
V_1T_3	10.15	10.71	7.11	10.08	10.65	7.53
V_1T_4	9.98	13.46	7.38	9.59	13.60	8.11
V_1T_5	10.36	12.65	8.14	10.91	12.82	8.19
V_1T_6	9.98	11.74	9.14	10.31	11.98	9.45
V_2T_0	8.29	9.46	8.17	8.59	9.89	8.14
V_2T_1	9.57	12.39	9.49	9.96	11.86	9.41
V_2T_2	8.75	10.41	7.31	8.73	10.88	7.31
V_2T_3	9.21	7.59	6.85	9.09	8.18	6.79
V_2T_4	8.49	8.68	7.94	8.72	8.57	7.88
V_2T_5	8.95	9.20	7.09	9.01	9.29	6.95
V_2T_6	9.07	10.22	8.09	8.96	9.77	8.83
V_3T_0	9.64	9.87	8.66	9.51	10.55	8.55
V_3T_1	8.96	13.03	9.75	9.24	12.98	10.25
V_3T_2	8.18	9.41	7.39	8.35	8.83	7.54
V_3T_3	9.54	8.39	8.06	9.43	8.82	8.43
V_3T_4	9.05	7.94	7.50	8.84	8.03	8.01
V_3T_5	9.98	11.20	8.03	10.04	11.82	8.23
V_3T_6	9.21	9.75	8.22	9.41	9.90	8.15
V_4T_0	8.85	11.36	9.77	8.94	12.50	10.56
V_4T_1	9.18	15.08	10.56	8.78	14.40	11.13
V_4T_2	8.52	10.53	7.74	8.61	10.82	7.32
V_4T_3	9.27	9.16	8.20	9.49	9.98	8.11
V_4T_4	8.14	7.45	7.12	8.29	7.29	7.21
V_4T_5	9.55	8.41	7.25	9.63	8.72	7.12
V_4T_6	8.63	9.25	8.41	8.62	9.33	8.14
S.Em.±	0.130	0.664	0.206	0.199	0.326	0.234
CD at 5%	0.370	1.881	0.583	0.565	0.923	0.662

V_1 - Pusa 1088, V_2 - Pusa 1053, V_3 - Pusa 1103 and V_4 - Pusa 547

T_0 - Continuous natural conditions, T_1 - Continuous elevated temperature conditions, T_2 - Initially elevated temperature conditions upto 30DAS and then natural conditions, T_3 - Initially natural conditions upto 30DAS, then 30-60DAS elevated temperature and finally shifted to natural conditions till harvest, T_4 - Initially natural conditions upto 60DAS, then 60-90DAS elevated temperature and finally shifted to natural conditions till harvest, T_5 - Natural conditions upto 90DAS, then 90-120 DAS under elevated temperature conditions and finally shifted to natural conditions till harvest and T_6 - Natural conditions upto 120 DAS and then elevated temperature conditions till harvest

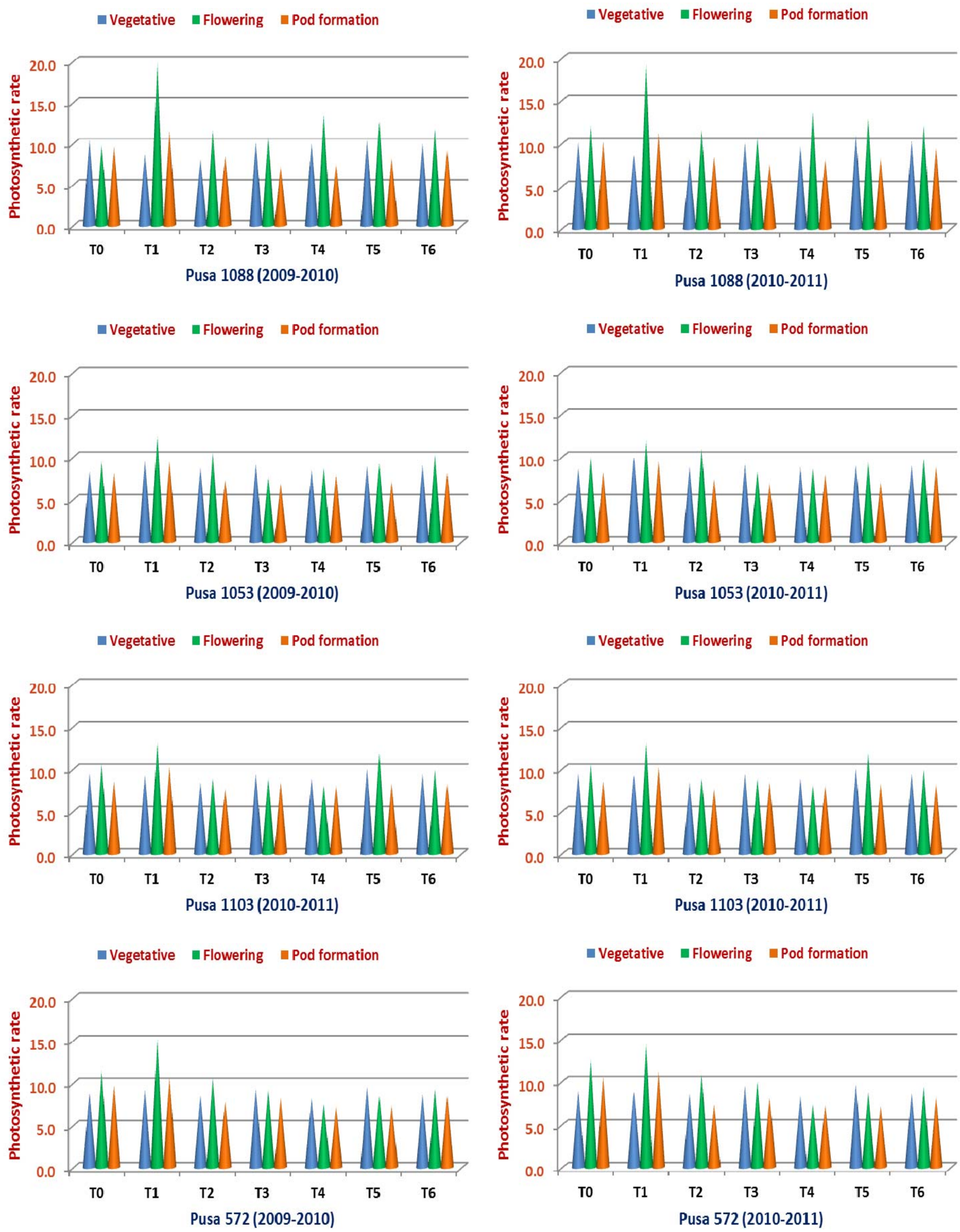

Fig. 1 Photosynthetic rate (μmol $CO_2m^{-2}s^{-1}$) as influenced by natural and elevated temperature conditions at different stages of growth and development in kabuli and desi cultivars of chickpea (both years)

capacity of plants especially of C_3 plants than C_4 plants (Yang *et al*. 2006). In most plants, changes in photosynthetic rate in response to temperature are significant over a range of 10-35°C, but exposure to temperature below or above this range may cause injury to the photosynthetic system. In the present study, significant increase in photosynthetic rate was observed in all the cultivars when plants grown under elevated temperature conditions.

Data on photosynthetic rate show that the photosynthetic rate were increased at flowering stage and then declined from the flowering stage to maturity in all the cultivars of chickpea in both years of experimentation (Table 1 and Fig. 1). Plants grown under natural conditions had produced 2.25% and plants grown initially up to 60DAS and then shifted in elevated temperature conditions had produced 4.95% more photosynthetic rate in comparison to plants grown under natural conditions at vegetative stage. During pod formation, the photosynthetic rate had gradually declined in comparison to flowering stage and maximum decreased in photosynthetic rate were recorded in Pusa-1088 at flowering stage than all other experimental cultivars of chickpea.. Maximum photosynthetic rate was recorded in Pusa-1088 (11.45 and 11.17) in Pusa-1088 and minimum in Pusa-1053 (9.49 and 9.41) grown under continuous elevated conditions.

At harvest, Pusa-1088 were produced 19.07% photosynthetic rate followed by Pusa-1053 (16.34), Pusa-547 (13.93%) and Pusa-1103 (8.12%) under continuous elevated temperature conditions in comparison to under continuous natural conditions. Among the treatments, the plants grown under elevated temperature conditions had produced 13.01% more significant data in comparison to the plants grown under continuous natural conditions. Furthermore, under high temperatures, degradation of chlorophyll "*a*" and "*b*" was more pronounced in developed compared to developing leaves (Karim *et al*. 1997, 1999). Such effects on chlorophyll or photosynthetic apparatus were suggested to be associated with the production of active oxygen species (Camejo *et al*. 2006, Guo *et al*. 2006).

3.2 Stomatal Conductance ($cm^{-1}s^{-1}$)

Data reveals that stomatal conductance were decreased from vegetative to flowering stage and thereafter increased from flowering to pod formation stage in all experimental cultivars of chickpea during experimentation (Table 2 and Fig. 2). Maximum stomatal conductance was recorded in Pusa-547 (0.773 and 0.760) and minimum in Pusa-1053 (0.711 and 0.715) under natural conditions, whereas maximum stomatal conductance was recorded in Pusa-1088 (0.436 and 0.423) and minimum in Pusa-1053 (0.408 and 0.402) under elevated conditions at vegetative stage. At flowering stage, plants grown upto 30DAS in natural conditions then shifted in to natural conditions had given significant data as compared to all other treatments except the plants grown upto 30DAS under natural and then shifted upto 60DAS under elevated temperature conditions in Pusa-1088 and Pusa-1053 in 2009-10, and except only in the plants grown upto 30DAS under natural and then shifted upto 60DAS under elevated temperature conditions in the year of 2010-11.

During pod formation stage, plants grown up to 120DAS under natural conditions had given significant data as 0.476 and 0.500 in Pusa-1088, 0.719 and 0.712 in Pusa-1053, 0.726 and 0.796 in Pusa-1103 and 0.504 and 0.525 in Pusa-547 as compared to the plants grown under elevated temperature conditions as 0.0442 and 0.439 in Pusa-1088, 0.732 and 0.776 in Pusa-1053, 0.684 and 0.707 in Pusa-1103 and 0.684 and 0.707 in Pusa-547 in both years.

Among the treatments, the plants grown under continuous natural conditions had produced 34.76% better stomatal conductance than plants grown under continuous elevated temperature conditions throughout the study. Among all four experimentation cultivars, Pusa-1103 showed

Table 2 Stomatal conductance ($cm^{-1}s^{-1}$) as influenced by natural and elevated temperature conditions at different stages of growth and development in kabuli and desi cultivars of chickpea (both years)

Treatments	2009-10			2010-11		
	Stages					
	Vegetative	Flowering	Pod formation	Vegetative	Flowering	Pod formation
V_1T_0	0.760	0.400	0.484	0.736	0.394	0.482
V_1T_1	0.436	0.212	0.374	0.423	0.249	0.360
V_1T_2	0.517	0.303	0.442	0.518	0.304	0.439
V_1T_3	0.479	0.184	0.313	0.484	0.164	0.366
V_1T_4	0.768	0.288	0.383	0.809	0.297	0.377
V_1T_5	0.755	0.382	0.463	0.776	0.399	0.440
V_1T_6	0.765	0.383	0.476	0.802	0.398	0.500
V_2T_0	0.711	0.221	0.762	0.715	0.279	0.781
V_2T_1	0.408	0.193	0.496	0.402	0.187	0.522
V_2T_2	0.544	0.211	0.732	0.517	0.223	0.776
V_2T_3	0.481	0.161	0.451	0.477	0.186	0.432
V_2T_4	0.723	0.242	0.506	0.770	0.266	0.518
V_2T_5	0.716	0.236	0.709	0.669	0.246	0.703
V_2T_6	0.716	0.237	0.719	0.739	0.287	0.712
V_3T_0	0.763	0.234	0.767	0.752	0.234	0.788
V_3T_1	0.423	0.203	0.519	0.424	0.215	0.520
V_3T_2	0.603	0.213	0.684	0.595	0.215	0.707
V_3T_3	0.494	0.185	0.478	0.500	0.185	0.527
V_3T_4	0.746	0.198	0.500	0.724	0.184	0.524
V_3T_5	0.743	0.262	0.695	0.744	0.281	0.763
V_3T_6	0.758	0.267	0.726	0.746	0.269	0.796
V_4T_0	0.773	0.278	0.564	0.760	0.285	0.551
V_4T_1	0.416	0.212	0.484	0.407	0.209	0.505
V_4T_2	0.540	0.193	0.519	0.555	0.176	0.513
V_4T_3	0.481	0.180	0.388	0.453	0.172	0.360
V_4T_4	0.756	0.201	0.520	0.750	0.212	0.518
V_4T_5	0.750	0.272	0.476	0.726	0.270	0.419
V_4T_6	0.757	0.289	0.504	0.762	0.288	0.525
S.Em.±	0.013	0.005	0.009	0.015	0.011	0.012
CD at 5%	0.036	0.015	0.025	0.043	0.031	0.034

V_1 - Pusa 1088, V_2 - Pusa 1053, V_3 - Pusa 1103 and V_4 - Pusa 547
T_0 - Continuous natural conditions, T_1 - Continuous elevated temperature conditions, T_2 - Initially elevated temperature conditions upto 30DAS and then natural conditions, T_3 - Initially natural conditions upto 30DAS, then 30-60DAS elevated temperature and finally shifted to natural conditions till harvest, T_4 - Initially natural conditions upto 60DAS, then 60-90DAS elevated temperature and finally shifted to natural conditions till harvest, T_5 - Natural conditions upto 90DAS, then 90-120 DAS under elevated temperature conditions and finally shifted to natural conditions till harvest and T_6 - Natural conditions upto 120 DAS and then elevated temperature conditions till harvest

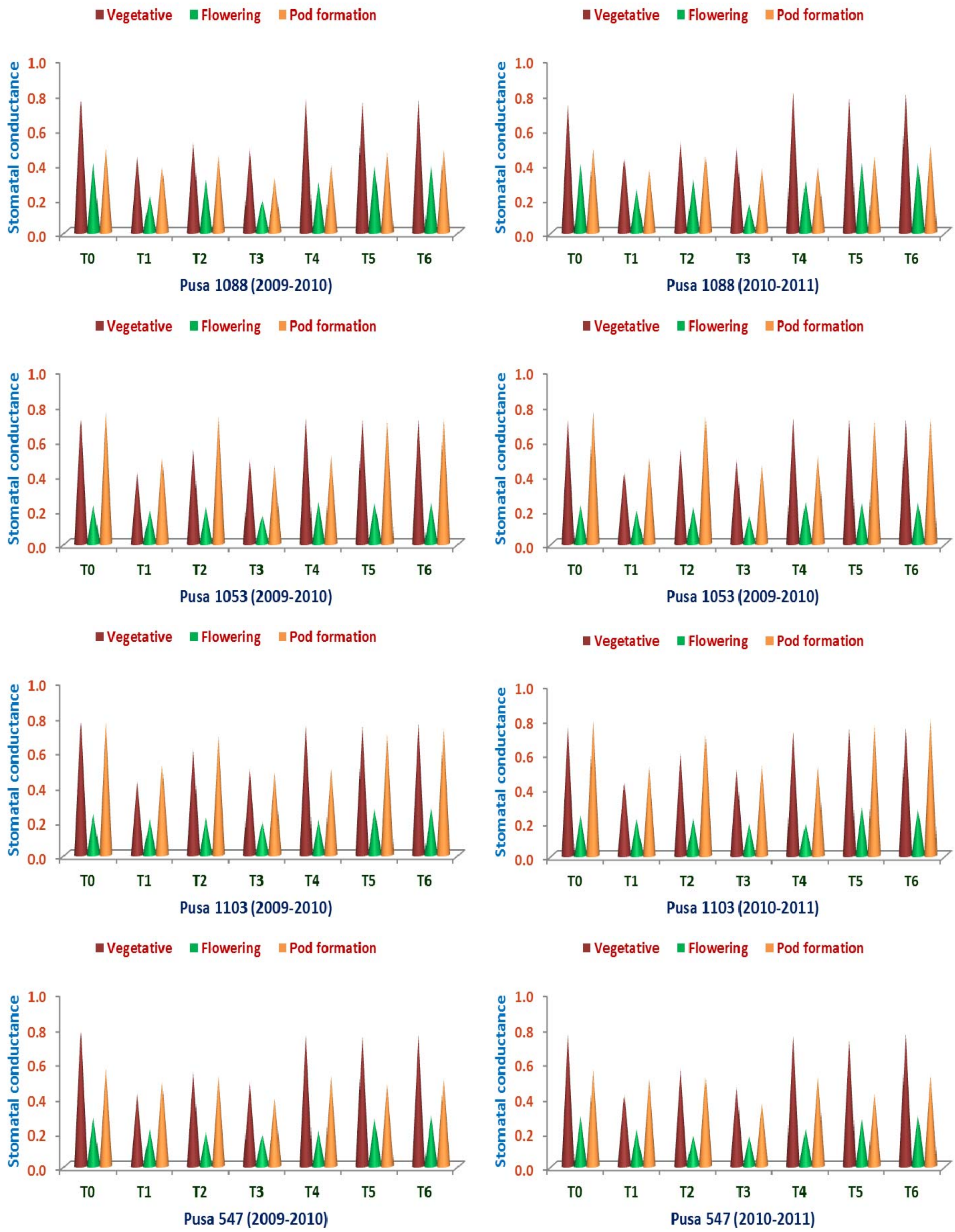

Fig. 2 Stomatal conductance ($cm^{-1}s^{-1}$) as influenced by natural and elevated temperature conditions at different stages of growth and development in kabuli and desi cultivars of chickpea (both years)

2.7% better stomatal conductance than Pusa-1053 followed by Pusa-1088 (8.9%) and Pusa-547 (10.3%) throughout the study. Stomatal conductance were reduced 44.25% under elevated temperature conditions than natural conditions, whereas 35.56%, when plants grown under initially natural conditions upto 30DAS, then 30-60DAS elevated temperature and finally shifted to natural conditions till harvest. Sikder and Paul (2010). The effects of elevated CO_2 concentration on plant growth and development, source-sink balance as well as its interactive mechanisms with other environmental factors including water availability, temperature and mineral nutrition (Reddy *et al*. 2010).

In case of Pusa-1103, stomatal conductance was maximum than rest of the cultivars as 2.7% from Pusa-1053, 8.9% from Pusa-1088, and 10.3% in Pusa-547 throughout the study. Rise in temperature might have resulted in moisture stress in the plants which led to the reduction in stomatal conductance. (Khetrapal *et al*. 2009). Initiation and expansion of the roots, shoots, leaves and reproductive organs over strongly given by the temperature (Morison and Lowler 1999). Warmer conditions both accelerate rate of organs initiation and shorter duration of organ growth thereby leading to reduced growing of plans organs at higher temperature. Chakraborty and Pradhan (2010) concluded that chlorophyll content also increased initially in IPL 81 and IPL 406 the varieties of lentil before declining but in variety Sehore it decreased at all high temperatures. Phenol contents increased initially but decreased at higher temperatures.

3.3 Cell Membrane Thermostability Index (%)

Membrane thermostability test is widely used to evaluate heat tolerance and sensitive cultivars (Tongten *et al*. 2006), and the heat susceptibility index issued to evaluate the yield parameters. Sustained function of the cellular membranes under stress is crucial for process such as photosynthesis and respiration (Blum 1988). Heat stress accelerates the kinetic energy and movement of molecules across the membrane thereby loosening chemical bonds within molecules of biological membranes, and 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 altercates enhance the permeability of the membranes as evident from increased loss of the electrolytes. The membrane disruption caused by high temperature may alter water ion and inorganic solutes movement, photosynthesis and respiration. Increased solute leaking as an indication of decreased cell membrane thermostability has long been used an indirect measurement of heat stress tolerance in diverse plant species including soybean (Martineau *et al*. 1979), tomato and potato (Chen *et al*. 1982), wheat (Blum *et al*. 2001), wheat and chickpea (Chakrabarti *et al*. 2013), cotton (Ashaf *et al*. 1994) and barley (Wahid and Shabbir 2005).

It is evident that cell membrane stability was maximum in the plants grown under continuous elevated temperature conditions and declined during the time of flowering than vegetative stage, and then further increased towards pod formation stage. Data revealed that the membrane thermostability index was maximum in Pusa-1103 (62.05 and 62.18) and minimum in Pusa-1088 (48.99 and 48.10) in both years under continuous elevated temperature conditions. Non-significant response was observed between Pusa-1053 and Pusa-1103 related to membrane thermostability in the plants grown under continuous elevated temperature conditions, whereas the plants grown under continuous elevated temperature conditions had produced 15.30% more significant membrane thermostability index in comparison to continuous natural conditions (Table 3 and Fig 3).

Membrane thermostability index were declined at flowering stage in comparison to vegetative

Table 3 Cell Membrane Thermostability Index (%) as influenced by natural and elevated temperature conditions at different stages of growth and development in kabuli and desi cultivars of chickpea (both years)

Treatments	2009-10			2010-11		
	Stages					
	Vegetative	Flowering	Pod formation	Vegetative	Flowering	Pod formation
V_1T_0	48.99	41.16	43.88	48.10	40.87	45.12
V_1T_1	58.40	49.21	52.57	57.14	48.60	54.92
V_1T_2	47.79	40.64	45.83	47.25	40.37	46.33
V_1T_3	55.77	46.43	52.38	56.47	48.12	52.37
V_1T_4	46.81	45.13	51.09	47.78	46.46	52.13
V_1T_5	48.95	41.95	48.37	48.12	42.35	48.05
V_1T_6	48.74	41.10	43.20	48.14	45.17	44.34
V_2T_0	52.76	45.17	48.31	53.91	45.46	48.45
V_2T_1	60.96	49.70	52.41	61.46	51.35	53.68
V_2T_2	51.06	43.11	48.15	51.07	42.72	48.58
V_2T_3	59.17	47.45	51.30	57.42	46.99	51.65
V_2T_4	53.67	46.38	52.06	54.04	49.08	50.42
V_2T_5	50.75	42.45	49.07	51.30	43.73	49.14
V_2T_6	52.00	45.02	50.59	50.26	46.64	50.12
V_3T_0	53.64	46.86	51.84	54.35	47.51	53.42
V_3T_1	62.05	55.43	57.62	62.18	56.51	59.12
V_3T_2	50.49	45.58	51.09	50.93	44.84	48.94
V_3T_3	61.30	44.99	53.59	62.89	45.03	54.13
V_3T_4	48.93	43.68	50.43	48.46	43.54	50.29
V_3T_5	51.88	45.77	52.39	51.32	46.55	53.04
V_3T_6	52.29	47.09	51.90	52.70	47.11	51.31
V_4T_0	55.05	46.67	48.23	56.88	50.73	49.15
V_4T_1	61.02	60.41	57.78	65.14	62.15	55.28
V_4T_2	51.32	43.88	49.05	50.57	44.35	47.87
V_4T_3	62.16	41.52	52.89	51.65	42.50	51.86
V_4T_4	51.42	42.17	50.65	48.68	40.88	50.18
V_4T_5	48.32	39.86	51.87	50.73	38.85	51.89
V_4T_6	51.64	49.39	49.65	52.39	48.97	50.05
S.Em.±	0.351	0.405	0.406	0.362	0.292	0.410
CD at 5%	0.996	1.147	1.149	1.025	0.827	1.163

V_1 - Pusa 1088, V_2 - Pusa 1053, V_3 - Pusa 1103 and V_4 - Pusa 547

T_0 - Continuous natural conditions, T_1 - Continuous elevated temperature conditions, T_2 - Initially elevated temperature conditions upto 30DAS and then natural conditions, T_3 - Initially natural conditions upto 30DAS, then 30-60DAS elevated temperature and finally shifted to natural conditions till harvest, T_4 - Initially natural conditions upto 60DAS, then 60-90DAS elevated temperature and finally shifted to natural conditions till harvest, T_5 - Natural conditions upto 90DAS, then 90-120 DAS under elevated temperature conditions and finally shifted to natural conditions till harvest and T_6 - Natural conditions upto 120 DAS and then elevated temperature conditions till harvest

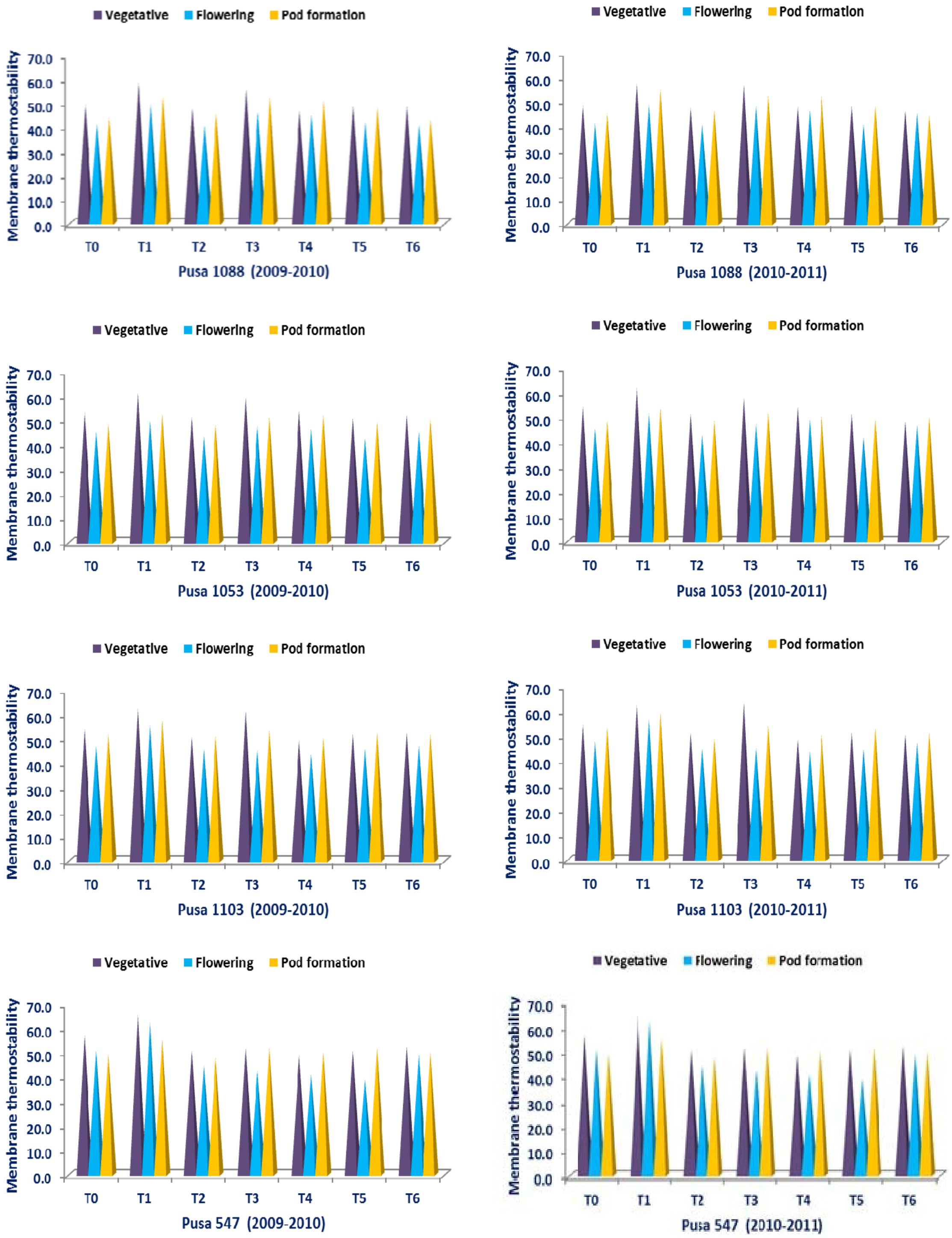

Fig. 3 Cell Membrane thermostability index (%) as influenced by natural and elevated temperature conditions at different stages of growth and development in kabuli and desi cultivars of chickpea (both years)

stage. Maximum thermostability was observed in Pusa-1103 at the flowering stage under elevated temperature conditions. The plants grown under elevated temperature conditions had given 19.40% and 18.44% more membrane thermostability index in comparison to the plants grown under natural conditions in the both years of the experimentation respectively. Significant data was recorded among all cultivars in the both years of experimentation, and plants grown in various treatments of elevated temperature had given significant response in comparison to the plant grown under continuous natural conditions, whereas the plants grown under continuous elevated temperature conditions had given 14.62% more membrane thermostability in comparison to the plants grown under continuous natural conditions. Among the cultivars, Pusa-1053 had given 2.8% more membrane thermostability index in comparison to Pusa-1088 and Pusa-1103 had given 1.6% more MTI in comparison to Pusa-547 throughout the study.

In present study, the plants grown under continuous elevated temperature conditions had produced 15.30% and 15.32% more significant membrane thermostability index in comparison to continuous natural conditions at vegetative stage and 19.40% and 18.44% at flowering stage, while the better response was recorded at pod formation stage. Pusa-1053 had given 2.8% more membrane thermostability index than Pusa-1088 and Pusa-1103 had given 1.6% more membrane thermostability index than Pusa-547 in the present study. Previous studies reported increased electrolytic leakage as a result of increased temperature in *Vigna unguiculata* (Ismail and Hall, 1999, Ibrahim and Quick, 2001). The effects of elevated CO_2 concentration on plant growth and development, source-sink balance as well as its interactive mechanisms with other environmental factors including water availability, temperature and mineral nutrition (Reddy *et al*. 2010) and in rice reported by Devasirvatham *et al*. (2010), Shah *et al*. (2011), Devasirvatham *et al*. (2012), Kumar *et al*. (2013), Farjam *et al*. (2014).

4. Conclusions

Alterations in various parameters under heat stress are good indicators of thermotolerance of the plant as they show correlations with growth. It seems the influence of temperature seems to be more dominant as compared to natural conditions in this particular phase. The increased availability of the temperature increased the photosynthetic rate and stomatal conductance may be responsible for the improvement in growth in various elevated temperature conditions. In kabuli types, Pusa-1053 was showed better response than Pusa-1103 and desi types, Pusa-547 showed more effective result than Pusa-1088. However, Pusa-547 showed more significant results in all traits than other cultivars of chickpea. Present study of stability parameters revealed that desi cultivars have better general adaptability, which indicated that desi types are well adapted than kabuli types. It is observed also that Pusa-547 was superior for several physiological aspects. These may be used in breeding programme effectively for increasing productivity level further under elevated temperature conditions. The simple trails like percent membrane thermostability index and chlorophyll contents may be used in screening of large number of genotypes for elevated temperature conditions.

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