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Effect of Temperature Constraints on Morphological and Cytogenetical Attributes in Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]

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Abstract

The drifting climatic scenario and constant changes in temperature profiles has culminated into heavy crop losses that have set up an alarming situation across the world. A slight modification in temperature ranges results in detrimental effects on the life processes of crop plants as well as on yield attributes. To pursue the effects of temperature stress on plants, both heat and cold stresses are vital cues; hence, they are investigated in this study. *Cyamopsis tetragonoloba* (L.) Taub, has been a test model for the present study due to its restricted pervasion and environmental limitations. The experimental setup included heat stress as well as cold stress (including chilling stress and freezing stress) given at the seedling stage in three replicates. Exposure to freezing stress affected the young seedlings severely, and they eventually collapsed and could not be studied further. The seedlings exposed to the chilling and heat-stress displayed varying degrees of survivability, and were carefully monitored till maturity. Various morphological parameters were recorded at the growing stage. With the advent of the reproductive stage, young floral buds were subjected to fixation in carnoy's fixative. The degree of cytological abnormalities showed a parallel ascend to the increasing stress, where cold stress had a more severe impact on microsporogenesis than heat stress. The morphological characters also exhibited a negative correlation after the treatment, but more profound deterrent results were retrieved in the case of cold stress. In conclusion, cold stress was found to introduce serious effects on plant growth and reproduction, and turned out to be more serious on plants compared with heat stress, for which plants express a degree of diligence and adaptability at short durations.

Keywords: *Cyamopsis tetragonoloba*, Meiosis, Morphological attributes, Temperature stress

1. Introduction

Perpetuation and pervasion patterns of various life forms to variable realms are dependent on wholesome cumulative requirements in terms of abiotic factors. This implies that abiotic factors are intrinsic in dictating biotic life. For instance, living entities of tropic and temperate zones display a vast deal of morphological differences which are the visible reciprocation of differential abiotic patterns in that area. This validates that climatic factors play an intrinsic role in organic sustenance. Among these, temperature is one such limiting attribute that controls and restricts the perpetuation of living beings, is among mainstays for incinerating vitality and vigorousity to the cells. Global temperature is forecasted to continuously increase by 1–3.7^{o} C by the end of the 21st century (IPCC, 2013). Temperature acts as a limiting factor for plants growth and their yield, and also for the geographical distributions of plants (Siddiqui *et al*., 2015).

Any deviation below or above the optimum temporal condition generates a set of stressful responses. Low temperature is one of the major environmental factors impacting plant growth, development, and ecological distribution (Allen and Ort, 2001). Cold stress prevents the expression of the genetic potential of plants directly through the inhibition of metabolic reactions, and indirectly through cold-induced osmotic, oxidative, and other stresses (Chinnusamy *et al.*, 2007) causing significant crop losses. A transient elevation in temperature, that is by 10–15^{0}C above the ambient condition, is considered a heat stress, which also alleviates crop losses. It causes multifarious and often adverse alterations to the plant growth, development, physiological processes and yield (Hasanuzzaman *et al*., 2013).

The morphological dissimilarities reflect the divergence at the cytogenetical and gene- expression level, since the different set of proteins and enzymes work synergistically and inclusively in combating stress constraints. On the genomic level, plant diversity correlates with a high degree of variation in the overall genome size, ploidy level, and chromosome number (Kellogg and Bennetzen, 2004), which results in a course of genome adaptation and change. In order to facilitate the acclimatization of the plant to a distinct niche, adaptive potentialities need to evolve within that life system. Different types of cognitive work on temperature stress have been conducted underlining a multitude of influences

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of temperature modulation on life (Barnabas *et al*., 2008; Hedhly *et al*., 2008; Hatfield and Preuger, 2015).

The most substantial impacts of abiotic stresses occur in the reproductive stages of plants and limit the plant productivity. According to Bione *et al*. (2000), meiosis is strongly influenced by environmental conditions, where both male and female gametogenesis gets affected; microsporogenesis dealing with pollen development is a highly stress-sensitive event. Several researches have been conducted on legumes, including *Vicia faba* (Siddiqui *et al*., 2015), and *Cicer arietinum* (Sharma and Nayyar, 2014). The cytomorphological responses of buckwheat to temperature stress have also been studied by (Kumar and Srivastava, 2015).The current study is designed to investigate such effects on anther meiosis in cluster beans.

Sophisticated acclimation strategies are being formulated for the sake of introducing plants to novel environments. These efforts may serve as a measure for amplifying quantitative gains. However, the introduction and cultivation of new crops in a given environment require management practices and trait selections that enable the crop species to perform to their full potential (Singh *et al*., 2008). Therefore, it is crucial to study the salient effects resulting from temperature disturbances to plants growth and metabolism. Crop production of *C. tetragonoloba* is limited to arid regions, and the plant has a curtailed range of temperature tolerance. This draws the plot for the present experimental work through which the cytogenetical and the morphological characteristics of *C. tetragonoloba* (L.) Taub., (commonly known as guar or cluster bean), is investigated in details. Cluster bean pods contain condensed tannins in addition to *p*-coumaric acid, caffeic acid, gallic acid, gentisic acid, quercetin, kaemferol and its 3-arabinoside, *p*-hydroxycinamyl, and coniferyl alcohol (Asolkar *et al*., 1992). Moreover, cluster beans are also valued for various ethnobotanical uses.

2. Material and Methods

2.1. Seed Procurement

Fresh seeds of *C. tetragonoloba* (L.) Taub., variety RGC-1038, were obtained from Central Arid Zone Research Institute (CAZRI), Rajasthan.

2.2. Treatment

The seeds were thoroughly washed for ten minutes with distilled water, and 0.1 % mercuric chloride was utilized for surface sterilization. The seeds were sown in pots (a mixture of soil and farmyard manure) provided with ambient environmental conditions for germination at the temperature 27 ± 2^0C, until the emergence of two cotyledonary stages. After the emergence of two cotyledons, the seedlings were subjected to temperature stress including heat and cold stress treatments in an incubator at a pre-requisite temperature for a different time durations. Cold stress was subdivided into chilling stress (at 4^o C) and freezing stress (at -4^o C) (Miura and Frumoto, 2013); for the duration of three hours, six hours, and nine hours respectively. The seedlings were subjected to heat stress at the temperature 50^o C for the same time durations. Following treatment, the seedlings were maintained in each set for a recovery period that was equal to the duration of treatment, and were then re-transferred to the pots in triplicates in a completely randomized block design (CRBD).

2.3. Cytogenetical Study

Plant growth was carefully monitored, and after reaching the reproductive stage, young floral buds were fixed in carnoy's fixative (3 parts Alcohol: 1 part Glacial Acetic Acid) for twenty-four hours, and were preserved in 70 % alcohol at 4°C. The buds were teased, and anthers were smeared in a drop of 2% acetocarmine stain for cytological investigation. The slides were observed at 40X resolution by the Nikon Phase Contrast microscope (Nikon Eclipse, E200, Japan), and the microphotography was done using the PCTV software. Based on the stainability criteria of glycero-acetocarmine stain, pollen fertility percentage was also calculated (Marks, 1954). Fully-stained globose-nucleated pollen grains were regarded fertile, whereas light-stained enucleated pollen grains were documented as sterile. Three independent slides were prepared from which ten microscopic views were documented for the scoring of data.

2.4. Morphological and Yield Study

Various morphological parameters were recorded to analyze the effects of temperature stress on the morphological characteristics. The parameters included were survivability percentage, plant height and days to 50 % flowering. Certain yield parameters studied were cluster per plants, pods per cluster, pod length and seeds per pod.

2.5. Statistical Analysis

A statistical calibration was done using SPSS 16.0 version software. The data were statistically analyzed by one-way analysis of variance (ANOVA). The means were compared at $P\leq0.5$ applying the Post hoc and Duncan Multiple Range Test (DMRT). A graphical representation of data was performed using Sigma Plot 10.0 software.

3. Results

3.1. Influence of Temperature Stress on Morphological Parameters

Various morphological parameters were delved to examine all adversities and effects. At the inception of the study, the seedlings showed certain morphological symptoms. In case of heat stress, scorching of seedlings was the most conspicuous symptom present. Occurrence of injuries such as surface pitting, ice formation, water soak spots, and internal discoloration of lesions were discernible in the freezing-stress sets at all of the three time durations. The seedlings were highly susceptible and eventually succumbed to die within two to three days; henceforth, the freezing stress was not monitored further. As for the surface lesions in the case of chilling stress, the injuries were comparatively less severe and included seedling shrinkage, epidermal distortion, and minor chlorotic sites.

The survivability percentage (as shown in Figure 1) was found to be highly affected in the case of chilling-stress treatment compared to the heat-stress treatment. In fact, survivability percentage was among the first hand clues for the effect on the two stresses investigated in this study. The chilling stress was comparatively more detrimental to the plant growth. Survivability percentage was recorded to be 95.33 ± 2.20^a in the case of the control.

It declined down to 68.88±5.87[c] in the case of heat stress, and was curtailed down to a low percentage of 39.99±3.84[d] in the case of chilling cold stress in nine hours of treatment. Also, a similar decline was observed in the plant height trend (Figure 2). Mean plant height in the control was recorded to be 92.16±1.69[a] cm, which declined from 88.60±1.40[a] cm to 73.06±1.55[c] cm at the heat stress, whereas the mean plant height went down from 83.46±1.33[b] to 52.53±1.63[d] cm in the case of chilling stress after nine and three hours of treatments respectively. The cold stress resulted in a delay in the initial onset of flowering, the trend of which is documented in the graph of days to 50% flowering (Figure 3). As for the control, days to 50% flowering was recorded to be 35.33±0.88[a] days, whereas it occurred after 41.66±1.45[b] days at the heat stress, and after 62.66±1.85[d] days in the case of cold stress after nine hours of treatment.

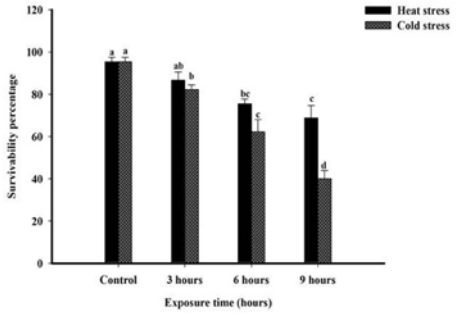

Figure1. Effect of temperature stress on survivability percentage in *Cyamopsis tetragonoloba* (L.) Taub.

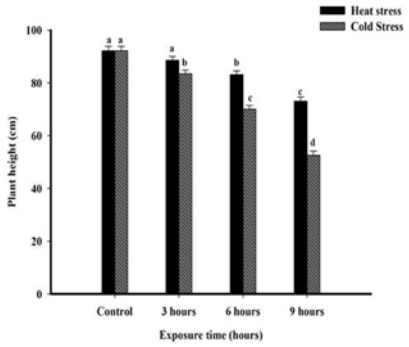

Figure 2. Effect of temperature stress on plant height in *Cyamopsis tetragonoloba* (L.) Taub.

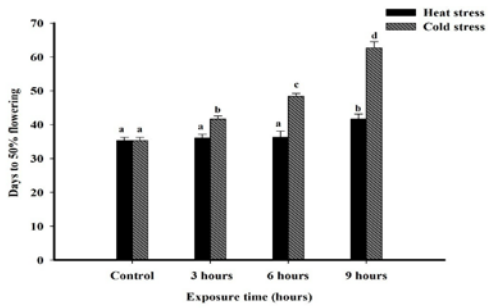

Figure 3. Effect of temperature stress on days to 50 % flowering in *Cyamopsis tetragonoloba* (L.) Taub.)

3.2. Influence of Temperature Stress on Microsporogenesis

The cytological imaging was obtained through the cytogenetical investigation of pollen mother cells. Meiotic events in the control set followed a normal course. The chromosomal morphology at various stages of meiosis I/II were examined and were found to be absolutely normal. Figure 4 shows the cytological plate representing various important meiotic stages. Metaphasic plate I displayed the presence of seven bivalents (Figure 4A) at the equatorial plate segregated synchronically at anaphase I (Figure4B), resulting in 7:7 poleward separation. However, a large proportion of chromosomal abnormality was witnessed in the case of the stress-treated sets. Table 1 displays the effect of temperature stress on the chromosomal morphology of *Cyamopsis tetragonoloba* (L.) Taub. The total abnormality percentage (TAB %), the criteria for adjudging the extent of chromosomal abnormality, increased from 2.65±0.25% to 11.15±0.19% in the case of heat stress, whereas after the cold stress treatments, an increment from 5.84±0.36% to 16.40±0.37% was reported. In comparison, it was perceived that the cold stress had left a marked genotoxicity on the chromosomal entity of this drought-tolerant plant. The preponderant abnormalities witnessed were secondary associations: stickiness (Figure 4G), unorientation, precocious movement, multivalents (Figure 4D), disturbed polarity (Figure 4J), laggard chromosome and anaphase bridge formation etc. In the case of heat stress, precocious movement (0.56±0.16 % to 1.56±0.07 %) and unorientation (0.37±0.24 % to 1.29±0.17 %) at metaphase I/II were the most predominant abnormalities found upon increasing the duration of treatment from three to nine hours. Multivalents, bridges and laggard formation were recorded at six and nine hours of treatments in the case of heat stress. In relation to responses to cold stress, stickiness at metaphase I/II was the most pronounced abnormality reported, which increased from 0.62±0.31% to 2.20±0.23% after three and nine hours of treatments respectively. Considerable frequency of univalent formation was also seen in the cold-stress treated set. Increment from 0.54±0.16 to 1.81±0.19 in the case of multivalents and from 0.53±0.14 to 1.21±0.36 in the case of bridges was recorded in the cold-stress treated set

Pollen fertility is a criterion of extreme significance that governs the reproductive success. Fertile pollens were globose, nucleated and darkly-stained with proper ornamentation on the exine wall. Pollen fertility in case of the control set was calculated to be 98±0.57[a] %. In the case of heat stress, it was calculated to be at 93±1.15[b]% in the three-hour-treatment set, and declined to 77.33±0.88[d] % after nine hours of treatment. At cold stress, it was recorded to be in 90.33±0.88[b]% after three hours of treatment, and descended to 61.33±0.88[d]% in the nine-hour-treatment set. A graphical representation of pollen fertility is provided in Figure 5. Sterile pollens are represented in Figure 4L.

Table 1. Effects of temperature stress on anther meiosis in *Cyamopsis tetragonoloba* (L.) Taub.

Treatment	Duration	Metaphasic Abnormality I/II (Mean ± SE)						Anaphasic Abnormality I/II (Mean ± SE)					Others	TAB%
		Sa	St	Un	Pr	Uni	Mt	St	Un	Dsp	Br	Lg		
Control	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat stress (50°C)	3 hours	0.47± 0.2	0.09± 0.09	0.37± 0.18	0.56± 0.16	-	-	-	0.47± 0.24	0.28± 0.16	-	-	0.37± 0.25	2.65 ± 0.25
	6 hours	0.54± 0.16	0.53± 0.31	1.16± 0.22	0.89± 0.17	0.27± 0.15	0.08± 0.08	0.45± 0.9	0.62± 0.07	0.54± 0.15	0.09± 0.09	0.71± 0.08	0.62± 0.07	6.52± 0.42
	9 hours	0.73± 0.08	0.82± 0.14	1.29± 0.12	1.56± 0.07	0.63± 0.22	0.46± 0.10	0.91± 0.10	0.83± 0.17	1.00 ± 0.08	0.73± 0.10	1.09± 0.13	1.01± 0.11	11.15± 0.19
Cold stress (4°C)	3 hours	0.35± 0.08	0.62± 0.31	0.62± 0.07	0.35± 0.23	0.44± 0.08	0.54± 0.16	0.71± 0.08	0.53± 0.14	0.18± 0.18	0.53± 0.14	0.18± 0.18	0.63± 0.18	5.84 ± 0.36
	6 hours	0.75± 0.09	1.41± 0.15	0.85± 0.18	0.83± 0.14	0.95± 0.27	1.03± 0.09	1.03± 0.07	0.85± 0.18	1.03± 0.07	0.74± 0.23	0.57± 0.29	0.74± 0.08	10.88± 0.33
	9hours	1.40± 0.18	2.20± 0.23	1.20± 0.16	1.10± 0.20	1.40± 0.20	1.81± 0.19	1.60± 0.10	1.10± 0.27	1.20± 0.31	1.21± 0.36	0.90± 0.15	0.99± 0.25	16.40± 0.37

Mean ± S.E. Values followed by the superscript differ at $p<0.05$ among treatments by the DMRT

Abbreviations – **Sa:** Secondary association; **St:** Stickiness; **Un:** Unorientation; **Pr:** Precocious movement; **Uni:** Univalents; **Mt:** Multivalents; **Dsp:** Disturbed polarity; **Br:** Bridge; **Lg:** Laggard formation; **TAB %:** Total Abnormality Percentage.

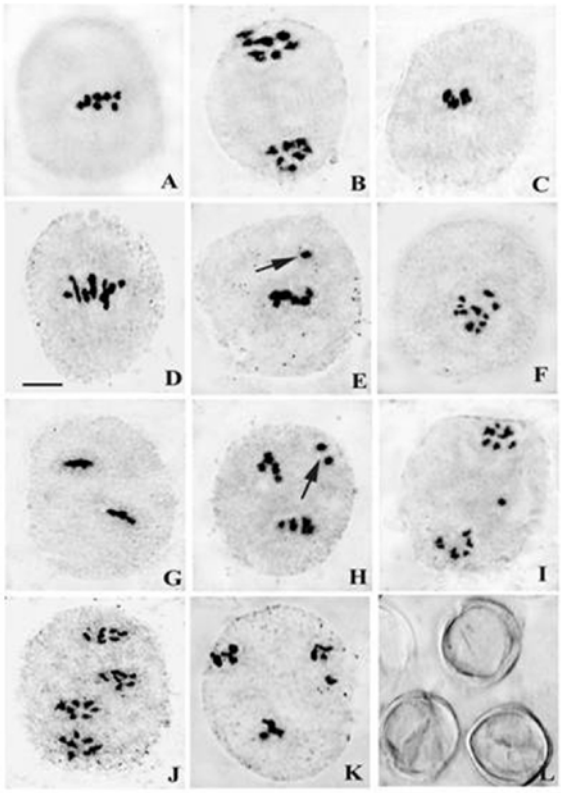

Figure 4. Cytological plate- **A:** Normal metaphase I (7 bivalents**), B:** Normal anaphase I (7:7 migration**), C:** Clumping at metaphase I**, D:** Multivalent at metaphase I**, E:** Precocious movement at metaphase I**, F:** Univalents at metaphase I**, G:** Stickiness with unorientation at metaphase II**, H:** Unoriented precocious metaphase II**, I:** Unoriented laggard formation at anaphase I**, J:** Disturbed polarity at anaphase II**, K:** Tripolarity**, L:** Sterile pollens**.** Scale Bar 1cm= 10.50 μm.

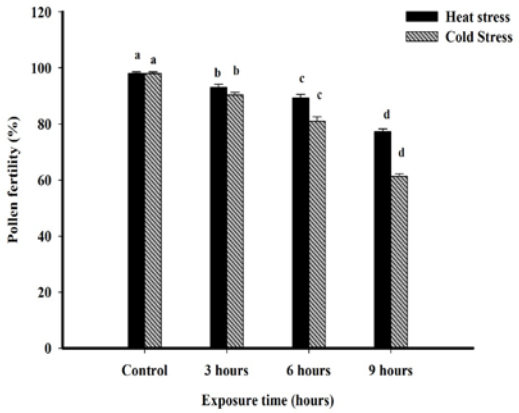

Figure 5. Effect of temperature stress on pollen fertility in *Cyamopsis tetragonoloba* (L.) Taub.

3.3. Influence of Temperature Stress on Yield Parameters

Yield contributing traits were also recorded, and it was found that ambient temperature is required for high-throughput quantitative results. Yield attributes such as pods per cluster, cluster per plant, seeds per pod and pod length were all investigated (as shown in Table 2). Apparently, both heat and cold-stress responses resulted in alteration in the quantitative attributes. However, cold stress resulted in more profound losses than the heat-stress. Data of cluster per plant was calculated to be 13.66 ± 0.57^{a} in the control which declined to 12.66 ± 0.88^{c} (heat stress) and 9.00 ± 0.57^{c} (at cold stress) after nine hours of treatment. In the control, pod per cluster, was calculated to be 5.00 ± 0.57^{a}, whereas at heat stress, it was calculated to be 4.66 ± 0.66^{a} (after three hours of treatment) and 3.66 ± 0.88^{a} (after nine hours of treatment). In the case of cold stress, pod per cluster was documented to be 4.00 ± 0.57^{b} after three hours of treatment, and declined to 2.33 ± 0.33^{c} after nine hours of treatment. Pod length was also measured; the value of which was 6.82 ± 0.17^{a} (in the

control), whereas at the longest duration of heat-stress, it was recorded to be 4.28±0.36[c] . After nine hours of cold-stress treatment, it was found to be 3.79±0.28[c]. The number of seeds per pod in the case of the control was 8.33±0.33[a], which declined to 6.33±0.33[a] (heat stress) and was 4.66±0.87[b] (cold stress) for the longest duration of time.

Table 2. A comparison of the impact of temperature stress on yield attributes in *Cyamopsis tetragonoloba* (L.) Taub.

Treatment	Exposure time	Cluster/ plant (Mean ± SE)	Pods/cluster (Mean ± SE)	Pod length (Mean ± SE)	Seeds/pod (Mean ± SE)
Control	-	13.66±0.88[a]	5.00±0.57[a]	6.82±0.17[a]	8.33±0.33[a]
Heat stress (50°C)	3 hours	13.55±0.71[a]	4.66±0.66[a]	6.08±0.32[a]	8.00±0.57[a]
	6 hours	14.47±0.53[a]	4.33±0.33[a]	4.85±0.35[b]	7.66±0.88[a]
	9 hours	12.66±0.88[c]	3.66±0.88[a]	4.28±0.36[b]	6.33±0.33[a]
Cold stress (4°C)	3 hours	15.33±0.33[b]	4.00±0.57[b]	5.27±0.16[b]	7.66±0.88[a]
	6 hours	11.00±0.57[c]	3.33±0.33[bc]	4.02±0.09[c]	6.00±0.57[ab]
	9 hours	9.00±0.57[c]	2.33±0.33[c]	3.79±0.28[c]	4.66±0.88[b]

Data representing Mean values followed by lowercase letters represent Standard errors that are statistically significant at $P \leq 0.05$.

4. Discussion

Understanding how different plants cope with stress during their reproductive (gametophytic) phase is critical in managing the future of agricultural productivity (Zinn *et al*., 2010).

4.1. Impact of Temperature on Morphological Behaviour

Ambient temperature is a pre-requisite for the survivability as well as perpetuation of plants. Temperature is a critical environmental cue that influences the seedling establishment. A slight difference of only few degrees may inevitably lead to notable changes in the growth and survival rate of plants (Salisbury and Ross, 1985). Plants exposed to low temperatures had marks of injuries as a result of the chilling stress. Chilling stress has been found to cause membrane disruption; according to Steponkus (1984), the most malicious effects of chilling stress are membrane damaging and loss of fluidity and dehydration. Heat-induced chlorosis is reported in the present work; it has also been reported in mung bean (Kumar *et al*., 2011) and chickpeas (Kumar *et al*., 2013).

Low survivability was observed at longer durations of both stresses with respect to the control due to temporal constraints. This is the case because temperature above and below the threshold limit is tough to be endured as the inclusive metabolic cues get affected. As far as flowering is concerned, the seedlings that were subjected to low temperature, reached their blooming and flowering stages late in comparison with the control at the exposure to heat stress. Flowering is a very crucial stage in plants, since it directly affects the seed yield. It is regulated by an elaborate network of genetic pathways responsive to endogenous and environmental stimuli (Andrés and Coupland, 2012). Perhaps, the plausible reason for this is that the plant initially had a retarded metabolism which affected the growth responses. With reimbursement after the initial distortion, the plants started to flourish. Exposure to a short-term cold stress, or an overexpression of cold-responsive genes, delays flowering by activating Flowering Locus C (FLC) (Seo *et al*., 2009), whereas the delay in flowering at the exposure to heat stress correlates with the reduced expression of FLOWERING LOCUS T-like 3 (FTL3), an FT homologue (Nakano *et al*., 2013)

4.2. Impact of Temperature on Cytogenetical Behaviour

In this study, the reproductive stage, which is an extremely critical stage, was found to be sensitive to temperature stresses. Both heat and cold stresses had led to disturbances in the sequential cellular cascade. In the process of microsporogenesis, the effects of cold and heat stresses are expressed in the form of blockage of meiosis, abnormal meiosis, and abnormal tapetal development (Whyte, 1975). Spindle dysfunctioning and malfunctioning are often linked to temperature-stress introduced ramifications of meiosis. Callan (1942) with *Triton* showed that low temperature manipulation can be used for the joint control of spindle development, spiralization, and nucleic acid metabolism. Similar results were recorded for high temperatures (5 hours to 2 days at 30°-40° C) at mitosis and meiosis *e.g.* PMC of *Fritillaria* (Barber,1940).

Chromosomal stickiness is characterized by chromosomal clustering during any phase of the cell cycle which may be attributed to genetic and environmental factors (Pagliarini, 2000). It may result from the defective functioning of specific nonhistone proteins involved in the chromosomes organization, which is needed for chromosome separation and segregation (Gaulden, 1987). Chromosomal pairing and synapsis is essential for the organization of bivalents. Some sorts of mutations in the cohesion proteins might lead to univalents (Kumar and Dwivedi, 2015). Cold-stress-sponsored disruption of synaptonemal complex affects the synaptic precision, and the failure to withhold the bivalents together might result in univalents**.** The bridges observed seem to be a result of the non-separation of chiasma due to stickiness (Kumar and Rai, 2007). The disturbed polarity and unorientation occurred as a result of the shifting of poles or because of spindle malfunctioning.

Pollen viability, an important criterion that regulates fidelity of fertilization, is a result of male meiotic events, and can assist in examining the effects communicated by temperature fluctuations on the reproductive stages. Heat stress proved to be comparatively less lethal for pollens compared with chilling stress. At low temperatures, lower levels of sucrose, glucose and fructose result in the

starvation of developing microspores which causes pollen sterility (Parish *et al.,* 2012). Heat stress can also cause pollen sterility by reducing carbohydrate deposition in pollen grains (Jain *et al.,* 2007) which induces tapetum degradation (Sakata *et al*., 2000). High temperatures may even affect the endoplasmic reticulum structure, and block its function in the tapetum causing earlier-than-usual degeneration of the tapetum (Omae *et al*., 2012).This degradation of the nutritive tissues of the tapetum may lead to pollen sterility. Carbohydrate mobilization of the tapetum and its genetic control may play an important role in the pollen development under stress conditions. Improvement of stress tolerance in crop species will, therefore, require a better understanding of the effects of stress on the sporophyte, as well as on the sporophyte-gametophyte communication (Pacini and Dolferus, 2016).

4.3. Impact of Temperature on Yield Parameters

According to Maulana and Teso (2011), cold-temperature stress at the seedling stage reduced the seedling vigour and dry weight significantly, and also delayed the time to reach flowering and maturity; these results are similar to those obtained in the present study. Alvarado and Hernaiz (2007) also reported a delay of maturity in rice due to the impact of low temperatures. Kazan and Lyons (2016) maintained that if flowering occurs prematurely under stressful environments, seed-set and grain filling may be compromised. Longer durations of stress for both sets had hampered the floral genesis, which resulted in less flowering and in the formation of rudimentary sterile flowers. It was found that yield contributing traits were negatively affected by low temperature ranges. Heat stress also led to a decline in the yield. In comparison, cold stress was more lethal for the yield attributes; similar results were obtained by Thakur *et al.,* (2010). Temperatures below 15°C abort chickpea flowers and reduce the number of pods per plant, and seeds per pod (Nayyar *et al*., 2005; Kaur *et al*., 2011). Barlow *et al*., (2015) revealed that frost led to the sterility and abortion of formed grains in wheat (*Triticum aestivum* L.), while excessive heat had caused a reduction in the grains number. Suzuki *et al*., (2001) reported a correlation between pollen fertility and pod setting in that poor pollen fertility led to low pod and seed setting.

Studies related to heat stress revealed that plants had an intrinsic adaptability potential. Plants can alter their metabolism in various ways in response, particularly by producing compatible solutes that are able to organize proteins and cellular structures, maintain cell turgor by osmotic adjustment, and to modify the antioxidant system to re-establish the cellular redox balance and homeostasis (Valliyodan and Nguyen, 2006; Munns and Tester, 2008).

5. Conclusion

The examination of stress and stress-related responses in plants is critical for devising stress-amelioration measures. The cardinal stages in a life cycle are growth and morphogenesis, flowering, and seed setting. These stages are intimately interwoven in a chain. The current study concludes that plants overall growth parameters including survival, microsporogenesis, and yield attributes are significantly influenced by stress. The investigation of the cytogenetical and the morphological parameters has shown that optimal temperature is a basic requirement for the vitalization to the living cells. Proper understanding is thus essential for stress-tolerance engineering. Sincere future attempts will enhance plants survivability and adaptation to hostile environment

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References

Allen DJ and Ort DR. 2001. Impacts of chilling temperatures on photosynthesis in warm-climate plants. *Trends in Plant Sci*,**6**: 36–42.

Alvarado R and Hernaiz S. 2007. Antecedentesgeneralessobre el arroz en Chile, in Arroz Manejo Tecnol´ogico, R. Alvarado, Ed., 162 of Bolet´ın INIA. 179, Instituto de InvestigacionesAgropecuarias INIA, Centro Regional de Investigaci´on Quilamapu, Chill´an, Chile.

Andrés F and Coupland G. 2012. The genetic basis of flowering responses to seasonal cues. *Nature Rev Genet*,**13**: 627–639.

Asolkar LV, Kakkar KK and Chakra OJ. 1992. Glossary of Indian medicinal plants with active principles, Part I (Publications and Information Directorate, CSIR New Delhi). 245.

Barber HN. 1940. The suppression of meiosis and the origin of diplochromosomes. *PRSB,* **128**:170-85.

Barlow KM, Christy BP, O'Leary GJ, Riffkin PA and Nuttall JG. 2015. Stimulating the impact of extreme heat and frost events on wheat crop production: a review. *Field Crops Res*,**171**: 109–119.

Barnabas B, Jager Kand Feher A. 2008. The effect of drought and heat stress on reproductive processes in cereals. *Plant, Cell Environ,* **31**: 11–38.

Bione ICP, Pagliarini MS and Toledo JFF. 2000. Meiotic behavior of several Brazilian soybean varieties. *Genet Mol Biol,* **23**: 23–631.

Callan HG. 1942. Heterochromatiri in *Triton. PRSB,* **130**:324-335.

Chinnusamy V, Zhu J and Zhu JK. 2007. Cold stress regulation of gene expression in plants. *Trends in Plant Sci,* **12**: 444–451.

Gaulden ME.1987. Hypothesis: some mutagens directly alter specific chromosomal proteins (DNA topoisomerase II and peripheral proteins) to produce chromosome stickiness, which causes chromosome aberrations. *Mutagenesis,* **2**: 357-365.

Hasanuzzaman M, Nahar K and Fujita M. 2013. Extreme temperatures, oxidative stress and antioxidant defense in plants. *In*: **Abiotic Stress: Plant Responses and Applications in Agriculture;** Vahdati K.and Leslie C.(Eds.), In Tech: Rijeka, Croatia; pp. 169–205.

Hatfield JL and Prueger JH. 2015. Temperature extremes: effect on plant growth and development. *Weather and Climate Extremes,* **10**: 4–10.

Hedhly A, Hormaza JI and Herrero M. 2008. Global warming and plant sexual reproduction. *Trends in Plant Sci,* **14**: 30–36.

IPCC, 2013: Climate Change 2013: **The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,** Stocker TF, Qin D, Plattner G-K. , Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V and Midgley PM. (Eds.).

Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp

Jain M, Prasad PVV, Boote KJ, Hartwell AL, Chourey PS. 2007. Effects of season-long high temperature growth conditions on sugar-to-starch metabolism in developing microspores of grain sorghum (*Sorghum bicolor* L. Moench). *Planta,* **227**: 67–79.

Kaur G, Kumar S, Thakur P, Malik JA, Bhandhari K, Sharma KD and Nayyar H. 2011. Involvement of proline in response of chickpea (*Cicer arietinum* L.) to chilling stress at reproductive stage. *Sci Hortic,* **128**: 174–181.

Kazan K and Lyons R. 2016. The link between flowering time and stress tolerance. *J Exp Bot,* **67**: 47–60.

Kellogg EA and Bennetzen JL. 2004. The evolution of nuclear genome structure in seed plants. *Am J Bot,* **91**: 1709–1725.

Kumar G and Rai P. 2007 EMS Induced Karyomorphological Variations in Maize (*Zea mays* L.) Inbreds. *Turk J Biol.,* **31**: 187-195

Kumar G and Dwivedi H. 2015. Ethyl methane sulphonate induced desynaptic variants in ajwain (*Trachyspermum ammi* (L.) Sprague). *Jordan J Biol Sci,* **8**: 237-241.

Kumar G and Srivastava A. 2015. Cytomorphological and Biochemical Impact of Temperature stress in Buckwheat (*Fagopyrum esculentum* Moench). *Int J Environ Sci Toxicol Res*,**3**(8): 134-143.

Kumar S, Kaur R, Kaur N, Bhandhari K, Kaushal N, Gupta K, Bains TS and Nayyar H. 2011. Heat-stress induced inhibition in growth and chlorosis in mungbean (*Phaseolus aureus* Roxb.) is partly mitigated by ascorbic acid application and is related to reduction in oxidative stress. *Acta Physiol Plantarum,* **33**: 2091–2101.

Kumar S, Thakur P, Kaushal N, Malik JA, Gaur P and Nayyar, H. 2013. Effect of varying high temperatures during reproductive growth on reproductive function, oxidative stress and seed yield in chickpea genotypes differing in heat sensitivity. *Arch Agronomy Soil Sci,* **59**: 23–843.

Marks GE. 1954. An aceto-carmine glycerol jelly for use in pollen fertility counts. *Stain Technol,* **29**: 277.

Maulana F and Teso TT. 2011. Cold temperature episode at seedling and flowering stages reduces growth and yield components in sorghum. *Crop Sci Soc Am,* **53**: 564–574.

Miura K and Frumoto T. 2013. Cold signalling and cold response in plants. *Int J Mol Sci*,**14**: 5312-5337.

Munns R and Tester M. 2008. Mechanisms of salinity tolerance. *Ann Rev Plant Biol,* **59**: 651–681.

Nakano Y, Higuchi Y, Sumitomo K and Hisamatsu T. 2013. Flowering retardation by high temperature in chrysanthemums: involvement of FLOWERING LOCUS T-like 3 gene repression. *J Exp Bot,* **64**: 909–920.

Nayyar H, Bains TS, Kumar S and Kaur G. 2005. Chilling effect during seed filling on accumulation of seed reserves and yield of chickpea. *J Sci Food Agric,***85**: 1925-1930.

Omae H, Kumar A and Shono M. 2012. Adaptation to high temperature and water deficit in the common bean (*Phaseolus vulgaris* L.) during the reproductive period. *Hindawi Publishing Corporation J Bot,*6.

Pacini E and Dolferus R. 2016. The trials and tribulations of the plant male gametophyte-Understanding reproductive stage stress tolerance. In: **Abiotic and Biotic Stress in Plants-Recent Advances and Future Perspectives**; Shanker AK and Shanker C. (Eds.); InTech: Rijeka, Croatia, pp. 703–754.

PagliariniMS. 2000. Meiotic behavior of economically important plant species: the relationship between fertility and male sterility. *Gene Mol Biol,* **23**: 997-1002.

Parish RW, Phan HA, Iacuone S and Li SF. 2012. Tapetal development and abiotic stress: A centre of vulnerability. *Functional Plant Biol,* **39**: 553-559.

Sakata T, Takahashi H, Nishiyama I and Higashitani A. 2000. Effects of high temperature on the development of pollen mother cells and microspores in barley *Hordeum vulgare* L. *J Plant Res,***11**: 395-402.

Salisbury FBand Ross CW. 1985**. Plant Physiology**. 3rd Edition. USA: Wadsworth, Inc.

Seo E, Lee H, Jeon J, ParkH, Kim J, Noh YS and Lee I. 2009. Crosstalk between cold response and flowering in *Arabidopsis* is mediated through the flowering-time gene SOC1 and its upstream negative regulator FLC. *Plant Cell,* **21**: 3185–3197.

Sharma KD and Nayyar H. 2014. Cold stress alters transcription in meiotic anthers of cold tolerant chickpea (*Cicer arietinum* L.). *BMC Res Notes*,**7**: 717:729.

Siddiqui MH, Al-Khaishany MY, Al-Qutami MA, Al-Whaibi MH, Grover A, Ali HM, Al-Whaibi, MS. 2015. Morphological and physiological characterization of different genotypes of faba bean under heat stress. *Saudi J Biol Sci,* **22**: 656–663.

Singh SK, Kakani VG, Brand D, Baldwin B and Reddy KR. 2008. Assessment of cold and heat tolerance of winter-grown canola (*Brassica napus* L.) cultivars by pollen-based parameters. *J Agro Crop Sci,* **194**: 225–236.

Steponkus PL. 1984. Role of the plasma membrane in freezing injury and cold acclimation. *Annu Rev Plant Physiol,* **35**: 543–584.

Suzuki K, Tsukaguchi T, Takeda H and Egawa Y. 2001. Decrease of pollen stainability of green bean at high temperatures and relationship to heat tolerance. *J Am Soc Hortic Sci,* **126**(5): 571–574.

Thakur P, Kumar S, Malik JA, Berger JD and Nayyar H. 2010. Cold stress effects on reproductive development in grain crops: an overview. *Environ Exp Bot,* **67**: 429–443.

Valliyodan B and Nguyen HT. 2006. Understanding regulatory networks and engineering for enhanced drought tolerance in plants. *Curr Opin Plant Biol,* **9**: 189–195.

Whyte RO. 1975. The geography of abnormal meiosis in plants. *The Nucleus,* **18**: 183-203.

Zinn KE, Tunc-Ozdemir M and Harper JF. 2010. Temperature stress and plant sexual reproduction: uncovering the weakest links. *J Exp Bot,* **61**: 1959-1968