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National Academy of Agricultural Science (NAAS) Rating : 3. 03

Cold Tolerance in Maize (*Zea mays*): Physiological and Morphological Traits

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Abstract: *Cold stress is a major environmental factor that limits the agricultural productivity of maize plants. Low temperature often affects plant growth and crop productivity, which causes major crop loss of the limited share of maize crop in the northern part of India. About 1300 lines of maize, in various stages of their derivation and diverse sources were screened against cold stress in field conditions. Observation recorded were days of germination, days of silking, days of anther shedding, stem colour, root colour, anther colour, silk colour, uniformity, vigour, no of cobs, height. The cold stress significantly affected all the growth and developmental traits and also physiological traits recorded. However, significant variability was observed for most of the traits among the lines. Based on these observations and taking into account the productivity of the lines in the experimental field of IARI, 52 lines which performed relatively better under cold stress, were identified. These selected lines will be subjected to re-screening in next Rabi season and also would be involved in a strategy aimed at generating hybrids specifically suitable for Rabi season in the Northern part of India.*

Keywords: *Anther, antioxidants, cold, maize.*

INTRODUCTION

Maize is currently the third most important crop after wheat and rice. It is a major source of food for millions of people around the world, as well as being used for fodder production and non-food industries (*e.g.* biofuel production). Though maize is a major crop in Kharif season, cultivation during winter season in the Indian sub-continent is assuming importance due to various factors. Identification of maize cultivars suitable for northern belt of the country, therefore assumes priority to cater to such agro-climatic conditions.

Crops are subjected to different biotic and abiotic stresses including drought, heat, cold and salinity leading to lowering of productivity. Cold stress, defined as temperature in the range low enough to suppress growth without ceasing cellular function is known to induce several abnormalities at various organisational levels of cells. Low temperature causes reduced cellular respiration[1], damaged membranes [2], elevated abscisic acid (ABA) levels [3] and cryoprotectants [1], increased reactive oxygen species, and enhanced expression of antioxidants [4,5,6,7,8]. Symptoms of cold stress include reduced growth and development [9, 10], reduced mineral and water uptake [11], photosynthesis, increased production of reactive oxygen species and activities of antioxidants [12, 11]. Cultivated crops differ with respect to requirement of temperature during full and specific growth stages. Broadly they are categorized as Kharif and Rabi season crops where temperature requirement play major role along with photoperiod. Some crops on account of greater flexibility in terms of temperature requirement can be cultivated during more than one cropping season.

Optimum temperature for growth in maize is 25-28°C and temperature below12-15°C may induce chilling stress [13]. Vegetative and reproductive growth depends on temperature [14, 15] and low temperature lowers the rate of both cell division and elongation [16]. Low temperatures slow down the rate of leaf initiation [15], which may reduce total leaf number. Due to low temperature, crop growth rate is reduced while growth duration is prolonged. Hence seedlings are weakened and grain yield is

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reduced. Though maize is a major Kharif season crop in India, its potentiality and amenability in Rabi season needs to be fully utilized. For realizing this, the genetic differences need to be systematically analyzed and field evaluation in Rabi season in northern India would be one of the practically useful approaches. As maize genotypes respond to different agro-climatic parameters in general and to temperature in the initial growth phase in particular, this would serve as an initial step in evaluating large number of lines. Objective of the present study was to find out tolerant and susceptible maize germplasm against low temperature stress.

MATERIALS AND METHOD

About 1300 lines of maize, in various stages of their derivation and representing diverse sources and groups, were screened against cold stress in field conditions. A field experiment was carried out in IARI, Delhi field in 2014. The genotypes were planted in twin rows, from each ear and observations were recorded as individual row basis. Data were recorded for days of germination, days of silking, days of anther shedding, stem colour, root colour, anther colour, silk colour, uniformity, vigour, number of cobs, height. Emergence was recorded as the number of coleoptiles appearing at the surface of the soil. The number of plants emerged in each replicate was counted daily. Counting continued until there was no change in the total number of seedlings in each replicate. Percent emergence was calculated as the number of seedlings emerged divided by the total number of seeds for each replication.

RESULT AND DISCUSSION

All the traits were significantly affected by cold stress (Table 1). Days of germination ranged from 23 to 32 days after sowing. Percent emergence in different genotypes was highly variable and ranged from 22.85% (140718-1-1) to 97.14% (140663-1). Few genotypes showed high emergence percent (97.14%, 94.28%, and 91.42%) while some showed very less (28.57%, 28.75%, 25.71, and 22.85%). Days of silking ranged from 83 to 110 days after sowing. Similarly days of pollen shedding ranged from 87 to 111 days. Extensive variability was found in stem colour, which ranged from light yellow to dark green including purple colour. Secondary roots colour ranged from light green to dark green including purple. Silk colours were brown and red. Anthers colour in the maize genotypes ranged from red brown to blue. It is widely understood that low temperature influences many plant traits at seedling stage and agronomic traits in turn, resulting in differences in adaptation and productivity. In the present experiment maize showed a poor seedling establishment at low temperature during cold stress as evident by prior study [17]. Maize germination, growth and rate of development were significantly influenced by the cold stress. Cold stress significantly affected days to anthesis which resulted in significant variation in anthesis-silking interval. Bechoux *et. al.*, 2000 [18] reported that chilling significantly affected the tassel morphogenesis, and significantly reduced number of tassel branches and spikelet pairs in maize.

Cold stress resulted in severe leaf chlorosis and extensive variability was found in leaf colours. These variations in leaf colour are likely to give differences in level of photosynthesis, may be reflected in the difference in stress tolerance level. Tolerance of photosynthesis apparatus to low temperature and high chlorophyll contents may contribute towards better performance of maize against early growth chilling stress [19]. Yellow and old leaves due to loss of chlorophyll lose their photosynthetic power [20]. Reduced chlorophyll content in maize leaves under cold stress has also been reported by others [21, 22]. Anthocynin pigmentation in leaves showed significant variation among genotypes under cold stress, which was more prominent when best and worst type of genotypes were compared. Maize lines capable of accumulating high amounts of anthocynin in the leaf surface may present an adaptive response to low temperature associated changes [23]. Highland maize, which is usually exposed to cold stress, accumulates anthocynin pigments in stems and leaves [24].

In the present evaluation of maize lines, genetic differences were clear in terms of chilling tolerance for different parameters. High level of variation was observed among accessions regarding different morphological and physiological traits, which indicated that alleles are available which can improve cold tolerance. Cold tolerance at seedling stage is a complex phenomenon because multiple levels and considerable duration reflecting lag phase of growth cycle of maize plant. Hence many genes are involved to control cold tolerance. Therefore a multi disciplinary approach which may include biochemistry, physiology, genetics and molecular biology will be the best way to understand responses of maize to cold stress at different stages.

Table 1
Different physiological and morphological traits of selected 52 maize lines (Rabi season-2014) affected by cold stress

S. No.	Genotypes	Days of Germination	No. of seedlings /row	% emergence	Days of Silking	Days of pollen shedding	Stem Color	Root Color	Silk Color	Anther Color	Plant height (cm)	Cob length (cm)	Vigour
1	102-1-1	28	10	28.75	83	87	Green	Green	Green	Yellow	105	45	10
2	140610-3	26	13	37.14	98	99	Green	Green	Red	Red	195	85	9
3	140611-1	23	22	62.85	102	103	Green	Green	Red	Red	180	90	9
4	140612-1	28	13	37.14	100	98	Green	Red	Red	Red	188	105	9
5	CM-138-3	26	15	42.85	94	92	Green	Red	Red	Yellow	190	95	8
6	140635-1-1	23	15	42.85	83	89	Green	Red	Green	Yellow	137	45	8
7	140645-1-2	23	20	57.14	87	90	Green	Red	Green	Yellow	140	65	7
8	140648-1-4	23	12	34.28	97	98	Green	Green	Green	Yellow	205	60	6
9	140650-1-1	28	15	42.85	92	89	Red	Red	Green	Red	160	100	6
10	140654-1-1	26	15	42.85	91	92	Red	Red	Green	Yellow	205	70	8
11	140659-1-1	26	24	68.57	91	90	Green	Red	Green	Red	115	75	8
12	140662-5-1	26	33	94.28	94	95	Green	Red	Green	Yellow	135	65	8
13	140663-1-1	26	34	97.14	94	95	Green	Red	Green	Yellow	142	60	8
14	140669-1-1	26	18	51.42	98	95	Green	Red	Green	Yellow	150	50	8
15	140672-1-2	26	13	37.14	94	95	Green	Green	Green	Yellow	168	50	8
16	140673-3-1	23	33	94.28	91	90	Green	Red	Green	Red	142	40	8
17	140676-1-1	28	13	37.14	92	94	Red	Red	Green	Yellow	175	60	8
18	140679-2-1	26	17	48.57	87	88	Green	Red	Green	Yellow	120	60	6
19	140680-1-2	28	16	45.71	97	95	Red	Red	Green	Yellow	108	55	7
20	140690-1-2	26	9	25.71	98	95	Green	Red	Green	Yellow	185	75	8
21	140691-2-2	26	19	54.28	99	100	Green	Green	Green	Yellow	158	60	8
22	140692-1-2	24	17	48.57	98	99	Red	Red	Green	Red	128	60	8
23	140695-3-3	23	32	91.42	101	100	Green	Red	Green	Yellow	148	70	9
24	140696-1-3	26	20	57.14	104	103	Green	Red	Green	Yellow	122	55	9
25	140697-1-4	32	18	51.42	98	96	Green	Red	Green	Red	165	45	9
26	140700-1-2	23	16	45.71	88	90	Green	Red	Red	Red	143	55	8
27	140702-1-1	26	13	37.14	107	105	Rreen	Red	Green	Yellow	203	105	9
28	140703-1-1	23	24	68.57	103	102	Green	Red	Green	Yellow	140	70	10
29	140704-1-1	28	24	68.57	104	102	Green	Red	Green	Yellow	155	90	10
30	140705-1-1	28	15	42.85	102	102	Green	Red	Green	Yellow	135	70	10
31	140706-1-1	28	16	45.71	102	100	Green	Red	Green	Yellow	165	90	10
32	140707-1-1	30	12	34.28	102	100	Green	Red	Green	Yellow	155	100	10
33	140708-1-1	23	18	51.42	102	103	Green	Red	Green	Yellow	150	80	10
34	140709-1-1	23	16	45.71	102	100	Rred	Red	Green	Yellow	150	70	10
35	140710-4-1	23	20	57.14	102	100	Red	Red	Green	Yellow	145	55	8
36	140711-3-2	26	15	42.85	103	103	Red	Red	Green	Yellow	130	90	8
37	140712-3-1	23	27	77.14	110	111	Red	Red	Green	Yellow	175	80	8
38	140714-1-3	26	12	34.28	102	103	Green	Red	Green	Yellow	145	70	8
39	140715-1-1	23	20	57.14	103	104	Green	Red	Green	Yellow	70	70	8
40	140716-2-1	23	34	97.14	96	92	Green	Red	Green	Yellow	90	35	8
41	140717-1-1	26	14	40	99	96	Green	Red	Green	Yellow	140	70	8
42	140718-1-1	23	8	22.85	95	94	Green	Red	Red	Red	170	80	8
43	140722-1-1	26	30	85.71	98	99	Green	Red	Green	Yellow	145	55	8
44	140723-2-4	23	33	94.28	98	95	Red	Red	Red	Yellow	210	90	8
45	140725-4-2	26	10	28.57	94	96	Green	Red	Red	Yellow	160	45	6
46	140732-1-2	23	33	94.28	94	92	Green	Red	Red	Red	165	95	9
47	140734-2-1	26	20	57.14	89	90	Red	Red	Green	Yellow	125	60	7
48	140735-2-2	23	15	42.85	94	95	Red	Red	Red	Yellow	150	30	7
49	140759-1-1	23	16	45.71	89	92	Red	Red	Green	Blue	190	60	7
50	140762-1	23	12	34.28	94	96	Red	Red	Green	Yellow	160	70	7
51	140763-1	26	11	31.42	102	99	Green	Red	Red	Yellow	180	55	7
52	140764-1	28	12	34.28	102	100	Red	Red	Red	Yellow	190	60	7

Based on these observations and taking into account the productivity of the lines as represented by the ear parameters and individual plant yield, preliminary selections were made. From the current study, 52 lines which performed relatively better under cold stress were identified. These selected 52 lines will form the source for re-screening in next Rabi season in more extensive experimental approach. Performance of 29 Lines in Kharif season is indicated in Table 2. Specific lines would be involved in generating hybrids more suitable for Rabi season in the Northern part of India. This strategy is expected to make use of wide flexibility and diversity of maize in terms of adaptation to varied climatic conditions and could serve as additional, economically viable option for the farmers.

REFERENCES

Lee CB, Hayashi H, Moon BY (1997) Stabilization by glycinebetaine of photosynthetic oxygen evolution by thylakoid membranes from *Synechococcus* PCC 7002. Molecular Cell **7**: 296–299.

Nayyar H, Bains T, Kumar S (2005) Low temperature induced floral abortion in chickpea: Relationship with abscisic acid and cryoprotectants in reproductive organs. Environmental and Experimental Botany **53**: 39–47.

Xing W, Rajashekar CB (2001) Glycine betaine involvement in freezing tolerance and water stress is Arabidopsis thaliana. Environmental and Experimental Botany **46**: 21–28.

Kratsch HA, Wise RR (2000) The ultrastructure of chilling stress. Plant, Cell & Environment **23**: 337–350.

Farooq M, Aziz T, Hussain M, Rehman H, Jabran K, Khan MB (2008*b*) Glycinebetaine improves chilling tolerance in hybrid maize. Journal of Agronomy and Crop Science **194**: 152–160.

Farooq M, Basra SMA, Hafeez K (2006*c*) Seed invigoration by osmohardening in fine and coarse rice. Seed Science and Technology **34**: 181–187.

Farooq M, Basra SMA, Khalid M, Tabassum R, Mehmood T (2006*d*) Nutrient homeostasis, reserves metabolism and seedling vigor as affected by seed priming in coarse rice. Canadian Journal of Botany **84**: 1196–1202.

Farooq M, Aziz T, Cheema ZA, Khaliq A, Hussain M (2008*e*) Activation of antioxidant system by KCl treatments improves the chilling tolerance in hybrid maize. Journal of Agronomy and Crop Science **194**: 438–448.

Verheul MJ, Hasselt PRV, Stamp P (1995) Comparison of maize inbred lines differing in low temperature tolerance effect of acclimation at suboptimal temperature on chloroplast functioning. Annals of Botany **76**: 7–14.

Sowinski P, Rudzinska-Langwald A, Adamczyk J, Kubica I, Fronk J (2005) Recovery of maize seedling growth, development and photosynthetic efficiency after initial growth at low temperature. Journal of Plant Physiology **162**: 67–80.

Aroca R, Vernieri P, Irigoyen JJ, Sancher-Diaz M, Tognoni F, Pardossi A (2003) Involvement of abscisic acid in leaf and root of maize (*Zea mays* L.) in avoiding chilling-induced water stress. Plant Science **165**: 671-679.

Foyer CH, Vanacker H, Gomez LD, Harbinson J (2002) Regulation of photosynthesis and antioxidant metabolism in maize leaves at optimal and chilling temperatures. Plant Physiology and Biochemistry **40**: 659–668.

Holá D, Langrova KM, Kocova M, Rothova O (2003) Photosynthetic parameters of maize (*Zea mays* L.) inbred lines and F1 hybrids: their different response to, and recovery from rapid or gradual onset of low temperature stress. Photosynthetica **41**: 429–442.

Warrington IJ, Kanemasu ET (1983*a*) Corn growth response to temperature and photoperiod I. Seedling emergence, tassel initiation, and anthesis. Agronomy Journal **75**: 749–754.

Warrington IJ, Kanemasu ET (1983*b*) Corn growth response to temperature andphotoperiod II. Leaf-initiation and leaf-appearance rates. *AgronomyJournal* **75**: 755–761.

Ben-Haj-Salah H, Tardieu F (1995) Temperature affects expansion rate of maize leaves without change in spatial distribution of cell length (analysis of the coordination between cell division and cell expansion). Plant Physiol **109**: 861–870

Ahmad I, Khaliq T, Ahmad A, Basra SMA, Hasnain Z and Ali A (2012) Effect of seed priming with ascorbic acid, salicylic acid and hydrogen peroxide on emergence, vigor and antioxidant activities of maize. Afr. J. Biotech. **11**: 1127-1132.

Bechoux N, Bernier G, Lejeune P (2000) Environmental effect on the early stages of tassel morphogenesis in maize (Zea mays L.). Plant Cell Environ **23**: 91-98.

Morroco A, Lorenzoni C and Fracheboud Y (2005) Chilling stress in maize. Maydica. **50**: 571-580.

Mahajan S and Tuteja N (2005) Cold, salinity and drought stresses: An overview. Archives of Bioch. and Biophysics. **444**: 139–158.

Leipner J, Fracheboud Y, STAMP P (1999) Effect of growing season on the photosynthetic apparatus and leaf antioxidative defenses in two maize genotypes of different chilling tolerance. Environ. Exp. Bot. **42**: 129-139

Lee EA, Staebler MA, Tollenaar M (2002) Genetic Variation in Physiological Discriminators for Cold Tolerance – Early Autotrophic Phase of Maize Development. Crop Sci. **42**: 1919- 1929.

Pietrini F, Iannelli MA, Massacci A (2002) Anthocyanin accumulation in the illuminated surface of maize leaves enhances protection from photo-inhibitory risks at low temperature, without further limitation to photosynthesis. Plant. Cell Environ. **25**: 1251-1259.

Chong C, Brawn RI (1969) Temperature comparisons of purple and dilute sun red anthocyanin colour types of maize. Canadian J. Plant Sci. **49**: 513-516.

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