Evaluation of maize inbred lines for drought tolerance under contrasting soil moisture regimes

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Abstract: Drought, one of the major abiotic stress factor that severely limit grain yield production, often causing extensive economic loss to agriculture. Improving drought tolerance in maize has become one of the top priorities in maize breeding programs. Identification of maize germplasm with superior drought tolerance is an essential and prerequisite for such propose. One hundred maize inbred lines were evaluated under field conditions and 15 inbred lines were identified *viz.*, DMIL101, DMIL103, DMIL112, DMIL117, DMIL122, DMIL125, DMIL129, DMIL130, DMIL136, DMIL140, DMIL145, DMIL147, DMIL150, DMIL152 and DMIL160 that showed high tolerance to drought. Tolerant inbred lines were able to maintain shorter anthesis-silking interval (ASI), low canopy temperature, lower drought susceptibility index (DSI), higher chlorophyll content and comparatively higher grain yield when subjected to drought stress. Whereas, inbred lines *viz.*, DMIL270, DMIL273 and DMIL431 showed wider ASI and recorded lowest grain yield among the inbred lines under water stress situation. Drought tolerant inbred lines identified in this study could be utilized for future breeding programme for the development of drought tolerant maize hybrids. Potential use of these lines to produce maize hybrids that are able to alleviate the negative impacts of drought on growth and development of maize grants is underway.

Key words: Anthesis to silking interval, Drought, Drought susceptibility index, Grain yield, Inbred lines

Introduction

Maize (*Zea mays* L.) is most important crop in global agriculture and ranks third next to wheat and rice in terms of production. Maize is physiologically more efficient, has higher grain yield potential and wider adaptation over a range of environmental conditions. Maize is a principal source of carbohydrates and proteins and is on par with other cereals in its other nutritional qualities. It has diversified uses as food, feed and as raw material for various industrial products. It has also become a key resource for industrial applications and bio energy production. In 2020, demand for maize in developing countries is expected to exceed 500 mt and will surpass the demand for both rice and wheat (Pingali and Heisey, 2001).

Maize is highly productive under optimal environmental and crop management conditions. However, maize plants are also very susceptible to abiotic stresses particularly, drought and heat; each year, an average of 15 to 20 per cent of the potential world maize production is lost due to these stresses (Lobell *et al.*, 2011). It is anticipated that the negative impacts of abiotic stresses on agricultural production are likely to be more in future. Now-a-days, climatic change adversely affect distribution pattern of rainfall, that will result in poor and scanty rainfall in one area and heavy rainfall in other area causing severe water deficit. Occurrence of drought is unpredictable, it can occur at any stage of the crop. Drought occurring between two weeks before and after the silking stage can cause significant yield loss to an extent of 20 to 50 per cent (Nielson, 2007).

To mitigate these effects, comprehensive and fully integrated approaches needed to sustain and enhance agricul-tural productivity in future. Soil conservation and water manage-ment practices can enhance the efficiency of agricultural water use and the control of soil erosion (Delgado *et al.*, 2007), but development of stress tolerant plant varieties will play more important role (Tester and Langridge, 2010). Identification and characterization of variations for drought tolerance in maize germplasm is a first and foremost step in devel-oping drought tolerant maize hybrids (Chen *et al.*, 2012). In this context, field experiments were conducted to screen 100 inbred lines for drought tolerance.

Material and methods

In the present investigation, 100 inbred lines received from Maize Scheme, University of Agricultural Sciences, Dharwad were utilized in the present study. These inbred lines included diverse genetic base and derived from CIMMYT, Mexico and IIMR, New Delhi and others were derived from popular public/ private hybrids (Table 1). These diverse inbred lines were evaluated for drought tolerance by following two factorial randomized block design with two replications under normal (without stress) and stress conditions. Hot and dry environments during the growing season are ideal for field evaluation of drought stress tolerance in maize. The weather data during the crop growth period till physiological maturity indicated that there were virtually no rains from December to March, thus facilitating a good evaluation for drought stress. Each entry was grown at a spacing of 60 x 30 cm with a row length of 4 m. Two seeds were dibbled per hill and later thinned to retain one seedling per hill. The genotypes under normal conditions were given recommended cultural practices besides regular irrigation (furrow) at an interval of 10-12 days to avoid water stress. In stress situation also, the same set of genotypes were given same recommended cultural practices but irrigation was withheld from 40 days after sowing till harvest so that they should experience moisture stress during flowering and grain filling period. The irrigated and managed stress experiments were separated by a four meter buffer zone of maize crop.

Table1. List of inbred lines used for drought screening study

S.No. Inbreds Pedigree / source population S.No. Inbreds Pedigree / source population DMIL101 CML337*CML338-X-X-5 S1 DMIL39 DMWNY1497-23 DMIL101 CML337*CML338-X-X-5 S2 DMIL301 DMWSCY4256-12-3-4 DMIL101 CML430*CML338-X-X-4 S4 DMIL301 DMWSCY4256-12-3-4 DMIL112 CML430*CML338-X-X-4 S4 DMIL350 DMWH0Y4321-1-3-1 6 DMIL21 CML410*CML468-X-X-4 S7 DMIL350 DMWY5075-3-6-7 7 DMIL221 CML411*CML468-X-X-4 S7 DMIL360 DMWY6025-2-4-34 9 DMIL224 CML411*CML468-X-X-7 S9 DMIL360 DMWY6025-2-9-11 10 DMIL235 NK6240*CML412-X-X-X-8 61 DMIL360 DMWY6025-2-9-11 11 DMIL217 NK6240*CML412-X-X-X-8 62 DMIL374 CMU23*CM142-2-3-5-11 12 DMIL237 NK6240*CML412-X-X-X-8 62 DMIL380 CM123*CM142-2-3-5-11 13 DMIL371 NK6240*CML413-X-X-X-8 62	Table	List of inbred	lines used for drought screening study			
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14 DMIL117 NK6240*CML451-X-X-X-13 64 DMIL382 CM136*CM111-1-4-7-42 15 DMIL242 NK6240*CML451-X-X-X-20 65 DMIL380 CM105*P1-1-2-6-101 16 DMIL244 NK6240* NE1412004 - X-X-X-3 66 DMIL380 CM205*P5-1-4-7-121 17 DMIL251 NK6240* NE1412004 - X-X-X-3 67 DMIL405 CM205*P5-1-4-7-121 18 DMIL250 900GOLD * NE1412004-X-X-X-2 69 DMIL408 CML432*CML425-2-4-8-3 20 DMIL252 900GOLD * NE1412004-X-X-X-2 69 DMIL418 CML422*CML425-2-4-8-3 21 DMIL225 900GOLD * NE1412004-X-X-X-14 70 DMIL418 CML422*CML425-2-4-8-3 22 DMIL255 NS*052030-X-X-X-X-5 72 DMIL418 CML422*CML425-2-4-8-3 23 DMIL260 NS*052030-X-X-X-X-7 73 DMIL431 CML422*CML425-2-4-8-3 24 DMIL260 NS*052030-X-X-X-7 73 DMIL431 CML422*CML425-2-3-1 25 DMIL260 NS*05030-X-X-X-7 75 DMIL445 DM124-4-47		DMIL240	NK6240*CML451-X-X-X-8			CM213*CM21-1-3-10-38
15 DMIL242 NK6240*CML451-X-X-X-20 65 DMIL386 CM115*P1-1-2-6-101 16 DMIL244 NK6240* NE1412004-X-X-X-3 66 DMIL395 CM205*P5-1-4-7-121 17 DMIL245 NK6240* NE1412004-X-X-X-5 67 DMIL401 CM203*P2-5-6-8-149 19 DMIL250 900GOLD * NE1412004-X-X-2 69 DMIL410 CML432*CML452-2-4-8-3 20 DMIL252 900GOLD * NE1412004-X-X-14 70 DMIL412 CML422*CML161-3-5-9-6 21 DMIL255 NS*052030-X-X-X-5 72 DMIL431 CML422*CML161-3-5-9-6 22 DMIL260 NS*052030-X-X-X-5 72 DMIL431 CML422*CML145-2-3-5-4 23 DMIL257 NS*052030-X-X-X-7 73 DMIL441 CML32*CML429-2-3-1 26 DMIL264 KS*4901-X-X-X-6 75 DMIL441 CML32*CML429-2-3-1 26 DMIL264 KS*4901-X-X-X-10 76 DMIL455 VA-23-65 29 DMIL264 KS*4901-X-X-X-11 77 DMIL463 DMH429-2-3-16						
16 DMIL244 NK6240 * NE1412004 - X-X-X-3 66 DMIL389 CM205*P5-1-4-7-121 17 DMIL247 NK6240 * NE1412004 - X-X-X-5 67 DMIL401 CM203*P5-5-6-8-149 18 DMIL250 900GOLD * NE1412004-X-X-X-2 69 DMIL408 CML432*CML425-2-4-8-3 20 DMIL252 900GOLD * NE1412004-X-X-X-14 70 DMIL418 CML432*CML4155-6-8-149 21 DMIL255 NS*052030-X-X-X-X-5 72 DMIL418 CML422*CML415-1-4-8-5 22 DMIL260 NS*052030-X-X-X-X-7 73 DMIL431 CML422*CML425-2-3-5-4 24 DMIL260 NS*052030-X-X-X-X-7 73 DMIL435 CML325*C6-5-20 25 DMIL261 SS*05203-X-X-X-7-13 74 DMIL435 CML325*C6-5-20 25 DMIL264 SS*4901-X-X-X-16 75 DMIL445 D9081-5-4-7-18 26 DMIL264 SS*4901-X-X-X-10 76 DMIL455 VA-23-65 29 DMIL264 SS*4901-X-X-X-10 80 DMIL455 VA-23-65 20						
17 DMIL245 NK6240 * NE1412004 - X-X-Y-5 67 DMIL395 CM215*CM201-1-2-6-142 18 DMIL250 900GOLD * NE1412004 - X-X-X-11 68 DMIL408 CML432*CML425-2-4-8-3 20 DMIL252 900GOLD * NE1412004-X-X-X-14 70 DMIL412 CML432*CML45-3-4-8-3 21 DMIL252 900GOLD * NE1412004-X-X-X-18 71 DMIL413 CML422*CML45-1-4-5-7 22 DMIL255 NS*052030-X-X-X-X-5 72 DMIL433 CML432*CML45-1-4-5-7 23 DMIL255 NS*052030-X-X-X-X-7 73 DMIL435 CML432*CML45-2-3-5-4 24 DMIL256 KS*4901-X-X-X-4 75 DMIL443 CML422*CML45-2-3-5-4 25 DMIL256 KS*4901-X-X-X-X-10 76 DMIL445 D9081-5-4-7-18 26 DMIL265 KS*4901-X-X-X-11 77 DMIL455 VA-2-3-65 29 DMIL264 KS*4901-X-X-X-11 80 DMIL455 VA-2-3-65 29 DMIL265 KI32*KI50-X-X-X-4 79 DMIL460 S-KR051-4-4-47 30 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
18 DMIL247 NK6240 * NE1412004 - X-X-X-11 68 DMIL401 CM203*P2-5-6-8-149 19 DMIL252 900GOLD * NE1412004-X-X-2-2 69 DMIL408 CML432*CML425-2-4-8-3 20 DMIL252 900GOLD * NE1412004-X-X-2-4 70 DMIL418 CML450*CML415-4-8-5 21 DMIL253 N8*052030-X-X-X-X-5 72 DMIL413 CML422*CML435-14-5-7 23 DMIL257 N8*052030-X-X-X-X-7 73 DMIL431 CML422*CML435-14-5-7 24 DMIL260 N8*052030-X-X-X-X-7 73 DMIL431 CML422*CML432-2-3-1 26 DMIL262 K8*4901-X-X-X-6 75 DMIL441 CML422*CML429-2-3-1 26 DMIL264 K8*4901-X-X-X-7 78 DMIL455 VA-2-3-65 27 DMIL264 K8*4901-X-X-X-4 79 DMIL460 S-K30-6-8-7-112 28 DMIL270 K12*K150-X-X-X-2 78 DMIL460 S-K60-5-1-4-139 30 DMIL275 NK6240*K121-X-X-X-4 81 DMIL466 S2K50-5-1-4-139 31 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td></t<>						
19 DMIL250 900GOLD * NE1412004-X-X-2 69 DMIL408 CML432*CML425-24-8-3 20 DMIL252 900GOLD * NE1412004-X-X-14 70 DMIL412 CML430*CML415-48-5 21 DMIL252 900GOLD * NE1412004-X-X-18 71 DMIL412 CML422*CML161-3-5-9-6 22 DMIL255 N8*052030-X-X-X-X-5 72 DMIL435 CML412*CML445-2-3-5-4 24 DMIL260 NS*052030-X-X-X-X-7 73 DMIL435 CML412*CML452-2-3-1 25 DMIL25 KS*4901-X-X-X-X-6 75 DMIL445 D9081-5-4-7-18 26 DMIL264 KS*4901-X-X-X-X-10 76 DMIL445 D9081-5-4-7-18 27 DMIL265 KI32*KI50-X-X-2 78 DMIL450 VA-23-65 28 DMIL264 KS*4901-X-X-X-4 79 DMIL460 S-NK30-6-8-7-112 30 DMIL273 NK6240*KI21-X-X-X-4 81 DMIL465 DMIR455 31 DMIL275 NK6240*KI21-X-X-X-10 82 DMIL145 M-G8011-6-2-4-147 32 DMIL275						
20 DMIL252 900GOLD * NE1412004-X-X-X-14 70 DMIL412 CML450*CML415-4-8-5 21 DMIL255 NS*052030-X-X-X-X-18 71 DMIL418 CML422*CML161-3-5-9-6 23 DMIL255 NS*052030-X-X-X-X-5 72 DMIL431 CML422*CML1435-1-4-5-7 24 DMIL260 NS*052030-X-X-X-X-7 73 DMIL430 CML322*CML325-6-5-20 25 DMIL261 KS*4901-X-X-X-X-6 75 DMIL445 D081-5-4-7-18 26 DMIL262 KS*4901-X-X-X-X-10 76 DMIL445 D081-5-4-71 27 DMIL265 K132*KI50-X-X-X-11 77 DMIL440 (K244)-1-5-4-47 28 DMIL266 K132*KI50-X-X-2 78 DMIL460 S-NK30-6-8-7-112 30 DMIL270 K132*KI50-X-X-2 78 DMIL460 S-NK30-6-8-7-112 30 DMIL270 K132*KI50-X-X-2 78 DMIL460 S-NK30-6-8-7-112 31 DMIL270 K6240*K121-X-X-4 81 DMIL460 S-NK30-6-8-7-112 32 DMIL275 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td></t<>						
21 DMIL122 900GOLD * NE1412004-X-X-X-18 71 DMIL431 CML422*CML161-3-5-9-6 22 DMIL255 NS*052030-X-X-X-X-5 72 DMIL431 CML422*CML435-1-4-5-7 23 DMIL260 NS*052030-X-X-X-X-7 73 DMIL435 CML412*CML445-2-3-5-4 24 DMIL260 NS*052030-X-X-X-X-13 74 DMIL435 CML422*CML429-2-3-1 25 DMIL264 KS*4901-X-X-X-X-10 76 DMIL445 D9081-5-4-7-18 27 DMIL264 KS*4901-X-X-X-X-11 77 DMIL445 D9081-5-4-7-18 28 DMIL264 KS*4901-X-X-X-X-11 77 DMIL440 (K244)-1-5-4-47 28 DMIL266 K132*KI50-X-X-X-2 78 DMIL460 S-NK30-6-8-7-112 30 DMIL270 K132*KI50-X-X-X-4 80 DMIL460 DS-K80-6-8-442 31 DMIL273 NK6240*K121-X-X-4 81 DMIL460 DS-K60-5-1-4-139 32 DMIL275 NK6240*K145-X-X-5 84 DMIL460 DKK60-5-1-4-139 34 DMIL280						
22 DMIL255 NS*052030-X-X-X-X-5 72 DMIL431 CML422*CML435-1-4-5-7 23 DMIL257 NS*052030-X-X-X-X-7 73 DMIL435 CML412*CML445-2-3-5-4 24 DMIL260 NS*052030-X-X-X-X-13 74 DMIL435 CML422*CML429-2-3-5-4 25 DMIL125 KS*4901-X-X-X-X-6 75 DMIL441 CML422*CML429-2-3-1 26 DMIL262 KS*4901-X-X-X-X-6 76 DMIL445 D9081-5-4-7-18 27 DMIL264 KS*4901-X-X-X-X-10 76 DMIL455 VA-2-3-65 29 DMIL266 K132*K150-X-X-X-2 78 DMIL460 S-NK30-6-8-7-112 30 DMIL270 K132*K150-X-X-X-4 79 DMIL463 DMH8255-6-8-4-42 31 DMIL270 K132*K150-X-X-X-11 80 DMIL466 25K60-5-1-4-139 32 DMIL280 NK6240*K121-X-X-X-4 81 DMIL466 SK560-5-1-4-139 33 DMIL280 NK6240*K145-X-X-7 85 DMIL150 SK55-3-9-7-55 34 DMIL280 NK624						
23 DMIL257 NS*052030-X-X-X-X-7 73 DMIL435 CML412*CML445-2-3-5-4 24 DMIL260 NS*052030-X-X-X-X-13 74 DMIL439 CML322*CML325-65-20 25 DMIL125 KS*4901-X-X-X-X-6 75 DMIL445 D9081-5-4-7-18 26 DMIL261 KS*4901-X-X-X-X-10 76 DMIL445 D9081-5-4-7-18 27 DMIL264 KS*4901-X-X-X-X-11 77 DMIL455 VA-2-3-65 29 DMIL266 K132*KI50-X-X-X-2 78 DMIL460 S-NK30-6-8-7-112 30 DMIL270 K132*KI50-X-X-X-21 80 DMIL463 DMH8255-6-8-4-42 31 DMIL275 NK6240*KI21-X-X-X-10 82 DMIL466 25K60-5-1-4-139 32 DMIL275 NK6240*KI21-X-X-X-10 82 DMIL459 M-G8011-6-2-4-147 33 DMIL280 NK6240*KI45-X-X-7 85 DMIL469 NK-61-6-3-22 34 DMIL286 NK6240*KI45-X-X-7 85 DMIL150 25K55-3-9-7-55 36 DMIL288 NK6240*KI45-X-X						
24 DMIL 260 NS*052030-X-X-X-X-13 74 DMIL 439 CML332*CML325-6-5-20 25 DMIL 125 KS*4901-X-X-X-X-6 75 DMIL 441 CML422*CML429-2-3-1 26 DMIL 262 KS*4901-X-X-X-X-10 76 DMIL445 D9081-5-4-7-18 27 DMIL 264 KS*4901-X-X-X-X-11 77 DMIL449 (K244)-1-5-4-47 28 DMIL 266 K132*KI50-X-X-X-2 78 DMIL455 VA-2-3-65 29 DMIL 266 K132*KI50-X-X-X-4 79 DMIL460 S-NK30-6-8-7-112 30 DMIL270 KK5240*K121-X-X-X-4 81 DMIL463 DMH8255-6-8-4-42 31 DMIL275 NK6240*K121-X-X-X-10 82 DMIL145 M-IG8011-6-2-4-147 33 DMIL280 NK6240*K145-X-X-X-10 82 DMIL145 M-IG8011-6-2-4-147 34 DMIL283 NK6240*K145-X-X-X-5 84 DMIL147 CLQ-RCYQ12-B-B-B 35 DMIL284 NK6240*K145-X-X-X-1 85 DMIL150 25K55-3-9-7.55 36 DMIL292						
25 DMIL125 KS*4901-X-X-X-X-6 75 DMIL441 CML422*CML429-2-3-1 26 DMIL262 KS*4901-X-X-X-X-10 76 DMIL445 D9081-5-4-7-18 27 DMIL264 KS*4901-X-X-X-X-11 77 DMIL445 D9081-5-4-7-18 28 DMIL264 KI32*KI50-X-X-X-2 78 DMIL455 VA-2-3-65 29 DMIL270 KI32*KI50-X-X-X-21 80 DMIL463 DMH8255-6-8-4-42 31 DMIL270 KI32*KI50-X-X-X-11 81 DMIL466 25K60-5-1-4-139 32 DMIL273 NK6240*KI21-X-X-44 81 DMIL460 NK-61-6-3-22 34 DMIL280 NK6240*KI21-X-X-X-11 83 DMIL475 MIC160-2-22 34 DMIL286 NK6240*KI45-X-X-X-7 85 DMIL150 25K55-3-9-7-55 36 DMIL286 NK6240*KI45-X-X-X-1 86 DMIL150 25K5-42-6-52 37 DMIL296 30V92*KI32-X-X-4 87 DMIL455 BIO6891-6-5-3 40 DMIL301 30V92*KI45-X-X-X-15 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td></td<>						
26 DMIL262 KS*4901-X-X-X-X-10 76 DMIL445 D9081-5-4-7-18 27 DMIL264 KS*4901-X-X-X-X-11 77 DMIL449 (K244)-1-5-4-47 28 DMIL265 KI32*KI50-X-X-X-2 78 DMIL455 VA-2-3-65 29 DMIL266 KI32*KI50-X-X-X-2 78 DMIL460 S-NK30-6-8-7-112 30 DMIL270 KI32*KI50-X-X-X-21 80 DMIL466 25K60-5-1-4-139 31 DMIL275 NK6240*KI21-X-X-X-4 81 DMIL466 25K60-5-1-4-139 32 DMIL275 NK6240*KI21-X-X-X-10 82 DMIL145 M-168011-6-2-4-147 33 DMIL280 NK6240*KI45-X-X-X-5 84 DMIL145 CLQ.RCYQ12-B-B-B 34 DMIL280 NK6240*KI45-X-X-7 85 DMIL150 25K55-3-9-7-55 36 DMIL288 NK6240*KI45-X-X-X-11 86 DMIL475 900M-2-3-1 38 DMIL292 30V92*KI32-X-X-4 87 DMIL480 NK6240-6-4-2-2 39 DMIL297 30V92*KI45-X-X-X-15						
27DMIL264KS*4901-X-X-X-X-1177DMIL449(K244)-1-5-4-4728DMIL265KI32*KI50-X-X-X-278DMIL455VA-2-3-6529DMIL266KI32*KI50-X-X-X-479DMIL460S-NK30-6-8-7-11230DMIL270KI32*KI50-X-X-X-1180DMIL463DMH8255-6-8-4-4231DMIL275NK6240*KI21-X-X-X-481DMIL46625K60-5-1-4-13932DMIL275NK6240*KI21-X-X-X-1082DMIL145M-IG8011-6-2-4-14733DMIL280NK6240*KI45-X-X-584DMIL147CLQ-RCYQ12-B-B-B34DMIL280NK6240*KI45-X-X-785DMIL15025K55-3-9-7.5536DMIL286NK6240*KI45-X-X-785DMIL152DMH8255-4-2-6-5237DMIL29230V92*KI32-X-X-1186DMIL475900M-2-3-138DMIL29630V92*KI32-X-X-1288DMIL480NK6240-6-4-2-239DMIL29730V92*KI32-X-X-1589DMIL485BI06891-6-5-340DMIL30130V92*KI45-X-X-792DMIL482DMH8255-3-4-8-641DMIL30130V92*KI45-X-X-793DMIL489DMH8255-3-4-8-642DMIL30PINNACLE*KI32-X-X-793DMIL492NK6240-6-7-2-744DMIL136PINNACLE*KI32-X-X-793DMIL497NK6240-6-8-15-845DMIL314PINNACLE*KI32-X-X-794DMIL501900M-8-9-12-946DMIL318NK6240*CML412-X-X-X-10-1296DMIL504NK6240-6-4-22 <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
28 DMIL265 KI32*KI50-X-X-X-2 78 DMIL455 VA-2-3-65 29 DMIL270 KI32*KI50-X-X-X-4 79 DMIL460 S-NK30-6-8-7-112 30 DMIL270 KI32*KI50-X-X-X-21 80 DMIL463 DMH8255-6-8-4-42 31 DMIL273 NK6240*KI21-X-X-X-4 81 DMIL465 DMIG8011-6-2-4-147 32 DMIL280 NK6240*KI21-X-X-X-10 82 DMIL145 M-IG8011-6-2-4-147 33 DMIL280 NK6240*KI45-X-X-X-5 84 DMIL147 CLQ-RCYQ12-B-B-B 34 DMIL283 NK6240*KI45-X-X-X-7 85 DMIL150 25K55-3-9-7-55 36 DMIL288 NK6240*KI45-X-X-X-7 85 DMIL150 25K5-4-2-6-52 37 DMIL292 30V92*KI32-X-X-X-11 86 DMIL480 NK6240-6-4-2-2 38 DMIL297 30V92*KI32-X-X-X-15 89 DMIL480 NK6240-6-4-2-2 39 DMIL301 30V92*KI45-X-X-X-6 90 DMIL489 DMH8255-3-4-8-41 42 DMIL308 30V92*KI45-X-X-						
29DMIL266KI32*KI50-X-X-X-479DMIL460S-NK30-6-8-7-11230DMIL270KI32*KI50-X-X-X-2180DMIL463DMH8255-6-8-4-4231DMIL273NK6240*KI21-X-X-X-481DMIL46625K60-5-1-4-13932DMIL275NK6240*KI21-X-X-X-1082DMIL145M-IG8011-6-2-4-14733DMIL280NK6240*KI45-X-X-1183DMIL469NK-61-6-3-2234DMIL283NK6240*KI45-X-X-584DMIL15025K55-3-9-7-5536DMIL286NK6240*KI45-X-X-7785DMIL15025K55-3-9-7-5536DMIL288NK6240*KI45-X-X-487DMIL475900M-2-3-138DMIL29230V92*KI32-X-X-487DMIL480NK6240-6-4-2-239DMIL29730V92*KI32-X-X-1288DMIL485BIO6891-6-5-340DMIL30130V92*KI45-X-X-793DMIL485BIO6891-6-5-341DMIL12930V92*KI45-X-X-793DMIL489DMH8255-3-4-8-4142DMIL30830V92*KI45-X-X-793DMIL497NK6240-6-4-3-643DMIL130PINNACLE*KI32-X-X-793DMIL493NK6240-6-4-3-644DMIL136PINNACLE*KI32-X-X-793DMIL497NK6240-6-8-15-845DMIL314PINNACLE*KI32-X-X-793DMIL497NK6240-6-8-15-845DMIL318NK6240*CML412-X-X-1-296DMIL501900M-9-11-1047DMIL318NK6240*CML412-X-X-1-296DMIL501900M-9-11-10 <tr< td=""><td></td><td></td><td></td><td></td><td></td><td></td></tr<>						
30 DMIL270 KI32*KI50-X-X-X-21 80 DMIL463 DMIR8255-6-8-4-42 31 DMIL273 NK6240*KI21-X-X-X-4 81 DMIL466 25K60-5-1-4-139 32 DMIL275 NK6240*KI21-X-X-X-10 82 DMIL145 M-IG8011-6-2-4-147 33 DMIL280 NK6240*KI21-X-X-X-11 83 DMIL469 NK-61-6-3-22 34 DMIL283 NK6240*KI45-X-X-5 84 DMIL147 CLQ-RCYQ12-B-B-B 35 DMIL286 NK6240*KI45-X-X-7 85 DMIL150 25K55-3-9-7-55 36 DMIL288 NK6240*KI45-X-X-X-11 86 DMIL152 DMH8255-4-2-6-52 37 DMIL292 30V92*KI32-X-X-X-12 88 DMIL480 NK6240-6-4-2-2 39 DMIL297 30V92*KI32-X-X-X-15 89 DMIL485 BIO6891-6-5-3 40 DMIL101 30V92*KI45-X-X-X-16 90 DMIL489 DMH8255-3-4-8-41 41 DMIL101 30V92*KI45-X-X-X-17 92 DMIL489 DMH8255-3-4-8-41 42 DMIL308 30V92*KI4						
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The traits *viz.*, plant height (cm), anthesis to silking Interval, cob height (cm), cob length (cm), cob girth (cm), number of kernel rows per cob, number of kernels per row, test weight (g) and chlorophyll content (mg cm⁻²) were recorded on five randomly selected competitive plants per replication per inbred line under both normal and stress conditions. The mean of five plants observations were computed for statistical analysis. The traits *viz.*, days to 50 per cent anthesis, days to 50 per cent

silking, days to 75 per cent brown husk and grain yield per plot (later expressed as kg ha⁻¹) were recorded on plot basis. Anthesis to silking interval was computed as the difference between silking and anthesis dates. Drought susceptibility index (DSI) was computed as suggested by Fisher and Maurer (1978). The chlorophyll content of the third leaf from the top was measured at 60 DAS on five random leaves using SPAD chlorophyll meter (SPAD-502, Konica Minolta make) in both normal and stress conditions. Canopy temperature was measured from top five leaves at 11.00 am to 12.00 noon using Infrared Thermometer in both normal and stress conditions. Analysis of variance for individual characters was carried out on the basis of mean value of the genotype per replication.

Results and discussion

Drought is a complex trait, expression of which depends on action and interaction of different morpho-physiological and biochemical reactions. The analysis of variance revealed that variation due to moisture stress was significant for all the traits. Similarly, variation due to genotypes and interaction between stress and genotypes was also significant for all the traits including grain yield. Significant effect of moisture stress was observed in almost all the traits studied however, moisture stress increased significantly the days required to 50 per cent silking, ASI and canopy temperature (Table 2). These results are similar to the findings of Kuchanur et al. (2013). The relative performance of inbred lines for drought related traits and in turn grain yield will give an idea of drought tolerance ability of the genotype. The performance promising drought tolerant maize inbred lines under normal and stress conditions are presented in Table 3. The inbred lines viz., DMIL136 (50.6 days), DMIL221 (51.0 days), DMIL262 (51.5 days), DMIL275 (53.0 days) and DMIL125 (53.3 days) showed the early flowering under water stress conditions and exhibited drought escape mechanism. Drought escape allows the plant to complete its life cycle during the period of sufficient water supply before the onset of drought.

The effect of moisture stress on morphological traits was drastic and significantly reduced the expression of many traits but significantly increased days to silking and ASI. The inbred lines *viz.*, DMIL101 (3.5 days), DMIL210 (2.6 days), DMIL112 (3.0 days), DMIL125 (3.0 days), DMIL117 (3.3 days), DMIL122 (3.8 days), DMIL145 (3.5 days) and DMIL150 (3.4 days) showed shorter ASI under water stress conditions. Therefore, these lines could be effectively utilized for developing maize hybrids suitable for drought/rainfed conditions. However, inbred lines *viz.*, DMIL270 (14.5 days), DMIL273 (15.0 days), DMIL431

(13.0 days) showed wider ASI coupled with low grain yield under water stress which clearly indicated that these genotypes were very much susceptible to water stress conditions. These findings are similar to the report of Meena Kumari *et al.* (2004) who suggested that under severe stress, the anthesis-silking interval ranged from 3-5 days in drought tolerant inbreds whereas 9-17 days in drought sensitive inbreds.

In the present findings, reduction in the plant height and cob height was observed in all the inbred lines. Ahsan *et al.* (2011) also observed the reduction in the shoot length in S_1 maize families during water stress condition. The inbreds *viz.*, DMIL112 (188.2 cm), DMIL130 (185.1 cm), DMIL145 (183.9 cm) and DMIL117 (181.2 cm) recorded highest plant height, whereas DMIL136 (117.5 cm), DMIL339 (109.9 cm) and DMIL335 (107.0 cm) exhibited maximum cob height under stress condition. Inbred lines *viz.*, DMIL112 (29.4 g), DMIL136 (29.5 g), DMIL122 (32.0 g) and DMIL103 (29.2 g) recorded maximum hundred seed weight under stress conditions and can be employed in maize breeding programme for developing drought tolerant hybrids.

Among the morpho-physiological traits studied, grain yield showed maximum reduction per cent due to water stress. Inbred lines *viz.*, DMIL101 (3755 kg/ha), DMIL103 (3525 kg/ha), DMIL112 (3850 kg/ha), DMIL117 (4382.5 kg/ha), DMIL122 (4045 kg/ha), DMIL125 (3972.5 kg/ha), DMIL129 (3750 kg/ha), DMIL130 (3902.5 kg/ha), DMIL136 (3827.5 kg/ha), DMIL140 (4085 kg/ha), DMIL145 (3592.5 kg/ha), DMIL147 (3720 kg/ha), DMIL150 (3517.5 kg/ha), DMIL152 (3567.5 kg/ha) and DMIL160 (4352.5 kg/ha) produced highest grain yield under water stress conditions and exhibited lowest drought susceptibility index. These inbred lines could be used as parents for developing drought tolerant single cross hybrids. Hossien *et al.* (2013) indicated that plant height, cob leaf area, tassel weight and thereby grain yield per ha decreased under water limitation at grain filling stage.

Meena Kumari *et al.* (2004) reported that chlorophyll content and stability index decreased under drought stress. The similar results are also observed in the present study but DMIL140

Table 2. Mean sum of squares and effect	of moisture stress on morpho-physiological trai	ts, grain yield and its components traits
Traits	Mean sum of square	Effect of moisture stress

Traits		Mean sum	of square		E	ffect of 1	noisture stres	SS
	Normal / Stress	Genotypes	Interaction	Error	Normal	Stress	Difference	CD at 5 %
Days to 50 per cent Anthesis	679.124**	76.571**	10.459**	3.84	64.0	61.4	2.6*	0.18
Days to 50 per cent silking	3840.281**	128.121**	35.169**	6.32	66.1	72.3	-6.2*	0.22
Anthesis to silking interval	7649.281**	33.481**	34.517**	1.22	2.1	9.5	-7.4*	0.21
Days 75 per cent brown husk	7204.614**	59.440**	22.472*	7.69	111.1	102.7	8.4*	0.37
Plant height (cm)	70883.738**	1857.889**	337.944*	75.66	167.7	141.6	26.1*	0.55
Cob height (cm)	23786.584**	760.664**	187.188*	30.87	88.9	73.5	15.4*	1.09
Cob length (cm)	711.289**	27.212**	5.428*	2.50	16.6	13.9	2.7*	0.24
Cob girth (cm)	376.748**	9.913**	2.427	1.90	13.8	11.8	2.0*	0.18
Number of kernel rows per cob	1048.141**	12.894**	4.926	1.93	14.5	11.3	3.2*	0.27
Number of kernels per row	5526.436**	146.193**	32.983*	6.83	27.2	19.8	7.4*	0.38
Test weight (g)	5742.608**	103.312**	33.899*	3.58	25.6	18.0	7.6*	0.28
Grain yield (kg/ha)	255532213.891**	3224474.857**	854430.557**	32787.28	3707.7	2109.1	1598.6*	35.70
Chlorophyll content (mg cm ⁻²)	1128.624**	183.910**	118.580*	3.23	48.0	37.1	10.9*	0.11
Canopy temperature (° C)	380.444**	38.97**	15.131*	2.56	29.9	34.5	-4.6*	0.13

* and ** significance at 0.05 and 0.01 level of probability, respectively.

١ys	Days to 50 %	Anthe	Anthesis to	Plant he	neight	Cob height	eight	Test v	Test weight	Grain	Grain yield	Chlorophyll	phyll	Canopy	opy	Drought
anthesis		silking interval	ng val	(cm)	U)	(cm)	U)	<u>.</u>	(g)	(kg/ha)	ha)	content (mg cm ⁻²)	int n ⁻²)	temperature (°C)	ature C)	suscepti- bility
Normal St	Strees	(days) Normal	S) Strees	Normal	Strees	Normal	Strees	Normal	Strees	Normal	Strace	Normal	Strees	Normal	Strace	index
	56.0	2.8	3.5	177.7	167.2	80.5	77.8	29.9	22.4	4535.0	3755.0	57.9	46.9	26.6	28.8	0.61
	61.1	2.5	3.8	185.4	170.5	121.5	86.5	29.8	29.2	4297.5	3525.0	50.9	50.0	28.4	31.4	0.64
	62.5	2.5	3.0	193.9	188.2	122.0	106.6	31.7	29.4	4427.5	3850.0	43.9	41.3	30.6	27.8	0.46
	61.3	2.0	3.3	194.7	181.2	97.1	94.7	27.3	25.5	4647.5	4382.5	41.9	40.0	30.0	32.6	0.20
	59.7	1.8	3.8	165.1	142.0	80.7	61.6	35.8	32.0	4410.0	4045.0	52.9	48.8	29.1	33.1	0.30
	53.3	2.0	3.1	179.9	176.7	102.9	94.1	21.9	16.9	4592.5	3972.5	52.0	47.5	32.1	32.4	0.48
	55.5	3.3	4.0	184.0	175.6	79.6	55.0	28.5	28.6	4297.5	3750.0	45.1	39.1	31.5	32.0	0.45
	58.2	1.5	4.3	190.7	185.1	86.2	84.4	25.9	21.9	4495.0	3902.5	55.0	44.9	26.4	28.5	0.46
	50.6	1.5	4.4	180.1	168.5	123.0	117.5	29.3	29.5	4395.0	3827.5	51.0	43.1	30.2	31.9	0.46
	61.6	1.8	4.1	192.9	173.1	109.5	81.5	31.7	27.3	4645.0	4085.0	58.1	53.3	30.1	31.9	0.43
	60.5	3.0	3.5	193.2	183.9	110.9	99.4	25.7	25.1	4752.5	3592.5	51.7	42.3	23.4	29.9	0.87
	56.0	1.8	4.9	191.4	174.0	66.6	60.5	28.7	12.1	4360.0	3720.0	49.8	42.0	27.9	28.3	0.52
	60.2	3.5	3.5	185.1	170.5	121.9	89.7	33.6	22.1	4255.0	3517.5	51.8	47.5	24.4	27.2	0.61
	61.0	3.5	4.8	200.2	170.6	115.2	99.1	25.5	23.1	3992.5	3567.5	51.8	44.0	28.4	30.0	0.38
	57.7	2.0	4.0	198.3	179.7	101.2	94.7	30.2	19.6	4552.5	4352.5	51.8	47.1	29.1	26.9	0.43
	51.0	1.5	14.5	177.5	175.4	91.0	89.1	22.3	12.2	3892.5	2387.5	41.9	27.5	34.0	43.8	1.38
	60.0	1.8	12.5	164.4	130.0	77.0	64.1	26.0	23.6	4100.0	3617.5	50.9	49.1	31.7	38.2	0.42
	51.5	3.3	11.2	196.5	139.8	102.7	96.6	20.7	22.4	4302.5	1402.5	49.7	39.5	31.0	36.9	2.41
	67.5	2.3	14.5	169.9	142.4	84.2	73.5	27.9	16.3	4155.0	1205.0	49.9	26.6	32.2	40.5	2.53
	55.2	2.5	15.0	142.4	136.5	76.1	72.4	66.0	17.6	3952.5	2855.0	53.0	43.0	30.8	36.8	0.99
	53.0	2.5	8.0	147.9	100.2	72.4	68.7	22.2	16.5	2035.0	570.0	40.0	29.1	29.9	35.2	2.56
	61.0	2.0	11.5	192.0	180.1	115.6	107.0	21.4	16.5	3850.0	2595.0	59.3	28.0	29.5	34.0	1.16
	59.8	1.8	7.2	188.5	162.8	110.8	109.9	22.0	11.4	4130.3	2995.0	46.9	35.0	27.9	38.0	0.96
	60.2	2.5	7.3	167.4	150.5	87.6	70.1	28.3	19.8	3802.5	2695.0	51.9	34.0	29.1	32.4	1.04
	63.1	1.3	13.0	146.5	144.0	66.5	57.2	29.5	12.5	3720.0	727.5	44.9	40.9	30.2	33.9	2.89
	58.5	1.8	6.1	166.5	153.0	81.8	73.4	24.2	22.3	4227.5	2792.5	51.0	31.1	27.2	29.6	1.21
	65.0	5.5	11.0	177.2	131.1	113.9	70.4	21.8	20.2	3617.5	2202.5	45.9	35.6	29.1	28.0	1.40
	54.5	1.8	8.2	167.5	160.7	74.4	67.4	31.6	21.4	4070.0	3001.3	45.9	34.2	30.0	27.0	0.94
	61.4	2.2	9.6	167.7	141.1	88.8	73.4	25.6	18.0	3707.7	2109.1	48.0	37.1	29.9	34.5	1.60
	1.23	0.77	1.20	2.49	3.10	3.15	7.22	1.24	1.04	206.3	147.84	2.32	1.18	1.71	1.57	0.15
	2.45	1.52	2.38	4.94	6.16	6.26	14.32	2.46	2.06	409.34	293.55	4.60	2.34	3.40	2.48	0.29
	3.24	2.01	3.15	6.53	8.15	8.28	18.96	3.26	2.72	541.83	388.30	6.09	3.10	4.49	3.29	0.39
I.																

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Table 4. Mean reduction	(%) of morpho-	physiological	l traits due to
water stress			

water stress			
Traits	Normal	Stress	Mean reduction
			(%)
Days to 50 per cent Anthesis	64.00	61.40	4.10
Days to 50 per cent silking	66.10	72.30	-9.40
Anthesis to silking Interval	2.10	9.50	-78.90
Days 75 per cent brown husk	111.10	102.70	7.60
Plant height (cm)	167.70	141.60	15.60
Cob height (cm)	88.90	73.50	17.30
Cob length (cm)	16.60	13.90	16.30
Cob girth (cm)	13.80	11.80	14.50
Number of kernel rows per cob	14.50	11.30	22.10
Number of kernels per row	27.20	19.80	27.20
Test weight (g)	25.60	18.00	29.70
Grain yield (kg/ha)	3707.70	2109.10	43.10
Chlorophyll content (mg cm ⁻²)	48.00	37.10	22.70
Canopy temperature (°C)	29.90	34.50	-15.40

(53.3 mg cm²), DMIL103 (50.0 mg cm²) and DMIL242 (49.1 mg cm²) recorded the maximum chlorophyll content under water stress condition and these could be utilized for development of maize genotypes with enhanced chlorophyll content during drought conditions. The present study also revealed that increase in canopy temperature under stress when compared to normal conditions. However, inbred lines *viz.*, DMIL160 (26.9°C), DMIL485 (27.0°C), DMIL150 (27.2°C), DMIL112 (27.8 °C) and DMIL475 (28.0°C) showed the minimum canopy temperature under stress is not uniform at

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all the stages of plant and its effect on various morphological traits depends not only on the magnitude but also on the physiological stage at which it occurs. Present study revealed that the traits grain yield (43.10%) showed maximum reduction per cent followed by test weight (29.70%) and number of kernels per row (27.20%) and minimum reduction per cent was observed in days to 50 per cent anthesis (4.10%) followed by days to 75 per cent brown husk (7.61%) (Table 4).

Maize is widely regarded to be more susceptible to drought at flowering than other rainfed crops. This is due to a combination of several factors including physical separation of male and female flowers, floral asynchrony, non receptivity of silk, tassel blasting, trapped anther and embryo abortion (Lu et al., 2011). Breeding for drought tolerant hybrids is a feasible strategy to increase/sustain yield levels under challenging environments. Identification of inbred lines with superior stress tolerant trait(s) is prerequisites for the success of such a breeding program. This study evaluated a set of maize inbred lines for drought tolerance under field conditions and identified 15 inbred lines viz., DMIL101, DMIL103, DMIL112, DMIL117, DMIL122, DMIL125, DMIL129, DMIL130, DMIL136, DMIL140, DMIL145, DMIL147, DMIL150, DMIL152 and DMIL160 based on shorter ASI, higher grain yield, chlorophyll content, lower canopy temperature and low drought susceptibility index (Table 3). These inbred lines with superior drought tolerance traits could be used as genetic materials for the breeding of drought-tolerant hybrids suitable for rainfed ecosystem and further development of drought tolerant population.

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