Available online at www.ijpab.com
DOI: http://dx.doi.org/10.18782/2320-7051.6148

ISSN: 2320 – 7051
Int. J. Pure App. Biosci. **6 (3):** 82-94 (2018)
Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Characterization of Maize Hybrids and Their Parents for Drought Tolerance Based on Shoot and Root Growth at Differential Soil Moisture

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Received: 5.01.2018 | Revised: 11.02.2018 | Accepted: 16.02.2018

ABSTRACT

Studying the genotypic variations in root and shoot growth is crucial for developing stress-resilient genotypes and several studies have reported significant association between root traits and crop performance under moisture stress. Ten selected maize hybrids, their parents and checks were grown in polybags and were subjected to grow at two soil moisture levels (100% and 50% field capacity) after 10 days of sowing to till 60 days. The growth parameters viz., plant height, leaf number, leaf area, shoot dry weight, root length, root volume and root dry weight were recorded after 60 DAS. Significant variation for different parameters among genotypes and moisture levels were observed. Genotypes showed varying degree of changes with moisture levels. DMIL 516 X DMIL 230, DMIL 553 X DMIL 447 and CML 425 X DMIL 516 these hybrids and their parents DMIL 516 and DMIL 553 found to be acceptable genotypes for drought based on the root and shoot growth.

Key words: *Genotypes, Soil, Root and Shoot, Maize*

INTRODUCTION

In Asian tropics maize is largely (about 80%) grown as rain-fed crop, which is prone to face vagaries of monsoon rains associated with an array of abiotic and biotic constraints. Erratic/un-even distribution patterns of monsoon rain occasionally causes drought at different crop growth stage(s), which is identified as a factor responsible for year-to-year fluctuation in production of rainfed maize in Asian tropics A pot experiment was conducted to study the effects of simulated moderate drought in whole growth period on root physiological traits of drought-tolerant maize hybrids and drought-sensitive maize hybrids along with two checks. Understanding how roots respond (or adjust) to stress conditions, and support adaptation to the stress is crucial for developing stress-resilient genotypes and there are several studies reported significant association between root traits and crop performance. However, in spite of well-known role, in general and under drought stress conditions in particular, most often this important hidden-half is "knowingly" ignored due to complexity involved in studying root traits.

Cite this article: Patil, A. and Mummigatti, U. V., Characterization of Maize Hybrids and their Parents for Drought Tolerance Based on Shoot and Root Growth at Differential Soil Moisture, *Int. J. Pure App. Biosci.* **6(3):** 82-94 (2018). doi: http://dx.doi.org/10.18782/2320-7051.6148

In recent years improvements of root traits to increase the efficiency of foraging the soil water and maintenance of productivity under drought and other abiotic stress is gaining momentum. Keeping in view complexity in direct studies on root traits, the alternative for studying the available genotypic variability of such complex traits is under taken in pot to identify superior hybrid/parent of maize to water stress.

MATERIAL AND METHODS

The study was carried out at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during rabi/summer season 2016-17 with an objective to evaluate maize hybrids and their parents for drought tolerance based on root and shoot traits. The experimental material consisted of 10 hybrids, their parents and 2 checks (cp-818 and Gh-2072). The genotypes were grown in polyethylene bags at two moisture levels i.e. 100% and 50 % field capacity. The polybags of 41 cm length X 24 cm width filled with 10 kg mixture of black soil, sand and vermicompost (2:1:1). Initially the amount of water required reach 100% field capacity for this soil mixture was worked out, which was 1000 ml. Two sets of polybags each maintained at two soil moisture levels (100% and 50% of field capacity) and three replications. The maize seeds of above genotypes were sown and watered to 100% field capacity. After 10 days two sets with separate moisture levels were maintained by adding required quantity of water every three days and allowed to grow till 60 days. After 60 days, the plants were extracted to record plant height, number of leaves, leaf area, shoot weight were recorded. Root parameters viz., root length, root volume were measured by WINRHIZO™ 9.1 (Regent instrument). Shoot and root dry weights was recorded and root to shoot weight was worked out.

Root to shoot ratio was worked out by following formula.

$$\text{Root to shoot ratio} = \frac{\text{Root dry weight g}}{\text{Shoot dry weight g}}$$

Statistical analysis

The data recorded are processed with statistical parameters *viz*, range, mean, The data was subjected to CRD two factor and Split plot design analysis. The statistical methods adopted are as follows.

Analysis of variance (ANOVA)

A two factorial completely randomized block design with two factors keeping water availability in the one factor and genotypes in second factor was followed with three replications.

Sources of Variation	Df	SS	MSS	F
Factor A	a-1	SSA	MSA	MSA/ MS (MPE)
Factor B	b-1	SSB	MSB	MSB/ MS (SPE)
A×B	(a-1) (b-1)	SS (A×B)	MS (A×B)	MS (A×B) / MS (SPE)
Error	(r-1) + (a-1) (b-1)	SS (SPE)	MS (SPE)	
Total	rab-1	TSS		

Where,

a = treatements imposed

b = number of genotypes

r = number of replication

RESULTS AND DISCUSSION

With an increased moisture level, there was a reduction in shoot length and increased the root length and toatal dry matter whereas shoot biomass decreased resulting in increased root to shoot ratio, the per cent change over the control in maize hybrids and their parents both in shoot and roots to identify the drought resistant and susceptible hybrid. The genotypes with least change it indicates drought resistant, Phenotypic variation for root functional traits was significantly high under both well-watered and drought stress conditions. Wiesler and Horst reported that roots of all the cultivars penetrated to 150 cm and significant differences among the cultivars for root length densities at silking. Constitutive differences in root traits like rooting depth play a major role in drought resistance of crops[5].

1. Shoot height (cm)

The shoot height ranged from 85.47 cm (NC 468) to 122.83 cm (CML 425 X DMIL 516) and from 46.95 cm (NC 468) to 86.30 cm (DMIL 607X DMIL 516), respectively, in the non-stress and stress treatments. The non-stress and stress mean was 104.56 cm and 67.48 cm, respectively. The shoot height was reduced in the stress compared with non-stress and the mean being 35.46 per cent the results revealed in (Table 1).

Among all genotypes there was higher plant height in normal condition compared to drought condition in the root dynamic study. There are some genotypes which are very sensitive to moisture stress and as they recorded significantly reduced plant height under moisture stress condition the other genotypes CML 425 (88.57 cm and 80.90 cm), CML 425 X DMIL 553 (119.33 cm and 70.56 cm) and irrespective of mean value (85.44 cm) per cent change over the control (29.66 %), and CML 425 X DMIL 607 (101.50 cm and 63.03 cm) irrespective of mean value (84.07 cm) per cent change over the control (40.03 %), DMIL 607 X DMIL 516 (105.67 cm and 86.30 cm) (95.98 cm) per cent change over the control (18.33 %) Thus genotypes may be suitable for drought tolerance. Recorded lesser percent reduction in plant height in drought condition and lesser difference between conditions (normal and drought), these genotypes has better surviving ability in the drought condition.

(DMIL 692 X DMIL 230) (118.13 cm and 73.67 cm) irrespective of mean value (96.00 cm) per cent change over the control (37.75%), NC 468 (85.47 cm and 46.95 cm) irrespective of mean value (66.21 cm) per cent change over the control (45.06 %) recorded highest decrease plant heights in drought and the hybrid (DMIL 715 X DMIL 607) (105.10 cm and 63.03 cm) irrespective of mean value (84.07 cm) (40.03 %), gh-7027 (28.67 %) per cent change over the control of this check is less as compared to other genotypes and NC 468 reduced plant heights as compare to other genotypes in normal condition. Thus this genotype has less flexibility nature of plant growth leads to highest percent of reduction in plant height under drought and normal condition. Hence the CML 425 X DMIL 607 and it was also shown same result in field and root studied has better adaptability to drought.

2. Number of leaves

This may be attributed to the fact that growth and development of leaves was curtailed by water stress. Similar findings of suppression of production and expansion of leaves at water stress situation was noticed Sabrado[14], Muchow and Carberry[7], Yadav *et al.*[17] and Hader[3] important morphological parameter which has relevance to the performance of a genotype in terms of productivity is the number of leaves and leaf area as they serve as a photosynthetically active source and considered as an important functional unit of plant which contributes to the formation of yield.

Recording the range from 10.67 (DMIL 516 X DMIL 230) to 12.33 (DMIL 553 X DMIL 447) and 9.00 (CML 425 X DMIL 516) to 11.67 (DMIL 607 X DMIL 516, CML 425 X DMIL 607, DMIL 516 X DMIL 447) under both the field capacity, and the overall mean values for this trait at 55 DAS 11.50 and 10.45 under both conditions hence the highest the wilting leaves under 50 % field capacity as compare to 100 % field capacity, irrespective of that mean (10.98) and percent change over the control (9.09 per cent).

The significant recorded hybrids DMIL 553 X DMIL 447 (12.33) mean value of for the (11.33) per cent change over the control (16.22 %) followed by NC 468 X DMIL 692 (12.00) mean value for (11.17) per cent change over the control (13.89 %) under 100 per cent field capacity and the significantly recorded highest number of leaves under stress condition by the hybrid

DMIL 516 X DMIL 447, DMIL 607 X DMIL 516, CML 425 X DMIL 607 and DMIL 692 X DMIL 230 (11.67) 3 hybrids viz., has recorded on par with each other irrespective of mean value of thse hybrids DMIL 607 X DMIL 516 , CML 425 X DMIL 607 (11.67) per cent change over the control (0.00 %) DMIL 516 X DMIL 447 (11.67) mean value of for the (11.33) per cent change over the control (-6.06 %) this hybrid has recorded highest number of leaves as compared to non stress. And other two hybrids DMIL 607 X DMIL 516 and CML 425 X DMIL 607 (11.67) mean value of for the (11.67) per cent change over the control (0.00 %) has recorded same amount of number leaves under both the situations. The lowest number of leaves as recorded by the hybrids DMIL 516 X DMIL 447 (11.00) mean value of for the (11.33) per cent change over the control (0.00 %) this hybrid has recorded same amount of lowest number leaves under both the situations the hybrid DMIL 715 X DMIL 607 (11.00) mean value of for the (10.50) per cent change over the control (9.09 %) on par with each other followed by the hybrid DMIL 516 X DMIL 230 (10.67) mean value of for the (10.50) per cent change over the control (3.12%) lowest per cent reduction of the change over the control as compared to other genotypes under non stress condition. in the stress condition the lowest number of leaves recorded by the hybrid DMIL 715 X DMIL 607 (10.00) mean value of for the (10.50) per cent change over the control (9.09 %) followed by the hybrid CML 425 X DMIL 516 (9.00) mean value of for the (10.33) per cent change over the control (22.86 %) this genotype has recorded highest the per cent reduction of change over the control as compared to other genotypes and checks under both the field capacity (Table 1).These results are in confirming with the findings of Bennet and Hammond[2], Jing and Hisiao[4]. They observed genotypes differences among the genotypes in leaf number and leaf area under varied stress situations.

3. Leaf area (cm^2)

The leaf area recorded at 50 DAS ranged from 4498.00 (DMIL 516 X DMIL 230) to 7272.50 (DMIL 715) and from 3183.07 cm2 (DMIL 692 X DMIL 553) to 5287.84 cm2 (CML 425), respectively, in the non-stress and stress treatments. The non-stress and stress mean was 5743.71 cm^2 and 4508.99 cm^2, respectively. The leaf area was higher in the non stress compared with stress and the mean being 21.50 per cent the results revealed in (Table 1).

The natural trend of decrease leaf area in drought condition was also observed in the present study. This trait has recorded significant variation among genotypes. Among all the genotypes there was higher leaf area in normal condition compared to drought condition. Significant recorded the highest leaf area recorded by the hybrid CML 425 X DMIL 607 (6314.20cm2) followed by DMIL 715 X DMIL 607 (6033.60 cm^2 and 4774.51 cm^2) under normal and stress condition. Respectively, under both the situations recorded highest leaf area compared to checks, recorded lesser percent reductions in leaf area in drought condition and also shown lesser difference between normal and drought condition, irrespective of the hybrid mean value (5660.84) per cent change over the control of two situations (20.69 %) followed by the respective hybrid mean value (5404.06) (20.87 %) thus these genotypes may be drought tolerance. There are some genotypes which are very sensitive to moisture stress and as they recorded significantly reduced leaf area under moisture stress condition than the other genotypes.

In our results, lower leaf area recorded by the hybrid NC 468 X DMIL 230 (4778.25 cm^2 and 3721.22 cm^2) followed by DMIL 692 X DMIL 553 (4604.58 cm^2 and 3183.07 cm^2) under both the situations of non stress and stress condition as compared to the lower than the checks and other genotypes recorded lowest differences in leaf area between normal and drought condition and normal condition indicates these genotypes have better elasticity of leaf area growth to adjust the drought. DMIL 715, DMIL 447 and DMIL 692 X DMIL 553 recorded wider difference in leaf area between normal and drought condition and normal condition, indicates these genotypes have lesser elasticity of leaf area growth to adjust the drought condition. The irrespective mean value of the two conditions of above those hybrids recorded significant lowest the leaf area at 50 DAS recorded by NC 468 X DMIL 230 (4249.74) difference between two conditions (22.12 %) followed by DMIL 692 X DMIL 553 (3893.82cm2) difference between two conditions (30.87 %) significant lower as compare to the parents and checks under both the situations (Table 59).

4. Maximum root length (cm)

Root traits play a major role in drought tolerance under terminal drought environments. In terms of root architecture, both more prolific root systems extracting more of the water in upper soil layers and longer root systems extracting soil moisture from deeper soil layers are important for maintaining yield under terminal drought[15]. The stressed genotypes had greater tap root length than control. This suggested that increase in tap root of maize plant and permits to survive under stress by accessing water from deeper in the soil profile. According to Pace *et al.*[9] the length of the taproot was greater in the drought treated genotypes than in the control genotypes. Root growth was not decreased in the drought treated genotypes, compared with the controls[1,6].

Significant difference was observed in the maximum root length under non-stress and stress condition in Table 2. The mean maximum root length ranged from 31.83 cm (DMIL 438) to 45.17 cm (CML 425 X DMIL 607) over al mean of maximum root length under non stress 38.59 cm and maximum root length ranged from 42.93 cm (DMIL 516 X DMIL 230) to 77.97 cm (DMIL 692 X DMIL 230) under stress and overall mean (54.06 cm) The mean maximum root length was found to be reduced in the non stress when compared with the stress (46.33 cm) The mean reduction was (-40.06 %) however the maximum root length was higher under drought condition. and their per cent change over the control from (-17.19%) CML 425 and (-100.77%) DMIL 692 X DMIL 230 hence this genotype has recorded higher the maximum root length as compared to non stress. The checks are significant lowest maximum root length as compared to hybrids and their parent under non-stress conditions. Thus such genotypes may be moisture stress tolerance. There are some genotypes which are very sensitive to moisture stress and as they recorded significantly reduced maximum root length under moisture stress condition than rest other genotypes DMIL 516 X DMIL 230, CML 425 X DMIL 607, DMIL 553 X DMIL 447 and cp-818. In normal and drought conditions, the drought condition was recorded higher mean value compared to the normal condition, because most of the genotypes recorded increased maximum root length in drought condition.

5. Total root length

Significant difference was observed in the maximum root length under non-stress and stress condition in Table 2. The mean total root length ranged from 100.14 cm (cp-818) to 1824.95 cm (DMIL 230) over al mean of total root length under non stress 1110.35 cm and total root length ranged from 234.01 cm (DMIL 230) to 1671.25 cm (CML 425 X DMIL 516) under stress and overall mean 679.42 cm The mean total root length was found to be reduced in the non stress when compared with the stress 894.88 cm The mean reduction was (-38.81 %) however the total root length was higher under irrigated condition. and their per cent change over the control from (-37.23 %) DMIL 553, (-52.89%) DMIL 516 X DMIL 230, (-59.95%) CML 425 X DMIL 516, (-766.48%) cp-818 and (-3.20 %) gh-7027 hence these genotype has recorded higher the total root length as compared to non stress. These genotypes are proved to be a tolerance to drought condition. Thus such genotypes may be moisture stress tolerance. There are some genotypes which are very sensitive to moisture stress and as they recorded significantly reduced total root length under moisture stress condition than rest other genotypes *viz.*, CML 425 X DMIL 516 (1671.25 cm) and DMIL 553 X DMIL 447 (1377.56 cm) these genotypes has recorded highest total root length as compared to other genotypes under drought condition, hence these genotypes are adjustable to drought as compared to other genotypes. In normal and drought conditions, DMIL 553, DMIL 516 X DMIL 230, CML 425 X DMIL 516 these genotypes was recorded higher total root length compared to the normal condition, because most of the genotypes recorded increased total root length in irrigated condition.

6. Root volume (cm^3)

Root volume indicates the total space occupied by the roots in the soil. More the root volume, more the water can the plant uptake. According to Parameshwarappa *et al.*[10], in chickpea (*Cicer arietinum* L.) the drought tolerance genotypes have highest root volume than rest other genotypes in moisture stress condition was recorded.

The range for root volume at 60 DAS under 100 per cent field capacity was 5.70 – 20.40 (cm^3), with the overall mean value of 13.65 cm^3. The higher root volume under normal condition was recorded by CML 425 X DMIL 607 (20.40 cm^3) followed by DMIL 516 X DMIL 230 (17.27 cm^3) the root volume where on par with hybrids except three parents *viz*., DMIL 230 (5.70 cm3) followed by DMIL 516 (9.83) and CML 425 (10.33 cm^3) was recorded significant lowest root volume as compared to checks cp-818 (-17.67 cm^3) under normal condition. Were as, the range for root volume 5.93 cm^3 (CML 425 X DMIL 553) to 12.43 cm^3 (cp-818), with overall mean value of 8.25 cm^3 under 50 per cent field capacity. The highest root volume was recorded by DMIL 516 X DMIL 230 (10.89 cm^3) followed by DMIL 553 X DMIL 447 (10.83 cm^3) and their per cent change over the control for that hybrids (14.08 % and 11.75 %) significant as compared with the parents and hybrids except one parent was recorded highest root volume *viz*., the DMIL 692 (10.93 cm^3) as their compared to check cp-818 (12.43 cm^3) per cent change over the control (29.62 %) there was significant lowest root volume under 50 per cent field capacity. In the present root study the drought tolerance genotypes recorded lesser percent reduction in root volume in drought condition than the other genotypes DMIL 516 X DMIL 230, DMIL 715 X DMIL 607, NC 468 X DMIL 692, DMIL 692 and (DMIL 692 X DMIL 230). Thus such genotypes may be suitable for drought condition. All genotypes are reduced root volume as compare to normal condition except above few genotypes are recorded higher the root volume as compared to other genotypes under drought condition. Thus those genotypes may be sensitive under water stress condition. Thus those genotype has less flexibility nature of root growth to adjust the drought situation the results revealed that (Table 2).

7. Shoot dry weight (g)

The shoot dry weight range was recorded from 86.78 g (DMIL 553 X DMIL 447) to 309.16 g (DMIL 715) and 38.67 g (DMIL 516 X DMIL 447) to 81.55g (DMIL 553) under both the field capacity. Respectively the mean values 140.69 g and 59.96 g under both the condition, however the per cent change over of two mean value 57.38 per cent dry shoot weight the results revealed in (Table 3).

Dry shoot weight reflects the amount of photosynthesis diverted towards the vegetative and reproductive parts of the shoot. It is one of the important trait significant changes in moisture stress condition and less affected by the environmental factor. Ball *et al.* suggesting that shoot dry weight could be used as selection criteria for drought tolerance because of their ease of their measurement and reliability. Many studies reported[9] when the drought cycles increases dry shoot weight decreases and significant variation was found for test, generation, generation into test, genotype, genotype into test and genotype into generation.

In our root study found significant variation among genotypes for this trait. NC 468 X DMIL 692 (178.17g) irrespective of mean value (113.65 g per plant) and difference between change over the control (72.42 %) followed by DMIL 715 X DMIL 607 (166.16 g per plant) irrespective of mean value (102.70 g per plant) and difference between change over the control (76.39 %) under 100 per cent field capacity these genotypes are higher the per cent reduction. CML 425 X DMIL 607 (77.70 g) irrespective of mean value (106.38) and difference between change over the control (42.47 %) followed by DMIL 516 X DMIL 230 (75.91 g per plant) irrespective of mean value (90.32 g per plant) and difference between change over the control (27.52%) under 50 % field capacity these genotypes recorded lesser the per cent reduction in dry shoot weight in drought condition and also shown less difference between normal and drought conditions. Indicates this genotype have better growth and wider adaptability during water stress condition. There are some genotypes which are very sensitive to moisture stress and as they recorded significantly reduced dry shoot weight in moisture stress condition than the other genotypes Whereas, the significant lowest shoot dry weight was recorded by CML 425 X DMIL 553 (104.50 g) irrespective of mean value (75.23 g per plant) and difference between change over the control (56.01 %) followed by DMIL 553 X DMIL 447 (86.78 g per plant) irrespective of mean value (73.48 g per plant) and difference between change over the control (30.65 %) under 100 % field capacity, similarly, the hybrids DMIL 715 X DMIL 607 (39.23 g per plant) irrespective of mean value (102.70 g per plant) and difference between change over the control (76.39 %) followed by DMIL 516 X DMIL 447 (38.67 g per pant) irrespective of mean value (93.67 g per plant) and difference between change over the control (73.99 %) under the 50 % field capacity higher the per cent reduction change over the control. Indicates this genotype have less adaptability during water stress condition. Among all the genotypes NC 468 X DMIL 607, DMIL 438, DMIL 553, DMIL 607 and DMIL 715 X DMIL 607 there was higher dry shoot weight in normal condition compared to drought condition.

8. Root dry weight (gm)

Dry root weight reflects the amount of photosynthetes diverted towards the roots. It is important trait to identifying the drought tolerance genotype compared to fresh root weight bases, because the fresh root weight involves varying amount of water hold in the root biomass. According to Rezaeieh and Eivazi,[11] root dry weight was recognized as the best indicator and easiest typical to determine the drought tolerance of maize. The drought treated maize genotypes had a lower dry weight per unit length than control[9].

The root dry weight ranged from 30.60 g (DMIL 230) to 64.47 g (gh-7027) in the non-stress and from 13.70 g (CML 425) to 46.18 g (DMIL 438) in the stress condition. The respective mean was 41.12 g and 26.93 g for the non-stress and stress treatments. The mean root dry weight was (34.02 g) found to be reduced in the stress when compared with the non-stress (34.55 %). The hybrid DMIL 516 X DMIL 230 (50.33 g) irrespective of mean value (46.10 g) and per cent change over the control (16.81 %) followed by the hybrid CML 425 X DMIL 516 (42.73 g) irrespective of mean value (32.77 g) and per cent change over the control (46.65 %) recorded highest root dry weight as compared to others hybrids and significant recorded lowest root dry weight as compared to checks cp-818 (62.17 g) irrespective of mean value (53.25 g) and per cent change over the control (28.69 %) and gh-7027 (64.47 g) irrespective of mean value (53.43 g) and per cent change over the control (34.23 %) under 100 per cent field capacity. Respectively, the hybrid DMIL 516 X DMIL 230 (41.87 g) irrespective of mean value (46.10 g) and per cent change over the control (16.81 %) followed by the hybrid DMIL 607 X DMIL 516 (34.97 g) irrespective of mean value (35.95 g) and per cent change over the control (5.32 %) recorded highest root dry weight as compared to others hybrid, except two parents *viz*., DMIL 438 (46.18 g) irrespective of mean value (40.26 g) and per cent change over the control (-34.50 %), DMIL 553 (36.93 g) irrespective of mean value (42.23 g) and per cent change over the control (22.30 %) and CML 425 (13.70 g) irrespective of mean value (24.94 g) and per cent change over the control (62.11 %) significant lowest root dry weight was recorded compared with checks, cp-818 (44.33 g) and gh-7027 (42.40 g) under 50 per cent field capacity The results revealed that (Table 3).

In our root study observed all the genotypes showed higher dry weight in normal condition than drought condition and larger genetic variability recorded in the different conditions (100 per cent field capacity, 50 per cent field capacity). There are some genotypes recorded lesser percent reduction in drought condition and also shown lesser difference between normal and drought conditions than the other genotypes CML 425 X DMIL 607 DMIL 715 X DMIL 607 and DMIL 516 X DMIL 230. DMIL 438 has recorded higher the root dry weight under drought as compare to normal condition. There are all genotypes which are very sensitive to moisture stress and as they recorded significantly reduced dry root weight in moisture stress condition. Except few above mentioned genotypes has recorded higher the root dry weight under drought condition and less difference between drought and normal condition. Thus this genotype has higher nature of flexibility in root growth to adjust the drought condition.

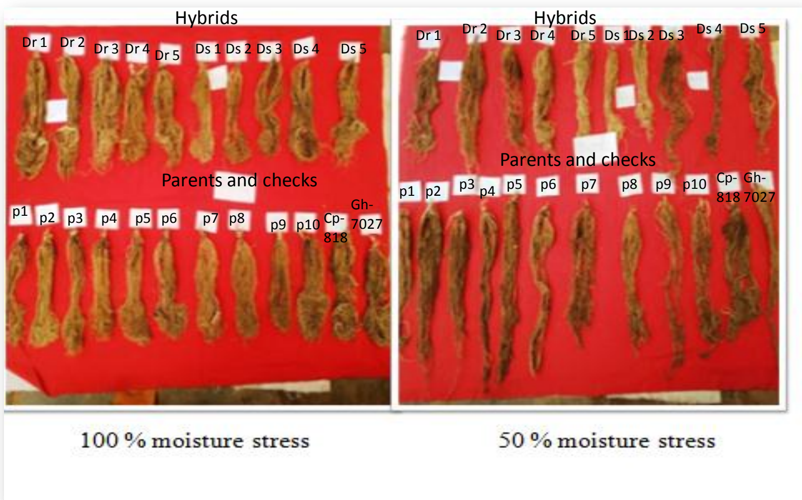
9. Root to shoot ratio

Root to shoot ratio range from 0.26 (DMIL 516) to 1.28 (CML 425) under non stress and the range from 0.17 (DMIL 715) to 0.66 (gh-7027) under stress. The respective overall the mean for both the condition 0.55 and 0.36 the mean of the both the situations change over the control 33.77 per cent the results revealed that (Table 3).

Maize responds to drought stress by redirecting root growth and dry matter accumulation away from the shoot to the root[12]. Under drought stress, plants seek to reduce the impact of the lack of water by reducing the transpiration rate and by increasing the efficiency of water acquisition from the[16]. In the present study Plants have developed numerous adaptive mechanisms for better growth under drought conditions such as modification of the root system, among all the genotypes few of them DMIL 516 X DMIL 230 (0.27 per cent) (0.31 per cent and 0.35 per cent) under both the condition the irrespective of mean and differences between over the control (21.35 %), DMIL 553 X DMIL 447 (0.46 and 0.65) under both the condition differences between over the control (0.55) (-40.03 %), CML 425 X DMIL 516 (0.30 per cent and 0.36 per cent) differences between over the control (0.33) (-21.05 %) and DMIL 516 (-73.97 %) the root to shoot ratio was higher under drought as compared to normal condition. Hence these genotypes are good adaptability to the drought environment. Indicating that proved to be a drought tolerance. Phenotypic relationships between root and shoot traits were reported in maize by Richner *et al.*[13] suggested that seedling root traits with other secondary traits could be used as indirect selection for shoot performance in maize.

In our study, the genotypes CML 425 X DMIL 553 (0.51 per cent and 0.27 per cent) under both the conditions the irrespective of mean and difference between over the control (0.39 per cent) (47.47 %) lesser the difference between drought and normal condition (0.25 per cent) and (18.52 %), NC 468 X DMIL 692 (0.35 per cent and 0.25 per cent) irrespective of mean and differences between over the control (0.30 per cent) (29.87 %), DMIL 447 (0.39 per cent and 0. 31 per cent) under both the field capacity and irrespective of mean and difference between over the control (0.35 per cent) (21.35 %) and gh-7027 (0.77 per cent and 0.66 per cent) and irrespective of mean and difference between over the control (0.71 per cent) (14.70 %) are more flexibility to drought and well adapted to drought environment. Higher the difference the CML 425 (71.09 %) is a drought sensitive. Natto *et al.*[8] reported that reduced soil water potential resulted in reduction in dry weight of root, stem, leaves and reproductive organ but increased the root:

Poly bag seedlings sets at 60th DAS and imposing treatments of two moisture levels



Root pictures of selected maize hybrids and their parents at two moisture level

Legends

Hybrids and their parents
Dr 1:DMIL 516 X DMIL 230
Dr 2:DMIL 553 X DMIL 447
Dr 3:CML 425 X DMIL 516
Dr 4:DMIL 607 X DMIL 516
Dr 5:CML 425 X DMIL 607
Ds 1:DMIL 715 X DMIL 607
Ds 2:NC 468 X DMIL 692
Ds 3:DMIL 692 X DMIL 230
Ds 4:CML 425 X DMIL 553
Ds 5:DMIL 516 X DMIL 447
P1:DMIL 230
P2:DMIL 438
P3:DMIL 447
P4:DMIL 516
P5:DMIL 553
P6:DMIL 607
P7:DMIL 692
P8:DMIL 715
P9:CML 425
P10:NC 468
Cp-818
Gh-7027

Table 1: Shoot height, leaf area per plant and number of leaves per plant in selected maize hybrids and their parents under two moisture levels

	Shoot height (cm)				Leaf area cm^2/plant				Number of leaves/ plant			
Treatments	**Non-stress**	**Stress**	**Mean**	**% changes**	**Non-stress**	**Stress**	**Mean**	**% changes**	**Non-stress**	**Stress**	**Mean**	**% changes**
DMIL 516 X DMIL 230	107.07	67.53	87.30	36.93	4498.00	4367.78	4432.89	2.90	10.67	10.33	10.50	3.12
DMIL 553 X DMIL 447	119.16	78.67	98.91	33.98	6033.60	4774.51	5404.06	20.87	12.33	10.33	11.33	16.22
CML 425 X DMIL 516	122.83	59.50	91.17	51.56	4604.58	3183.07	3893.82	30.87	11.67	9.00	10.33	22.86
DMIL 607 X DMIL 516	105.67	86.30	95.98	18.33	6314.20	5007.48	5660.84	20.69	11.67	11.67	11.67	0.00
CML 425 X DMIL 607	101.50	78.00	89.75	23.15	5325.00	4730.52	5027.76	11.16	11.67	11.67	11.67	0.00
DMIL 715 X DMIL 607	105.10	63.03	84.07	40.03	4778.25	3721.22	4249.74	22.12	11.00	10.00	10.50	9.09
NC 468 X DMIL 692	100.32	70.56	85.44	29.66	5655.40	4187.95	4921.67	25.95	12.00	10.33	11.17	13.89
DMIL 692 X DMIL 230	118.33	73.67	96.00	37.75	6073.38	4693.98	5383.68	22.71	11.67	10.67	11.17	8.57
CML 425 X DMIL 553	119.33	65.00	92.17	45.53	5301.56	4199.10	4750.33	20.79	11.33	11.33	11.33	0.00
DMIL 516 X DMIL 447	93.22	67.43	80.33	27.66	5248.80	3921.56	4585.18	25.29	11.00	11.67	11.33	-6.06
DMIL 230	87.20	52.48	69.84	39.82	6273.45	4815.73	5544.59	23.24	11.00	10.33	10.67	6.06
DMIL 447	114.00	65.55	89.78	42.50	6066.96	3867.84	4967.40	36.25	11.00	10.33	10.67	6.06
DMIL 516	95.55	66.81	81.18	30.08	6602.85	5009.23	5806.04	24.14	10.67	10.33	10.50	3.12
DMIL 553	109.83	77.67	93.75	29.29	6768.98	5165.22	5967.10	23.69	11.33	10.67	11.00	5.88
DMIL 607	104.71	54.00	79.35	48.43	5887.63	4435.87	5161.75	24.66	12.00	9.67	10.83	19.44
DMIL 692	91.47	57.36	74.42	37.28	5502.90	4793.80	5148.35	12.89	12.33	10.00	11.00	16.67
DMIL 715	120.67	64.87	92.77	46.24	7272.50	4584.15	5928.32	36.97	11.67	10.33	11.33	16.22
CML 425	88.57	80.90	84.73	8.66	6153.25	5287.84	5720.54	14.06	10.67	10.33	11.00	11.43
NC 468	85.47	46.95	66.21	45.06	4774.00	4594.64	4684.32	3.76	10.67	10.67	10.67	0.00
Cp-818	103.33	70.43	86.88	31.84	5520.54	4853.26	5186.90	12.09	12.00	10.67	11.33	11.11
Gh-7027	85.72	61.14	73.43	28.67	5926.15	4201.93	5064.04	29.10	11.33	9.33	10.33	17.65
Mean	**104.56**	**67.48**	**86.02**	**35.46**	**5743.71**	**4508.99**	**5126.35**	**21.50**	**11.50**	**10.45**	**10.98**	**9.09**
	Genotypes	**Condition**	**interaction**		**Genotypes**	**Condition**	**interaction**		**Genotypes**	**Condition**	**interaction**	
S. Em	**4.10**	**1.51**	**7.10**		**344.32**	**127.15**	**596.38**		**0.53**	**0.20**	**0.91**	
CD @5 %	**11.52**	**4.25**	**19.96**		**967.69**	**357.34**	**1676.08**		**1.48**	**0.55**	**2.57**	

Table 2: Maximum root length, total root length and root volume in selected single cross maize hybrids and their parents under two moisture levels

	Maximum root length (cm)				Total root length (cm)				Root volume (cm^3)			
Treatments	**Non-stress**	**Stress**	**Mean**	**% changes**	**Non-stress**	**Stress**	**Mean**	**% changes**	**Non-stress**	**Stress**	**Mean**	**% changes**
DMIL 516 X DMIL 230	39.97	42.93	41.45	-7.41	756.72	1156.97	956.85	-52.89	17.27	10.89	14.08	36.94
DMIL 553 X DMIL 447	37.87	62.57	50.22	-65.22	1432.67	1377.56	1405.12	3.85	12.67	10.83	11.75	14.47
CML 425 X DMIL 516	40.17	49.10	44.63	-22.23	1044.84	1671.25	1358.04	-59.95	15.97	10.73	13.35	32.78
DMIL 607 X DMIL 516	40.83	43.37	42.10	-6.22	703.78	536.42	620.10	23.78	14.17	8.83	11.50	37.65
CML 425 X DMIL 607	45.17	53.30	49.23	-18.00	1741.37	609.25	1175.31	65.01	20.40	7.73	14.07	62.09
DMIL 715 X DMIL 607	38.13	43.73	40.93	-14.69	1017.75	433.93	725.84	57.36	13.23	6.63	9.93	49.87
NC 468 X DMIL 692	36.13	47.97	42.05	-32.77	1076.01	619.33	847.67	42.44	12.70	6.67	9.68	47.51
DMIL 692 X DMIL 230	38.83	77.97	58.44	-100.80	1394.64	563.68	979.16	59.58	15.93	7.60	11.77	52.30
CML 425 X DMIL 553	34.43	50.37	42.40	-46.30	1586.64	355.57	971.10	77.59	14.37	5.93	10.15	58.70
DMIL 516 X DMIL 447	33.50	44.30	38.90	-32.24	904.94	375.85	640.40	58.47	10.93	8.03	9.48	26.52
DMIL 230	34.37	53.73	44.05	-56.33	1824.95	234.01	1029.48	87.18	5.70	7.60	6.65	-33.33
DMIL 447	35.15	53.03	44.09	-50.87	1278.59	240.81	759.70	81.17	15.87	8.53	12.20	46.22
DMIL 516	33.63	54.40	44.02	-61.76	1155.95	768.06	962.00	33.56	9.83	7.27	8.55	26.10
DMIL 553	42.20	59.80	51.00	-41.71	817.88	1122.35	970.11	-37.23	14.47	7.73	11.10	46.54
DMIL 607	33.27	51.53	42.40	-54.88	710.23	613.21	661.72	13.66	11.93	6.90	9.42	42.18
DMIL 692	36.57	54.03	45.30	-47.74	1278.59	240.81	759.70	81.17	14.10	10.93	12.52	22.46
DMIL 715	43.13	51.00	47.07	-18.25	1363.24	455.94	909.59	66.55	13.87	6.93	10.40	50.00
CML 425	51.20	60.00	55.60	-17.19	1788.71	583.23	1185.97	67.39	10.33	6.60	8.47	36.13
NC 468	41.20	59.13	50.17	-43.52	775.91	713.52	744.72	8.04	14.03	8.30	11.17	40.86
Cp-818	37.13	43.63	40.38	-17.51	100.14	867.68	483.91	-766.48	17.67	12.43	15.05	29.62
Gh-7027	44.37	73.37	58.87	-65.36	1029.52	1062.46	1045.99	-3.20	13.67	8.43	11.05	38.29
Mean	**38.59**	**54.06**	**46.33**	**-40.09**	**1110.35**	**679.42**	**894.88**	**38.81**	**13.65**	**8.25**	**10.95**	**39.51**
	Genotypes	**Condition**	**interaction**		**Genotypes**	**Condition**	**interaction**		**Genotypes**	**Condition**	**interaction**	
S. Em	**1.03**	**0.38**	**1.78**		**22.99**	**8.49**	**39.82**		**0.26**	**0.10**	**0.45**	
CD @5 %	**2.89**	**1.07**	**5.01**		**64.62**	**23.86**	**111.93**		**0.74**	**0.27**	**1.28**	

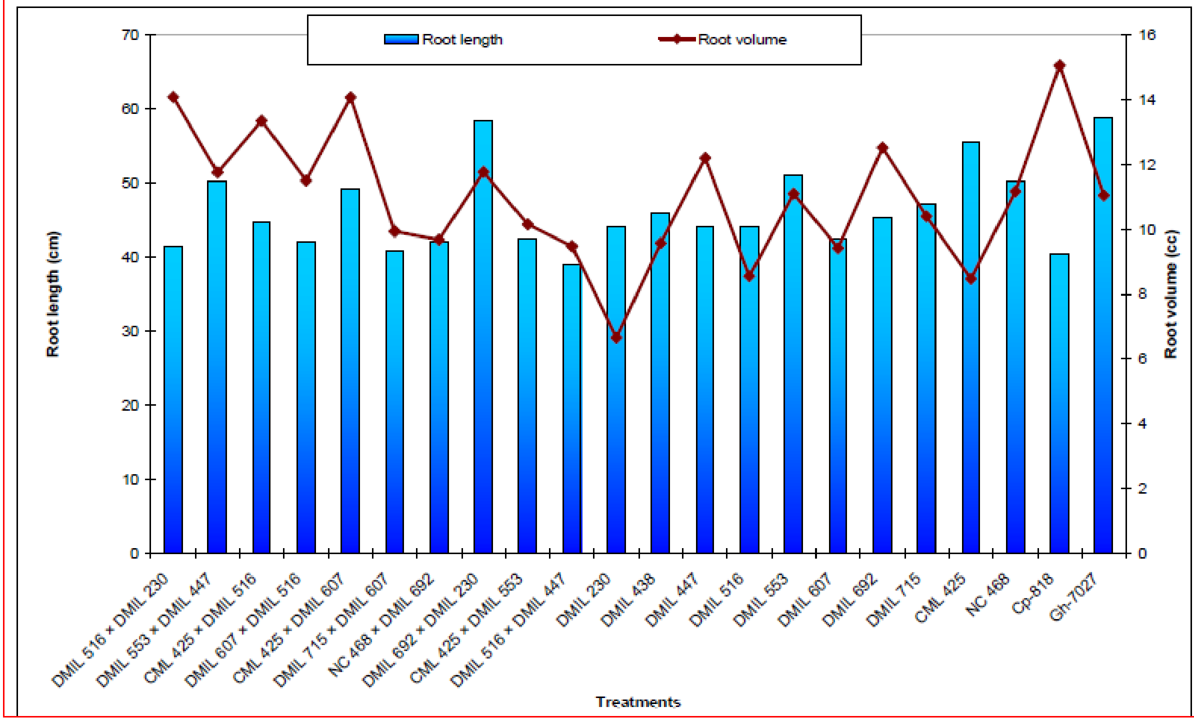


Fig. 1: Root length and Root volume in selected maize hybrids and their parents under two moisture levels

Table 3: Shoot dry weight, root dry weight and root to shoot ratio in selected maize hybrids and their parents under two moisture levels

Treatments	Shoot dry weight (g)				Root dry weight (g)				Root to shoot ratio			
	Non-stress	Stress	Mean	% changes	Non-stress	Stress	Mean	% changes	Non-stress	Stress	Mean	% changes
DMIL 516 X DMIL 230	104.73	75.91	90.32	27.52	50.33	41.87	46.10	16.81	0.27	0.31	0.29	-16.02
DMIL 553 X DMIL 447	86.78	60.18	73.48	30.65	41.93	31.38	36.66	25.17	0.46	0.65	0.55	-40.03
CML 425 X DMIL 516	111.78	70.10	90.94	37.29	42.73	22.80	32.77	46.65	0.30	0.36	0.33	-21.05
DMIL 607 X DMIL 516	117.80	62.83	90.32	46.66	36.93	34.97	35.95	5.32	0.27	0.22	0.25	18.52
CML 425 X DMIL 607	135.07	77.70	106.38	42.47	38.27	23.70	30.98	38.07	0.35	0.31	0.33	12.55
DMIL 715 X DMIL 607	166.16	39.23	102.70	76.39	31.17	22.43	26.80	28.02	0.30	0.23	0.26	24.83
NC 468 X DMIL 692	178.17	49.13	113.65	72.42	38.13	15.88	27.01	58.35	0.35	0.25	0.30	29.87
DMIL 692 X DMIL 230	134.87	64.78	99.82	51.97	35.87	21.73	28.80	39.41	0.37	0.23	0.30	37.05
CML 425 X DMIL 553	104.50	45.97	75.23	56.01	34.37	23.00	28.68	33.07	0.51	0.27	0.39	47.47
DMIL 516 X DMIL 447	148.67	38.67	93.67	73.99	35.20	25.43	30.32	27.76	0.57	0.33	0.45	41.74
DMIL 230	99.57	39.55	69.56	60.28	30.60	19.77	25.18	35.40	0.87	0.29	0.58	66.91
DMIL 447	96.86	53.30	75.08	44.97	40.07	17.83	28.95	55.49	0.39	0.31	0.35	21.35
DMIL 516	93.48	49.75	71.61	46.78	41.27	16.80	29.03	59.29	0.26	0.46	0.36	-73.97
DMIL 553	170.05	81.55	125.8	52.05	47.53	36.93	42.23	22.30	0.62	0.46	0.54	25.93
DMIL 607	161.38	56.99	109.19	64.69	45.17	20.83	33.00	53.87	0.90	0.56	0.73	38.16
DMIL 692	133.30	50.40	91.85	62.19	44.27	28.55	36.41	35.51	0.62	0.28	0.45	54.94
DMIL 715	309.16	66.30	187.73	78.55	38.93	20.03	29.48	48.54	0.38	0.17	0.28	54.91
CML 425	197.63	77.70	137.67	60.68	36.17	13.70	24.94	62.11	1.28	0.37	0.83	71.09
NC 468	115.49	47.57	81.53	58.81	34.80	21.53	28.17	38.12	0.69	0.33	0.51	52.17
Cp-818	138.45	69.74	104.09	49.63	62.17	44.33	53.25	28.69	0.76	0.40	0.58	48.03
Gh-7027	132.97	68.73	100.85	48.31	64.47	42.40	53.43	34.23	0.77	0.66	0.71	14.70
Mean	**140.69**	**59.96**	**100.33**	**57.38**	**41.12**	**26.91**	**34.02**	**34.55**	**0.55**	**0.36**	**0.45**	**33.93**
	Genotypes	**Condition**	**interaction**		**Genotypes**	**Condition**	**interaction**		**Genotypes**	**Condition**	**interaction**	
S. Em	**12.53**	**4.63**	**21.71**		**2.77**	**1.02**	**4.80**		**0.11**	**0.04**	**0.18**	
CD @5 %	**35.22**	**13.01**	**61.00**		**7.79**	**2.88**	**13.49**		**0.3**	**0.11**	**0.51**	

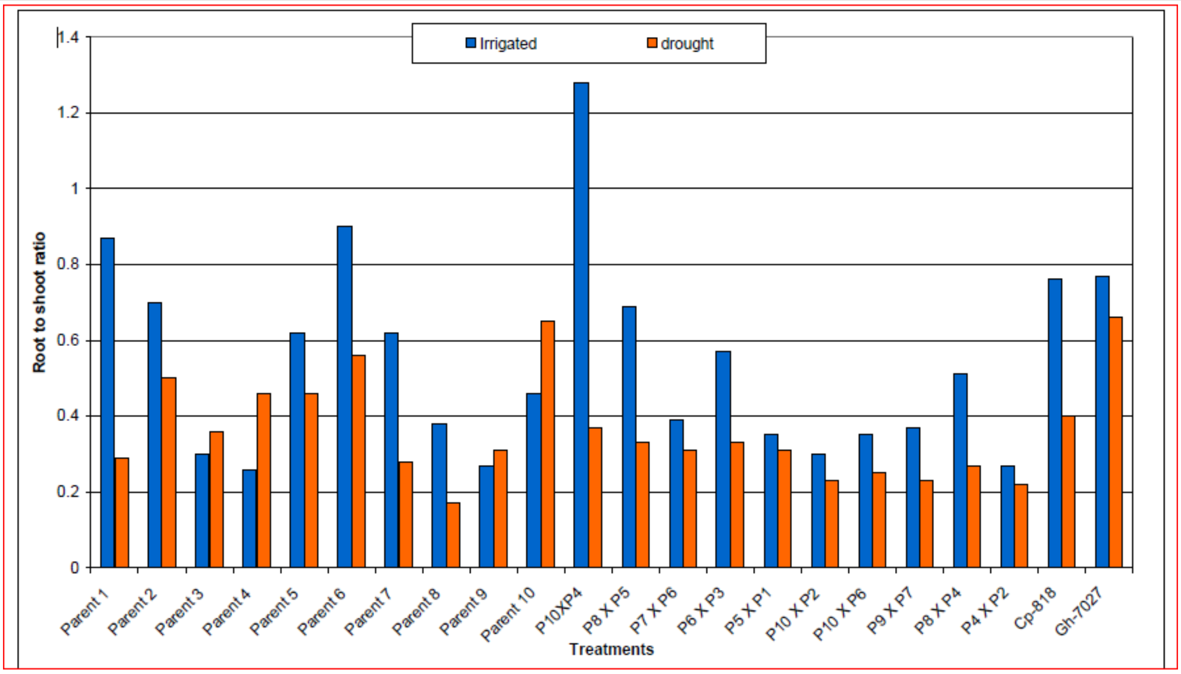


Fig. 2: Root to shoot ratio in selected maize hybrids and their parents under two moisture levels

Table 4: Two way ANOVA Shoot and root parameters of selected maize hybrids and their parents at two moisture levels

Source of variance	d.f.	Shoot height (cm)	Number of leaves	Leaf area (cm^2 /plant)	Maximum root length (cm)	Total root length (cm)	Root volume(cm3)	Shoot dry weight (g)	Root dry weight (gm)	Root to Shoot ratio
Replication	1	-976788.00	-15906.05	-3.50E+09	-283277.00	623431.30	-2571721.80	-1328608.00	-152753.00	-27.04
Genotypes (G)	21	24023.32**	380.22**	85101059.00**	7035.99**	3085394.00**	151730.25**	1218478.62**	4211.09**	0.89**
Conditions (C)	1	709786.78**	10398.46**	2.34E+09**	197146.77**	78821484.00**	2206254.41**	-78198.77**	110283.65**	19.46**
C*G	21	-54891.00	-871.41	-1.90E+08	-15725.80	-5562248.00	-64379.48	942.23	-8620.34	-1.50
Error	88	100.85	1.67	711327.10	6.36	3172.005.00	24265.63	3482.94	46.10	0.07
Total	131	537.72	1.76	1233817.00	116.19	206768.60	47145.01	1218479.00	166.00	0.10

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