Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 7 [8] July 2018 : 86-90

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.876
Universal Impact Factor 0.9804
NAAS Rating 4.95

ORIGINAL ARTICLE **OPEN ACCESS**

Assessment of Natural Variation for Root Architectural Traits in Maize Genotypes using Agar Mediated Screening

I.A.Dar*.,Kamaluddin., Z.A.Dar., P.A. Sofi., A.A.Lone., D. Singh**
*, Division of GPB, FoA/RRS Wadura (SKUAST-Kashmir)
**, AICMIP-Udaipur Centre (MPUAT-Udaipur)

ABSTRACT
Roots provide essential functions including the uptake of water and nutrients for plant growth, serve a role as storage organs, anchor the plants to the soil and are the site of interactions with pathogenic and beneficial organisms in the rhizosphere. Roots are also crucial for nutrient and water acquisition and can be targeted to enhance plant productivity. A current challenge for plant breeding is the limited ability to phenotype and select for desirable root characteristics due to their underground location. Available approaches for root phenotyping in laboratory, greenhouse and field encompass simple agar plates to labor-intensive root digging. The present study was conducted in the laboratory conditions of Division of Genetics and Plant Breeding, Faculty of Agriculture, Wadura. Thirteen released varieties of maize were evaluated in the present study. PM-5 had shallowest root angle and PM-4 had steepest root angle. No of seminal roots were highest in KG-2 and lowest in AM-1. Length of tap root was highest in KG-1 and lowest in PM-4.The results obtained from this study suggest that selection for root angles, either of seminal roots or of lateral roots, may help to identify genotypes with a root system architecture better adapted to water-limited environments.
Keywords: *Root; Phenotyping; Breeding; Root angle; Root system architecture*

Received 11.04.2018 Revised 23.06.2018 Accepted 04.07.2018

INTRODUCTION

Drought is a rising threat of the world and most of the countries of the world are facing the problem of drought. It is the creeping disaster, slowly taking hold of an area and tightening its grip with time [12].The first and foremost effect of drought is impaired germination and poor stand establishment [4]. Cell growth is considered one of the most drought sensitive physiological processes due to the reduction in turgor pressure. Under severe water deficiency, cell elongation of higher plants can be inhibited by interruption of water flow from the xylem to the surrounding elongating cells [14].Drought can damage a field at any time throughout the season. The fate of seedlings will determine the structure and dynamics of most plant populations according to the "stress gradient hypothesis" [3, 5]. One of the major challenges before plants under limited moisture situations is to acquire more water from deeper layers due to quick exhaustion by evaporative losses from both plants as well as top soil. Prolific root systems invariably confer the advantage in extracting water from deeper as well as shallower soil layers that is otherwise easily lost by evaporation. Drought tolerant genotypes have either a higher number seminal or lateral roots. The distribution of nutrients across different layers of the soil and the availability of these nutrients in different environments make the root system architecture a fundamental trait for resource acquisition. Drought stress has deleterious effects on the seedling establishment, vegetative growth, photosynthesis, root growth, anthesis, anthesis-silking interval, pollination and grain formation in maize crop [1].Constitutive variation for root traits is an important adaptation under drought prone conditions [13].
Roots provide essential functions including the uptake of water and nutrients for plant growth, serve a role as storage organs, anchor the plants to the soil and are the site of interactions with pathogenic and beneficial organisms in the rhizosphere. Rooting depth is one of the most frequently evaluated traits because crops with deeper roots have better access to stored water and nutrients such as N, a soluble nutrient that tends to leach into the deeper layers of the soil. Lateral roots add to the total root biomass, total root length and root surface area. As such, it has been assumed that increased lateral root density is associated with greater nutrient and water uptake. The observed variation for both seminal root angle

and seminal root no in this study was resulted mostly due to the high variation between the different groups of genotypes.In maize, seminal roots play important roles in plant establishment, in supplying water and nutrients during early growth stages [24]. Growth angle of seminal roots is considered as one of the principal determinants of root system architecture [10], thus influencing the root angles of nodal roots. Thus, phenotypical evaluation at the seedling stage is regarded as an attractive approach because it is a high-throughput and low cost method that saves space and time [11]. Overall, the results obtained from this study suggest that selection for root angles, either of seminal roots or of lateral roots, may help to identify genotypes with a root system architecture better adapted to water-limited environments. Numerous studies have been conducted to understand the molecular mechanism and the genes responsible for these traits [17].Nevertheless, a breeding program focused on identifying traits linked to drought tolerance will help in increasing productivity under water-limiting condition. A promising strategy to encounter drought stress relies on deep roots which suck water from deep layers of soil when water becomes limiting in upper layers which eventually help in increasing yield [16].Such a program requires a good definition of major drought scenarios in the target environment and needs to be conducted under repeatable experimental conditions reflecting those scenarios.
The aim of this study was to assess the natural variation for root architectural traits like seminal root angle, seminal root no, primary root length, no of lateral roots, root length and root biomass.

MATERIAL AND METHODS

Thirteen genotypes of maize were evaluated in the present study viz., Shalimar Maize Composite-4 (C-4), C-6, C-8,C-15, Shalimar Maize Composite -7 (KDM-72), Kishan Ganga-1 (KG-1), Kishan Ganga-2 (KG-2), PratapMakka -3 (PM-3), Pratap Makka-4 (PM-4), Pratap Makka-5 (PM-5), Pratap Makka-Chari-6 (PM Chari-6), Aravali Makka-1 (AM-1), Gujrat Makka-6 (GM-6) under laboratory conditions. For the measurement of traits viz., seminal root angle, seminal root no, primary root length, no of lateral roots, root length, root biomass, seeds were germinated in transparent gel (2% agar) filled in plastic petri plates [2]. Four seeds for each genotype were surface sterilized with 0.5% NaOCl for one minute, rinsed thoroughly with distilled water and were put in the petri plates containing moist filter paper. Two days after, the seeds germinated and the radicle emerged and were transferred to the 15x15 cm^2 plastic petri plates containing 2% sterilized solid agar medium (2% w/v) in darkness in germinator at 25^oC. The germinating seeds were placed from cut sides of the petri plates with radicle inserted into the agar and kept for six days under darkness at room temperature and after six days data were recorded for seminal root angle, seminal root no, primary root length, no of lateral roots, root length, root biomass. Seminal root angle was measured as average of the angles of primary root from the vertical plane. The design used was CRD with four replications.

RESULTS

The data pertaining to response to Agar is presented in table-1 and elaborated under appropriate headings. Analysis of variance for various root traits scored under laboratory conditions is presented in table-2 which shows that mean square due to genotypes was significant for all the traits.

I. **Seminal Root angle:** The seminal root angle had a mean value of 54.769with highest value recorded in PM-5 (76.66) followed by C-4 (68.33) and PM Chari-6 (63.33) and was lowest in PM-4 (39.0).
II. **Length of tap root (cm):** The length of tap root had a mean value of 15.825 with highest value recorded in KG-1 (17.66) followed by AM-1 (17.40) and PM- Chari-6 (17.33) and was lowest in PM-4 (13.00).
III. **Total Root Length (cm):** The total root length had a mean value of 11.166 with highest value recorded in PM Chari-6 (15.0) followed by C-6 (14.0) and GM-6 (12.8) and was lowest in KG-1 (8.6).
IV. **Root Weight (g):** The root weight had a mean value of 0.218with highest value recorded in PM-Chari-6 (0.313) followed by C-8 (0.281) and PM-5 (0.273) and was lowest in PM-4 (0.122).
V. **No of Seminal Roots:** The no of seminal roots had a mean value of 2.076with highest value recorded in KG-2 (3.33) followed by C-15 (2.66) and PM Chari-6 (2.66) and was lowest in AM-1 (1.33).
VI. **No of Lateral Roots:** The no of lateral roots had a mean value of 41.076with highest value recorded in C-15 (51.66) followed by KDM-72 (51.33) and PM Chari-6 (46.66) and was found lowest in PM-4 (29.66).

DISCUSSION

In the present study significant variation was recorded for seminal root angle, length of tap root, total root length, root weight, no of seminal roots and no of lateral roots. PM-5 had shallowest root angle and PM-4 had steepest root angle (Figure 1). No of seminal roots were highest in KG-2 and lowest in AM-1. Length of tap root was highest in KG-1 and lowest in PM-4.Rooting depth is closely related to depth of soil resource acquisition, with shallow growth angles playing predominant role for topsoil foraging [8], while roots with steep angles play predominant role for water acquisition from deeper soil layers under drought [9]. Significant correlations between seminal root traits and adult field traits have been reported, and for shoot weight versus adult plant height, and lateral root length versus brace root development [6, 15]. Manschadi *et al*. [10] have also suggested that selection for seminal root growth angle and the number of roots might help to identify genotypes with root system architecture adapted to drought tolerance. This approach has been successfully used to develop drought tolerant varieties in cowpea [20, 21], cotton [7], wheat [23], and maize [11, 15., 18]. During drought conditions plants manifest some of unique traits classified under adaptive traits like deep roots or more root biomass etc. for maximum utilization of receding water. This complexity of drought can be reduced by employing analytical breeding approaches to specifically target traits having major roles in drought tolerance like roots traits [25] or water use efficiency [19] which have a direct effect on yield [22]. The combination of long root hairs and shallow basal roots results in a synergistic effect on P acquisition that translates to a 300% increase in biomass in cultivars with both traits. Lateral roots add to the total root biomass, total root length and root surface area. As such, it has been assumed that increased lateral root density is associated with greater nutrient and water uptake. Overall, the results obtained from this study suggest that selection for root angles, either of seminal roots or of lateral roots, may help to identify genotypes with a root system architecture better adapted to water-limited environments. The utilization of a combination of root phenotyping strategies proposed here can be used to incorporate “root breeding” strategies aimed at enhancing plant performance through more efficient utilization of water and nutrients that will contribute to the sustainability of agricultural systems worldwide.

Table 1:Mean performance of maize (*Zea mays* L.) genotypes for root traits under laboratory screening

Genotypes	Seminal Root Angle	Length of Tap Root (cm)	Total Root Length (cm)	Root Weight (g)	No of Seminal Roots	No of Lateral Roots
PM-5	76.667	15.167	11.667	0.273	2.000	39.000
Aravali Makka-1	48.000	17.400	8.633	0.187	1.333	42.000
C-6	48.333	15.167	14.000	0.176	2.333	37.333
PM-Chari-6	63.333	17.333	15.000	0.313	2.667	46.667
KG-2	58.333	13.667	11.500	0.215	3.333	42.333
PM-4	39.000	13.000	9.000	0.122	2.333	29.667
C-15	56.667	16.833	11.733	0.213	2.667	51.667
C-8	45.000	16.333	9.600	0.281	1.333	40.000
GM-6	48.333	14.000	12.800	0.189	1.333	32.333
C-4	68.333	16.833	11.333	0.259	2.000	34.000
PM-3	58.333	16.000	12.067	0.164	2.000	44.333
KDM-72	45.000	16.333	9.233	0.213	1.667	51.333
KG-1	56.667	17.667	8.600	0.238	2.000	43.333
Mean	**54.769**	**15.825**	**11.166**	**0.218**	**2.076**	**41.076**
C.D (p ≤ 0.05)	25.054	3.356	3.978	0.080	1.198	20.234

Table 2: Analysis of variance for root traits scored under laboratory screening in maize (*Zea mays* L.)

Source of variation	d.f.	Seminal Root Angle	Length of Tap Root (cm)	Total Root Length (cm)	Root Weight (g)	No of Seminal Roots	No of Lateral Roots
Genotypes	12	334.410**	6.891**	12.701**	0.008**	1.064**	135.731**
Error	26	235.385	4.222	5.557	0.002	0.538	153.538

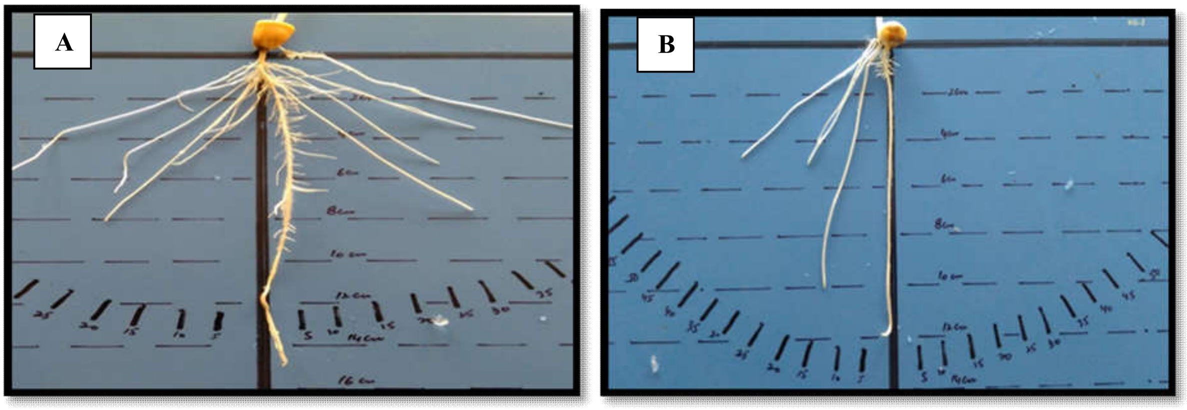

Figure 1. Maize root architectural traits **A**) Shallow roots **B**) Steep roots

REFERENCES

1. Aslam, M., Zamir, M.S.I., Afzal, I., Yaseen, M., Mubeen, M. and Shoaib, A. (2013).Drought stress, its effect on maize production and development of drought tolerance through potassium application. *CercetariAgronomice in Moldova***46**(2): 99-114.
2. Christopher, J., Christopher, M., Jennings, R., Jones, S., Fletcher, S., Borrel, A., Ahmad, M., Jordan, D., Mace, E. and Hammer, G. (2012). QTL for root angle and number in a population developed from bread wheats with contrasting adaptation to water limited environments. *Theoretical Applied Genetics***126**: 1563-1574.
3. De La Cruz, M., Romao, R.L., Escudero, A. and Maestre, F.T. (2008). Where do seedlings go? A spatio temporal analysis of seedling mortality in a semi-arid gypsophyte. *Ecography* **31**(6): 720-730.
4. Harris, D., Tripathi, R.S. and Joshi, A. (2002).On-farm seed priming to improve crop establishment and yield in dry direct-seeded rice. Direct seeding: Research Strategies and Opportunities, International Research Institute, Manila, Philippines 231-240.
5. Kitajima, K. and Fenner, M. (2000). Ecology of seedling regeneration. In: Fenner, M. (ed.) Seeds: the ecology of regeneration in plant communities*. Centre for Agriculture and Bioscience International Publishing*, Wallingford 331–359.
6. Landi, P., Giuliani, M.M., Sanguineti, M.C. and Albrecht, B. (1998).Seedling characteristics in hydroponic culture and field performance of maize genotypes with different resistance to root lodging [*Zea mays* L.]. *Maydica (Italy)*.
7. Longenberger, P.S., Smith, C.W., Thaxton, P.S. and McMichael, B.L. (2006).Development of a screening method for drought tolerance in cotton seedlings. *Crop Science* **46**(5): 2104-2110.
8. Lynch, J.P. and Brown, K.M. (2012). New roots for agriculture: exploiting the root phenome. *Philosophical Transactions of the Royal Society of London Biological Sciences* **367**(1595): 1598-1604.
9. Mace, E.S., Singh, V., Van Oosterom, E.J., Hammer, G.L., Hunt, C.H. and Jordan, D.R. (2012). QTL for nodal root angle in sorghum (*Sorghum bicolor* L. Moench) co-locate with QTL for traits associated with drought adaptation. *Theoretical and Applied Genetics* **124**(1): 97-109.
10. Manschadi, A.M., Hammer, G.L. and Christopher, J.T. (2008).Genotypic variation in seedling root architectural traits and implications for drought adaptation in wheat (*Triticum aestivum* L.). *Plant and Soil* **303**(1-2): 115-129.
11. Meeks, M., Murray, S.C., Hague, S. and Hays, D. (2013). Measuring maize seedling drought response in search of tolerant germplasm. *Agronomy* **3**(1): 135-147.
12. Misra, A.N., Biswal, A.K. and Misra, M. (2002).Physiological, biochemical and molecular aspects of water stress responses in plants and the biotechnological applications. *Proceedings of the National Academy* of *Sciences* **72**: 115– 134.
13. Nguyen, H.T., Manavalan, L.P. and Musket, T. (2012). Natural genetic variation for root traits among diversity lines of maize (*Zea mays* L.). *Maydica* **56**(1).
14. Nonami, H. (1998). Plant water relations and control of cell elongation at low water potentials. *Journal of Plant Research* **111**(3): 373-382.
15. Pace, J., Lee, N., Naik, H.S., Ganapathysubramanian, B. and Lubberstedt, T. (2014). Analysis of maize (Zea mays L.) seedling roots with the high-throughput image analysis tool ARIA (Automatic Root Image Analysis). *PLoS One* **9**(9): 108255.
16. Parthasarathi, T., Vanitha, K., Mohandass, S. and Vered, E. (2014). Importance Of Large Root System On Increasing Yield In Drip IrrigatedAerobic Rice. *The Bioscan***9**(4): 1541-1544.
17. Reddy, S. S., Verma, S. K., Xalxo, S. M., Saxena, R. R. and Verulkar, S. B. (2013).Identification of Molecular Marker(s) for Root Length InRice (*Oryza sativa* L.). *The Bioscan***8**(4): 1511-1514.
18. Ruta, N., Stamp, P., Liedgens, M., Fracheboud, Y. and Hund, A. 2010. Collocations of QTLs for seedling traits and yield components of tropical maize under water stress conditions. *Crop Science* **50**(4): 1385.
19. Sheshshayee, M. S., Mohankumar, M. V., Raju, B. R., Pratibha, M. D., Rajanna, M. P., Mohanraju, B. and Udayakumar, M. (2013). Enhancing water use efficiency besides effective use of water is apotential strategy in developing rice cultivars suitable for semi-irrigated aerobic cultivation. International Dialogue on perception

Prospects of Designer Rice Society for Advancement of Rice Research, Directorate of Rice Research, Hyderabad, India pp 261-272.

20. Singh, B.B. and Matsui, T. (2002). Cowpea varieties for drought tolerance. Challenges and opportunities for enhancing sustainable cowpea production 287-300.
21. Singh, B.B., Mai-Kodomi, Y. and Terao, T. (1999).A simple screening method for drought tolerance in cowpea. *The Indian Journal of Genetics and Plant Breeding* **59**(2): 211-220
22. Suma, M. R., Manjunath, K. and Shashidhar, H. E. (2014).Correlation And Path Coefficient Analysis Of Shoot, Root Morphological Traits And Micronutrient (Fe And Zn) Content On Grain Yield In Rice (*Oryza sativa* L.) Under Contrasting Moisture Regimes.*The Bioscan***9**(4): 1833-1841.
23. Tomar, S.M.S. and Kumar, G.T. (2004).Seedling survivability as a selection criterion for drought tolerance in wheat. *Plant Breeding* **123**(4): 392-394.
24. Tuberosa, R., Sanguineti, M.C., Landi, P., Giuliani, M.M., Salvi, S. and Conti, S. (2002).Identification of QTLs for root characteristics in maize grown in hydroponics and analysis of their overlap with QTLs for grain yield in the field at two water regimes. *Plant Molecular Biology* **48**(5-6): 697-712.
25. Uga, Y., Sugimoto, K., Ogawa, S., Rane, J. and Ishitani, M. (2013). Control of root system architecture by DEEPER ROOTING 1 increasesrice yield under drought conditions. *Nat. Genet.* **45**: 1097-1102.

CITATION OF THIS ARTICLE

I.A.Dar, Kamaluddin., Z.A.Dar., P.A. Sofi., A.A.Lone., D. Singh. Assessment of Natural Variation for Root Architectural Traits in Maize Genotypes using Agar Mediated Screening. Bull. Env. Pharmacol. Life Sci., Vol 7 [8] July 2018 : 86-90