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# Genotypic differences in root architecture and physiological characteristics in mango (*Mangifera indica*) under drought

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## ABSTRACT

An experiment was conducted at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi during 2020 and 2021 to study the genotypic differences in root architecture and physiological characteristics in mango (*Mangifera indica* L.) under drought. One-year-old polyembryonic 7 mango rootstock genotypes were exposed to normal irrigation and drought conditions for 24 days. The drought-induced increased total plant weight and dry weight in Kurukkan. The shoot dry weight decreased in all genotypes ranging from 5.13% in OLP-Z-6/1 to 81.82% in Kurukkan. There was a lesser reduction in membrane stability index in Kurukkan and K-5, stomata count in Kurukkan, Olour and OPK-3-7/12 at the end of the drought period. Root surface area increased under drought in Kurukkan, while it decreased more in K-5. Correlation studies confirmed a strong positive relationship between relative water content (RWC) and membrane stability index (MSI), number of stomata (SC), number of leaves (NL), root tips (RT) and root forks (NRF); MSI and number of root tips (NRT); dry weight of the whole plant and root surface area (RSA); the dry weight of roots and root volume (RV), RSA, and plant height (Ph); root length (RL) and RSA, RT, and NRF. Kurukkan was identified as drought-tolerant based on a higher SC, RWC, RV, RSA, dry mass, NRT and NRF. Results indicated that the root indices offer a promising strategy for the screening of drought-tolerant mango genotypes.

**Keywords**: Coefficient correlation, Drought, Mango, Moisture stress

Climate change is a serious challenge to most of the crops grown in tropical and sub-tropical areas globally. It is argued that by the year 2025, roughly 1.8 billion people will face absolute water shortage and 65% of the world's population will live under water-stressed conditions (Anonymous 2015). Tolerance to water stress is a complex phenomenon, in which crops' performance can be affected by several characteristics. Moreover, crop plants expand the number of physiological and biochemical mechanisms and initiate defences (Chaves and Oliveira 2004) to cope with water stress. Trees can tolerate water deficit using two mechanisms i.e., drought avoidance and dehydration tolerance. Mango (*Mangifera indica* L.) is one of the major fruit crops, extensively grown in tropical and subtropical parts of the world and considered sensitive to abiotic stresses like drought and salinity. Drought conditions are often accompanied by high-salinity stress for trees and affecting more than 10% of arable land and causes a more than 50% decline in the average yield of important crops across the world (Bray *et al.* 2000). Drought stress can be impacted by many factors such as plant genotype, growth stage, severity and duration of stress, physiological process of growth (Chaves and Oliveira *et al.* 2004). Drought stress effects can be managed by the production of the most appropriate plant genotypes, plant growth regulators, use of osmoprotectants, silicon, and some other strategies. The use of drought-tolerant rootstocks may be an alternative approach to face the challenge. However, the response of polyembryonic genotypes of mango to drought stress is poorly understood at physiochemical and molecular levels. Therefore, the present study was carried out to identify drought-tolerant rootstock genotype(s) in mango.

## MATERIALS AND METHODS

*Plant material*: The present study was carried out at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi during 2020–2021. The mature fruits of 7 polyembryonic mango genotypes, viz. Kurukkan, Olour, K-3, K-5, OLOP-Z-6/1 (IC-0635075), OLOP-Z-6/2(IC-0635076), OPK-3-7/12 (IC-0635077) were collected from the rootstock evaluation block of the Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi. The stones from fruits were extracted and thereafter treated with 0.3% solution of copper

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oxychloride. Treated stones were sown immediately on raised beds located in the nursery area. The one-year-old nucellar seedlings with uniform health were transplanted into 12-inch plastic pots containing native orchard soil and farmyard manure in a 1:1 ratio at the experimental orchard. Seedlings were irrigated regularly and supplied once with 20 g NPK (19:19:19). After 3-month of transplanting, the final established seedlings were imposed to the irrigation withholding for 24 days. The soil moisture content was determined by using gravimetric method, which was 6.5–7.5% after 24 days of withholding irrigation. The evaluation was done at the beginning and end of the drought period.

*Evaluating the role of various plant growth-related parameters*

Morphological traits: The height of the plant, number of leaves and stem diameter were measured before the start of the drought and the end of the drought treatment. The fresh weight of the whole plant, shoot fresh weights and root fresh weight were measured at the moment of the harvesting, while dry weights of whole plant (DwtP), dry weight of shoot (DwtS) and dry weight of root (DwtR) were determined after oven-drying at 70°C until a constant weight was reached.

Root indices: Root indices like Total root length (TRL), root volume (RV), root surface area (RSA), the number of root tips (NRT) and the number of root forks (NRF), per plant were determined using the root image analysis software, Win RHIZO version 5.0 (Arsenault *et al.* 1995).

Physiological parameters: The number of stomata per field (1 $mm^2$) was counted at 10X magnification by using a light microscope (Magvision tool) to determine the stomatal density. The relative water content (RWC) in recently matured leaves was ascertained using the method of Barrs and Weatherley (1962). Moreover, the membrane stability index (MSI) was measured as suggested by Sairam (1994).

*Statistical analysis*: The experiment was laid out in the field with a completely randomized block and with 3 replications. Data were analyzed with SAS 9.3 version software (SAS, USA INC) in factorial arrangement with Proc GLM process. The linear relationship tested by Pearson's correlation coefficients (r) among the selected variables was also determined by the correlation matrix of combined data. Principal component analysis (PCA) was carried out using R/ADEGENET package (Jombart 2008).

## RESULTS AND DISCUSSION

*Morphological traits*: The number of leaves varied significantly among studied genotypes. During the drought period, a significant reduction of leaf number was found in all genotypes except in Kurukkan and K-3 genotypes (Table 1), whereas the number of leaves was at par with control conditions, while the maximum reduction in drought was recorded in Olour (>70%). Visualization of the data showed more decrease in the dry weight of the shoot under drought in most of the genotypes, except K-3. Compared to normal irrigation, an increase was noticed in all genotypes under drought in dry weight of roots except K-5 and OLOP-Z-6/2 but a higher increase (>100%) was found for Kurukkan (Table 1). Lozano Montana *et al.* (2021) noticed similar reduction in morphological trait like leaf number, height, shoot to root ratio and accumulation of dry mass, which is probably related to a decrease in carbon gain under drought stress. Earlier, it was also reported that drought inhibited the number of leaves in susceptible genotypes of mango (Luvaha *et al.* 2010). Our result indicated that Kurukkan and K-5 were able to sustain higher drought stress than others.

*Root indices*: At the end of the drought, the maximum root volume was observed in Olour followed by K-5 (Table 2). Like a normal moisture regime, K-3 exhibited the minimum values for the root volume. An increase was noticed in root volume in all the genotypes under drought as compared to normal moisture conditions. When considering the alterations of root volume after an imposed drought of 24 days, the higher upsurge was recorded in Kurukkan (132.33%), Olour (99.04%) and OPK-3-/12 (90.97%), while the least increase was registered in OLOP-Z-6/2 (1.56%). At the end of the drought period, a significantly higher root surface area was recorded in Olour followed by Kurukkan which showed a non-significant difference with K-5. Genotype K-3, OLOP-Z-6/1 and OPK-3-7/12 exhibited lower root surface area than others. When considering the changes in root surface area after imposing a drought of 24 days, a decline in root surface area was noticed in all genotypes being the lowest inhibition in OPK-3-7/12 (4.67%) followed by OLOP-Z-6/2 (11.44%), while it was K-5, which showed higher reduction in root surface area (<45%) under drought. Number of root tips (NRT) and root forks varied significantly with genotypes and moisture conditions (Table 2). Number of root tips (NRT) exhibited the higher value in K-5 under normal moisture conditions, but NRT was found maximum in Olour. A reduction in NRT was found in all genotypes at varying degrees under drought. The lowest reduction in NRT was noted in K-3 (37.67%), but lower inhibition in NRF was found in K-3 (34.68%), OLOP-Z-6/2 (34.74%), and Kurukkan (57.16%) under drought (Fig 1A and 1B).

Dry weight increased under drought in all genotypes except K-5 with higher value in Kurukkan. Dry mass recovery also showed varying performance and Kurukkan and OLOP-Z-6/1 exhibited an increase in dry mass, while others showed a decrease with the maximum decline in OLPOP-Z-6/2. The data indicate that due to less reduction in length of roots of Kurukkan indicated its ability to maintain a greater number of root hairs under drought compared to other genotypes which is consistent with the another study by Geng *et al.* (2019) who reported longer roots and high root to shoot ratio of *Malus sieversii* which is a drought tolerant rootstock. The root hairs in many plants are associated with improved accumulation of water and nutrients, as well as responsiveness to stresses (Vetterlein *et al.* 2022).

*Assessing physiology related parameters*: Compared to normal irrigation, a decrease in RWC was found in all genotypes with a higher reduction in K-3 and Olour (>15%),

Table 1 Comparative number of leaves/plant and dry weight of plant, shoot and root of different polyembryonic mango genotypes under normal moisture conditions and 24 days of drought

| Genotype | Leaves/plant | | | Plant dry weight (g) | | |
|---|---|---|---|---|---|---|
| | Normal irrigation | Drought | Mean | Normal irrigation | Drought | Mean |
| K-5 | $12.80^{cd}$ | $11.60^{de}$ | $12.20^{B}$ | $13.67^{ab}$ | $8.83^{cd}$ | $11.25^{AB}$ |
| Olour | $14.40^{c}$ | $4.20^{j}$ | $9.30^{C}$ | $15.50^{a}$ | $12.17^{abc}$ | $13.83^{A}$ |
| OLOP-Z-6/2 | $11.80^{de}$ | $4.60^{ij}$ | $8.20^{CD}$ | $11.67^{bc}$ | $5.67^{defg}$ | $8.67^{BC}$ |
| Kurukkan | $18.60^{a}$ | $16.60^{b}$ | $17.60^{A}$ | $7.40^{def}$ | $5.55^{ab}$ | $6.48^{CD}$ |
| K-3 | $10.60^{ef}$ | $6.60^{h}$ | $8.60^{CD}$ | $3.50^{g}$ | $4.00^{fg}$ | $3.75^{D}$ |
| OLOP-Z-6/1 | $9.60^{fg}$ | $6.20^{hi}$ | $7.90^{D}$ | $8.67^{cd}$ | $8.67^{cd}$ | $8.67^{BC}$ |
| OPK-3-7/12 | $13.80^{c}$ | $8.60^{g}$ | $11.20^{B}$ | $7.67^{de}$ | $4.83^{efg}$ | $6.25^{CD}$ |
| Mean | $13.08^{A}$ | $8.34^{B}$ | | $9.72^{A}$ | $7.10^{B}$ | |
| LSD ($P \leq 0.05$) | | | | | | |
| Genotype (G) | | 1.35 | | | 2.59 | |
| Moisture condition (MC) | | 0.72 | | | 1.38 | |
| G × MC | | 1.90 | | | 3.66 | |
| *Genotype* | | *Shoot dry weight (g)* | | | *Root dry weight (g)* | |
| K-5 | $9.00^{abc}$ | $6.17^{de}$ | $7.58^{A}$ | 4.67ab | 2.67de | $3.67^{B}$ |
| Olour | $11.50^{a}$ | $6.83^{cde}$ | $9.17^{A}$ | 4.00bc | 5.33a | $4.67^{A}$ |
| OLOP-Z-6/2 | $8.50^{bcd}$ | $3.33^{fgh}$ | $5.92^{BC}$ | 3.17cd | 2.33def | $2.75^{C}$ |
| Kurukkan | $5.50^{efg}$ | $10.00^{ab}$ | $7.75^{AB}$ | 1.90ef | 4.17bc | $3.03^{BC}$ |
| K-3 | $2.67^{h}$ | $2.67^{h}$ | $2.67^{D}$ | 0.83g | 1.33fg | $1.08^{E}$ |
| OLOP-Z-6/1 | $6.50^{cde}$ | $6.17^{de}$ | $6.33^{B}$ | 2.17def | 2.50de | $2.33^{CD}$ |
| OPK-3-7/12 | $5.67^{ef}$ | $2.83^{gh}$ | $4.25^{CD}$ | 2.00ef | 2.00ef | $2.00^{D}$ |
| Mean | $7.04^{A}$ | $5.43^{B}$ | | $2.68^{A}$ | $2.90^{A}$ | |
| LSD ($P \leq 0.05$) | | | | | | |
| Genotype (G) | | 1.97 | | | 0.73 | |
| Moisture condition (MC) | | 1.05 | | | 0.39 | |
| G × MC | | 2.79 | | | 1.03 | |

Table 2 Comparative number of root tips, number of root forks, root volume and root surface area of different polyembryonic mango genotypes under normal moisture conditions and 24 days of drought

| Genotype | Number of root tips | | | Number of root forks | | |
|---|---|---|---|---|---|---|
| | Normal irrigation | Drought | Mean | Normal irrigation | Drought | Mean |
| K-5 | $454.33^{b}$ | $52.00^{i}$ | $253.17^{C}$ | $623^{a}$ | $98.33^{g}$ | $360.67^{A}$ |
| Olour | $510.00^{a}$ | $63.67^{i}$ | $286.83^{AB}$ | $495^{b}$ | $61.33^{g}$ | $278.17^{B}$ |
| OLOP-Z-6/2 | $367.33^{d}$ | $86.00^{hi}$ | $226.67^{D}$ | $149.67^{f}$ | $97.67^{g}$ | $123.67^{E}$ |
| Kurukkan | $451.33^{b}$ | $107.67^{gh}$ | $279.50^{AB}$ | $232.67^{cd}$ | $99.67^{g}$ | $166.17^{D}$ |
| K-3 | $323.00^{e}$ | $201.33^{f}$ | $262.17^{BC}$ | $256.67^{c}$ | $193.33^{de}$ | $225.00^{C}$ |
| OLOP-Z-6/1 | $468.00^{b}$ | $127.33^{g}$ | $297.50^{A}$ | $252.33^{c}$ | $80^{g}$ | $166.33^{D}$ |
| OPK-3-7/12 | $410.00^{c}$ | $138.33^{g}$ | $274.17^{ABC}$ | $186^{ef}$ | $75.67^{g}$ | $130.83^{E}$ |
| Mean | $426.24^{A}$ | $110.91^{B}$ | | $313.62^{A}$ | $100.91^{B}$ | |
| LSD ($P \leq 0.05$) | | | | | | |
| Genotype (G) | | 25.31 | | | 28.11 | |
| Moisture condition (MC) | | 13.53 | | | 15.03 | |
| G × MC | | 35.80 | | | 39.76 | |

*Contd.*

Table 2 (*Concluded*)

| Genotype | Number of root tips | | | Number of root forks | | |
|---|---|---|---|---|---|---|
| | Normal irrigation | Drought | Mean | Normal irrigation | Drought | Mean |
| *Genotype* | | *Root volume (cm$^3$)* | | | *Root surface area (cm$^2$)* | |
| K-5 | 4.63$^{c}$ | 5.21$^{bc}$ | 4.92$^{B}$ | 93.58$^{a}$ | 50.82$^{d}$ | 72.20$^{A}$ |
| Olour | 3.67$^{d}$ | 7.30$^{a}$ | 5.48$^{A}$ | 68.47$^{b}$ | 60.63$^{bc}$ | 64.55$^{B}$ |
| OLOP-Z-6/2 | 2.67$^{ef}$ | 2.71$^{ef}$ | 2.69$^{D}$ | 40.31$^{efg}$ | 32.57$^{gh}$ | 36.44$^{D}$ |
| Kurukkan | 2.27$^{fg}$ | 5.28$^{b}$ | 3.78$^{C}$ | 42.53$^{def}$ | 51.69$^{cd}$ | 47.11$^{C}$ |
| K-3 | 1.15$^{h}$ | 1.39$^{h}$ | 1.27$^{E}$ | 25.86$^{h}$ | 33.05$^{fhg}$ | 29.45$^{E}$ |
| OLOP-Z-6/1 | 2.41$^{f}$ | 2.88$^{ef}$ | 2.64$^{D}$ | 47.30$^{de}$ | 30.76$^{gh}$ | 39.03$^{D}$ |
| OPK-3-7/12 | 1.66$^{gh}$ | 3.17$^{de}$ | 2.42$^{D}$ | 35.04$^{fgh}$ | 36.68$^{fg}$ | 35.86$^{DE}$ |
| Mean | 2.64$^{B}$ | 3.99$^{A}$ | | 50.44$^{A}$ | 42.32$^{B}$ | |
| LSD (P≤0.05) | | | | | | |
| Genotype (G) | | 0.45 | | | 6.82 | |
| Moisture condition (MC) | | 0.24 | | | 3.64 | |
| G × MC | | 2.05 | | | 9.64 | |

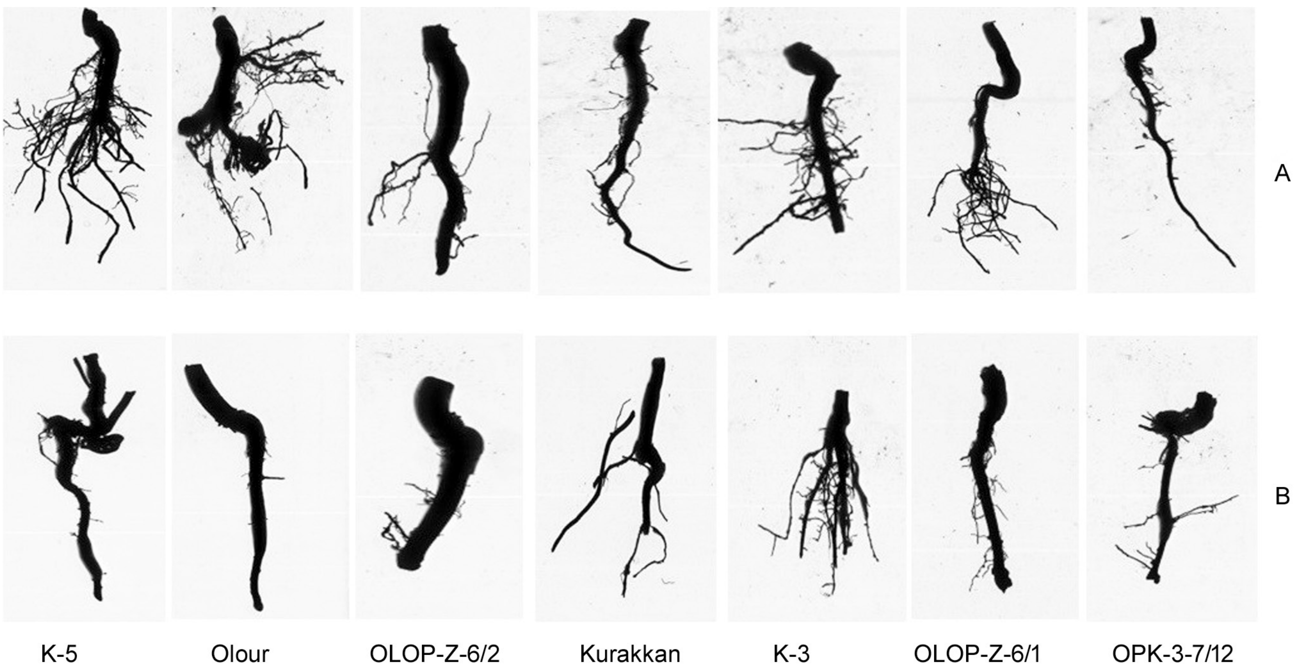


Fig 1 Image of roots of different polyembryonic mango rootstock genotypes under normal moisture (A) and after 24 days of drought conditions (B).

while genotypes such as K-5, OLOP-Z-6/1, OLOP-Z-6/2, OPK-3-7/12, and Kurukkan exhibited lower inhibition in RWC under drought (>12%). Similarly, significant differences in membrane stability index (MSI) were also noticed at the end of the drought period (Table 3). All genotypes had lower MSI than their control counterpart, however, the lower decrease in MSI was exhibited by K-5 (24.58%). The genotype OLOP-Z-1/6 and OPK-Z-7/12 demonstrated a higher decrease in MSI (>45%) at the end of the drought period (Table 3). In general, significant genotypic variation in stomata count was noticed under both normal moisture and drought conditions (Table 3). Compared to normal moisture conditions, a higher reduction in the number of stomata was recorded in OLOP-Z-2/6 and K-3 (<50%), while the minimum reduction was recorded in Kurukkan (<5.0%). All the rootstock genotypes tested in the present study exhibited decreased leaf relative water content (RWC) under water deficit at varying degrees. In effects of drought treatment, leaf RWC of K-5 and Kurukkan declined severely at the end of the drought period as of its control and both these genotypes retained higher RWC even under both water regimes. It proved that Kurukkan and

Table 3 Comparative relative water content (RWC), membrane stability index (MSI) and stomatal count (SC) of different polyembryonic mango genotypes under normal moisture conditions and 24 days drought

| Genotype | RWC (%) | | |
|---|---|---|---|
| | Normal irrigation | Drought | Mean |
| K-5 | 96.47$^{a}$ | 84.29$^{d}$ | 90.38$^{A}$ |
| Olour | 93.60$^{b}$ | 77.70$^{g}$ | 85.65$^{D}$ |
| OLOP-Z-6/2 | 94.64$^{ab}$ | 80.91$^{ef}$ | 87.77$^{C}$ |
| Kurukkan | 96.84$^{a}$ | 82.82$^{ed}$ | 89.83$^{A}$ |
| K-3 | 96.67$^{a}$ | 79.93$^{fg}$ | 88.30B$^{C}$ |
| OLOP-Z-6/1 | 90.91$^{ab}$ | 79.65$^{fg}$ | 85.28$^{D}$ |
| OPK-3-7/12 | 93.45$^{b}$ | 79.98$^{fg}$ | 86.72$^{CD}$ |
| Mean | 94.66$^{A}$ | 80.75$^{B}$ | |
| LSD (P≤0.05) | | | |
| Genotype (G) | | 1.76 | |
| Moisture condition (MC) | | 0.94 | |
| G × MC | | 2.48 | |
| Genotype | MSI (%) | | |
| K-5 | 76.62$^{c}$ | 57.78$^{d}$ | 67.20$^{A}$ |
| Olour | 80.61$^{c}$ | 44.52$^{e}$ | 62.57$^{BC}$ |
| OLOP-Z-6/2 | 77.19$^{c}$ | 43.06$^{e}$ | 60.13$^{C}$ |
| Kurukkan | 81.40b$^{c}$ | 47.05$^{e}$ | 64.22$^{AB}$ |
| K-3 | 80.58$^{c}$ | 54.57$^{d}$ | 67.57$^{A}$ |
| OLOP-Z-6/1 | 87.15$^{a}$ | 44.21$^{e}$ | 65.68$^{AB}$ |
| OPK-3-7/12 | 85.99$^{ab}$ | 45.49$^{e}$ | 65.74$^{AB}$ |
| Mean | 81.36$^{A}$ | 48.10$^{B}$ | |
| LSD (P≤0.05) | | | |
| Genotype (G) | | 3.57 | |
| Moisture condition (MC) | | 1.90 | |
| G × MC | | 5.05 | |
| Genotype | Stomata count/mm$^{2}$ | | |
| K-5 | 98.00$^{c}$ | 85.67$^{ef}$ | 91.83$^{A}$ |
| Olour | 87.67$^{def}$ | 80.67$^{fg}$ | 84.17$^{B}$ |
| OLOP-Z-6/2 | 111.33$^{b}$ | 46.33$^{k}$ | 78.83$^{B}$ |
| Kurukkan | 94.33$^{cd}$ | 90.00$^{de}$ | 92.17$^{A}$ |
| K-3 | 123.00$^{a}$ | 61.00$^{j}$ | 92.00$^{A}$ |
| OLOP-Z-6/1 | 85.33$^{efg}$ | 77.67$^{gh}$ | 81.50$^{A}$ |
| OPK-3-7/12 | 71.33$^{hi}$ | 67.33$^{ij}$ | 69.33$^{C}$ |
| Mean | 95.88$^{A}$ | 72.67$^{B}$ | |
| LSD (P≤0.05) | | | |
| Genotype (G) | | 5.64 | |
| Moisture condition (MC) | | 3.01 | |
| G × MC | | 7.97 | |

K-5 maintained higher RWC, and fully resurrected when imposed to drought treatment. Khoyerdi *et al.* (2016) in pistachio genotypes also reported, 85% RWC in non-drought stressed seedlings which reduced to 54% in water deficit. The results were in consonance with findings observed in apple seedlings (Bolat *et al.* 2014).

*Pearson's correlation coefficients*: Pearson's correlation coefficients among the different physiological and root traits showed statistically significant associations between relative water content (RWC) and membrane stability index (MSI), number of stomata (SC), number of leaves (NL), root tips (RT) and root forks (NRF), the dry weight of roots and root volume (RV), root surface area (RSA) and plant height (Ph), root tips (RT) and number of root forks (NRF) signify their use as selection indices for selecting promising mango genotypes under moisture stress. Whereas, a strongly negative correlation with root diameter (RD) and root-to-shoot ratio; SC and R/S; RD, and RT suggest their use as an indicator for regulating drought tolerance requires further validation. These results of linear relationships among the studied variables agree with the reports of Wang *et al.* (2012), who postulated reduced stomatal conductivity due to drought stress, which resulted in the enhanced generation of ROS.

*Principal component analysis*: Principal component analysis studies revealed a total of 6 principal components mainly influence the morpho-physiological and root architectures of mango genotypes under drought as well as in normal irrigated conditions. Although, mango genotypes showed different morpho-physiological and root architecture in normal irrigated and drought conditions. This is well explained by a principal component according to Eigenvalue. In both conditions (normal irrigated v/s drought), PC5 and PC6 showed Eigen values less than 1 so there was very less effect of these components. Fig 2 (A and B) depicts that under normal irrigated conditions Olour, OLOP1 (OLOP-Z-6/1) and OPK- 3-7/12 clustered together, and Kurukkan, K-3, K-5 and OLOP2 (OLOP-Z-6/2) clustered together. Whereas, in drought conditions genotypes Kurukkan, OLOP1 (OLOP-Z-6/1), OPK-3-7/12, K-3 and K-5 cluster together. Whereas, genotypes OLOP2 and Olour showed more similarity. The biplot revealed that RWC, SC, DwtS, DwtR, R/S, RSA, RT, RF are major contributors for variance under normal irrigation conditions whereas RWC, MSI, SC, Dry mass DwtS, DwtR, RSA, A, T, RT and RF major contributor in PC1 and PC 2 under drought condition. In drought conditions, genotypes Kurukkan, OLOP1 (OLOP-Z-6/1); OPK-3-7/12, K-3 and K-5 clustered together based on maximum variability contributed by above traits. These traits were showing similar pattern in variability contribution as studied by Zahid *et al.* (2021) in cotton for drought tolerance study. Several regions of the world have witnessed significant changes in the pattern and amount of rainfall, thus raising the interest in growing water scarcity and frequency of crop failure. Our study supports the necessity to prioritize the selection and development of drought-resilient polyembryonic mango rootstock genotypes to extend mango cultivation in areas facing frequent drought

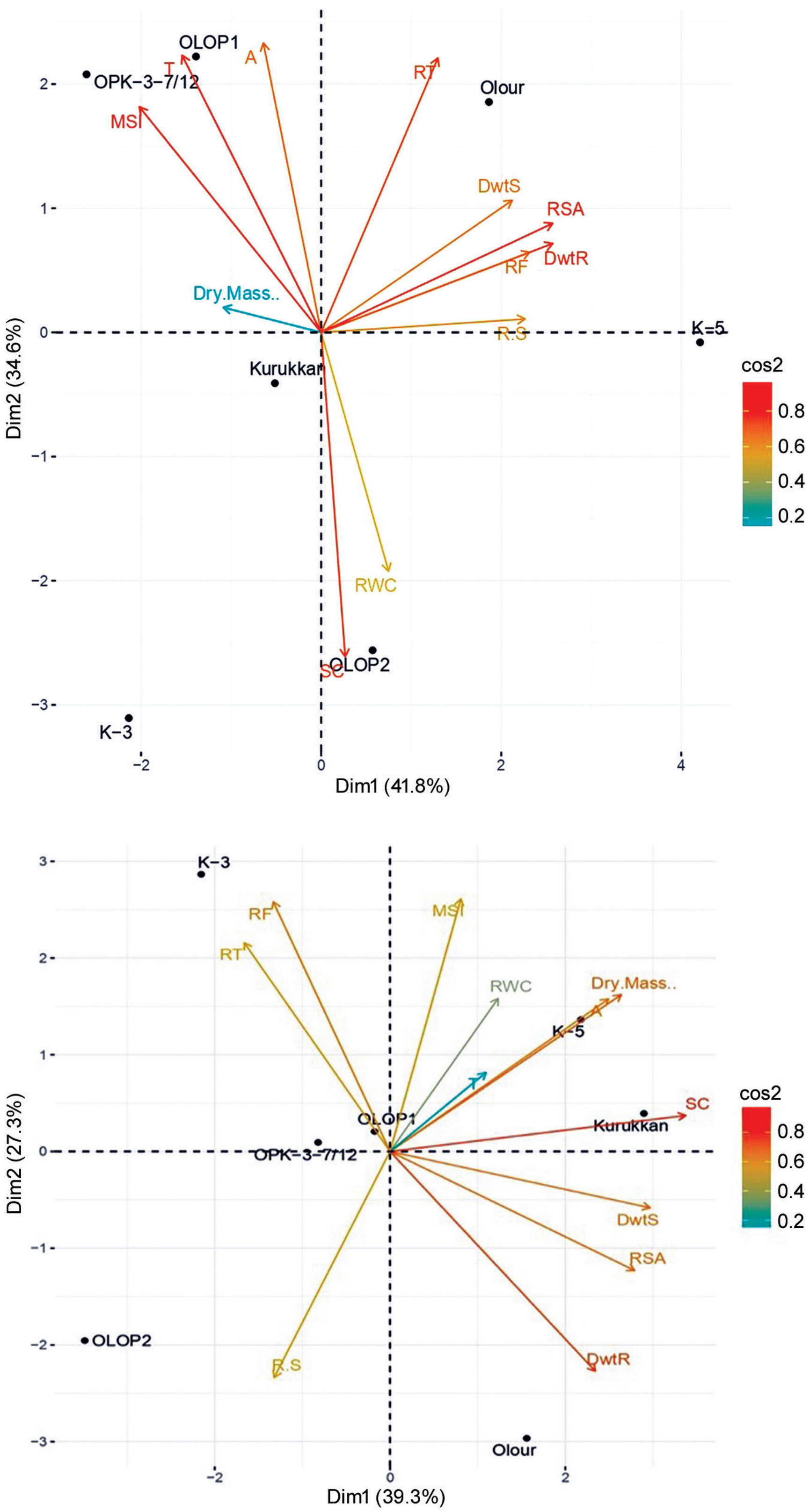


Fig 2 Biplot of Principle Component analysis under normal (A) and drought (B) conditions of mango genotypes based on morpho-physiological and root architectural traits. RWC, relative water content; MSI, membrane stability index; dwtS, dry weight of shoot, DwtR, dry weight of root; SC, Stomata count; A, photosynthetic rate; T transpiration rate; RSA, root surface area; DM, dry mass; R.S, root to shoot ratio; RT, root tips; RF, number of root forks, OLOP-1, OLOP-Z-6/1; OLOP-2, OLOP-Z-6/2.

with minimum quality and yield losses. Based on the results, it could be said that constant or slight improvement in root volume, root surface area and the number of root forks along with less defoliation can be considered reliable indices for screening mango genotype under drought. The lower sensitivity of plant growth of Kurukkan was associated with the higher root surface area, the number of root tips, root forks, transpiration, and the number of stomata, maintaining photosynthate and growth. Finally, mango genotypes Kurukkan can be considered drought-tolerant genotypes and be utilized as suitable rootstock for growing mango under water scarcity conditions.

## REFERENCES

Anonymous. 2015. UN Department of Economic and Social Affairs, United Nations website, United Nations, <https://www. https://www.un.org/waterforlifedecade/ index.shtml

Arsenault J L, Poulcur S, Messier C and Guay R. 1995. WinRHIZO™, a root-measuring system with a unique overlap correction method. *Horticulture Science* **30**(4): 906D–06.

Barrs H D and Weatherley P E. 1962. A re-examination of the relative turgidity technique for estimating water deficits in leaves. *Australian Journal of Biological Sciences* **15**(3): 413–28.

Bolat I, Dikilitas M, Ercisli S, Ikinci A and Tonkaz T. 2014. The effect of water stress on some morphological, physiological, and biochemical characteristics and bud success on apple and quince rootstocks. *Scientific World* **2014**: 769–32.

Bray E A, Bailey-Serres J and Weretilnyk E. 2000. Responses to abiotic stress. *Biochemistry and Molecular Biology of Plants,* pp. 1158–1203. American Society of Plant Physiology, Rockville USA.

Chaves M M and Oliveira M M. 2004. Mechanisms underlying plant resilience to water deficits: Prospects for water-saving agriculture. *Journal of Experimental Botany* **55**: 2365–84.

Geng D L, Lu L Y, Yan, M J, Shen X X, Jiang L J, Li H Y and Guan Q M. 2019. Physiological and transcriptomic analyses of roots from *Malus sieversii* under drought stress. *Journal of Integrative Agriculture* **18**(6): 1280–94.

Jombart T. 2008. Adegenet: An R package for the multivariate analysis of genetic markers. *Bioinformatics* **24**: 1403–05.

Khoyerdi F F, Shamshiri M H and Estaji A. 2016. Changes in some physiological and osmotic parameters of several pistachio genotypes under drought stress. *Scientia Horticulturae* **198**: 44–51.

Lozano-Montana P A, Sarmiento F, Mejia-Sequera L M, Alvarez-Florez F and Melgarejo L M.2021. Physiological, biochemical and transcriptional responses of *Passiflora edulis* Sims f. edulis under progressive drought stress. *Scientia Horticulturae* **275**: 109655.

Luvaha E, Netondo G W and Ouma G. 2010. Effect of water deficit on the physiological and morphological characteristics of Mango (*Mangifera indica*) rootstock seedlings. *American Journal of Plant Physiology* **5**(1): 7–21.

Sairam R K. 1994. Effect of moisture stress on physiological activities of two contrasting wheat genotypes. *Indian Journal of Experimental Biology* **32**: 594–97.

Vetterlein D, Phalempin M, Lippold E, Schluter S, Schreiter S, Ahmed M A, Wang S, Liang D, Li C, Hao Y, Ma F and Shu H.2012. Influence of drought stress on the cellular ultrastructure and antioxidant system in leaves of drought-tolerant and drought-sensitive apple rootstocks. *Plant physiology and Biochemistry* **51**: 81–89.

Wang, S, Liang D, Li C, Hao Y, Ma F and Shu H.2012. Influence of drought stress on the cellular ultrastructure and antioxidant system in leaves of drought-tolerant and drought-sensitive apple rootstocks. *Plant Physiology and Biochemistry* **51**: 81–89.

Zahid Z, Khan M K R, Hameed A, Akhtar M, Ditta A, Hassan H M and Farid G. 2021. Dissection of drought tolerance in upland cotton through morpho-physiological and biochemical traits at seedling stage. *Frontiers in Plant Science* **12**: 627107.