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# Genetic variability for root and shoot traits under moisture stress in *G. hirsutum* cotton

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**Abstract:** The aim of this study was to examine the extent of genotypic variability in a diverse set of 320 cotton germplasm collections for root and shoot traits in 85 days old plants which experienced natural moisture stress due to low rainfall, 27.66 % (549 mm) of the past 20 years average (759 mm). The cotton germplasm lines were evaluated in randomized complete block design with five checks viz., Sahana, Surabhi, MCU-5, DS-28 and ARBH-813. High PCV and GCV for number of secondary roots, secondary root length, fresh leaf and shoot weight, number of squares, dry leaf, shoot and root weight, total dry matter accumulation, fresh and dry root to shoot ratio and seed cotton yield in germplasm lines. The traits which showed high heritability was associated with high genetic advance for number of secondary roots, fresh shoot weight, number of squares per plant, moisture content of squares and dry leaf, shoot and root weight. This shows the variation was due to additive gene effects. The germplasm lines *viz.,* CPD-424, CPD-2007-4, CPD-443, RDT-17 and HBS-123 recorded 25% higher secondary root length (30.8 to 38.0 cm) than ARBH 813 (24.26 cm) and their primary root length (19.0 to 29.5cm), number of secondary roots (17.0 to 34.5) and root weight (11.5 to 18.0 g/plant) were comparable to checks. The genotypes *viz,* AKA-081, EC560327, GISV-272, JBWR-23, HBS-102 and RDT-17 recorded 40 percent more number of secondary roots (34.5 to 41.0) than superior check, DS 28 (24.5). They recorded primary root length (20.0 to 26.0 cm) and secondary root length (10.5 to 31.0 cm) comparable to checks.

**Key Words:** Moisture stress, Root and shoot traits, Genetic variability

## Introduction

Plants are thought to have evolved numerous strategies for coping with limited water availability including changes in phenological, developmental and physiological traits (Passioura, 1996; Araus *et al*., 2002). Such traits which are evolved under water limited condition are adaptive and have only survival significance with little or no advantage for crop growth and productivity (Collins *et al*., 2008). The traits associated with roots and efficient use of water for biomass production has great relevance in determining the yield levels and deep rooted plants have shown to be better productive under water limited conditions (Mohankumar *et al.,* 2011). Plants respond to their changing environment in a complex, integrated way that allows them to react to the specific set of conditions and constraints present at a given time.

Therefore, the genetic control of tolerance to abiotic stresses is not only complex, but is also highly influenced by environmental factors and by the developmental stage of the plant. The physiological responses of plants to moisture deficit include leaf wilting, a reduction in leaf area, and the stimulation of root growth by directing nutrients to the underground parts of the plants. Cotton is an important commercial crop providing lint as a raw material to the textile industry. Cultivars are needed that can endure and recover from drought so as to minimize the losses in rainfed areas. An understanding of the response of plants to water stress is important in efforts to model cotton growth, estimate irrigation needs and breed drought resistant cultivars (Pace *et al.,* 1999). Knowledge regarding identification of the specific traits that determine crop performance under water deficit conditions, and which one is amendable through breeding approaches could help cotton breeders to create drought tolerant crop cultivars (Turner, 1997). Plants are more susceptible to drought during flowering and seed development stages, as plant's resources are deviated to support root growth (Waseem *et al.,* 2011). Basal *et al*. (2005) evaluated root growth under drought of selected converted race stock, TAM 94L-25, and Lankart 142. They identified two converted race stocks as robust rooting had longer tap root length, higher lateral root number, greater total root dry weight, greater root weight per unit length of tap root and greater shoot dry weight in both drought and well-watered conditions than two converted race stocks identified as non-robust. Two cycles of seedling drought resulted in an increase in lateral root number in one robust rooting converted race stock and in TAM 94L-25 and Lankart 142. They concluded that root traits in genetically variable converted race stocks could be useful for enhancing drought tolerance in cotton. When the conditions of water and nutrient are favorable, the roots and shoots of crops would function normally and benefit each other. Moderate water stress may induce the spread of roots in deeper layers of the soil, so that plants would obtain a larger spatial distribution from which to uptake more nutrients and water (Yan *et al*., 2008).

We were evaluating the germplasm lines for their genetic diversity for yield, yield contributing and fiber quality traits during 2012-13 year. Due to deficit rainfall during the season right from the beginning, the cotton genotypes experienced natural moisture stress due to low rainfall, 27.66 % (549 mm) of the past 20 years average (759 mm). The advantage of this moisture stress situation was taken with the aim to examine the extent of genotypic variability in a diverse set of 320 cotton germplasm collections for root and shoot traits which are influencing moisture stress tolerance in 85 days old cotton plants.

## Materials and Methods

The study on "genetic variability for root and shoot traits under moisture stress in cotton' was conducted at Agricultural Research Station, Dharwad Farm, which is situated in the northern transitional zone (Zone No. 8) of Karnataka with latitude of 15° 26[1] north, longitude of 76° 7[1] east and altitude of 678m above mean sea level (MSL) during 2012-13 utilizing 320 diverse cotton germplasm collections (breeding lines developed in various breeding schemes, commercially released varieties, exotic and indigenous germplasm collections) evaluated in randomized complete block design with five checks *viz.,* Sahana, Surabhi, MCU-5, DS-28 and ARBH-813. During the 2012-13, moisture stress was occurred naturally due to low rainfall (549 mm) compared to the average of past 20 years (759 mm). The rainfall deficit estimated is 27.66 %, which is considered as moisture stress condition at the peak flowering stage which is critical stage for cotton growth. Hence the 85 days old plants were used for recording observations to know how much variability exist for these traits in germplasm pool. The four plants were uprooted from the field and observations namely, primary root length (PRL), number of secondary roots, secondary roots length (SRL), fresh root weight (FRW), fresh leaf weight (FLW), fresh shoot weight (FSW), fresh square weight (FSW) and number of squares per plant were recorded. Then these samples were pre-dried and kept in hot air oven for 48 hours for complete drying. Total dry matter accumulation and root to shoot ratio on fresh and dry weight basis were calculated. The moisture content was calculated from their dry weight.

Moisture content (%) = [(Fresh wt. - Dry wt.) / Fresh Wt.] x 100

From these observations, total dry matter accumulation, and root to shoot ratio, on fresh and dry weight basis were also determined. The data were subjected to statistical analysis such as to analysis of variance (Panse and Sukhatme, 1967), phenotypic and genotypic variances and their respective co-efficients of variation (Johnson *et al.*, 1955) and their values are categorized as low, moderate and high as indicated by Sivasubramanian and Menon (1973). Heritability in broad sense was computed in per cent using the formula suggested by Hanson *et al.* (1956) and categorized as low, moderate and high as given by Robinson *et al.* (1949). The extent of genetic advance to be expected from selecting five per cent of the superior progeny and categorized as low, moderate and high given by Johnson *et al*. (1955). All the data analysis were carried out using software, Windostat version 9.1.

## Results and Discussion

In the present study, Variability parameters *viz.,* range, genotypic and phenotypic coefficient of variation, heritability and genetic advance as percent of mean for different root and shoot traits are presented in table-1. The year of testing of these germplasm lines (2012-13) was drought year as total rainfall received was 27.66 percent (549 mm) less than average rainfall of past 20 years (759.0 mm) therefore the traits related to roots, shoots and moisture content in roots and shoots was recorded at 85 days after sowing. In this experiment, we included five checks, the mean and range for the checks were also presented in table-1.

In the present study, there was greater range of variation for all traits in germplasm lines than the range in checks. It indicated that the germplasm lines are genetically variable. The traits like *viz.,* number of secondary roots (21.36%, 61.8% and 34.65), fresh shoot weight (32.97%, 61.4% and 53.23%), number of squares (28.75%, 61.9% and 46.62%), dry shoot weight (32.49%, 65.7% and 54.28%) and dry root weight (29.4%, 68.5% and 50.15%) recorded high GCV coupled with high heritability and high genetic advance as percent of mean respectively which indicates their control by additive gene action. Similar results were reported by Irum *et al*., (2011) for various variability parameters for root length, root weight, shoot weight, and ratio of shoot weight to root evaluated in the 30 cotton genotypes, they reported high GCV and PCV values were observed for root length, root weight, while moderate values for shoot weight and ratio of root to shoot weight. Moderate heritability for the root length, root and shoot weight, while low heritability was observed for ratio of root to shoot ratio. High genetic advance for root length, root and shoot weight and moderate values for ratio of root to shoot weight. Significant differences were reported for water stress tolerance indices based upon root and shoot lengths of 80 genotypes in water stress condition (Iqbal *et al.*, 2010). Imran *et al.,* (2011) reported that high heritability for all traits except seedling shoot length and high genetic advance was observed for seed cotton yield/ ha, root length, root weight, shoot weight and shoot root length ratio.

Root traits play an important role in moisture stress tolerance. The cotton plants produce a tap root of 5 to 8 inches, earlier studies with cotton have indicated that the growth and development of the root system are under genetic control, but may be modified by environmental influences (Mcmichael *et al*., 1991). There is evidence for environmentally mediated differences in the development of total root length and the degree of branching in cotton root systems. These differences can be a major factor in the ability of the plant to explore the available soil volume for water and nutrients. The partitioning of biomass into roots and shoots that can impact the productivity and drought tolerance capabilities of the plant since the roots and shoots are in constant competition for available photosynthates. The coordination of the growth between roots and shoots becomes important since the development of either part is dependent on the other. The total biomass produced by a cotton root system makes up 10-15% of the total biomass produced by the plant in a growing season (Dilbeck *et al*., 1984). Pace *et al.*, (1999) reported significant differences for leaf and stem dry weight, taproot length, taproot dry weight and secondary root dry weight and its length between drought treated and control plants of two cultivars 'Stoneville 506' (long season) and 'Tamcot HQ95' (short season) at recovery period of 59 days after planting.

In the present study, the superior lines selected based on four root traits such as primary root length (cm), secondary root length, number of secondary roots and root weight are presented in table-2. Among these selected germplasm lines for four root traits in this study, highest seed cotton yield was recorded by CPD-443 (823.6 kg/ha) and statistically at par with superior check, Surabhi (848.2 Kg/ha). Five genotypes namely HLS-321729 (35.5 cm), CPD-2007-B (33.0 cm), CAK-081 (33.0 cm), Raj-2 (32.0 cm) and DRC-305 (32.0 cm) recorded 10 percent longer primary root length and statistically at par with superior check, DS 28 (28.85 cm). However these genotypes with higher primary root length recorded lesser number of secondary roots (11 to 16), than all checks (18.6 to 24.5). They also recorded lesser secondary root length (8.8 cm to 27.3 cm) and root weight (8 to 12g) compared to checks (15.81 to 24.26 cm and 9.15 to 16.55 g) respectively.

Jiang and Huang (2000) took into account of extensive deep root system as an important characteristic of drought resistant plants in their study. Such root system facilitated water uptake and increases plant tolerance to drought and heat. These stresses and their combined influence on reduced root growth in the surface soil layer. Plants under drought developed more extensive root systems than plants under normal water supply conditions. According to Allah *et al.,* (2010) the total root length is strongly related to drought tolerance in rice under upland conditions. Greater total root length (TRL) during drought stress might cause better water uptake, as indicated by their higher grain yield in rice. Effect of moisture deficit stress on the physiology of cotton has been documented. A field

**Table-1:** variability parameters for various root and shoot traits in *G. hirsutum* germplasm lines evaluated during 2012-13

| Characters | Mean | Range | | GCV (%) | PCV(%) | $h^2$ (Broad | Gen. Adv. as % of Mean | |
|---|---|---|---|---|---|---|---|---|
| | | checks | Genotypes | | | Sesne, %) | 5% | 1% |
| Primary root length (cm) | 22.11 | 20.8 – 28.85 | 9.0 - 35.5 | 11.86 | 16.69 | 0.505 | 17.36 | 22.25 |
| Number of secondary roots | 21.00 | 18.6 – 24.5 | 4.5 – 41.0 | 21.36 | 27.17 | 0.618 | 34.6 | 44.34 |
| Secondary root length (cm) | 17.93 | 15.82 – 24.27 | 7.0 -38.0 | 20.16 | 28.48 | 0.501 | 29.39 | 37.67 |
| Root weight. (g) | 9.66 | 9.15 – 16.55 | 4.0 - 23.0 | 19.72 | 30.37 | 0.421 | 26.38 | 33.81 |
| Fresh leaf weight (g) | 38.09 | 35.6 – 47.7 | 9.0 -102.0 | 31.54 | 42.85 | 0.542 | 47.83 | 61.3 |
| Fresh shoot weightt (g) | 31.57 | 30.4 – 35.9 | 11.0 – 105.5 | 32.97 | 42.07 | 0.614 | 53.23 | 68.21 |
| Number of squares | 16.75 | 16.15 – 17.9 | 3.5 – 46.0 | 28.75 | 36.53 | 0.619 | 46.62 | 59.75 |
| Fresh square weight (g) | 13.20 | 12.05 – 19.4 | 2.0 – 38.0 | 19.34 | 44.08 | 0.192 | 17.48 | 22.4 |
| Dry leaf weight. (g) | 10.79 | 9.42 – 12.22 | 3.0 – 27.0 | 28.28 | 37.33 | 0.573 | 44.13 | 56.56 |
| Dry shoot weight (g) | 10.47 | 8.55 – 10.15 | 2.0 – 29.0 | 32.49 | 40.07 | 0.657 | 54.28 | 69.57 |
| Dry root weight (g) | 4.05 | 3.0 – 4.95 | 1.0 – 12.0 | 29.4 | 35.5 | 0.685 | 50.15 | 64.28 |
| Dry square weight (g) | 2.85 | 2.72 – 3.12 | 1.0 – 8.0 | - | - | - | - | - |
| Leaf moisture (%) | 70.55 | 71.27 – 74.33 | 40.91 – 86.80 | 6.91 | 8.98 | 0.593 | 10.96 | 14.05 |
| Shoot moisture (%) | 66.16 | 69.09 – 71.96 | 31.82 – 88.89 | 8.175 | 10.8 | 0.573 | 12.74 | 16.33 |
| Root moisture (%) | 57.95 | 66.4 – 72.25 | 30.0 – 80.0 | 11.46 | 15.24 | 0.565 | 17.75 | 22.75 |
| Square moisture (%) | 76.98 | 76.2 – 84.42 | 25.0 – 93.42 | - | - | - | - | - |
| Total dry matter (g) | 28.16 | 23.97 – 29.7 | 8.0 – 67.0 | 25.64 | 33.42 | 0.589 | 40.52 | 51.94 |
| Root to shoot ratio (fresh) | 0.33 | 0.31 – 0.48 | 0.104 – 0.750 | 21.35 | 31.99 | 0.445 | 29.35 | 37.62 |
| Root to shoot ratio (dry) | 0.42 | 0.35 – 0.51 | 0.118 – 0.846 | 23.39 | 32.54 | 0.516 | 34.62 | 44.37 |
| Seed cotton yield (Kg/ha) | 575.3 | 517.1 - 982.8 | 276.4 – 1448.4 | 31.70 | 33.54 | 0.893 | 61.74 | 79.12 |

**Table-2:** Performance of selected superior germplasm lines for four root traits

**Lines exhibiting high primary root length**

| Germplasm | PRL | NSR | SRL | RW | SCY |
|---|---|---|---|---|---|
| HLS-321729 | 35.5 | 12.0 | 15.5 | 11.0 | 628.1 |
| CPD-2007-B | 33.0 | 15.5 | 10.5 | 8.0 | 766.3 |
| CAK-081 | 33.0 | 11.0 | 23.0 | 10.0 | 764.4 |
| Raj-2 | 32.0 | 16.0 | 27.3 | 12.0 | 665.7 |
| DRC-305 | 32.0 | 13.0 | 8.8 | 10.0 | 499.8 |

**Lines exhibiting high number of secondary roots**

| Germplasm | NSR | PRL | SRL | RW | SCY |
|---|---|---|---|---|---|
| AKA-081 | 41.0 | 22.5 | 17.8 | 9.0 | 536.1 |
| EC560327 | 40.0 | 26.0 | 19.8 | 16.0 | 799.0 |
| GISV-272 | 39.0 | 20.0 | 15.3 | 12.0 | 621.3 |
| JBWR-23 | 36.5 | 26.0 | 13.5 | 11.0 | 377.3 |
| HBS-102 | 34.5 | 22.5 | 10.5 | 6.0 | 751.4 |
| RDT-17 | 34.5 | 22.0 | 31.0 | 13.0 | 523.9 |

**Lines exhibiting high root weight**

| Germplasm | RW | PRL | NSR | SRL | SCY |
|---|---|---|---|---|---|
| CCH-1831 | 23.0 | 21.0 | 26.5 | 19.3 | 503.3 |
| NH-111/1 | 20.0 | 21.0 | 33.5 | 14.5 | 658.3 |
| CPD-465 | 19.1 | 27.5 | 19.0 | 20.3 | 526.3 |
| Abadhita | 19.1 | 30.0 | 25.0 | 15.3 | 653.8 |

**Lines exhibiting high secondary root length**

| Germplasm | SRL | PRL | NSR | RW | SCY |
|---|---|---|---|---|---|
| CPD-424 | 38.0 | 23.5 | 26.0 | 13.0 | 505.4 |
| CPD-2007-4 | 34.8 | 29.5 | 19.0 | 15.0 | 822.3 |
| CPD-443 | 33.8 | 19.0 | 17.0 | 11.5 | 823.6 |
| RDT-17 | 31.0 | 22.0 | 34.5 | 13.0 | 523.9 |
| HBS-123 | 30.8 | 23.5 | 25.0 | 18.0 | 420.2 |

**Mean performance of check lines in the experiment**

| Checks | PRI | NSR | SRL | RW | SCY |
|---|---|---|---|---|---|
| Sahana (C) | 20.80 | 22.35 | 19.34 | 9.15 | 364.1 |
| Surabhi (C) | 27.65 | 23.35 | 15.92 | 10.85 | 848.2 |
| MCU-5 (C) | 21.05 | 19.00 | 21.76 | 9.70 | 581.3 |
| DS-28 (C) | 28.85 | 24.50 | 15.81 | 13.20 | 753.0 |
| ARBH-813 (C) | 21.35 | 18.60 | 24.26 | 16.55 | 636.3 |
| Mean | 23.94 | 21.56 | 19.418 | 11.89 | 636.6 |
| CD @ 5% | 8.16 | 8.22 | 11.36 | 7.01 | 127.6 |

**Where:** PRL-Primary root length (cm); NSR- Number of secondary roots SRL – Secondary root length (cm); RW – Root weight (g) study under dryland and irrigated areas with eight cotton genotypes detected genotypic variation for many of the components of photosynthetic process (Pettigrew, 2004).

Germplasm lines like CPD-424 (38.0 cm), CPD-2007-4 (34.8 cm), CPD-443 (33.8 cm), RDT-17 (31.0 cm) and HBS-123 (30.8 cm) recorded higher secondary root length which is about 25 percent more than highest check ARBH 813 (24.26cm). Genotypes with higher secondary root length (30.8cm to 38.0cm) also possessed primary root length (19.0 to 29.5cm) comparable or on par with checks (20.8 to 28.85cm). Their secondary root numbers (17.0 to 34.5) are comparable with checks (18.6 to 24.5) and similarly they recorded statistically on par root weight (11.5 to 18.0 g/plant) to checks (9.15 to 16.55 g/plant). Genotypes *viz,* AKA-081 (41.0), EC560327 (40.0), GISV-272 (39.0), JBWR-23 (36.5), HBS-102 (34.5) and RDT-17 (34.5) recorded significantly higher and 40 percent more number of secondary roots than check, DS 28 (24.5) possessing highest number of secondary roots among checks. They recorded primary root length (20.0 to 26.0 cm) and secondary root length (10.5 to 31.0 cm) comparable to checks. Genotypes like CCH-1831 (23.0 g), NH-111/1 (20.0 g), CPD-465 (19.1 g) and Abadhita (19.1 g) recorded 15 percent higher root weight than high root weight check ARBH 813 (16.55g). According to Rezaeieh and Eivazi (2012), root dry weight was recognized as the best indicator and easiest typical to determine the drought tolerance of maize. Riaz *et al* (2013) found wide variation and high broad sense heritability for various root and shoot traits. Germplasm lines which recorded seed cotton yield on par with superior check, Surabhi (848.2 Kg/ha) also recorded higher primary root length of 33.0 cm (CPD-2007-B and CAK-081), higher secondary root length in CPD-2007-4 (34.8 cm) and CPD-443 (33.8cm) and more number of secondary roots in EC 560327 (40) and HBS 102 (34.5) may be the best candidate genetic resource in breeding for moisture stress tolerance. Genotypes highest primary root length (HLS-321729, Raj-2 and DRC-305), high secondary root length (CPD-424, RDT-17 and HBS-123) and more number of secondary roots (AKA-081, GISV-272, RDT-17 and JBWR-23) although, recorded significantly lower seed cotton yield than commercial check varieties, they may be used as genetic resource for incorporation of these desirable traits into high yielding genotypes which can withstand severe moisture stress.

In conclusion, we found substantial differences for root and shoot traits among cotton germplasm lines in our study. The impact of these findings for future breeding programmes related to moisture stress tolerance needs to be demonstrated. The shortlisted germplasm lines can be effectively used in future drought breeding programs. Selection of germplasm lines based on primary root length, root weight, number of secondary roots and length of secondary roots might be the successful predictor of moisture stress tolerance in the field. Further studies are required to relate studied cotton germplasm root traits with their performance at various moisture stress situations.

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