Identification of traits associated with drought tolerance in Cotton (*Gossypium hirsutum*L.)

ABSTRACT:

The cotton genotypes studied under greenhouse conditions at seedling stage during *kharif*, 2022-23 at RARS, Nandyal*viz*; NDLH-1935 ,NDLH-1943, NDLH-1949, NDLH-1976, NDLH-1979, NDLH-2019, Sivanandi and NDLH-2005-4 recorded comparatively higher mean values for primary root length, shoot length, shoot dry weight, root dry weight, relative water content and root/shoot ratio both under controlled and moisture-stress conditions out of 30 genotypes studied. Moderate to low estimates of variability,high heritability coupledwith highergenetic advance over mean under controlledand moisture-stress conditions revealed the importance of additive gene action for all the characters studied. Primary root length had positive and significant association with shoot length), root dry weight and root/ shoot ratio under controlled conditions at phenotypic level while the same character showed negative correlations under drought stress conditions.Shoot length had non significant associations with all the characters studied under both theconditions. The associations between shoot dry weight and root dry weight and root dry weight with root/ shoot ratio were significant and positive association at phenotypic level under controlled and moisture-stress conditions, respectively. Relative water content had non significant associations whereas root/ shoot ratio showed positive and significant associations with primary root length and non significant associations with all other characters under both the conditions. Primary root length, shoot dry weight, root dry weight and root/shoot ratio may be considered as important parameters of drought tolerance while selecting genotypes for improving drought tolerance ability in upland cotton.

Key words: Upland Cotton, Seedling characters, Drought tolerance, genetic parameters, correlation analysis

INTRODUCTION

Cotton is an important commercial crop mostly grown under rainfed conditions in Andhra Pradesh in an area of 6.02 lakh hectares with a production of 17.85 lakh metric tonnes of lint and productivity of 504kg/ha(DES. A.P. Govt, 2021-22).Hence, the chances of crop experiencing drought atany one stagesof the crop growth are more. Therefore, development of drought-tolerant cultivars to achieve economic yield under rainfed conditions is one of the major objective in cotton improvement. It is one of the most important abiotic stress factor that cause significant product loss in cotton.Drought stress affects photosynthesis, stomatal regulation, reduction in root –shoot growth, leaf area, transpiration and osmo-regulation .Several molecular, biochemical, physiological, morphological and ecological traits and processes of plants are impaired under drought conditions (Jayant *et al*. 2022). Root growth, shoot length, shoot dry weight, leaf area, relative water content, stomatal density and stomatal conductance are affected significantly under drought stress(Veesar*et al*. 2021). They also reported that relative water content has been considered as a reliable selection criteria for drought tolerance as drought tolerant genotypes retain higher water content under moisture stress conditions in the leaf tissue. Drought stress for longer period affects plant biomass, stem weight, plant development,plant population, crop growth, boll size, kappas yield and lint quality .The seedling, flowering and boll formation are the moistures sensitive periods in cotton. The seedling stage is highly sensitive period of crop to environmental conditions in cotton. The first plant organ that is exposed to water stress is the roots which in turn transmit the stress tothe plant through morphological, physiological and metabolic changes. Roots are the sensors of plants, detect osmotic stress and thus roots play a role in the plant drought tolerance mechanism (Mahamood and Muhammad , 2022) .Plants with deep root systems show better drought tolerance and improve water and nitrogen uptake .Variability among genotypes for drought tolerance for root growth characters *viz*; root length and root dry weight and shoot length, shoot dry weight under drought conditions was reported in cotton(Naidu *et al*. 1995; Basal *et al*.2005 ; Singh *et al*.2018 and Jayant *et al* . 2022) . Positive and significant associations among shoot and root characters we reported by Reddy *etal*. 2017 and Iqbal *etal*. 2020). *Gossypium hirsutum* is sensitive to abiotic stress conditions whereas

Gossypium arboreum has more biotic and abiotic stress tolerance andadaptation (Liu *et al*. 2006). In the present study assessment of drought stress tolerance ability of predominantly cultivated upland cotton (*Gossypium hirsutum L)* genotypes at the seedling stage was carried out so as to identify the characters associated with drought tolerance and the genotypes possessing drought tolerance.

MATERIAL AND METHODS

The studywas carried out during *Kharif,* 2022-23 at Regional Agricultural Research Station (RARS), Nandyal, A. P located at 15° 29' N latitude and 78°29' Elongitude from an altitude of 211.76 M above sea level involving30 genotypes in a completely randomized design with three replications both under stress (treatment) and non-stress (control) conditions. The experiment was conducted at the green houseconditions. Watering was given till the development of the first true leaf in both the conditions. Thereafter, daily watering was given to genotypes grown under controlled conditions. Water stress condition was created by completely withholding water supply to the genotypes grown under stress conditions. The experiment was continued out for 45 days (August to September, 2022) from the date of emergence of the seedlings as per the standard procedure (Dahab *et al*. 2016). Data onprimary root length, shoot length, shoot dry weight; root dry weightand relative water content were recordedon five randomly selected plants. Root to shoot ratio was determined based on shoot and root dry weights. Statistical analysis was carried out as per Panse and Sukhatme(1985). Relative water content was determined adapting methodologies of Clark and Townley –Smith (1986). Correlation coefficients were estimated as suggested by Dewey and Lu (1959). Genetic parameters were calculated as per standard methods of Burton (1952), Lush (1940)and Jhonson*et.al* (1955).

RESULTS AND DISCUSSION

Analysis of varince indicated existence of significantdifferences among the genotypes for all characters studied at seedling stage both under moisture stress and controlled conditions. Mean, range, coefficients of variability, estimates of heritability and expected genetic advance as percent mean recorded for primary root length , shoot length,shoot dry weight , root dry weight, relative water content and root- shoot /ratio and phenotypic correlations under moisture stress and controlled conditions were presented in Table1 ,2 and 3, respectively .

Primary root length (cm plant-1)

Primary root length under controlled conditions ranged from 12.88 (NDLH-1979) to 28.64 cm (NDLH-1931) with a mean of 19.14 cm while under moisture-stress conditions, it ranged from 15.24 (NDLH-1866) to 31.18 cm (NDLH-1976) with a mean of 21.40 cm (Table 1).All the genotypes except NDLH1931, NDLH1979 and NDLH 1928 recorded lower mean values for this character under moisture stress conditions compared to controlled conditions.Estimates of PCV (16.68% and14.37%)) and GCV (16.50% and 14.17%) were moderateunder controlled and moisture stress conditions, respectively. High heritability (98.00 and 97.17%) and genetic advance as a per cent of mean (33.67%and 28.76%) were noted for primary root length under both the conditions (Table 2 and 3). High heritability and highgenetic advance as per cent of mean coupled with moderate variability suggests that additive type of gene action is operating for thischaracter. Hence, Primary root length can be easily fixed by simple selection in the early generations aimed at developing improvedcotton genotypes possessingtolerance to drought.

Shoot length (cm plant-1)

A mean value of 39.35 cm was recorded for this character ranging from 24.70 (NDLH-1905) to 51.08 cm (Sivanandi) under controlled conditions while it varied from 13.98 (Narasimha) to 28.94 cm (NDLH-2019) with a mean of 22.04 under moisture stress conditions (Table 1). All the genotypes registered lower mean values for this character under moistures stresscompared to controlled conditions. However, NDLH1979, NDLH2019, NDLH1935and NDLH1943 recoded higher values compared to other genotypes under moisture stress conditions. Moderate values of PCV (14.23% and17.87%) and GCV (13.96%and 17.69%) ,high heritability (97.12% and 97.98%) and genetic advance as per cent of mean (28.32% and 36.06%)were recorded both under controlled and under moisture-stress conditions for shoot length(Table 2 and3). Moderate estimates of PCV and GCV alongwith high heritability and genetic advance as per cent of mean indicate that shoot length is mostly governed by additive gene action.

Shoot dry weight (g plant-1)

This characterranged from 5.20 (NDLH-1984) to 9.85 g plant-1 (Sivanandi) among the genotypes with a mean of 8.25 g plant-1 under controlled conditions whereas under moisture-stress conditions it varied from 1.60 (NDLH-2028) to 2.82 g plant-1 (NDLH-2005-4) with a mean of 2.24 g plant-1 (Table 1). All the genotypes registered lower mean values for this character under moistures stress compared to controlled conditions. However, NDLH1989, NDLH 2019,NDLH1935 NDLH1976, NDLH1949, NDLH 2005-4 and Sivanandi recorded higher values compared to other genotypes under moisture stress conditions .Moderate estimates of PCV (14.16% and 19.82%) to GCV (13.95% and 19.59%)) and higher heritability (97.12% and 97.73%),) and genetic advance (28.32% and 39.90%)were recorded for shoot dry weight (Table 2 and 3). High genetic advance over mean and high heritability observed under boththe conditions suggeststhat shoot dry weight is governed by additive gene action of higher GCV,PCV, heritability and genetic advance forthis characterin cotton.

Root dry weight (g plant-1)

Root dry weight ranged from 0.80 (NDLH-2019) to 2.01 g plant-1 (NDLH-1949) with a mean value of 1.44 g plant-1 under controlled conditions while it ranged from 0.30 (NDLH-1866) to 0.70 (Sivanandi) g plant-1 with a mean of 0.49 g plant-1 under moisture-stress conditions(Table 1) . All the genotypes registered lower mean values for this character under moistures stress compared to controlledconditions. However, NDLH1935, NDLH 1984,NDLH2013, NDLH1949, NDLH 2005-1, NDLH 2005-4 and Sivanandi recoded higher values compared to other genotypes under moisture stress conditions.Higher estimates of heritability (98.62% and 93.01%) and genetic advance as a percentage of mean values (44.48% and 28.28%) and lower values of PCV (9.54% and %) and GCV (9.20% and %) registered under controlled and moisture-stress conditions for this character suggests that root dry weight under the control of additive gene action(Table 2and3).

Relative water content (%)

Relative water content varied from 27.03 (NDLH-1992) to 72.67 (NDLH-2028-2) with a mean value of 44.87per cent under controlledconditions and it varied from 20.05 (NDLH-2004) to 61.22 (NDLH-2005-4) with an average of 32.58 per cent under moisture stress conditions (Table 1) .All the genotypes registered lower mean values for this character under moistures stress compared to controlledconditions. However, NDLH1979, NDLH1931,NDLH1935, NDLH1959, NDLH1976, NDLH 2028, NDLH 2005-4, NDLH1971, NDLH 1905, NDLH 1943 and Sivanandi recoded higher values compared to other genotypes under moisture stress conditions. Higher estimates of PCV (24.67% and 25.22%), GCV (24.54% and 25.01%) , heritability (96.40%and 98.30%) and geneticadvance over mean (30.28% and 51.07%) were recorded under both the conditions revealed that relative water content (RWC) isgoverned by additive gene action (Table 2 and3). Hence, RWCcould be improved by simple selection.

Root to shoot ratio

Root to shoot ratio ranged from 0.13 (NDLH-1866, NDLH-1979) and NDLH-1992) to 0.22 (NDLH-2005-4) with an average of 0.17 under controlled conditions while it varied from 0.16 (NDLH-2019) to 0.29 (NDLH-1976) with a mean of 0.22under moisture-stress conditions (Table 1).In general, all the genotypes under moisture stress conditions recorded higher root to shoot ratio values for this character. Moderate values of PCV (14.98% and 15.91%) and GCV (14.76% and 15.68%), higher estimates of heritability (97.15% and 97.15%) coupled with higher genetic advance as per cent of mean (29.98% and 31.84%) were registered under controlled and moisture stress conditions , respectively for root shoot ratio suggests the importance of additive gene action(Table 2 and3). Hence, root to shoot ratio couldbe manipulated through simpleselection in the early generations.

Moderate estimatesof PCV and GCV, high heritability and genetic advance as per cent of mean for primary root length by Irum*et al.* (2011), Riaz *et al.* (2013), Farooq *et al.* (2018) and Abdelmoghny*et al.* (2020) ; Irum *et al.* (2011) and Farooq *et al*. (2018) for shoot length; Handi and Katageri (2016) and Farooq *et al*. (2018) for shoot dry weight; low PCV and GCV but high heritability and genetic advance for root dry weight by Riaz *et al.* (2013) ,Abdelmoghny*et al*. (2020) and Parre and patil , 2021) and moderate estimates of PCV and GCV , high heritability and genetic advance by Riaz *et al.* (2013) and Abdelmoghny*et al*. (2020) for relative water content and moderate estimates of PCV and GCV , high heritability and genetic advance for root to shoot ratio were reported in cotton . The present findings of moderate coefficients of variation coupled with high heritability and genetic advance observedsuggests that all the above characters were governed by additive gene action and amenable for simple selection.

In the present study the genotypes *viz.,* NDLH-1935 ,NDLH-1943, NDLH-1949, NDLH-1976, NDLH-1979, NDLH-2019, Sivanandi and NDLH-2005-4 recorded comparatively higher mean values for primary root length, shoot length, shoot dry weight, root dry weight and relative water content both under controlled and moisture-stress conditions and can be used as parental lines in breeding for drought tolerance as tolerant genotypes can increase growth rate , maintain growth and encourage root growth under drought stress. Variability among cotton genotypes as registered in the present study for root growth characters were also reported by Basal et al. (2005) , Singh et al. (2018) and Jyoti *et al*. (2021while Iqbal et al. (2011), Parida *et al*. (2017) and Zou et al. (2020)for root, stem and RWC characters in cotton under stress conditions . Pace et al. (1999) observed a significant increase in root thickness and root length in seedling stage under drought stress than control after the drought recovery. A reduction in root to shoot ratio under controlledconditions and higher values under moisture stress conditions reveal the response of genotypes to favourable and less favourable environments, respectively.Jayant et al. (2022) indicated that no single index canfully andaccurately evaluate the drought resistance of crops and hence to identify reliable parameters of droughttolerance. Du and Huang (2011) considered more than 20 physiological and biochemical indices for determining drought tolerance in cotton .Reduction in shoot and root growth characters under drought stress in some of the genotypes in the present study could be due to less assimilation and reduction in the uptake of nutrients byroots due low water potential under osmotic stress.

Correlation analysis

Simple phenotypiccorrelation coefficients worked out between and among the characters indicated that primary root length had positive and significant association with shoot length (0.0.3105) , root dry weight (0.3294) and root/ shoot ratio (0.3668) under controlled conditions while the same character showed either negative or non-significant correlations under drought stress conditions .Shoot length had non significant associations with all the characters studied under both conditions . The associations between shoot dry weight and root dry weight (0 .7168 and 0.5204) and root dry weight with root/ shoot ratio (0.8115 and0.5119) weresignificant and positive under controlled and moisture-stress conditions, respectively. Relative water content had non significant associations whereas root/ shoot ratio showed either non significant or negative associations with all the characters studied under both the conditions. Associations among root and shoot growth characters havesignificant effects on enduring stress conditions. Hence, primary root length, shoot dry weight, root dry weight and root/shoot ratio may be considered as important parameters of drought tolerance while selecting genotypes for improving drought tolerance ability in upland cotton. Similar observations were made by Basal *et al*(2015), Maruti and Katageri (2015), Manjunath *et al.* 2017, Reddy *et al*. (2017) Mvula *et al*. (2018) and Veesar*et al* . (2021) in cotton.

CONCLUSIONS

The genotypes *viz.,*NDLH-1935, NDLH-1943, NDLH-1949, NDLH-1976, NDLH-1979, NDLH-2019, Sivanandi and NDLH-2005-4 werefound to be superior genotypesfor inclusion in breeding programmes aimed at development of high yielding genotypes with drought tolerance ability under moisture stress conditions. Additive gene action was found to be predominant for primary root length, shoot length, shoot dry weight, root dry weight, relative water content and root to shoot ratio both under controlled and moisture stress conditions. Primary root length, shoot dry weight, root dry weight and root/shoot ratio may be considered as important parameters while selecting genotypes for drought tolerance ability in upland cotton.

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Table 1: Estimates of mean, variability, heritability (broad sense) and genetic advance as per cent of mean for drought tolerance related traits under control conditions in uplandcotton(*Gossypium hirsutum*L.)during*kharif*,2022-23

S.No.	Character	Mean	Range		Coefficient of variation		Heritability (broad sense) (%)	Genetic advance as per cent of mean
			Minimum	Maximum	PCV (%)	GCV (%)		
1	Shoot length	39.35	20.46	56.08	14.387	14.181	97.20	28.793
2	Root length	18.81	12.88	23.06	17.87	17.689	98.00	36.069
3	Root dry weight	1.44	0.8	2.01	19.823	19.597	97.70	39.91
4	Shoot dry weight	8.25	5.2	9.85	9.544	9.205	93.00	18.287
5	Root to shoot ratio	0.17	0.13	0.22	25.222	25.007	98.30	51.075
6	Relative water content	44.87	27.03	72.67	15.242	14.968	96.40	30.28

Table 2: Estimates of mean, variability, heritability (broad sense) and genetic advance as per cent of mean for drought tolerance related traits under moisture stress conditions in uplandcotton(*Gossypium hirsutum*L.)during*kharif*,2022-23

S.No.	Character	Mean	Range		Coefficient of variation		Heritability (broad sense) (%)	Genetic advance as per cent of mean
			Minimum	Maximum	PCV (%)	GCV (%)		
1	Shoot length	19.35	12.06	27.36	16.679	16.516	98.10	33.69
2	Root length	21.26	15.24	31.18	14.229	13.96	96.30	28.215
3	Root dry weight	0.49	0.3	0.3	14.156	13.95	97.10	28.319
4	Shoot dry weight	2.24	1.6	2.82	21.897	21.745	98.60	44.485
5	Root to shoot ratio	0.22	0.16	0.29	24.669	24.544	99.00	50.307
6	Relative water content	32.5	20.05	61.22	15.242	14.968	96.40	30.28

Table 3: Mean performance of drought tolerance related traits of upland cotton (*Gossypium hirsutum* L.) under control and moisture-stress conditions

S.No	Genotype	Shoot length		Root length		Root dry weight		Shoot dry weight		Root to shoot ratio		Relative water content	
		Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
1	NDLH-2008	39.98	25.78	17.78	18.40	1.24	0.91	3.27	2.03	0.17	0.20	46.67	26.80
2	NDLH-1979	41.28	27.88	12.88	16.94	1.02	0.97	3.81	2.21	0.13	0.21	40.38	36.63
3	NDLH-2019	41.08	28.94	18.56	21.94	0.80	0.92	2.62	1.80	0.14	0.16	61.70	39.13
4	NDLH-1989	39.80	23.82	15.82	16.92	1.11	0.99	2.92	2.60	0.16	0.19	45.83	36.80
5	NDLH-1866	37.42	21.24	12.94	15.24	1.21	0.80	3.12	1.85	0.13	0.16	42.22	39.09
6	NDLH-1993	34.04	20.54	13.92	20.54	1.15	0.94	3.53	1.61	0.15	0.27	37.00	27.00
7	NDLH-1931	43.72	25.40	28.64	31.18	1.81	0.93	2.42	1.75	0.19	0.25	48.05	36.84
8	NDLH-1932	34.90	18.46	19.14	20.20	1.62	0.95	4.81	2.12	0.18	0.21	50.00	30.00
9	NDLH-1935	44.70	27.06	23.06	24.38	1.10	0.92	2.20	1.62	0.16	0.23	44.68	43.64
10	NDLH-1959	39.30	25.16	19.00	21.84	1.62	0.98	2.82	1.40	0.16	0.20	38.18	36.49
11	NDLH-1969	41.60	25.04	21.82	22.04	1.24	0.91	4.13	2.32	0.15	0.17	42.00	41.00
12	NDLH-2013	37.86	19.72	17.12	18.78	1.21	1.11	3.61	2.43	0.16	0.25	50.98	27.85
13	NDLH-1976	30.24	16.78	17.14	19.44	1.24	1.15	4.82	2.62	0.14	0.25	53.40	23.23
14	NDLH-1984	20.46	21.20	19.36	21.30	1.12	1.05	2.20	1.20	0.19	0.29	31.51	29.02
15	NDLH-1992	54.68	19.10	19.10	23.10	1.21	0.93	4.00	2.40	0.13	0.18	27.03	25.83
16	NDLH-2004-3	35.98	19.82	20.98	23.00	1.43	0.97	3.60	2.10	0.18	0.22	35.09	30.74
17	NDLH-2028	32.36	18.50	17.14	24.56	1.70	0.92	3.20	1.60	0.21	0.26	43.55	37.24
18	NDLH-1971	37.50	19.58	22.50	23.64	1.41	0.96	4.60	2.20	0.16	0.21	71.93	37.06
19	NDLH-1905	29.70	19.79	21.80	23.20	1.27	0.90	3.63	2.06	0.17	0.19	33.33	24.75
20	NDLH-1943	49.48	27.20	18.72	19.06	1.83	1.01	5.12	2.41	0.20	0.21	36.90	30.15
21	NDLH-1949	45.42	20.50	20.44	23.50	2.01	1.14	5.42	2.60	0.21	0.25	34.03	29.23
22	NDLH-2004	34.70	18.80	17.00	17.32	1.71	1.02	5.63	2.50	0.18	0.21	38.20	20.05
23	NDLH-1313	37.08	20.28	18.98	21.36	1.42	0.93	5.11	2.43	0.16	0.18	36.76	35.60
24	NDLH-1928	39.56	24.06	21.30	23.66	1.25	0.92	3.80	1.81	0.16	0.23	42.86	20.05
25	NDLH-2005-4	44.08	24.18	21.00	23.40	1.83	1.12	4.45	2.82	0.22	0.22	43.01	28.24
26	NDLH-2051-1	37.18	23.00	19.92	20.80	1.65	1.00	3.21	2.20	0.18	0.23	63.16	26.88
27	NDLH-2028-2	41.20	14.50	16.78	20.02	1.81	1.11	3.60	2.16	0.21	0.28	72.67	61.22
28	Narasimha	40.08	13.98	20.60	23.06	1.61	0.91	3.22	1.82	0.20	0.23	50.00	28.80
29	Sivanandi	56.08	25.36	20.96	21.52	1.98	1.20	4.85	2.81	0.20	0.25	37.50	33.88
30	Srirama	39.16	25.44	19.94	21.58	1.64	1.00	4.62	1.81	0.19	0.28	47.31	31.72
	Mean	**39.35**	**22.04**	**19.14**	**21.40**	**1.44**	**0.99**	**2.81**	**2.11**	**0.17**	**0.22**	**44.87**	**32.50**

Range Lowest	20.46	13.98	12.88	15.24	0.80	0.80	2.20	1.20	0.13	0.16	27.03	20.05
Range Highest	56.08	28.94	28.64	31.18	2.01	1.20	5.63	2.82	0.22	0.29	72.67	61.22
SE m	0.72	0.32	0.26	0.30	0.02	0.01	0.06	0.04	0.003	0.003	0.65	0.63
C.D. 5%	2.03	0.91	0.73	0.84	0.06	0.04	0.18	0.10	0.007	0.010	1.83	1.80
CV	**3.15**	**2.53**	**2.33**	**2.39**	**2.61**	**2.47**	**2.94**	**2.91**	**2.578**	**2.653**	**2.50**	**3.38**