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

ABSTRACT:

The cotton 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, relative water content and root/shoot ratio both under controlled and moisture-stress conditions out of 30 genotypes studied under greenhouse conditions at seedling stage during kharif , 2022-23 at RARS, Nandyal. Low to moderate rangeof phenotypic coefficients variability (9.54-25.22 and 14.16-24.67),higher heritability (93.00-98.30 and 96.30-99.80) coupledwith higher genetic advance over mean (18.29-51.07 and 28.22-50.31) registered under controlledand moisture-stress conditions, respectively revealed the importance of additive gene action for all the characters studied.Primary root length had positive and significantphenotypic and genotypic associationswith shoot length (0.3105**and 0.3211**) , root dry weight (0.3294**and 0.3332**) and root/ shoot ratio (0.3688 **and 0.3753**) under controlledconditions while the same character showedeither non significant or significant negative correlations (0.0355and 0.0342, -0.0830 and -0.0702 and 0.2126** and -0.2230**) under moisture stress conditions.Shoot length showed non significant associations with all the characters studied under both theconditions. Thephenotypic associations between shoot dry weight and root dry weight (0.7168** and 0.5431**) and root dry weight with root/ shoot ratio (0.8115** and 0.5515**) were significant and positive association at phenotypic level under controlled and moisture-stress conditions, respectively. Relative water content had non significantassociations 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. Based on mean values , heritability and genetic advance for primary root length, shoot dry weight, root dry weight and root/shoot ratio under both controlled and moisture stress conditions , the above characters may be considered as important parameters 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 in Andhra Pradesh mostly grown under rainfed conditions 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 droughtare more atany one stagesof the crop growth. Therefore, development of drought-tolerant cultivars to achieve economic yield under rainfed conditions is one of the major objective in cotton improvement. Drought 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 .Severalmorphological ,ecological traits ,molecular, biochemical, physiological processes 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 based on 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 seed cotton and lint quality .The seedling, flowering and boll formation are the moistures sensitive phenol-phases in cotton. The seedling stage is highly sensitive stage of the crop to environmental conditions in cotton. The first plant organ that is exposed to moisture 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 moisture and nitrogen uptake .Variability for root growth characters *viz*;root length and root dry weight and shoot length, shoot dry weight under drought conditions for drought tolerance 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 were 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). Through the present studycultivated upland cotton (*Gossypium hirsutum L)* genotypes at the seedling stage were evaluated in green house conditions under controlled and moisture stress conditions so as to identify the characters imparting drought tolerance and also the cotton genotypes possessing drought tolerance ability.

MATERIAL AND METHODS

The studywas carriedout involving30 genotypes 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 at the green houseconditions. The type of soils are black cotton with medium available nitrogen, high in phosphorus and medium in potassium. The completely randomized design was adopted with three replications both under moisture stress (treatment) and non-moisture stress (control) conditions.Watering was given till the development of the first true leaf underboth the conditions. Moisture stress condition was created by withholding water supply to the genotypes grown under moisture stress conditions. Thereafter, need based watering was given to the genotypes grown controlled conditions . The experiment was continued 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(coefficients of variability, heritability and genetic advance were calculated as per standard methods of Burton (1952), Lush (1940)and Jhonson*et.al* (1955), respectively .

RESULTS AND DISCUSSION

Analysis of variance indicated existence of significantdifferences among the genotypes for all charactersstudied at seedling stage underbothcontrolled and moisture stress conditions. Mean, range of variability, estimates of genetic parameters (PCV, GCV, heritability and expected genetic advance as percent mean) recordedfor primary root length , shoot length,shoot dry weight , root dry weight, relative water content and root- shoot /ratiounder controlled and moisture stress 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 low 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 .

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 low mean values for this character under m 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 low 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 under both controlled and moisture stress conditions for shoot dry weight (Table 2 and 3).Moderate coefficients of variability ,higher genetic advance over mean and heritability recorded for this character under boththe conditions suggeststhat shoot dry weight is governed by additive gene actionin 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 low 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 low estimates of PCV (9.54% and %) and GCV (9.20% and %) registered under controlled and moisture-stress conditions for this character reveals that root dry weight is 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 low 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 studied 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%)recorded under both the conditions revealed that relative water content (RWC) isgoverned mostly 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).Ingeneral, 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%) registered under both controlled and moisture stress conditions , respectively for root to 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, higher 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 higher 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 , higher 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 , higher heritability and genetic advance for root to shoot ratio were reported in cotton . The present findings of low to moderate coefficients of variation coupled with higher heritability and genetic advancesuggests that all the characters studied were governed by additive gene action and are amenable for simple selection.

In the present study, NDLH-1935 ,NDLH-1943, NDLH-1949, NDLH-1976, NDLH-1979, NDLH-2019, Sivanandi and NDLH-2005-4 genotypes recorded comparatively higher mean values for primary root length, shoot length, shoot dry weight, root dry weight and relative water content both under both 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 moisture stress. Variability among cotton genotypes as registered in the present study for root growth characters by Basal et al. (2005) ,Singh et al. (2018) and Jyoti *et al*. (2021) whereas Iqbal et al. (2011), Parida *et al*. (2017) and Zou et al. (2020)for root, stem and RWC characters were reported in cotton under moisture 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 it is necessary to identify a combination of reliable parameters for 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 genotypesobserved in the present study could be due to less assimilation and reduction in the uptake of nutrients byroots because of low water potential under osmotic stress.

Correlation analysis

Character associations between and among the characters estimated indicated that primary root length had positive and significant association with shoot length (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 the conditi**) 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 cotton genotypes *viz.,*NDLH-1935, NDLH-1943, NDLH-1949, NDLH-1976, NDLH-1979, NDLH-2019, Sivanandi and NDLH-2005-4 werefound to be superior genotypesfor drought tolerance and may be used in breeding programmes aimed at development of high yielding genotypes with drought tolerance ability. 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 and thus these characters can be improved through simple selection .Based on mean , variability and genetic parameters , Primary root length, shoot dry weight, root dry weight and root/shoot ratio may be considered as important characters while selecting genotypes for drought tolerance ability in upland cotton.

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Table2: Estimates of mean, variability, heritability (broad sense) and genetic advance as per cent of mean for drought tolerance related traits under controlled 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(cm plant-1)	39.35	20.46	56.08	14.387	14.181	97.20	28.793
2	Root length(cm plant-1)	18.81	12.88	23.06	17.87	17.689	98.00	36.069
3	Root dry weight(g plant-1)	1.44	0.8	2.01	19.823	19.597	97.70	39.91
4	Shoot dry weight(g plant-1)	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

Table3: 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(cm plant-1)	19.35	12.06	27.36	16.679	16.516	98.10	33.69
2	Root length(cm plant-1)	21.26	15.24	31.18	14.229	13.96	96.30	28.215
3	Root dry weight(g plant-1)	0.49	0.3	0.3	14.156	13.95	97.10	28.319
4	Shoot dry weight(g plant-1)	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

Table1: Mean performance of drought tolerance related traits of upland cotton (*Gossypium hirsutum* L.) under controlled 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.Dat 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**