Research Article

Correlation and Path Analysis of Drought Tolerance Traits on Fruit Yield in Tomato (*Solanum Lycopersicum* L.) under Drought Stress Condition

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Abstract

Thirty-two genotypes of tomato were collected and used for analysis of correlation co-efficient and path coefficient among seventeen attributes. Correlation analysis manifested that the fruit yield per plant was significantly and positively correlated with plant height, root fresh weight, root dry weight, root length, number of flower per cluster, number of clusters per plant, individual fruit weight, number of fruits per plant, chlorophyll stability index, relative water content and proline content under water stress treatments and path analysis revealed that number of clusters per plant exerted very high direct effect upon yield per plant followed by individual fruit weight and root fresh weight. Therefore, selection based on root fresh weight, number of clusters per plant, individual fruit weight, number of fruits per plant, chlorophyll stability index, relative water content and proline content would be reliable and rewarding as they have a high direct effect on yield per plant and also possess strong positive and significant association with yield which will assist in achieving higher fruit yield coupled with tolerance to drought in tomato under drought stress conditions.

Keywords: Fruit yield, direct effect, indirect effect, drought stress, tomato yield

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Introduction

Drought is a complex, slow onset phenomenon which results from an insufficient rainfall or shifts in rainfall pattern coupled with high temperature where available water in the soil is reduced and atmospheric conditions causes a continuous loss of water by transpiration or evaporation [1]. Drought affects every living being especially people causing serious economic, social and environmental losses. A sharp rise in temperature across various parts of our country since mid-March has already raised concerns of an approaching water crisis. The government of India has declared eight states *viz.*, Kerela, Rajasthan, Madhya Pradesh, Karnataka, Uttarakhand, Uttar Pradesh, Andhra Pradesh including Tamil Nadu as drought affected states on April 6th, 2017. According to a recent report, the Ministry of Agriculture and Farmer's welfare, government of India has filed a response in the Rajya Sabha on the 29th April, 2016 that 266 districts across 11 states have officially declared drought in 2016. Desperate times as these call for desperate measures which goes out to the breeders, physiologists and farmers to work together in developing and breeding crop cultivars or hybrids that can tolerate drought and bring about higher yield simultaneously.

Tomato (*Solanum lycopersicum* L.) is one of the most consumed and economically important vegetable cultivated globally [2, 3]. It is grown for its edible fruits which can be consumed either as fresh, cooked or in processed forms. It serves as a protective food as it contains dietary nutrients and anti-oxidants, and being a readily available source of bioactive compounds (vitamins, minerals and organic acids), emphasis is laid on the genetic improvement of several physiological traits which confer drought tolerance without much compromising with the yield reduction.

Despite its importance and widespread cultivation, biotic as well as abiotic factors such as drought, heat stress, salinity and mineral imbalance are the major causes of the reduction of fruit yield in tomato [4]. Drought induced by frequent inadequate water availability in the soil accompanied with high temperature have become a major limiting factor affecting tomato fruit growth and productivity by causing a significant reduction in fruit size, increment in flower abscission, low percentage of fruit set, reducing the yield, its contributing traits and also affecting the fruit quality attributes such as an ant-oxidant, lycopene which is the red pigment in tomato that is highly sensitive to drought and heat stress [5]. In order to tackle this issue, breeding and developing of superior varieties and hybrids that are drought tolerant is effective by selection of genotypes that have very rich and wide variations in important agronomic traits.

The success of selection depends on the choice of selection criteria for improving fruit yield in which studies on correlation will provide information regarding the association among various traits and offers opportunity for selecting genotypes that have desirable traits simultaneously [6]. Adequate knowledge about the magnitude and degree of association between fruit yield and other yield attributes would assist the breeder to understand the strength of correlated traits that would help in the decision process for the simultaneous improvement of more than one trait in breeding program [7, 8].

Since yield is a combination of many traits, which are polygenic in nature, selection of yield based on multiple traits is usually better than selection based on yield alone [8], which is the simplest way of improving yield indirectly i.e. by selecting traits that are highly associated with fruit yield and having high heritability. However, correlation alone does not present enough information on the contribution of associated traits, which necessitate the cause and effect relationship between different traits [9]. Hence, indirect selection through related attributes will contribute towards improving yield. Path-coefficient analysis divides the components of direct and indirect traits and provides information on direct and indirect effects of interrelated components on yield. However, there is insufficient availability of information regarding correlation coefficient and path analysis under drought stress for tomato. Therefore, the present study is an attempt to estimate the genotypic correlation coefficient of several traits with fruit yield of tomato and to determine the direct and indirect effects of the studied traits by path analysis under drought stress treatment with the goal of determining appropriate selection criteria which will improve the efficiency of breeding programme in tomato for drought stress environment.

Materials and Methods

The field experiment was performed in the field of the College Orchard belonging to the Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The plant material consists of thirty-two tomato genotypes as mentioned in **Table 1**.The experiments were laid out in randomized complete block design (RCBD) with three replications under pot culture conditions inside a polyhouse using two treatments *viz.*, 100 per cent field capacity (well-watered) and 50 per cent field capacity (water-stressed). The field capacity was determined by estimating the amount of water applied based on plant water use by the control treatment, which was measured by weighing the pots every day. After twenty-days of sowing, the seedlings were transplanted with one seedling in each pot. The tomato seedlings were exposed to both control and drought stress treatments. All the recommended cultural and protection practices were followed from sowing until harvesting for tomato cultivation. Observations were recorded from five randomly chosen plants in each replication for both the quantitative and qualitative traits. The association between yield and its component traits were computed based on the *per se* performance of the genotypes as genotypic and phenotypic correlation coefficient [10]. The path coefficient analysis using significant genotypic correlation coefficients was carried out according to Dewey and Lu [11] Statistical analyses were conducted using a computer software programme SPSS version 16.0.

Table 1 List of thirty-two tomato genotypes used in the study

Sl. No.	Accession No.	Source	Sl. No.	Acession No.	Source
1.	EC – 167860		17.	Arka Vikas	
2.	EC – 168281		18.	Arka Ashish	
3.	EC - 168282		19.	IIHR – 709	IIHR, Bangalore
4.	EC – 168283		20.	IIHR – 2388	
5.	EC – 168290		21.	Vybhav	
6.	EC – 169966		22.	EC - 608395	
7.	EC – 170047	NBPGR, Hyderabad	23.	EC – 608406	
8.	EC – 170089		24.	EC - 608456	
9.	EC – 175957		25.	BRML	
10.	EC – 177325		26.	IIVR – L	TNAU, Coimbatore
11.	EC – 177343		27.	LE – 27	
12.	EC – 177360		28.	LE – 57	
13.	EC – 177371		29.	LE – 114	
14.	EC – 177393		30.	LE - 118	
15.	EC – 177824		31.	LE - 612	
16.	Arka Meghali		32.	PKM -1	

Results and Discussion

Correlation between fruit yield and its components

Yield is a complex trait associated with a number of component traits. It is the prime concern of the plant breeder and is the ultimate factor on which selection programmes are to be envisaged. All changes in yield must be accompanied by changes in one or more characters. However, all changes in the components need not be expressed by changes in yield which is because of varying degrees of positive and negative correlations between yield and its components and among themselves. Besides favourable association of characters with yield, an inter-association of characters would simplify the selection programme. The knowledge of the nature and magnitude of interrelationships among yield and its components is necessary for the simultaneous improvement of the characters and yield improvement [12]. An understanding of the interdependence will be useful in evolving efficient selection and breeding strategies for simultaneous improvement of all positively related characters [13], minimizing the negative effects and for maximizing the synergistic effects. Hence, it is imperative to know the association between root traits, reproductive traits and physiological traits in drought tolerance breeding programme of tomato.

In the present investigation, the result indicated a fairly strong inherent association between the characters which is presented in **Table 2**. Plant height showed positive significant association with fruit yield which is in consonance with the findings of other studies [14, 15].

Table 2 Genotypic correlation coefficients of different characters under drought stress condition

Traits	PH	DFI	RFW	RDW	RL	LA	LW	NFC	NCP	IFW	NFD	NFRP	SLW	CSI	RWC	PRO	FY
PH	1	-0.10	0.72**	0.72**	0.70**	0.03	0.24	0.44*	0.66**	0.70**	-0.30	0.63**	-0.11	0.56**	0.54**	0.55**	0.46**
DFI		1	-0.28	-0.25	-0.43	0.02	0.10	-0.33	-0.28	0.09	0.71**	-0.34	0.32	-0.28	-0.04	-0.27	-0.24
RFW			1	0.99**	1.00**	0.16	0.26	0.43*	0.62**	0.60**	-0.6**	0.60**	0.22	0.55**	0.46*	0.60**	0.42*
RDW				1	0.96**	0.12	0.24	0.46*	0.63**	0.63**	-0.5**	0.62**	0.25	0.57**	0.49**	0.62**	0.45*
RL					1	0.20	0.30	0.47*	0.62**	0.56**	-0.60	0.67**	0.20	0.56**	0.42*	0.62**	0.44*
LA						1	0.83**	-0.01	-0.18	0.26	-0.14	-0.15	0.23	0.08	-0.03	0.15	0.02
LW							1	0.20	0.18	0.47*	-0.06	0.20	1.48**	0.39*	0.38*	0.36*	0.13
NFC								1	0.62**	0.56**	-0.20	0.80**	0.09	0.56**	0.33	0.34	0.51**
NCP									1	0.46**	-0.08	0.95**	0.30	0.61**	0.55**	0.62**	0.65**
IFW										1	-0.28	0.57**	0.74**	0.66**	0.73**	0.64**	0.63**
NFD											1	-0.28	0.24	-0.182	-0.10	-0.32	-0.16
NFRP												1	0.29	0.63**	0.57**	0.61	0.73**
SLW													1	0.44*	0.74**	0.49**	-0.06
CSI														1	0.70**	0.62**	0.40
RWC															1	0.63**	0.51**
PRO																1	0.53**

* Significant at 1% level and ** significance at 5% level

PH-Plant height, DFI- Days to flower initiation, RFW-Root fresh weight, RDW- Root dry weight, RL-Root length, LA -Leaf area, LW-Leaf weight, NFC-Number of flowers/cluster, NCP-Number of clusters/plant, NFD - Number of flower drop, IFW – Individual fruit weight, NFRP-Number of fruits per plant, SLW-Specific leaf weight, CSI-Chlorophyll stability index, RWC- Relative water content, PRO – Proline and FY-Fruit yield, FC- Field capacity.

On the other hand, earlier findings [16, 17] revealed negative significant association with fruit yield per plant. Inter-correlation of plant height revealed positive significant association with number of clusters per plant, individual fruit weight, number of fruits per plant as reported by several workers [18-22]. These results indicated that as the plant height increases the number of clusters per plant, number of fruits per plant and yield per plant, would also increase which is in line with the previous findings [23]. Plant height also exerted positive significant association with root traits such as root fresh weight, root dry weight, root length and physiological traits such as chlorophyll stability index, relative water content and proline content also. Days to first flowering exhibited negative non-significant association with fruit yield. However, studies by some researchers [24-26] and revealed positive significant association of days to first flowering with yield per plant. The inter-correlation showed positive and significant association with number of flowers drop but negative and significant association with root length.

Root fresh weight, root dry weight and root length exhibited positive significant association with fruit yield which suggested that selection based on root traits would be effective for increasing yield under drought stress condition. The inter-association showed that all three root characters showed positive significant correlation with each other and also with number of flowers per cluster, number of cluster per plant, individual fruit weight, number of fruits per plant, chlorophyll stability index, relative water content and proline content.

This suggested the importance of root in achieving higher yield under water-limiting environment. This also shows that genotype with deep root development will maintain higher leaf water potential under drought stressed conditions whereas, if the genotype has high root restriction, the genotype will suffer from low leaf water potential status which clearly indicates that a well developed and deeper root system will help the plant in maintaining high plant water status [27] which will therefore result in the increase in total biomass as well as yield. Kanbar [28] revealed that maximum root length, root fresh weight, root dry weight and high relative water content are a better combination under low moisture stress conditions.

Leaf area and leaf weight showed positive but non-significant correlation with fruit yield. On the other hand, inter correlation between leaf weight with individual fruit weight, specific leaf weight, chlorophyll stability index, relative water content and proline content was positive and significant showing a strong interaction between these traits when a plant is exposed to water- deficit condition. Positive and significant association of number of flower per cluster with fruit yield per plant was observed which is similar to the earlier findings [29]. Inter association of number of flower per cluster with number of clusters per plant, individual fruit weight, number of fruits per plant and chlorophyll stability index content was positive and significant. Some studies [30, 31] also showed the association of number of flower per cluster with number of clusters per plant and number of fruits per plant. Individual fruit weight was positively and significantly correlated with fruit yield which was in propinquity with the findings of some workers [17, 26, 32, 33]. Individual fruit weight exerted positive and significant association with number of fruits per plant which is similar to the previous findings [30]. Number of fruits per plant was positively and significantly associated with fruit yield per plant which was in agreement with findings by many researchers [4, 16, 19, 34, 35]. The association of number of fruits per plant with fruit yield indicated better partitioning ability of assimilates towards fruit development during drought stress period [1].

Among the physiological traits, the correlation between chlorophyll stability index and relative water content was positive and significant and the same was observed for specific leaf weight with chlorophyll stability index, relative water content and proline content. The chlorophyll stability index was positively and significantly correlated with fruit yield. The association between yield and chlorophyll content can be seen even under limited water conditions as the increased in drought stress could be attributed to a decline in chlorophyll content, leaf area and efficiency of carbon fixation and stomatal closure [36]. Chlorophyll content, which indicates the nitrogen status of the plant, is very important during the fruit formation in tomato. This nitrogen content indicates the sink strength of plants, in which high chlorophyll content indicates high sink strength of the plants and higher sink strength would produce higher tomato yield [37].

Relative water content and proline content showed positive and significant association with fruit yield which is in agreement with the results of [38]. This author revealed that the reduction in relative water content caused a strong reduction in photosynthesis, transpiration and stomatal conductance which suggest that plants with high relative water content tend to yield higher than those with lower relative water content and most of the water is required for the development of reproductive organs since the growth of the flowers and fruit involves the rapid accumulation of dry matter and water [39].

There also exist a positive significant correlation between chlorophyll stability index with relative water content and proline content, and also relative water content with proline content. The proline content of tomato leaves was shown to be strongly related to the relative water content of leaves which confirm the findings [40] in tomato. This suggests that during drought stress period, plants having an increased proline content with higher relative water content tend to tolerate moisture deficit condition as proline accumulates under stress period renders energy for growth and survival and ultimately helps the plant to tolerate stress [41].

Table 3 Direct (diagonal) and indirect effects (off diagonal) of different characters on fruit yield under drought stress condition

Traits	PH	DFI	RFW	RDW	RL	LA	LW	NFC	NCP	IFW	NFD	NFRP	SLW	CSI	RWC	PRO	FY
PH	-0.66	0.07	-0.15	-0.10	-0.06	0.03	-0.23	-0.19	1.38	1.38	-0.04	-0.44	-0.01	-0.24	-0.01	-0.26	0.46**
DFI	0.07	-0.67	0.06	0.03	0.04	0.01	-0.09	0.15	-0.60	0.18	0.09	0.23	0.03	0.12	0.00	0.13	-0.24
RFW	-0.48	0.19	1.99	-0.13	-0.08	0.14	-0.25	-0.19	1.29	1.18	-0.08	-0.42	0.02	-0.24	-0.01	-0.28	0.42*
RDW	-0.48	0.17	-0.21	-0.14	-0.08	0.10	-0.24	-0.20	1.32	1.23	-0.07	-0.43	0.00	-0.24	-0.01	-0.29	0.45*
RL	-0.47	0.29	-0.21	-0.13	-0.08	0.17	-0.29	-0.21	1.30	1.10	-0.08	-0.43	0.02	-0.24	-0.01	-0.29	0.44*
LA	-0.02	-0.01	-0.03	-0.02	-0.02	0.83	-0.80	0.00	-0.39	0.52	-0.02	0.07	0.02	-0.04	0.00	-0.07	0.02
LW	-0.16	-0.06	-0.05	-0.03	-0.02	0.69	-0.97	-0.09	0.38	0.92	-0.01	-0.14	0.15	-0.17	-0.01	-0.17	0.13
NFC	-0.29	0.22	-0.09	-0.06	-0.04	-0.01	-0.19	-0.44	1.30	1.10	-0.03	-0.56	0.01	-0.24	-0.01	-0.16	0.51**
NCP	-0.44	-0.19	-0.13	-0.09	-0.05	-0.15	-0.18	-0.27	2.10	0.90	-0.01	-0.66	0.03	-0.26	-0.02	-0.29	0.65**
IFW	-0.47	-0.06	-0.13	-0.09	-0.05	0.22	-0.46	-0.25	0.97	1.96	-0.04	-0.40	0.08	-0.28	-0.02	-0.30	0.63**
NFD	0.20	-0.47	0.12	0.07	0.05	-0.11	0.06	0.09	-0.16	-0.56	0.13	0.20	0.02	0.08	0.00	0.15	-0.16
NFRP	-0.42	0.23	-0.13	-0.09	-0.05	-0.09	-0.19	-0.36	2.00	1.12	-0.04	0.69	0.03	-0.27	-0.02	-0.29	0.73**
SLW	0.07	-0.21	-0.05	-0.03	-0.02	0.17	-1.43	-0.04	0.64	1.44	0.03	-0.21	0.10	-0.19	-0.02	-0.23	-0.06
CSI	-0.37	0.19	-0.12	-0.08	-0.05	0.07	-0.38	-0.25	1.28	1.29	-0.02	-0.44	0.05	-0.42	-0.02	-0.29	0.4
RWC	-0.36	0.03	-0.10	-0.07	-0.04	-0.03	-0.37	-0.15	1.16	1.44	-0.01	-0.40	0.80	-0.30	-0.03	-0.30	0.51**
PRO	-0.37	0.18	-0.12	-0.08	-0.05	0.12	-0.35	-0.15	1.29	1.26	-0.04	-0.43	0.05	-0.26	-0.02	-0.47	0.53**

* Significant at 1% level and ** significance at 5% level, Residual effect = 0.179
PH-Plant height, DFI- Days to flower initiation, RFW-Root fresh weight, RDW- Root dry weight, RL-Root length, LA -Leaf area, LW-Leaf weight, NFC-Number of flowers/cluster, NCP-Number of clusters/plant, NFD - Number of flower drop, IFW – Individual fruit weight, NFRP- Number of fruits per plant, SLW-Specific leaf weight, CSI-Chlorophyll stability index, RWC- Relative water content, PRO – Proline and FY- Fruit yield, FC- Field capacity.

Path coefficient analysis

Path coefficient analysis provides a thorough understanding of contribution of various characters by partitioning the correlation coefficient into components of direct and indirect effects. As yield is influenced by many factors, selection based on correlation may be misleading because it measures only the mutual association between two variables, whereas path coefficient analysis specifically measures the relative importance of different yield components. To find out the direct and indirect effects and to measure the relative importance of causal factors, path coefficient analysis is useful, which permits critical examination of the specific forces acting to produce a given correlation.

Path-coefficient analysis at phenotypic level was carried out for 17 selected traits, with yield as dependent variable. The path-coefficient analysis for different component characters is presented in **Table 3**. Among all the sixteen characters, the number of clusters per plant, individual fruit weight and root fresh weight exerted very high direct effect upon yield per plant respectively. The number of clusters per plant exerted a high positive indirect effect through individual fruit weight, negligible indirect effect through specific leaf weight while the rest of the traits showed a negative indirect influence on fruit yield. However, the individual fruit weight influenced the yield indirectly and positive through number of clusters per plant while other traits showed negligible and negative indirect effect.

Root fresh weight exerted a very high positive direct effect on yield through traits such as number of clusters per plant and individual fruit weight which suggested that under drought stress condition, the influence of root fresh weight on yield is of high consideration. The indirect effect through days to first flowering and leaf area were low while specific leaf weight showed negligible indirect effect. As per the findings [42] in tomato, among the various traits that help in assessing drought tolerance, root traits are more reliable on account of their high correlation with drought tolerance mechanism. Leaf area showed a high direct effect on yield per plant. The positive indirect effects through number of flowers per cluster, number of fruits per plant, specific leaf weight and relative water content were negligible. This indicated that better leaf area would have resulted in better sink by the individual fruit for the photo assimilates which would increase the fruit weight resulting in increased yield. The residual effect was 0.179 suggesting that the number of characters considered for path analysis were appropriate.

Conclusion

Correlation and path coefficient studies suggested that the selection should be primarily, based on the component characters which exhibited significant positive correlation with yield and also had either direct or indirect effect on yield. This may lead to development of high yielding and drought tolerant germplasm in tomato. In the present study, results from correlation and path coefficient analyses strongly confirm the reliability of the characters *viz*., root fresh weight, number of clusters per plant, individual fruit weight, number of fruits per plant, chlorophyll stability index, relative water content and proline content as they have a high direct effect on yield per plant and also possess strong positive and significant association with yield. This suggested that below ground traits i.e. root traits has a direct relevance in improving the fruit yield of tomato under water-deficit conditions along with the improvement of several reproductive (number of clusters per plant, individual fruit weight, number of fruits per plant), physiological (chlorophyll stability index, relative water content) and biochemical (proline content) traits. Therefore, it is rewarding to emphasize the above traits in selecting a superior type for yield per plant under drought stress conditions in tomato which is in agreement with the earlier findings [31, 43, 44, 45] in tomato. The information obtained from the present findings helps in giving proper weightage to the various characters during selection or other tomato breeding programme so that the improvement of desirable traits can be achieved effectively.

Acknowledgement

I thank the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, Indian Institute of Horticulture (IIHR), Bangalore and Indian Institute of Vegetable Research (IIVR), Varanasi for providing me with the seed materials for my research programme and also the University Grants Commission for providing a fellowship during the period of research.

References

[1] K. Nahar, S.M. Ullah, Bangladesh J. Agr. Res., 2012, 37(2), 355–360.
[2] D. Goel, D., A.K. Singh, V. Yadav, S.B. Babbar, K.C. Bansal, Protoplasma, 2010, 245 (1-4), 133-141.
[3] K. Nahar, S.M. Ullah, J. Sci. Res., 2011, 3(3), 677–682.
[4] S.H. Habu, S.O. Afolayan, S.G. Ado, M.Y. Yeye, I.S. Usman, A. Usman, A. Ahmed, M.S. Jibrin, V.H. Musa, Internat. J. Scientific Res. Engineering Studies, 2016, 3 (3), 36-41.
[5] E.A. Tambussi, C. G. Bartoli, J. Beltrano, J. J. Guiamet, J. L. Araus, Physiol. Plant., 2000, 108, 398-404.
[6] M.A. Ali, N.N. Nawab, A. Abbas, M. Sajjad, Austr. J. Crop Sci., 2009, 3, 65-70.
[7] K. Sivaprasad, M.Sc. (Agri.) Thesis). University of Agricultural Science, Dharwad, India, 2008.
[8] E.L. Monamodi, D.M. Lungu, G.L. Fite, Botswana J. Agric. Appl. Sci., 2013, 9(1), 29-40.
[9] M.E. McGiffen, D.J. Pantone, J.B. Masiunas, J. Am. Soc. Hort. Sci., 1994, 119, 6-11.
[10] C.H. Goulden, Methods of statistical analysis. John Wiley and sons. Inc., New York, 1952.
[11] D.R. Dewey, K.H. Lu, Agron. J., 1959, 51, 515-518.
[12] R.V. Doku, Ghana J. Agric. Sci., 1970, 3, 145-149.
[13] G. Kalloo, Vegetable breeding, Volume I. C.R.C. Press. Inc. Boca Raton, Florida, 1988, p 105-128.
[14] M.D. Regassa, A. Mohammed, K. Bantte, Afr. J. Plant Sci. Biotechnol., 2012, 6, 45-49.
[15] C.S. Ahirwar, V Bahadur, V. Prakash, Int. J. Agri. Sci, 2013, 9(1), 172-176.
[16] N.K. Nagariya, R. Bhardwaj, N. Sharma, S. Mukherjee, Umesh, Internat. J. Farm Sci., 2015, 5 (4), 111-117.
[17] B. Thapa, A.K. Pandey, V.K. Agrawal, N. Kumar, S.K. Mahato, Internat. J. Agric. Sci., 2016, 8 (1), 934-937.
[18] D.R. Meseret, M. Ali, B. Kassahum, Afr. J. Plant Sci. Biotechnol., 2012, 6, 45-49.
[19] K. Nadeem, M. Muneeb, S.C. Ahmed, Universal J. Agric. Res., 2013, 1(4), 155-159.
[20] A.M.A. Rashwan, J. Am. Sci., 2015, 11, 45-50.
[21] M.M. Hasan, M.A. Al Bari, M.A. Hossain, Universal J. Plant Sci., 2016, 4(3), 23-34.
[22] A.A.H. El-Shaieny, Afr. J. Agric. Res., 2017, 12 (23), 1993-2001.
[23] B. M. R. Islam, N. A. Ivy, M. G. Rasul, M. Zakaria, Bangladesh J. Pl. Breed. Genet., 2010, 23(1), 13-18.
[24] A. Haydar, M.B. Ahmed, M.M. Hannan, R. Karim, M.A. Razvy, U.K. Roy, M. Salahin, Middle-East J. Scientific. Res., 2007, 2 (3-4), 139-142.
[25] S. Kumari, M.K. Sharma, Veg. Sci., 2013, 40 (1), 83-86.
[26] M. Henareh, A. Dursun, B.A. Mandoulakani, J. Faculty Agri., 2014, 45(2), 63-70.
[27] Y. Kato, A. Kamoshita, J. Yamagishi, H. Imoto, J. Abe, Plant Prod. Sci., 2007, 10, 3-13.

[28] Kanbar, M. Toorchi, H. Shashidhar, Cereal Res. Commun., 2009, 37(2), 261-268.
[29] R. Saini, A.S. Sidhu, D. Singh, A. Kumar, J. Hortl. Sci., 2013, 8(1), 21-24.
[30] O.P. Meena and V. Bahadur, Agric. Sci. Digest., 2014, 34 (4), 245 – 250.
[31] P. Kumar, V. Sathish, D. Ramesh, N.D. Bhutia, A.V.V. Koundinya, P. Hazra International J. Agri. Sci., 2016, 8(54), 2870-2873.
[32] K. Manoj, B.S. Dudi, Electron. J. Pl. Breed., 2011, 2(3), 453-460.
[33] M. Manna, A. Paul, Horti Flora Res. Spectrum, 2012, 1(2), 110-116.
[34] K.M. Meitei, G.C. Bora, S.J. Singh, A.K. Sinha, American Eurasian J. Agri. Environ. Sci, 2014, 14(10), 1105-1111.
[35] S. Pemba, N. Pandiarana, V. D. Shende, T. Seth, S. Mukherjee, A. Chattopadhyay. Electron. J. Plant Breed., 2014, 5(3), 552-562.
[36] K. O. Tembe, G. N. Chemining’wa, J. Ambuko, W. Owino, Int. J. Agron. Agri. Res., 2017, 10 (2), 78-85.
[37] M.F. Cocaliadis, R. Fernandez-Munoz, C. Pons, D. Orzaez, A. Granell. J. Exp. Bot., 2014, 65 (16), 4589–4598.
[38] W. David, Ann. Bot., 2002, 89, 871-885.
[39] T.T. Kozlowski, London Academic Press, 1972, p 91-111.
[40] W. Claussen, Plant Science, 2005, 168, 241–248.
[41] A. Jamwal, S. Puri, S. Sharma, S. Bhattacharya, NeBIO, 2012, 3 (2), 118-123.
[42] T.T. Chang, G. C. Loresto, J. C. Toole, J. L. Armenta-Soto, In: Drought resistance in crops with emphasis on rice, IRRI, Philippines, 1982, p 217-244.
[43] B. Das, M.H. Hazarika, P.K. Das, Ann. Agril. Res., 1998, 19 (1), 77-80.
[44] A. Sankari, Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, 2000.
[45] C. Indu Rani, D. Veeraragavathatham, S.Sanjutha, J. Appl. Sci. Res., 4(3), 2008, 287-295.

Publication History
Received 02nd July 2017
Revised 18th July 2017
Accepted 20th July 2017
Online 30th July 2017