Environment & Ecology 35 (2D) : 1595—1604, April—June 2017
Website: environmentandecology.com ISSN 0970-0420

Effects of Water Stress on Morphological Parameters of Finger Millet (*Eleusine coracana* L.)

Hina Khatoon, Vir Singh

Received 20 August 2016; Accepted 24 September 2016; Published online 12 October 2016

Abstract Effects of water stress on morphological parameters like plant height, leaf area, total dry matter (TDM), root/shoot ration by weight and length, grain yield and harvest index in two landraces of finger millet, i.e. black and brown finger millet, through different levels of drought (15, 30, 45 days) as compared to control were examined. Plant height (10.5 and 11.4 cm), leaf area (2.64 and 3.62 cm^2), TDM (1.76 and 1.83 g), grain yield per plant (0.43 and 0.47 g) and root-shoot ratio by length (1.923 and 1.947) in black and brown landraces of finger millet under different drought levels respectively recorded significant (p<0.05) differences, whereas root-shoot ratio by weight (0.105 and 0.135) and harvest index (24.57 and 25.81%) for the black and brown finger millet landraces respectively registered non-significant (p>0.05) difference. It was concluded that brown finger millet had higher degree of tolerance for water stress compared to black finger millet and these parameters could be useful indices for selection of drought resistant landrace of finger millet.

Keywords Finger millet (*Eleusine coracana* L.), Black and brown landraces, Drought level, Morphological parameters, Water stress.

H. Khatoon*, V. Singh
Department of Environmental Science
GB Pant University of Agriculture and Technology
Pantnagar 2631145, Uttarakhand, India
e-mail : hinakhatoon 29@gmail.com
*Correspondence

Introduction

Water stress is one of the major limitations to the agricultural productivity worldwide, particularly in warm, arid and semi-arid parts of the world [1]. The world population is expanding rapidly and is expected to be around 8 billion by the year 2025 [2]. Not only quantity but also quality of the yields is affected due to water stress. Nearly 50% of the world's population will face acute water shortage by 2030 [3]. Agriculture is highly dependent on weather and therefore, changes in global climate could have major effects on crop water needs and yields and thus on world food supplies. Water stress becomes more severe under climate change because higher temperature coupled with higher radiation receipts increases evapo-transpiration (ET) [4]. Climate change is preducted to bring about increased temperatures across the world in the range of 1.6°C to as much as 6°C by 2050. According to IPCC [5] and other studies, temperature increases

Table 1. Physicochemical parameters of soil sample.

Sl. No.	Physical and chemical characteristics of soil	
1	pH	6.08
2.	Nitrogen %	0.128 %
3.	Phosphorus (kg/ha)	21.66 kg/ha
4.	Potassium (kg/ha)	254.44 kg/ha
5.	% Carbon	1.40%
6.	% Organic matter	2.42%
7.	% moisture	30.28%
8.	Color	Light brown
9.	Texture	Clay Loam

of 1 to 2°C will result in an increase in production of some of the world's major staples with increasingly negative impacts. The world human population is expected to reach 8.0 billion by 2025 and 8.9 billion by 2050 [6]. As population will also increase, it would be pretty tough for government to serve such a large population with a piece of land which will already go barren by stresses [7].

Millets, a family of cereals, are grown in many regions throughout the world with their differential socio-economic and cultural importance [8]. Finger millet accounts for 12% of the global millets area grown in more than 25 countries of the world with Uganda, India, Nepal and China being the major producing countries [9]. Finger millet offers both nutritional and livelihood security for human beings and also feed security for diverse livestock populations in dry land regions of rural India [10]. This millet is also a good source of micro and macro-nutrients with high neutraceutical and anti-oxidant properties and is also rich in proteins, fats, crude fiber, iron, other minerals and vitamins [9]. Further, this millet has a wide base of genetic diversity [9, 11] cultivated in South Asian and African countries.

This crop is highly adaptable and stress tolerant compared to most other major crops like rice and wheat. Finger millet is inveriably cultivated in rain-fed areas exclusively dependent on rains. In recent times, water stress has emerged as a global issue challenging survival of plant growth and development [12]. Many workers [13—16] have also brought about some information based on relating issues facing finger millet in different areas of India.

Under the spell of climate change, it is more likely that rain-fed areas in agriculture would face more acute water stress than the irrigated areas. Such a scenario will be compelling for the farmers to redesign their strategies by choosing crop cultivars/varieties/ landraces that are more efficient in confronting water stress conditions. One such crop, that is finger millet, embraces many landraces with varying degree of water stress tolerance. An attempt has been made in this paper to compare two finger millet landraces predominantly grown in the mountain areas of Uttarakhand State of India.

In the light of this reasoning, therefore, efforts need to be directed towards such indigenous crops that could thrive amidst the scenario of water scarcity. The present study was carried out to determine morphological parameters in two landraces of *Eleusine coracana* under water stress at different developmental stages.

(The authors are thankful to the Department of Environmental Science, GB Pant University of Agriculture and Technology, Pantnagar, for total support under the research).

Materials and Methods

The present investigation was carried out during October to January, 2013–2014 at the glass house of the college of Basic Sciences and Humanities, GB Pant University of Agriculture and Technology, Pantnagar for 120 days. This site is situated at 29°N latitude, 79°29E longitude and an altitude of 243.84 m above the mean sea level which lies in the foot hills of the Himalayas in a narrow strip called tarai. The climate of Pantnagar is humid subtropical with severe cool and hot dry during winter and summer respectively. Average temperature recorded during the experimental period was 28±5°C.

Experimental material

The seeds of two finger millet (*Eleusine coracana* L.) landraces quite popular in the region were procured from a mid-altitude Himalayan village of Poona situated in district Almora in Uttarakhand. The two

Table 2. Effect of different levels of drought stress on plant height, leaf area and TDM in finger millet landraces at developmental stages. **Highly significant, *Significant at $p<0.05$ and ns-non-significant at $p>0.05$.

		Plant height (cm) Developmental stages		Leaf area (cm^2) Developmental stages		Total dry matter (g) Developmental stages		
Landraces	Drought levels	Vegetative stage	Reproductive stage	Vegetative stage	Reproductive stage	Vegetative stage	Reproductive stage	Maturity stage
Black	Control	45.9	49.7	9.32	12.79	2.38	3.40	4.47
Finger	15 day	37.4	41.6	6.21	8.78	1.82	2.27	3.56
Millet	30 day	18.2	22.2	3.05	5.07	1.19	1.62	2.17
	45 day	7.6	10.5	1.58	2.64	0.86	1.14	1.76
Brown	Control	47.4	51.7	11.76	15.80	2.44	3.47	4.55
Finger	15 day	39.3	43.7	8.39	11.91	1.87	2.56	3.62
Millet	30 day	21.1	24.3	4.74	6.64	1.21	1.62	2.23
	45 day	8.8	11.4	2.31	3.62	0.91	1.16	1.83
		SEm	cd at 5%	SEm	cd%	SEm	cd%	
I factor a		2.16	6.24	0.573	1.65	0.098	0.279	
II factor b		3.05	8.78	0.810	2.34	0.138	0.395	
III factor c		2.16	6.24	0.573	1.65	0.120	0.342	
a × b		4.32	12.48	1.146	3.31	0.196	0.559	
b × c		4.32	12.48	1.146	3.31	0.240	0.684	
a × c		3.05	8.78	0.810	2.34	0.170	0.484	
a × b × c		6.11	17.65	1.620	4.68	0.340	0.968	
a= Landraces		a	ns	a	•	a	ns	
b=Drought levels		b	**	b	**	b	**	
c=Developmental		c	*	c	*	c	ns	
stages		a×b	ns	a×b	ns	a×b	ns	
		b×c	ns	b×c	ns	b×c	**	
		a×c	ns	a×c	ns	a×c	ns	
		a×b×c	ns	a×b×c	ns	a×b×c	ns	

landraces of finger millet, popular amongst farmers on the basis of their grain colors as *Kala Mandua* and *Safed Mandua* were collected for the experiment. The *Safed Mandua* seeds are light brown in color. We have referred this landrace as brown finger millet and the seeds of *Kala Mandua* are black in color. We have referred this landrace as black finger millet.

Experimental details

The plants of finger millet landraces were grown in plastic pots containing clay loam soil used without applying any fertilizers. Plants were grown in glass house but not under controlled conditions. The glass house was chosen to conduct the experimental only to provide protection to plants from rainfall, fog, mist. Experiment was laid out in randomized complete block design (RCBD) with three replications for both the landraces.

Water treatment

In this experiment regular irrigation treatments were imposed after 7 days to maintain control conditions and water stress was imposed by reducing irrigation at 15, 30, 45, 60, 75, 90 and 105 days intervals in different pots. In each water treatment 200 ml water was given at the fixed period of time. It was observed that the finger millet plants were not able to survive without water after 45 days. So, only 15, 30 and 45 day water-treated plants were chosen for firther experimental observations. Various physical and chemical characteristics of the soil used for growing experimental plants in the pods are presented in Table 1.

Morphological measurements

The morphological parameters like plant height of the crop were recorded in centimeters by taking average

Table 3. Effect of different levels of drought stress on root-shoot ratio by weight and length, grain yield and harvest index in finger millet landraces at developmental stages. *Significant, ** Highly significant at $p<0.05$ and ns-non-significant at $p>0.05$.

Drought levels	Root-shoot ratio by weight Landraces		Root-shoot ratio by length Landraces		Grain yield per plant (g) Landraces		Harvest index (%) Landraces	
	Black finger millet	Brown finger millet	Black finger millet	Brown finger millet	Black finger millet	Brown finger millet	Black finger millet	Brown finger millet
Control	0.194	0.202	0.233	0.241	1.86	1.94	41.75	42.63
15 day	0.172	0.194	0.331	0.347	1.27	1.35	35.54	37.47
30 day	0.162	0.178	0.737	0.753	0.64	0.75	29.48	33.62
45 day	0.105	0.135	1.923	1.947	0.43	0.47	24.57	25.81
	SEm	CD at 5%	SEm	CD at 5%	SEm	CD at 5%	SEm	CD at 5%
I factor a	0.105	0.319	0.334	0.101	0.429	0.130	2.57	7.81
II factor b	0.148	0.451	0.472	0.143	0.608	0.184	3.64	11.05
a × b	0.210	0.638	0.668	0.202	0.859	0.260	5.15	15.63
a= Landraces	a	ns	a	**	a	**	a	ns
b=Drought levels	b	ns	b	**	b	**	b	ns
	a×b	ns	a×b	**	a×b	ns	a×b	ns

height of three randomly selected plants from soil base upto the top of the uppermost fully expanded leaf. It was measured with the help of meter scale at vegetative and reproductive stage.

Leaf area was measured with leaf length (from the ligule to leaftip) and width (midway between ligule and tip) using a meter scale. The uppermost fully expended leaf was selected for the estimation of flag leaf area. A factor of 0.75 was used to calculate the flag leaf area. It was expressed as cm^2. Leaf area was calculated following [17].

$$\text{Flag leaf area } (cm^2) = \text{Length (cm)} \times \text{Width (cm)} \times K \text{ (Factor 0.75)}$$

The total dry matter per plant was calculated at vegetative, reproductive and maturity stage by uprooting the complete plant and then placing the plant sample at 65°C in an oven for one day.

Shoot weight of plants was recorded at maturity stage by directly weighing them in electronic balance, after uprooting the complete plant from pots. Root weight was recorded at maturity stage by weighing them in electronic balance, after uprooting the plant from the pots and roots were washed by tap water; it then was dried in oven for 1 hour. Then the root: shoot ratio by weight was calculated by using following formula.

$$\text{Root: shoot ratio by weight} = \frac{\text{Weight of root (g)}}{\text{Weight of shoot (g)}}$$

The length of shoot was recorded by taking average length of three randomly selected plants from soil base to top of the plant. It was measured with the help of meter scale at maturity stage. The length of root was recorded by taking average length of three randomly selected plant roots, after uprooting the plant from the pots and roots were washed by tap water and dried in oven. Length was measured with the help of meter scale at maturity stage. Then the root: shoot ratio by length was calculated by using following formula.

$$\text{Root: shoot ratio by length} = \frac{\text{Length of root (cm)}}{\text{Length of shoot (cm)}}$$

The grain yield per plant was recorded by measuring the total weight of grains harvested from each replicate and finally expressed as g/plant. After recording economic yield (grain yield per plant) and

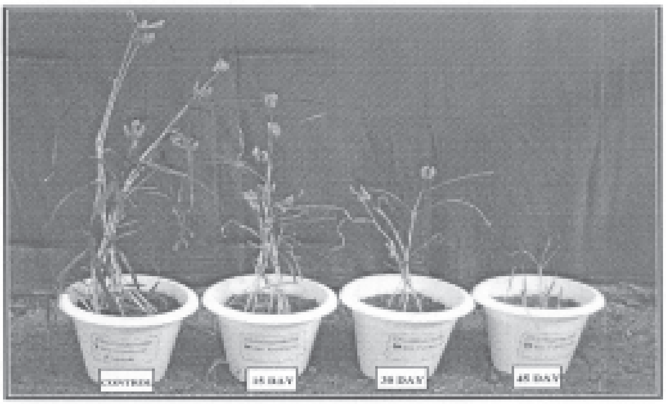

Fig. 1.1.

biological yield (TDM), the harvest index was calculated by using following formula.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

At last observations for these parameters were recorded as per the descriptors for *Eleusine coracana* [18].

Statistical analysis

The statistical analysis for the above mentioned parameters was carried out using three and two way analysis of variance (ANOVA) technique according to Gomez and Gomez [19] procedure for RCBD, through microcomputer 32 (with the help of STPR-15 and 2) at the computer center of GB Pant University of Agriculture and Technology.

Results and Discussion

Morphological parameters

Plant height

Water stress imposes adverse effect on growth characteristics of plants. The periodic observations related with plant growth (plant height) were recorded in both finger millet landraces used in drought experi-

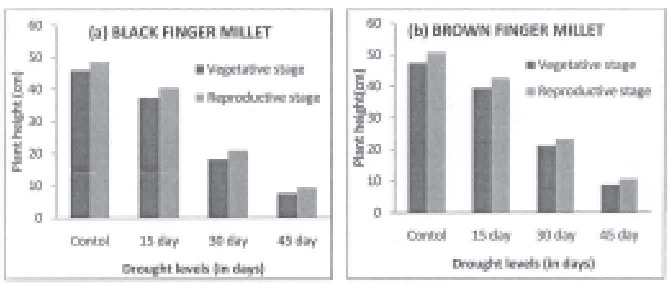

Fig. 1.2.

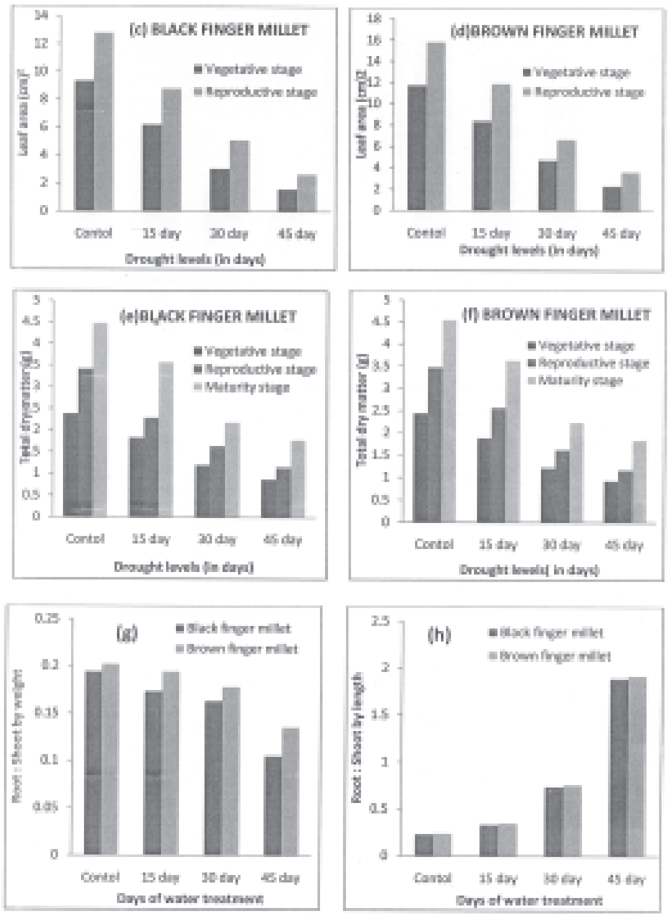

Fig. 1.1. 1.2. 1.3. Gradual decrease in plant height of finger millet due to increasing drought levels (Days of water treatment: Control, 15 day, 30 day and 45 day) from left to right.

ment. The data revealed that water stress effects between the landraces were different non-significantly (p>0.05). Length of the imposed water stress, or drought period, led to a significant (p<0.05) decrease in plant growth. Marked decrease in plant height owing to decreased availability of water was recorded in both the landraces. The minimum and maximum height acquired by black finger millet plants under water stress during developmental stages ranged between 7.6 cm (45 day) and 49.7 cm (control), while in brown finger millet it was 8.8 cm (45 day) and 51.7 cm (control) respectively (Table 2). Thus water stress affected an overall phenology of finger millet landraces. It was also found that plant height increased in all water treated plants of both the landraces at reproductive stage because when again the plants were relieved of water stress (by providing measured amount of water) at developmental stages, they attained vigor for development. So, they adapted to the drought level, hence plant height increased [20]. A decrease in plant height was observed at different drought levels in comparison to control under water stress for both the finger millet landraces (Fig. 1). Similar results were found in other studies in finger millet [21], rice [22], bean [23]. avocado [24], sunflower cultivars [25], dill (*Anethum graveolens* L.) [20].

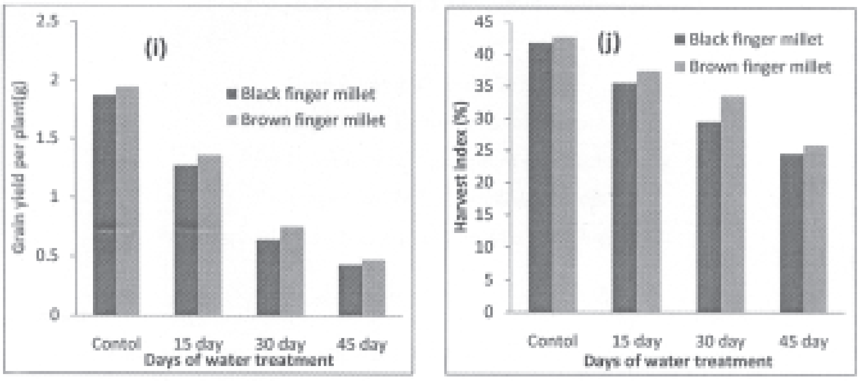

Fig. 2. Effect of different levels of drought stress on plant height of black finger millet (a) and brown finger millet (b), leaf area of black finger millet (c) and brown finger millet (d) and total dry matter of black finger millet (e) and brown finger millet (f), root/shoot ratio by weight (g), root/shoot ratio by lengt (h), grain yield per plant (i) and harvest index (j) during developmental stages.

Leaf area

Leaf area per plant is an important determinant in production and photosynthesis [26]. The leaf area varied significantly at all drought stages (water treatment intervals). The data indicated that water stress affected both the landraces significantly ($p<0.05$) at drought levels and developmental stages. The higher level of drought treatment (45 day) during vagetative stage led to decrease in leaf area in both the landraces significantly, but at reproductive stage leaf area increased due to further water irrigation (Table 2; Fig. 2). The optimal and minimum leaf area acquired by black finger millet was 12.79 at reproductive stage in control and 1.58 cm^2 at vegetative stage in case of 45 day water-treated plants (drought condition). In brown finger millet it was 15.80 at reproductive stage in control and 2.31 cm^2 at vegetative stage in case of 45 days-treated pants (drought condition) respectively. The leaf area increased in all water treated plants of both landraces at reproductive stage because when again water was given to plants at developmental stages, they were capable to resume development. So, they adapted to the drought level, hence leaf area increased. The larger leaf area was recorded in brown finger millet as compared to black finger millet. The similar observation was also reported in finger millet [21], cassava [27], rice [28], wheat [29], bean [23], olive cultivars [30]. According to a study by Rucker et al. [31] drought can reduce leaf area which can consequently decrease photosynthesis. Moreover, the number of leaves per plant, leaf size and leaf longevity can be shrunk by water stress [32].

Total dry matter

A non-significant ($p>0.05$) increase in total dry matter along developmental stages of the plants was recorded. But the decrease in dry matter with different stages of water stress (drought levels) was found to be significant ($p<0.05$). The maximum dry matter accumulation was found to be 4.55 g in brown finger millet and 4.47 g in black finger millet at maturity stage under control conditions. A downward trend in total dry matter along an increase in water stress period (15 to 45 days) as compared to control was observed. The total dry matter recorded a significant decrease with increasing levels of drought (Table 2, Fig. 2). Maqsood and Azam [4] found corroborative results in their experiment on finger millet. Similar trend in total dry matter was observed by Hussain et al. [33] in wheat, [34] in rice, [23] in bean and in maize [35].

Root/Shoot ratio by weight

The root/shoot ratio by weight decreased non-significantly (p>0.05) with different days of water treatment (drought levels). In black finger millet minimum and maximum values root-shoot ratio by weight were 0.105 (45 day) and 0.194 (control), while in brown finger millet minimum root-shoot ratio by weight was 0.135 (45 day) and maximum root: shoot ratio by weight was 0.202 (control) (Table 3, Fig. 2). The root-shoot ratio by weight was almost similar in both landraces: Brown finger millet and black finger millet. Pace et al. [36] and Vandoorne et al. [37] observed corroborative results in cotton and *Cichorium intybus* respectively.

Root/Shoot ratio
by length

A highly significant (p<0.05) effect of water stress on root-shoot ratio by length was observed with the advancement of drought severity. In the present experiment root-shoot ratio by length increased as the drought levels (water treatment intervals) increased from 15 days to 45 days in both the landraces of finger millet. Highest root-shoot ratio by length was reported in plants with 45 days water treatment interval. The ratios were 1.923 and 1.947 at maturity stage in case of black and brown finger millet respectively. The root-shoot ratio by length was narrower in control plants; 0.233 and 0.241 in black brown finger millets (Fig. 2, Table 3). When there is water scarcity a plant allocates more energy to increase length of roots so that water could be searched at deeper layers of soil [38] which appears to be the reason of significant root-shoot ratio by length with the advancement of drought severity. Similar results were observed by Makbul et al. [39] in soybean by Zhang et al. [40] in forage triticale.

Grain yield per plant

In the present experiment grain yield per plant decreased significantly (p<0.05) as the drought levels (days of water treatment) increased from 15 days to 45 days in both the landraces of finger millet. Highest reduction in grain yield was reported in plants with water treatment on 45 days' interval and it was reported 0.43 g at maturity stage in case of black finger millet and 0.47 g in case of brown finger millet. The grain yield was highest in control plants; in black finger millet it was 1.86 g and in brown finger millet 1.94 g. The grains yield during water stress was found significantly (p<0.05) higher in brown finger millet as compared to black finger millet (Table 3, Fig. 2). It is reported that the severe drought stress prolonged the maturity period with significant correlation with yield reduction [41]. Many other results were observed in finger millet [4, 21], rice [22] and wheat [42] which corroborated with this experiment.

Harvest index (%)

In both finger millet landraces, it was found that there was a non-significant decrease (p>0.05) in harvest index along the days of water treatment and a non-significant (p>0.05) increase during developmental stages. In black finger millet minimum harvest index was 24.57% (control) and maximum 41.75% (45 day) at maturity stage, while in brown finger millet minimum harvest index was 25.81% (control) and maximum 42.63% (45 day) (Table 3, Fig. 2). Decrease in harvest index was found occurring in soybean due to non-availability of adequate water which influenced both economical yield and biological yield [43]. The effect of water stress on harvest index (HI) has also been reported by Hall et al. [44]. Although economic yields decrease with the severity of drought, the biological yields also record a simultaneous decrease; therefore their was no significant decrease in harvest index percentage in this experiment. Similar findings were reported in rice [45] and wheat [46].

Conclusion

On the basis of the above-mentioned results, it could be suggested that brown finger millet has higher drought stress tolerance as compared to black finger millet. The finger millet crop in the hills appears to be highly adapted to water-stress conditions which are likely to aggravate amidst the climate change scenario. Many landraces of the crop are cultivated in the hills. However, those with better adaptation capabilities, like the brown finger millet, would be more promising under the increasing seasonal threats of water scarcity in the hill region. So, looking overall results, it is clear that these parameters could explain some of the mechanisms which indicate tolerance to water stress in finger millet landraces.

References

1. Boyer JS (1982) Plant productivity and environmental potential for increasing crop plant productivity, genotypic selection. J Sci 218 : 443—448.
2. Pinstrup-Andersen P, Pandya-Loech R, Rosegrant MW (1999) World food prospects: Critical issues for the early twenty-first century. 2020 Vision food policy report. Int Food Policy Res Inst, Washington, DC.
3. Sreenivasulu N, Varshney RK, Kavi Kishor PB, Weschke W (2004) Functional genomics for tolerance to abiotic stress in cereals. In: Gupta PK, Varshney RK (eds) Cereal genomics Kluwer Acad Publ, New York, pp 483—514.
4. Maqsood M, Azam Ali SN (2007) Effects of environmental stress on growth, radiation use efficiency and yield of finger millet. Pak J Bot 39 : 463—474.
5. IPCC (2007) Climate change 2007: Impacts, adapta tion and vulnerability. Contribution of working Group II to the Forth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland.
6. FAO (2006) World agriculture: Towards 2030/2050. Prospects for food, nutrition, agriculture and major commodity groups. Global perspective studies unit food and agriculture organization of the United Nations, Rome, Italy.
7. Hatch U, Jagtap S, Jones J, Lamb M (1999) Potential effects of climate change on agricultural water use in the southeast US. J Am Water Resour Assoc 35 : 1551—1561.
8. Dida MM, Devos KM (2006) Finger millet. In: Kole C (ed). Genome mapping and molecular breeding in plants. Vol I. Cereals and Millets. Springer-Verlag Berlin Heildelberg, pp 333—343.
9. Vetriventham M, Upadhyay HD, Dwivedi SL (2016) Finger and foxtail millets. In Singh M, Upadhyay HD (eds). Genetic and genomic resources for grain cereals improvement. Academic Press, Sen Diego, USA, pp 291—311.
10. Pradhan A, Nag SK, Patil SK (2010) Dietary management of finger millet (*Eleusine coracana* L. Gaerth) controls diabetes. Curt Sci 98 : 763—765.
11. Ramesh S, Sowmya HR, Mohan Rao A, Barathi S, Gowda A (2015) Rapid marker-based genetic diversity among released finger millet (*Eleucine coracana,* Gaertn.) cultivars with known pedigree. The Bioscan 10 : 741—746.
12. Nakayama N, Saneoka H, Moghaieb REA, Premachandra GS, Fujita K (2007) Response of growth, photosynthetic gas exchange, translocation of 13C labelled photosynthate and N accumulation in two soyabean (*Glycine max* L. Merrill) cultivars to drought stress. Int J Agric Biol 9 :669—674.
13. Kandpal RP, Rao NA (1985) Alterations in the biosynthesis of proteins and nucleic acids in finger millet (*Eleucine coracana*) seedlings during water stress and the effect of proline on protein biosynthesis. Pl Sci 40 : 73—79.
14. Bhatt D, Negi M, Sharma P, Saxena SC, Dobriyal AK, Arora S (2011) Response to drought induced oxidative stress in five finger millet varieties differeing in their geographical distribution. Physiol Mol Biol Pl 17 : 347—353.
15. Babu DV, Sudhakar P, Reddy YSK (2013) Screening of theremotolerant ragi genotypes at seedling stage using TIR technique. The Bioscan 8 : 1493—1495.
16. Babu DV, Reddy YSK, Sudhakar P (2014) Evaluation of physiological efficiency and yield potential of ragi genotypes under imposed moisture stress conditions. The Bioscan 9 : 1777—1780.
17. Clifton-Brown JC, Lewandowski I (2000) Water use efficiency and biomass partitioning of three different miscanthus genotypes with limiled and unlimited water supply. Ann Bot 86 : 191—200.
18. IBPGR-International Board for Plant Genetic Resources (1985) Descriptors for finger millet. IBPGR Secretariat. Rome, pp 20.
19. Gomez KA, Gomez AA (1984) Randomized complete block design analysis. In: Statistical procedures for agricultural research. John Willey and Sons, New York.
20. Ghassemi-Golezani K, Andalibi B, Zehtab-Salmasi S, Saba J (2008) Effect of water stress during vegetative and reproductive stages on seed yield and essential oil content of dill (*Anethum graveolens* L.). J Food Agric Environ 6 : 282—284.
21. Assefa A, Fetene M (2013) Agro-morphological, physiological and yield related performances of finger millet [*Eleusine coracana* (L.) Gaertn.] accessions evaluated for drought resistance under field condition. Asian J Agric and Rural Develop 3 : 709—720.
22. Sadeghi SM, Danesh RK (2011) Effect of water deficit role at different stages of reproductive growth on yield component of rice. World App Sci J 13 : 2021—2026.
23. Emam Y, Shekoofa A, Salehi F, Jalali AH (2010) Water stress effects on two common bean cultivars with contrasting growth habits. Am Euras J Agric and Environ Sci 9 : 495—499.
24. Chartzoulakis K, Patakas A, Kofidis G, Bosabalidis A, Nastou A (2002) Water stress affects leaf anatomy, gas exchange, water relations and growth of two avocado cultivars. Scientia Horticulturae 95 : 39—50.
25. Manivannan P, Jaleel CA, Somasundaram R, Panneerselvam R (2008) Osmoregulation and antioxidant metabolism in drought-stressed *Helianthus annuus* under triadimefon drenching. Comp Rend Biol 331 : 418—425.
26. Watson DJ (1947) Comparative physiological studies on the growth of field crops. Ann Bot 11 : 101.
27. Calatayud PA, Llovera E, Bois JF, Lamaze T (2000) Photosynthesis in drought adapted cassava. Photosynthetica 38 : 97—104.
28. Kramer PJ (1969) Plant and soil water relationships: A modern synthesis. McGraw-Hill Co, New York.
29. Singh TN, Paleg LG, Aspinall D (1973) Stress metabolism. I. Nitrogen metabolism and growth in the barley plant duringwater stress. Aust J Biol Sci 26 : 45—56.
30. Shaheen MA, Hegazi AA, Ibrahim SA (2011) Effect of water stress on vegetative characteristics and leaves chemical constituents of some transplants olive cultivars. Am Euras J Agric and Environ Sci 11 : 663—670.
31. Rucker KS, Kvien CK, Holbrook CC, Hook JE (1995)

Identification of peanut genotypes with improved drought avoidance traits. Peanut Sci 24 : 14—18.
32. Shao HB, Chu LY, Jaleel CA, Zhao CX (2008) Water-deficit stress-induced anatomical changes in higher plants. Comptes Rendus 331 : 215—225.
33. Hussain M, Kirmani MAS, Ehsan-ul-Haque (2004) Pathotypes and man guided evolution of puccinia striiformis West and sp tritici in Pakistan. Page 21, In: Abstracts, Second Regional Yellow Rust Conference for Central & West Asia and North Africa, 22–26 March 2004, Islamabad, Pakistan.
34. Sürek H, Beser N (1999) The effect of water stress on grain and total biological yield and harvest index in rice (*Oryza sativa* L.). Chataigner J (ed). Future of water management for rice in Mediterranean climate areas: Proceedings of the Workshops Montpellier : CIHEAM. Cahiers Méditerranéennes, pp 61—68.
35. Bouazzama B, Xanthoulis D, Bouaziz A, Ruelle P, Mailhol JC (2012) Effect of water stress on growth, water consumption and yield of silage maize under flood irrigation in a semi-arid climate of Tadla (Morocco). Biotech Agron Soc Environ 16 : 468—477.
36. Pace PF, Cralle HT, El-Halawany SH, Cothren JT, Senseman SA (1999) Drought-induced changes in shoot and root growth of young cotton plants. J Cotton Sci 3 : 183—187.
37. Vandoorne B, Mathieu AS, Van den Ende W, Vergauwen R, Pé rilleux C, Javaux M, Lutts S (2012) Water stress drastically reduces root growth and inulin yield in *Cichorium intybus* (var sativum) independently of photosynthesis. J Exp Bot 63 : 4359—4373.
38. Moles MC (2005) Ecology: Concepts and applications. Mc Graw Hill, New York, pp 622.
39. Makbul S, Gûler NS, Durmus N, Gûven S (2011) Changes in anatomical and physiological parameters of soybean under drought stress. Turk J Bot 35 : 369—377.
40. Zhang W, Li C, Qian C, Cao L (2009) Studies on the responses of root, shoot and drought resistance in the seedlings of forage triticale to water stress. J Agric Sci 1 : 50—57.
41. Dikshit UN, Parida D, Satpathy D (1987) Response of short duration rice cultivars to drought stress. IRRI Newsl 12 : 14—15.
42. Kilic H, Yağbasanlar T (2010) The effect of drought stress on grain yield, yield components and some quality traits of durum wheat (*Triticum turgidum* spp.*durum*) cultivars. Not Bot Hort Agrobot Cluj 38 : 164—170.
43. Pandey RK, Herrera WAT, Pendleton JW (1984) Drought response of grain legumes under irrigation gradient. 1: Yield and yield components. Agron J 76 : 549—553.
44. Hall AE, Singh BB, Ehlers JD (1997) Cowpea breeding. Plant breeding reviewas. Jules Janick (ed). John Wiley and Sons, Inc 15 : 215—274.
45. Surek H, Korkut ZK, Bilgin O (1998) Correlation and path analysis for yield and yield components in rice in a parent half diallel set of crosses. Oryza 35 : 15—18.
46. Jatoi WA, Baloch MJ, Kmumbhar MB, Khan NU, Kerio MI (2011) Effect of water stress on physiological and yield parameters at anthesis stage in elite spring wheat cultivars. Sarhad J Agric 27 : 59.