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Studies on morpho-physiological characters of different *Avena* species under stress conditions

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Seven species of oat (*Avena*) were evaluated for their relative drought tolerance under soil moisture stress. The plant height, leaf area production and biomass yield reduced under soil moisture stress. Among the species tested, minimum reduction in height was recorded in *Avena vaviloviana*, *Avena abyssinica* and *Avena sterilis* at vegetative and flowering stages. Significant decrease in leaf area production was recorded at vegetative stage, whereas at flowering stage, the decrease in leaf area production was marginal in *A. sterilis* followed by *A. abyssinica* predicting their more adaption to stress environment. The increase in specific leaf weight (SLW) of all the species of *Avena* showed increase in leaf thickness, exhibiting high water retention capacity under soil moisture stress condition which is a requisite trait for drought tolerance. Soil moisture stress imposed at vegetative and flowering stages reduced fresh biomass yield in all the species. Minimum reduction in dry biomass accumulation under stress environment at vegetative stage was recorded in *A. sterilis* followed by *A. strigosa* and *A. sativa*, exhibiting their tolerance to drought at early stages of growth. However, at flowering stage, minimum decrease in dry biomass production was recorded in *A. sterilis* (3.47%) followed by *A. marocana* (12.56%) indicating their relative drought tolerance at flowering stage of crop growth. A significant positive correlation between total leaf area and dry biomass (r^2=0.738) under stress environment indicates that dry biomass accumulation was governed by total leaf area production. *A. sterilis* accumulated maximum fresh and dry biomass under soil moisture stress with minimum reduction over the non stress environment, indicating its drought tolerance potential as compared to other genotypes tested.

Key words: *Avena,* biomass, flowering stage, leaf area, soil moisture stress, vegetative stage.

INTRODUCTION

Water is expected to be one of the most critical inputs to maintain the agricultural production in the twenty-first century. The identification of crop species and varieties capable to optimize productivity under stress environment will get more and more attention in the present and future research. Drought stress is the major causes for crop loss worldwide, reducing average yields with 50% and above (Wang et al., 2003). A number of physiological and biochemical attributes have been employed to screen crop plants for their drought tolerance (Singh et al., 1972; Jones and Rawson, 1979; Yadav and Bhatt, 1989). The genus *Avena* comprises several hexaploid, tetraploid and diploid species of which the widely cultivated hexaploid species is *Avena sativa*. Several other species have

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Table 1. Plant height and tiller production in *Avena* species under water stress and non stress at vegetative and flowering stage (data in parentheses indicates percent decrease over control).

Species	Plant height (cm)				Tiller number			
	Vegetative stage		Flowering stage		Vegetative stage		Flowering stage	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
A. strigosa	58.67	45.33 (22.73)	135.33	114.67 (15.27)	11	10 (9.09)	21	9 (57.14)
A. brevis	52.33	36.33 (30.57)	144.67	138.67 (4.33)	17	17 (0.0)	15	11 (26.67)
A. vaviloviana	46.67	43.67 (6.43)	130.33	129.67 (0.51)	18	14 (22.22)	18	13 (27.78)
A. abyssinica	50.00	42.67 (14.66)	93.33	93.00 (0.35)	12	10 (16.67)	22	15 (31.82)
A. sativa	52.33	40.00 (23.56)	120.67	114.67 (4.97)	10	10 (0.0)	20	14 (30.00)
A. marocana	34.33	25.67 (25.23)	69.67	67.33 (3.35)	40	27 (32.5)	26	19 (26.92)
A. sterilis	31.67	26.33 (16.86)	70.67	70.33 (0.481)	24	24 (0.00)	26	26 (0.0)
Mean	46.57	37.14	109.24	104.05	18.85	16	21.14	15.28
CD at 5%	T : 2.303 S : 6.410 T x S : 9.065		T : 1.836 S : 2.797 T x S : 3.955		T : 3.916 S : 4.578 T x S : 6.474		T : 0.547 S : 2.595 T x S : 3.670	

T, Treatment; S, species.

the potential to grow under wide range of edaphic and climatic variability and lend themselves for economic exploitation as a grain/pasture/cultivated forage crop. Oat is one of the major cultivated fodder crops in Indian sub continent. In a study by Pandey et al. (2012), at vegetative stage, all the seven species of *Avena* were grouped under three categories in response to the extent of moisture stress. The group one comprised of three species viz. *Avena brevis*, *Avena marocana* and *Avena sterilis* showing the maximum stress up to the 16th day water holding. The second group comprised of three species (*Avena strigosa*, *Avena vaviloviana* and *Avena abyssinica*) showing tolerance up to the 12th day and in the third group, the stress tolerance went up to 9th day with only one species (*A. sativa*). The present investigation was undertaken to evaluate the promising species of oats (*Avena*) under soil moisture stress for their relative growth and biomass production potential and also to select the drought tolerant species for further multiplication and improvement programme.

MATERIALS AND METHODS

Seed of seven oat species (*viz*. *Avena strigosa*, *Avena brevis*, *A. vaviloviana*, *A. abyssinica*, *Avena sativa*, *A. marocana* and *A. sterilis*) were sown in porcelain pots (30” x 20”) containing garden soil at pot culture experimental site of IGFRI, Jhansi (25 °N and 78 °E, 275 amsl) during 2006 to 2007. After uniform germination, three plants from each species in every pot was maintained. All species were planted in three pots. After 15 days of germination, one set of pot was kept under stress and another set of pots was watered regularly. The water stress was created with holding of irrigation at vegetative and flowering stage of crop growth. After extreme stress, plants were re-watered. The crop was grown as per recommended agronomical practices. The observations on plant height, the number of tiller, fresh and dry biomass and leaf area per plant were recorded at 35 days after germination at vegetative stage and at 50% flowering stage. For recording of morphological and growth parameters, three plants of each species were uprooted under each treatment and the data presented is the mean of three pots. The leaf area of fresh leaves was measured by using automatic portable leaf area meter (LI 3000, LICOR, USA). Specific leaf weight (SLW) was expressed as the dry weight of leaf per unit leaf area in mg/cm^2 (Yoshida et al., 1976). The specific leaf area was calculated as the leaf area/leaf dry weight and expressed in cm^2 g^{-1}. The plant samples were harvested and separated into leaves, stem and root and fresh weight of different parts were recorded. The plant samples were dried at 80°C for 48 h to record the dry weight. The dry weight of the individual portions was recorded and the sum of their weight was taken as total dry weight.

RESULTS AND DISCUSSION

Although no definite trend was observed in the reduction of plant height under soil moisture stress as imposed at vegetative and flowering stage of crop growth (Table 1), minimum reduction was recorded in *A. vaviloviana* (6.43%) followed by *A. abyssinica* (14.66%) and *A. sterilis* (16.86%) at vegetative stage. At flowering stage, minimum reduction in plant height was observed in *A. abyssinica* (0.35%) followed by *A. sterilis* (0.48%). The primary effect of soil moisture stress is to decrease water content and water potential in the plant cells. The decrease in water potential affects water movement into growing regions and hence cell elongation rate decreases (Bradford and Hsiao, 1982). It is also reported that internal moisture stress in plant causes reduction in cell division and cell elongation which causes stunted plant growth (Steinberg et al., 1990). At vegetative stage, there was absolutely no effect of the moisture stress on tiller production in *A. sterilis, A. brevis* and *A. sativa.* However, at flowering stage, the stress had no effect on

Table 2. Effect of soil moisture stress on leaf area (cm^2/plant) in *Avena* species at vegetative and flowering stage (data in parentheses indicates percent decrease over control).

Species	Vegetative stage		Flowering stage	
	Control	Stress	Control	Stress
A. strigosa	162.52	80.10 (50.71)	1825.48	1070.03 (41.38)
A. brevis	200.84	58.57 (70.84)	466.13	321.34 (31.06)
A. vaviloviana	248.70	119.16 (52.08)	1467.41	512.74 (65.06)
A. abyssinica	391.46	80.91 (79.33)	747.30	615.98 (17.57)
A. sativa	131.28	63.26 (51.81)	2215.62	1182.98 (46.61)
A. marocana	390.41	105.73 (72.92)	1882.97	721.11 (61.70)
A. sterilis	252.40	96.20 (61.88)	2361.89	2348.89 (0.55)
Mean	253.94	86.27 (66.02)	1566.69	967.58 (38.24)
CD at 5%	T : 21.35 S : 14.56 T x S : 31.21		T : 19.34 S : 16.43 T x S : 29.12	

tiller production of *A. marocana* and *A. sterilis* (Table 1). Hence, *A. sterilis* showed tolerance to moisture stress with respect to growth in plant height and tiller production.

Total leaf area production was recorded at the time of harvest at vegetative and flowering stage of the crop growth and presented on per plant basis (Table 2). On average of all the species, the leaf area production decreased to 66 and 38% at vegetative and flowering stage, respectively. However, the percentage of decrease in leaf area varied from species to species. The minimum decrease in leaf area was recorded in *A. sterilis* (0.55%) followed by *A. abyssinica* (17.57%) as recorded at 50% flowering stage. Leaf extension has been shown to be very sensitive to water stress (Boyer and Younis, 1984). Garg et al. (2001) also found that increasing water stress progressively decreased water potential and leaf area production in moth bean genotypes. The specific leaf area (SLA) decreased under water stress in all the species (Table 3). At vegetative stage, minimum decrease in SLA was recorded in *A. sterilis* (5.8%) followed by *A. brevis* (9.67%) and *A. strigosa* (12.29%) over the control. However, at flowering stage, minimum decrease was recorded in *A. strigosa* (5.24%) followed by *A. sterilis* (13.36%) over the control. The SLW showed an increasing trend under moisture stress environment over the well watered plant. The increase in SLW indicates increase in leaf thickness, showing high water retention capacity under moisture stress situation which is a requisite parameter under stress environment. On the other hand, the decrease in SLA indicated the slow leaf expansion with less leaf surface area to control transpiration and evaporation from the leaf surface during the moisture stress period. *A. sterilis* showed the drought tolerant characters in terms of leaf expansion and the specific leaf weight may be because of the fundamental differences in species characteristics like thicker leaves than other species by which the water retention capacity of the leaf increased to combat the moisture stress environment.

Total fresh and dry biomass production as per plant basis was recorded at vegetative and flowering stages (Table 4). Water stress imposed at vegetative stage reduced total fresh biomass in all the species of *Avena* and the reduction was 50% or even more than the control but at flowering stage, the reduction ranged from 25.21 (*A. abyssinica*) to 67.52% (*A. strigosa*). The minimum decrease in fresh biomass production at vegetative stage was recorded in *A. sterilis* and *A. sativa* followed by *A. strigosa* over the non stress. However, at flowering stage, minimum decrease in the fresh biomass production was in *A. abyssinica* followed by *A. marocana* and *A. sterilis* over the control. All the species showed significant differences in dry biomass production under stress and non stress environment (Table 4). The decrease in dry biomass accumulation under soil moisture stress varied from species to species.

In vegetative stage, minimum decrease in dry biomass production was recorded in *A. sterilis* (30.38%) whereas *A. strigosa* (34.58%) and *A. sativa* (35.87%) were at par. However, at flowering stage, minimum decrease in dry biomass production was recorded in *A. sterilis* (3.47%) followed by *A. marocana* (12.56%) over the plants grown under well watered environment as compared to other species tested. Minimum reduction in dry matter accumulation in *A. sterilis* indicates its drought tolerance potential. It has been reported that in restricted water supply, high moisture stress caused rapid respiration (Kramer and Kozlowski, 1960) which lead to reduction in dry matter accumulation of plant components (Steinberg et al., 1990). There was a significant positive correlation between total leaf area production and dry biomass (r^2 = 0.738) at flowering stage (Figure 1). It seems that biomass accumulation is completely governed by leaf area production. Partitioning of biomass in root, stem and

Table 3. Change in specific leaf area (SLA) and specific leaf weight (SLW) under water stress in *Avena* species at vegetative and flowering stage.

Species	SLA (cm^2/g) (Data in parentheses: percentage decrease over control)				SLW (mg/cm^2) (Data in parentheses: percentage increase over control)			
	Vegetative stage		Flowering stage		Vegetative stage		Flowering stage	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
A. strigosa	171.58	150.49 (12.292)	225.59	213.76 (5.244)	5.828	6.645 (12.295)	4.433	4.678 (5.419)
A. brevis	151.62	136.96 (9.669)	182.82	137.56 (24.757)	6.595	7.302 (9.682)	5.470	7.270 (24.759)
A. vaviloviana	219.31	183.43 (16.360)	254.17	180.06 (29.158)	4.560	5.452 (16.361)	3.934	5.554 (29.168)
A. abyssinica	246.31	188.33 (23.539)	222.65	155.99 (29.939)	4.060	5.310 (23.540)	4.491	6.411 (29.949)
A. sativa	127.67	103.89 (18.626)	226.86	162.95 (28.172)	7.833	9.626 (18.627)	4.408	6.137 (28.173)
A. marocana	231.96	171.01 (26.276)	286.23	146.84 (48.699)	4.311	5.848 (26.282)	3.494	6.810 (48.693)
A. sterilis	151.53	142.74 (5.801)	164.41	142.45 (13.357)	6.599	7.006 (5.809)	6.082	7.020 (13.362)
Mean	185.71	153.83 (16.080)	223.25	162.80 (25.618)	5.684	6.741 (16.085)	4.616	6.268 (25.646)
CD at 5%	T : 7.923 S : 44.149 T x S : 62.436		T : 27.021 S : 48.305 T x S : 68.314		T : 0.152 S : 1.053 T x S : 1.490		T : 0.653 S : 1.360 T x S : 1.924	

Table 4. Effect of soil moisture stress on fresh and dry biomass production in *Avena* species at vegetative and flowering stage (data in parentheses indicates percentage decrease over control).

Species	Fresh weight (g/plant)				Dry weight (g/plant)			
	Vegetative stage		Flowering stage		Vegetative stage		Flowering stage	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
A. strigosa	22.41	11.00 (50.91)	147.32	47.85 (67.52)	4.51	2.95 (34.58)	41.31	22.85 (47.81)
A. brevis	31.63	11.48 (63.70)	80.12	49.96 (37.64)	7.29	2.93 (59.80)	23.85	17.90 (24.95)
A. vaviloviana	22.44	9.42 (58.02)	89.88	36.31 (59.60)	4.32	2.33 (46.06)	22.29	14.85 (33.38)
A. abyssinica	22.72	8.25 (63.69)	55.65	41.62 (25.21)	4.73	2.39 (49.47)	17.79	11.82 (33.56)
A. sativa	21.06	10.71 (49.15)	163.22	80.45 (50.71)	4.21	2.70 (35.87)	38.31	28.22 (26.34)
A. marocana	23.67	8.09 (65.82)	72.27	50.85 (29.63)	4.33	2.37 (45.27)	25.08	21.93 (12.56)
A. sterilis	21.41	10.50 (49.00)	185.30	123.27 (33.27)	4.18	2.91 (30.38)	44.91	43.35 (3.47)
Mean	23.62	9.92	113.39	62.90	4.79	2.65	30.86	24.021
CD at 5%	T : 3.463 S : 5.598 T x S : 7.916		T : 11.285 S : 20.148 T x S : 28.493		T : 0.678 S : 1.301 T x S : 1.840		T : 4.365 S : 6.424 T x S : 9.085	

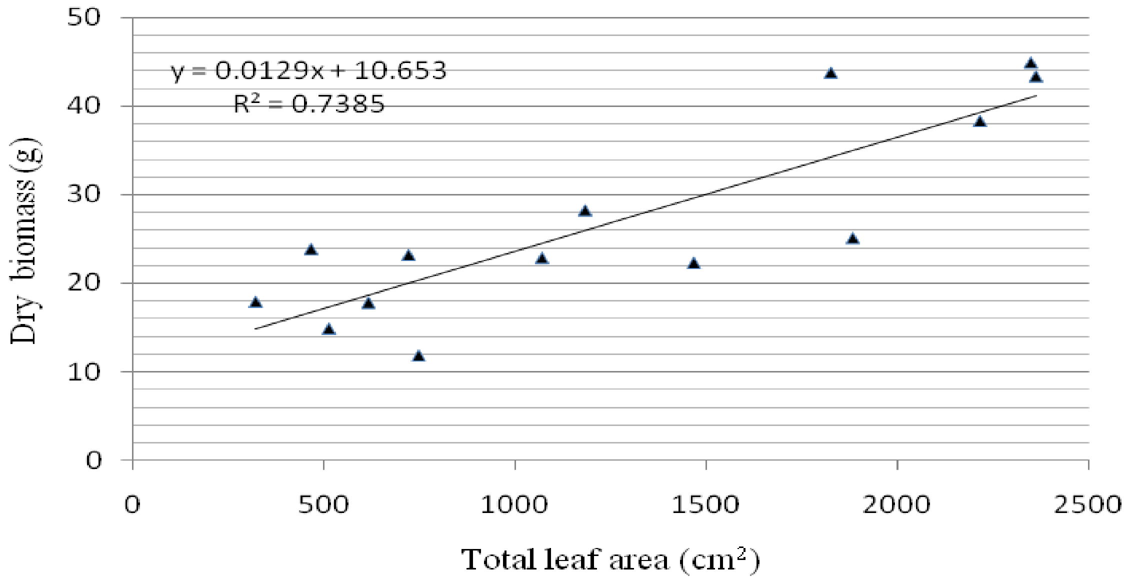

Figure 1. Linear relationship between dry biomass yield vs. total leaf area.

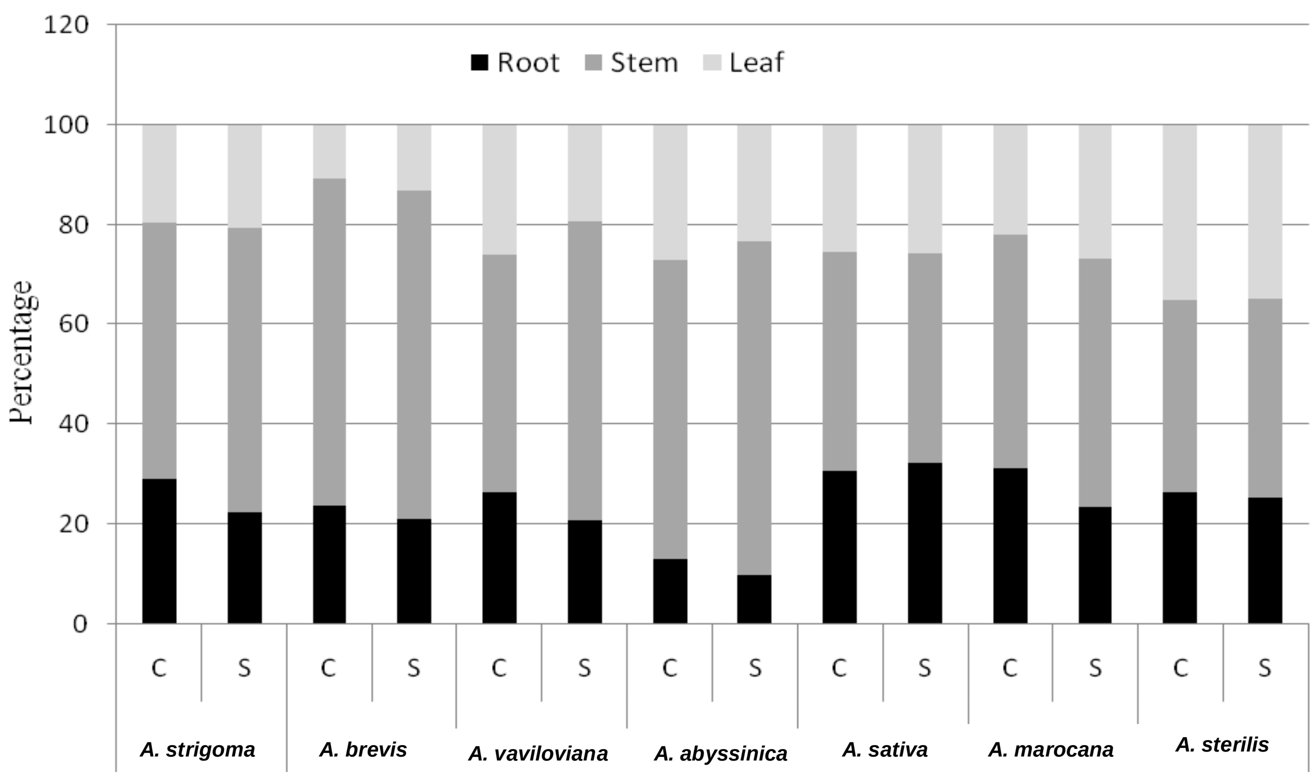

Figure 2. Partitioning of biomass in root, stem and leaves of different species of oat under control (C) and stress (S) environment at 50% flowering stage.

leaves under stress and non stress environment at 50% flowering stage was calculated and presented in Figure 2. Maximum biomass partitioning was observed in stem in all the species under soil moisture stress. No definite pattern was observed in biomass partitioning in leaves and roots but in *A. sterilis*, partitioning of biomass was almost equal in all the parts under soil moisture stress and non stress indicating that there was no adverse effect of drought on the allocation of biomass in different parts even under stress environment.

Thus, on the basis of the above results, it is concluded that *A. sterilis* maintained leaf area production under stress environment leading to the higher biomass accumulations which indicates its suitability for drought situations and can be further taken for improvement programme for the development of drought resistant varieties in oats.

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REFERENCES

Boyer J, Younis H (1984). Molecular aspects of photosynthesis at low leaf water potentials. In: Sybesma C (ed.) Advances in Photosynthesis Research Martinus - Nijhoff. Dr. W. Junk Publishers, The Hague, IV:359-364.

Bradford KJ, Hsiao TC (1982). Physiological responses to moderate water stress. In "Physiological Plant Ecology II. Water Relations and Carbon Assimilation: (*Eds* O.L. Lange, P.S. Nobel, C.B. Osmond and H. Ziegler). Encyclopedia of Plant Physiology, NS, 1213:263-324 (Springer-Verlog: Berlin).

Garg BK, Kathju S, Burman U (2001). Influence of water stress on water relations, Photosynthetic Parameters and nitrogen metabolism of moth bean genotypes. Biol. Plant. 44:289-292.

Jones MM, Rawson HM (1979). Influence of role of development of leaf water deficits upon photosynthesis, leaf conductance, water use efficiency and osmotic potential in sorghum. Physiol. Plant. 45:103-111.

Kramer Paul J, Kozlowski Theodore T (1960). Physiology of Trees. McGraw-Hill Book Company. New York.

Pandey H C, Baig M J, Bhatt R K (2012). Effect of moisture stress on chlorophyll accumulation and nitrate reductase activity at vegetative and flowering stage in *Avena* species. Agric. Sci. Res. J. 2(3):111-118.

Singh TN, Aspinal D, Paleg LG (1972). Proline accumulation and varietal adaptability to drought in barley. A potential metabolic measure of drought resistance. Nature. 236:185-190.

Steinberg SL, Jr. Miller JC, McFarland M.J (1990). Dry matter partitioning and vegetative growth of young peach trees under water stress. Aust. J Plant Physiol. 17:23-26.

Wang W, Vinocur B, Altman A (2003). Plant responses to drought, salinity and extreme temperature: towards genetic engineering for stress tolerance. Planta. 218:1-14.

Yadav RBR, Bhatt RK (1989). Physiological evaluation of drought resistance in oats. J. Agron. Crop Sci. 163:138-140.

Yoshida S, Formo DA, Cock JH, Gomez K.A (1976). Laboratory manual for physiological studies of rice (3rd Ed). IRRI, Los Banos, Phillipines. p. 83.