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Mitigation of Drought through Physiological Modification in Ragi under Rainfed Conditions

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A B S T R A C T

The field experiment were conducted during September 2010 to December 2010 at the Regional Research Station, Tamil Nadu Agricultural University, Paiyur to assess the effect of drought stress on growth and productivity of rainfed ragi and to identify suitable management practices through physiological modifications to mitigate the drought effect. The experiment was laid out in factorial randomized block design with three replications. The treatments comprised of four chemicals *viz.*, TNAU Nutrient Mix (1.00 %), TNAU Nutrient Mix (1.50 %), Brassino steroids (0.1 ppm) and Cycocel (50 ppm) along with one untreated control in three ragi varieties- Paiyur 2, L-5 and GPU 28. The foliar spray method was used to spray nutrients and growth hormones at flowering stage for suitable management for stress alleviation. The effect of treatments was assessed by periodical observations on the morphological characters, dry matter partitioning, growth rates during critical stages and ultimately the yield. In this experiment, a significant difference was observed in plant height, number of tillers per plant, number of ear heads per plant and dry matter production per plant. Except Cycocel (50 ppm), all the other treatments showed positive influence in increasing the morphology, growth and development of the plant. Among the treatments, TNAU nutrient mix (1.5%) with a mean yield of 2078 kg/ha and a yield advantage of 22.1 % over control was found to be best treatment in alleviating the drought stress. Application of TNAU nutrient mix (1.0%) and Brassino steroids (0.1 ppm) were also found to be effective as these treatments were on par with the best treatment. The overall performance of Paiyur 2 was the best among the three varieties tested and confirms its suitability for all seasons.

Introduction

Millets are major food and feed sources in the developing world especially in the semiarid tropical regions of Africa and Asia. The most widely cultivated millets are pearl millet (*Pennisetum glaucum* (L.) R. Br.), finger millet (*Eleusine coracana* (L.) Gaertn), foxtail millet (*Setaria italica* (L.) P. Beauvois), Japanese barnyard millet (*Echinochloa esculneta* (A. Braun) H. Scholz), Indian Barnyard millet (*Echinochloa frumetacea* Link), kodo millet (*Paspalum scrobiculatum* L.), little millet (*Panicum sumatrense* Roth.ex.Roem. and Schult.), proso millet (*Panicum miliaceum* L.), tef (*Eragrostis tef* (Zucc.) Trotter) and fonio or acha (*Digitaria exilis* (Kippist) Stapf and *D. iburua* Stapf). Millets are resilient to extreme environmental conditions especially to inadequate moisture and are rich in nutrients. Millets are also considered to be a healthy food, mainly due to the lack of gluten (a substance that causes coeliac disease) in their grain. Despite these agronomic, nutritional and health-related benefits, millets produce very low yield compared to major cereals such as wheat and rice. This extremely low productivity is related to the challenging environment in which they are extensively cultivated and to the little research investment in these crops (Martel, 1997).

However, the contribution of Indiato global millet production is significant. In 2013, India produced over 30% of the global millet yield from only 25% of the global millet area, mainly due to improved productivity. In the same year, while the mean seed yield of millet in India was 1.2 t ha–1, it was only 0.8 t ha^{-1} for other countries. Millets are resilient to the extreme climatic and soil conditions prevalent in the semi-arid Regions Similar to maize and sorghum, finger millets possess a C4 photosynthesis system (Brutnell, 2010); hence, they prevent photorespiration and, as a consequence, efficiently utilize the scarce moisture present in the semi-arid regions. Since C4 plants are able to close their stomata for long periods, they can significantly reduce moisture loss through the leaves. In addition to its tolerance to drought, tef is tolerant to waterlogging especially in poorly drained soils where other crops such as maize and wheat could not survive.

Biotic stresses such as insect pests and diseases are a cause for substantial yield losses to diverse types of millets. However, abiotic stresses are the biggest contributor to losses every year. Although, in general, millets perform better than cereals such as wheat and rice in semi-arid environments, these challenging climatic and soil conditions are by no means an optimum environment for millet cultivation. In semi-arid and arid environments where finger millet and other millets are the dominant crops, drought or inadequate moisture is the major abiotic stress affecting productivity (Warner, 1988). With a view to elicit information on these aspects, field and laboratory investigations were undertaken to meet out the objectives of to assess the effect of drought on growth and productivity and to identify the suitable management practices through physiological modification to mitigate the drought stress.

Materials and Methods

The field experiment was conducted at the Regional Research Station, Tamil Nadu Agricultural University, Paiyur. The experiment was laid out in factorial randomized block design with three replications (Table 1). The treatments comprised of four chemicals *viz.*, TNAU Nutrient Mix (1.00 %), TNAU Nutrient Mix (1.50 %), Brassinosteroids (0.1 ppm) and Cycocel (50 ppm) along with one untreated control in three ragi varieties- Paiyur 2, L-5 and GPU 28 with the spacing of 30cm x 10cm (Table 2). The Foliar spray using Knapsack sprayer fitted with hollow cone nozzle @ 500 lit ha^{-1} of spray volume during flower initiation stage.

The morphological and yield observations were recorded at 70 DAS and at Harvest stages viz., plant height, Root length, Number of tillers, Total dry matter production, Number of ear heads and grain yield. The physiological growth attributes character of Crop Growth Rate and Relative Growth Rate was recorded between 70 DAS and Harvest stage.

Results and Discussion

Morphological observations were recorded on the day of imposition of treatments (70 DAS) and at harvest. The observations recorded are given in tables 3–7.

Significant difference was observed in plant height between the varieties at both the stages of observation (70 DAS and harvest). The variety GPU 28 recorded the maximum plant height of 111.9 cm at 70 DAS and 118.5 cm at harvest respectively and was significantly superior to Paiyur 2 and L 5. Though numerical differences were observed due to treatment effect, it was not significant at both the stages of observation. There was no significant difference between varieties, treatments and the interaction for root length (70 DAS) and number of ear heads per hill (70 DAS and at harvest).

There was significant difference for total dry matter production among varieties at both the stages of observation. The variety GPU 28 recorded the maximum dry weight of 36.30 g/plant at 70 DAS and 90.59 g/plant at harvest and was significantly superior to Paiyur 2 at both the stages of observation and on par with L 5 at harvest. Though there was no significant difference among the treatments at 70 DAS, the effect of treatment was significant at harvest. The treatment, TNAU nutrient mix (1.5%) recorded the highest mean total dry matter of 91.21 g/plant and was on par with TNAU nutrient mix (1.0%) and Brassino steroids (0.1ppm). Cao and Chen (1995), who reported that, BR-induced expansion is accompanied by proton extrusion and hyperpolarization of cell membranes and these effects have also been observed in the asymmetric expansion of the joint pulvini of rice laminae and it was accelerate the growth cycle in rice plant. Cycocel (50 ppm) recorded the least dry weight of 74.15 g/plant and was on par with the control (79.18 g/plant).

Table.1 Crop wise details of the field experiment conducted

Details	Crop I
Plot size	3.0 m x 3.0 m
Date of sowing	13.09.2010
Date of application of treatments	22.11.2010
Date of harvest	24.12.2010
Rainfall (mm)	450.6
No. of rainy days	31

Table.2 Nutrient composition of TNAU nutrient mixture (mg L^{-1})

Chemical	**TNAU Nutrient Mix (1.0 %)**	**TNAU Nutrient Mix (1.5 %)**
Ferrous sulphate	3000	4500
Zinc sulphate	3000	4500
Potassium nitrate	2000	3000
Magnesium sulphate	750	1125
Borax	750	1125
Citric acid	250	375
Salicylic acid	150	225
Giberellic acid	100	150
Total	**10000**	**15000**

Table.3 Physiological modification on plant height (cm) and root length (cm) in Ragi under rainfed conditions at 70 DAS

Treatments	Plant height (cm)				Root length (cm)			
	Paiyur 2	L 5	GPU 28	Mean	Paiyur 2	L 5	GPU 28	Mean
TNAU nut. mix (1.0%)	82.3	89.0	107.7	**93.0**	21.0	23.0	19.3	**21.1**
TNAU nut. mix (1.5%)	92.7	97.3	105.3	**98.4**	22.0	20.3	22.3	**21.5**
Brassinosteroids(0.1 ppm)	87.0	91.7	116.3	**98.3**	24.3	22.7	22.0	**23.0**
Cycocel (50 ppm)	84.0	94.3	117.7	**98.7**	23.7	20.7	19.3	**21.2**
Control	91.0	94.0	112.3	**99.1**	22.7	22.0	22.0	**22.2**
Mean	**87.4**	**93.3**	**111.9**		**22.7**	**21.7**	**21.0**	
	V	T	V x T		V	T	V x T	
SED	2.96	3.82	13.57		1.54	1.99	3.45	
CD(0.05)	6.07	NS	NS		NS	NS	NS	

Table.4 Physiological modification on number of tillers hill^{-1} and total dry matter g plant^{-1} in ragi under rainfed conditions at 70 DAS

Treatments	No. of tillers per hill				Total dry matter (g) per plant			
	Paiyur 2	L 5	GPU 28	Mean	Paiyur 2	L 5	GPU 28	Mean
TNAU nut. mix (1.0%)	2.23	2.27	2.33	**2.27**	18.12	22.72	35.93	**25.59**
TNAU nut. mix (1.5%)	2.23	2.13	2.47	**2.27**	19.41	22.32	38.49	**26.74**
Brassinosteroids(0.1 ppm)	2.10	2.23	2.67	**2.33**	17.37	21.58	35.87	**24.94**
Cycocel (50 ppm)	2.43	2.13	2.50	**2.35**	17.88	24.67	35.49	**26.01**
Control	2.33	2.27	2.20	**2.26**	19.67	23.69	35.70	**26.35**
Mean	**2.26**	**2.20**	**2.43**		**18.49**	**23.00**	**36.30**	
	V	T	V x T		V	T	V x T	
SED	0.18	0.23	0.40		2.05	2.65	4.60	
CD(0.05)	NS	NS	NS		4.21	NS	NS	

Table.5 Physiological modification on plant height (cm) and root length (cm) in ragi under rainfed conditions at harvest stage

Treatments	Plant height (cm)				No. of ear heads per hill			
	Paiyur 2	L 5	GPU 28	Mean	Paiyur 2	L 5	GPU 28	Mean
TNAU nut. mix (1.0%)	96.7	97.3	121.3	**105.1**	9.3	5.7	7.0	**7.3**
TNAU nut. mix (1.5%)	97.7	101.3	121.7	**106.9**	7.3	7.3	7.7	**7.4**
Brassinosteroids(0.1 ppm)	99.0	98.7	123.3	**107.0**	8.3	5.3	7.3	**7.0**
Cycocel (50 ppm)	91.3	97.7	112.7	**100.6**	5.0	4.3	6.3	**5.2**
Control	93.7	99.3	113.3	**102.1**	6.0	4.7	7.3	**6.0**
Mean	**95.8**	**98.9**	**118.5**		**7.2**	**5.5**	**7.1**	
	V	T	V x T		V	T	V x T	
SED	2.38	3.07	5.32		1.09	1.41	2.45	
CD(0.05)	4.87	NS	NS		NS	NS	NS	

Table.6 Physiological modification on total dry matter g plant^{-1} and grain yield (kg ha^{-1}) in Ragi under rainfed conditions at harvest stage

Treatments	Total dry matter (g/plant)				Grain Yield (kg/ ha)			
	Paiyur 2	L 5	GPU 28	Mean	Paiyur 2	L 5	GPU 28	Mean
TNAU nut. mix (1.0%)	76.86	96.43	91.23	**88.11**	2502	2502	2520	**2508**
TNAU nut. mix (1.5%)	78.56	96.55	98.51	**91.21**	2442	2669	2873	**2661**
Brassino steroids(0.1 ppm)	72.93	94.64	89.55	**85.74**	2273	2487	2527	**2429**
Cycocel (50 ppm)	58.07	78.07	86.33	**74.15**	1856	2331	2207	**2131**
Control	68.40	81.81	87.33	**79.18**	2036	2211	2456	**2234**
Mean	**70.93**	**89.50**	**90.59**		**2222**	**2440**	**2516**	
	V	T	V x T		V	T	V x T	
SED	4.36	5.64	9.76		151	195	339	
CD(0.05)	8.93	11.55	NS		NS	401	NS	

Table.7 Physiological modification on crop growth rate and relative growth rate in ragi under rainfed conditions at harvest stage

Treatments	Crop Growth Rate (g/m^2/day)				Relative Growth Rate (mg/g/day)			
	Paiyur 2	L 5	GPU 28	Mean	Paiyur 2	L 5	GPU 28	Mean
TNAU nut. mix (1.0%)	59.33	74.45	55.86	**63.22**	19.02	19.02	12.26	**16.77**
TNAU nut. mix (1.5%)	59.75	74.98	60.63	**65.12**	18.40	19.27	12.37	**16.88**
Brassino steroids(0.1 ppm)	56.12	72.79	54.22	**61.04**	18.88	18.86	12.04	**16.59**
Cycocel (50 ppm)	40.60	53.94	51.35	**48.63**	15.50	15.16	11.70	**14.12**
Control	49.22	58.71	52.15	**53.36**	16.40	16.31	11.77	**14.83**
Mean	**53.00**	**66.97**	**54.84**		**17.64**	**17.73**	**12.03**	
	V	T	V x T		V	T	V x T	
SED	1.60	2.06	3.57		0.24	0.31	0.55	
CD(0.05)	3.27	4.22	7.31		0.50	0.65	1.12	

Significant difference was recorded between treatments for grain yield. The maximum mean grain yield of 2661 kg/ ha was recorded in TNAU nutrient mix (1.5%) treatment followed by TNAU nutrient mix (1.0%) with 2508 kg/ha and Brassino steroids (0.1ppm) with 2429 kg/ha and these treatments were on par with each other. Cycocel (50 ppm) recorded the lowest yield 2131kg/ ha and was on par with the control (2234 kg/ha). Among the varieties, GPU 28 recorded the mean grain yield of 2516 kg/ha followed by L 5 with 2440 kg/ ha and Paiyur 2 with 2222 kg/ha. All the three varieties were on par with each other. The interaction effect for variety and treatment was insignificant.

Growth parameters *viz.*, Crop Growth Rate (CGR) and Relative Growth Rate (RGR) from flowering to maturity were calculated based on the dry weight recorded at both the stages. Significant difference was observed for Crop Growth Rate and Relative Growth Rate for varieties and treatments. Among the three varieties, L- 5 recorded the maximum CGR of 66.97 g/m^2/day and RGR of 17.73 mg/g/day was significantly superior to Paiyur 2 and GPU 28 for CGR and was on par with Paiyur

2 for RGR. TNAU nutrient mix (1.5%) recorded the maximum CGR (65.12 $g/m^2/day$) and RGR (16.88 mg/g/day) and was on par with TNAU nutrient mix (1.0%) and Brassino steroids (0.1 ppm).

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