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Effect of stress ameliorants on pearl millet (*Pennisetum glaucum* L.) growth and productivity under different moisture regimes

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Abstract

A field experiment was conducted in Tamil Nadu Agricultural University located in Coimbatore during summer 2021. The objectives of the study were to identify the effect of moisture stress at critical stages on growth and yield of pearl millet and to assess the effect of stress ameliorants on growth and productivity enhancement in pearl millet. The experiment was laid out in split plot design and replicated thrice with skipping irrigation at critical growth stages (M-Main plot factor) and foliar spray of stress ameliorants (S-Subplot factor). The main plot factor comprised of skipping irrigations at active tillering stage (M_1), flowering stage (M_2) and in both active tillering stage and flowering stages (M_3) and adequate irrigation at all stages (M_4). The subplot factor consisted of foliar spray of stress ameliorants *viz.*, 1% Potassium chloride (KCl) on 20 and 40 days after sowing (S_1), 100 ppm salicylic acid on 20 and 40 days after sowing (S_2), 2% Pink Pigmented Facultative Methylotrophs (PPFM) on 20 and 40 days after sowing (S_3), 1% Potassium chloride (KCl) on 20 days after sowing and 100 ppm salicylic acid on 40 days after sowing (S_4), 1% Potassium chloride (KCl) on 20 days after sowing and 2% Pink Pigmented Facultative Methylotrophs (PPFM) on 40 days after sowing (S_5) and water spray (S_6) as control. The results showed that skipping irrigation at active tillering stage and flowering stage had severe effect on growth, phenology and productivity followed by skipping irrigation at flowering stage. Among stress ameliorants used, the foliar spray of 1% Potassium chloride (KCl) on 20 days after sowing and 2% Pink Pigmented Facultative Methylotrophs (PPFM) on 40 days after sowing recorded higher growth and yield followed by 2% Pink Pigmented Facultative Methylotrophs (PPFM) spray on 20 and 40 days after sowing. Lower grain yield was obtained under water spray.

Keywords: Skipping irrigation, stress ameliorants, KCl, salicylic acid, PPFM, yield

1. Introduction

Due to climate change, several abiotic and biotic stresses are strongly influencing the agricultural production. Among the different abiotic stresses, the drought is found to be more problematic one. Drought causes severe moisture stress in plants especially during critical growth stages which have direct impact on productivity of crop and will result in lessened crop yield. Drought results in several changes in morphological and physiological nature of the plants such as reduced plant height, decreased photosynthesis, membrane damage, stomatal closure, increased rate of transpiration, accumulation of reactive oxygen species, lowered grain filling and lessened yield (Moonmoon *et al.*, 2017) [12]. Pearl millet is one of the nutritive crops and grabbing an immense attention in day-to-day human diet. It is known to be widely cultivated because of its ability to grow against adverse environmental conditions as a climate resilient crop. Even though it can grow against adverse conditions, the loss due to drought is a considerable one. The drought resulted in 25% decrease in crop growth and productivity in pearl millet (Choudhary and Padaria, 2015) [4] and this yield reduction due to drought make us to meet out the food demand of the future population. Several plant breeding research and molecular studies are ongoing to improve the drought tolerant ability of the plant. But the best method to alleviate the effect of moisture stress in standing crop is usage of stress ameliorants. The production of reactive oxygen species during moisture stress will cause drastic effect on plant metabolism and this effect will be mitigated by the stress ameliorants (Zhanassova *et al.*, 2021) [19]. So, in view of above mentioned factors, the study was undertaken to identify the effect of moisture stress in critical growth stages on pearl millet and the role of stress ameliorants in enhancing the productivity in summer irrigated pearl millet in Tamil Nadu.

2. Materials and Methods

The field experiment was undertaken during summer 2021 in Field No. 37 F of Eastern Block Farm, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. The experiment field falls under Western Agro Climatic Zone of Tamil Nadu. The texture of the experimental soil is sandy clay loam with bulk density of 1.14 g/cc and porosity of 40%. The soil was found to be slightly alkaline with p^H of 7.48 and with low soluble salts of 1.229 dS/m. The nutrient status of the soil was found to be low in available nitrogen (267 kg/ha), medium in available phosphorus (17.8 kg/ha) and high in available potassium (765 kg/ha) with high range of organic carbon content (0.76%). The experiment was laid out in split plot design with four levels of main plot factor (M) and six levels of subplot factor (S) under three replications. The main plot factor consisted of skipping irrigation at critical crop growth stages (M_1-at active tillering stage, M_2-flowering stage, M_3-both active tillering and flowering stages, M_4-Irrigation at all stages) whereas, the subplot factor comprised of foliar spray of stress ameliorants (S_1-1% KCl at 20 and 40 DAS, S_2-100 ppm salicylic acid on 20 and 40 DAS, S_3-2% PPFM on 20 and 40 DAS, S_4-1% KCl on 20 DAS and 100 ppm salicylic acid on 40 DAS, S_5-1% KCl on 20 DAS and 2% PPFM on 40 DAS, S_6- Water spray as control).

The experimental field was prepared by ploughing with tractor drawn cultivator twice followed by rotavator. The animal drawn ridger was used to make ridges of 45 cm and rectified manually. The recommended dose of 80:40:40 NPK kg/ha was supplied through urea, SSP and MOP, of which full dosage of P and K were given at basal while, 1/4 of recommended dose of N was applied as basal and the remaining N dose was split up and applied as 1/2 of N on 15 DAS and 1/4 N on 30 DAS. Zinc sulphate at 25 kg/ha and biofertilizers *viz*., *Azospirillum* and *Phosphobacteria* at 2 kg/ha were applied as basal. All the necessary and recommended practices were carried out in the field. The five plants were randomly selected and tagged for recording biometric observations and the grain yield and straw yield were obtained from the whole net plots. The data were statistically analysed by Analysis of Variance (ANOVA) suggested by Gomez and Gomez (1984) [7].

3. Results and discussion

The results obtained on the effect of moisture stress and stress ameliorants on growth, phenology, yield parameters and yield in pearl millet are provided in Tables 1, 2 and Fig 1.

3.1 Effect of moisture stress and stress ameliorants on growth attributes of pearl millet at harvest

On perusal of the study, significant influence was observed by moisture stress and stress ameliorants on growth attributes such as plant height, number of tillers per plant, drymatter production, days to 50% flowering and days to physiological maturity and the data are provided in Table 1.

Table 1: Effect of moisture stress and stress ameliorants on growth attributes and phenology of pearl millet at harvest

Treatments	Plant height (cm)	No. of tillers/plant	DMP (kg/ha)	Days to 50% flowering	Days to physiological maturity
Skipping irrigation at critical stages (M)					
M_1	179.2	4.9	10196	51.1	71.8
M_2	175.4	4.6	9115	52.9	74.0
M_3	168.6	4.4	8580	53.6	74.3
M_4	182.3	5.3	10434	50.9	70.1
SEd.	1.95	0.11	259.7	0.26	0.35
CD (at 5%)	4.78	0.27	635.4	0.64	0.85
Foliar spray of stress ameliorants (S)					
S_1	176.9	4.8	9658	52.2	72.7
S_2	175.1	4.7	9540	52.2	72.3
S_3	177.7	5.0	9732	51.3	71.9
S_4	175.2	4.8	9587	52.3	72.5
S_5	179.7	5.1	9791	51.6	71.7
S_6	173.6	4.6	9179	53.2	74.3
SEd.	3.63	0.09	257.3	0.27	0.26
CD (at 5%)	NS	0.19	NS	0.54	0.53

3.1.1 Plant height (cm)

The plant height was significantly influenced by the moisture stress during critical crop growth stages. The highest plant height (187.2 cm) was recorded with the plants which received irrigation during all growth stages (M_4) which was on par with the plants in which active tillering stage alone (M_1) was exposed to moisture stress (182.9 cm). Comparatively, the moisture stress imposed during flowering stage (M_2) made the plants to attain low plant height (179.2 cm) which was on par with the treatment of moisture stress (M_3) imposed during both active tillering and flowering stages (178.6 cm). During flowering stage, due to the devoid of optimum moisture near the root zone, the plants might not get sufficient nutrients for growth and development which inturn resulted in reduced shoot length. This result was in accordance with the findings of Batool *et al.* (2021) [2]. Foliar spray of stress ameliorants on increasing the plant height was not significant at harvest.

3.1.2 Number of tillers/plant

The tiller production in pearl mill*et al*so got altered significantly by the moisture stress and application of stress ameliorants. Highest number of tillers was recorded in plants which were watered in all growth stages (M_4) with 5.2/plant and concurrently the plants with moisture stress imposed during active tillering stage and flowering stage (M_2) recorded lowest number of tillers as 4.4/plant which was on par with plants imposed with moisture stress at flowering stage (M_2) as 4.6/plant. Due to the prevalence of moisture stress during flowering stage, the significant reduction in photosynthetic rate, reduction in translocation of photosynthates and drying of tillers got initiated but it was reclaimed in plants of M_1 after receiving irrigation at flowering. This might be the reason for recording low number of tillers due to moisture stress at flowering stage. The obtained result was correlated with the results of Lokesh *et al.* (2020) [10]. The foliar spray of 1% KCl on 20 DAS followed by the application of 2% PPFM on 40

DAS (S_5) helped the plants in maintaining more number of tillers as 5.1/plant and it was statistically comparable with foliar spray of 2% PPFM on 20 and 40 DAS (S_3) as 5.0/plant, while on the contrary the control (S_6) had recorded lower number of tillers as 4.6/plant at harvest.

3.1.3 Drymatter production (kg/ha)

Drymatter production of pearl millet was influenced significantly by the impact of moisture stress. The accumulation of drymatter got increased with the sufficient amount of moisture during different crop growth stages. The plants irrigated at all stages (M_4) recorded high DMP of 10434 kg/ha which was found to be on par with moisture stress occurred at active tillering stage (M_1) as 10196 kg/ha. The lower DMP was recorded in plants with moisture stress imposed at flowering stage (M_2) as 9115 kg/ha and it was on par with moisture stress at both active tillering and flowering stages (M_3) which recorded 8580 kg/ha. Due to the increased respiration in plants and devoid of moisture near root zone the accumulation of photosynthates got decreased in M_2 and M_3 and on re-watering during flowering stage, the translocation of photosynthates became normal in M_1 plants. This was in accordance with the findings of Moolman *et al.* (1996) [11]. However, stress ameliorants had no significant effect towards drymatter production in plants at harvest.

3.1.4 Days to 50% flowering

The experimental results showed that the moisture stress had significant effect on days to 50% flowering. The irrigation supplied during flowering stage made the plants to attain earlier flowering. Significantly lower number of days to attain 50% flowering was obtained in irrigated plants at all stages (M_4) of 50.9 days which was on par with moisture stress imposed at active tillering (M_1) of 51.1 days and higher number of days was observed in moisture stress imposed at both active tillering stage and flowering stage (M_3) of 53.6 days which was on par with moisture stress imposed at flowering stage (M_2) of 52.9 days. The moisture stress especially occurred at reproductive stage delayed the days to 50% flowering. This was in accordance with the findings of Kholova *et al.* (2010) [9]. The foliar spray of 1% KCl on 20 DAS and 2% PPFM on 40 DAS (S_5) significantly took lower number of days to attain 50% flowering (51.3 days) which was on par with foliar spray of 2% PPFM on 20 DAS and on 40 DAS (S_5) which took 51.6 days.

3.1.5 Days to physiological maturity

The number of days to attain physiological maturity was significantly influenced by moisture stress and stress ameliorants. The plants provided with adequate irrigation at all stages reached the physiological maturity first than the stressed. Plants with adequate irrigation at all stages (M_4) attained earlier physiological maturity (70.1 days) followed by plants with moisture stress imposed at active tillering stage (M_1) which attained physiological maturity at 71.8 days. Plants with moisture stress imposed at both active tillering stage and flowering stage (M_3) took more days attain physiological maturity (74.3 days) and that was on par with moisture stress imposed at flowering stage (M_2) with (74.0 days). Among foliar treatments, application of 1% KCl on 20 DAS and 2% PPFM on 40 DAS significantly took lower number of days to attain physiological maturity (71.7 days) which was on par with foliar spray of 2% PPFM on 20 DAS and on 40 DAS (71.9 days).

3.2 Effect of moisture stress and stress ameliorants on yield parameters of pearl millet

The results obtained from the experiment showed that the moisture stress occurred during various crop growth stages had significant impact on yield parameters such as number of productive tillers per plant, number of grains per earhead, test weight, grain yield and stover yield in pearl millet and are furnished in Table 2 and Fig 1.

Table 2: Effect of moisture stress and stress ameliorants on yield parameters in pearl millet

Treatments	No. of productive tillers/plant	No. of grains/earhead	Test weight (g)	Grain Yield (kg/ha)	Stover yield (kg/ha)
Skipping irrigation at critical stages (M)					
M_1	3.3	2165	13.6	3264	4886
M_2	3.2	1930	13.5	2757	4569
M_3	3.1	1869	13.5	2705	4524
M_4	3.8	2276	14.0	3299	5162
SEd.	0.08	102.3	0.13	49.54	131.5
CD(p=0.05)	0.21	250.5	0.33	121.2	321.8
Foliar spray of stress ameliorants (S)					
S_1	3.3	2061	13.7	3069	4770
S_2	3.3	1976	13.5	2896	4759
S_3	3.6	2152	13.9	3130	4841
S_4	3.3	1977	13.6	2920	4758
S_5	3.7	2272	14.0	3184	4960
S_6	3.1	1921	13.3	2839	4623
SEd.	0.11	56.68	0.32	121.6	134.9
CD(p=0.05)	0.22	114.6	NS	245.8	NS

3.2.1 Number of productive tillers/plant

Highest number of productive tillers was produced in irrigated plants in all growth stages (M_4) with 3.8/plant. The moisture stress occurred during active tillering stage (M_1) produced higher number of productive tillers to about 3.3/plant, and it was on par with other treatments and numerically the plants exposed to moisture stress during active tillering stage as well as flowering stage (M_3) recorded lower number of productive tillers with 3.1/plant. Due to severe moisture stress during flowering, the plants might fail to translocate the photosynthates from source to sink which absolutely resulted in decreased number of productive tillers as stated by Nilanthi *et al.* (2014) [13]. Among stress ameliorants, 1% KCl on 20 DAS & 2% PPFM on 40 DAS (S_5) significantly resulted in higher number of productive tillers (3.7/plant) followed by 2% PPFM spray on 20 & 40 DAS (S_3) with 3.6/plant. The results obtained might be due to the .impact of moisture stress and the increased demand of potassium during moisture stress was supplied through foliar spray of KCl as indicated by Damon and Rengal (2007); Zhao *et al.* (2001) [5, 18] and the worthy action of PPFM in increasing the nutrient availability and vigour of plants, and elucidating drymatter production in plants as given in the findings of Raja and Sundaram (2006) [15]. The water spray (control) produced significantly lower number of productive tillers (3.1/plant).

3.2.2 Number of grains per earhead

The number of grains per earhead was significantly altered by moisture stress. Maximum number of grains was produced in plants supplied with sufficient moisture at all stages (M_4) as 2276 grains per earhead and it was statistically comparable with M_1 (2165 grains per earhead) and lower number of grains per earhead was statistically observed in M_3 (1869 grains per earhead). The moisture stress at flowering stage might affect the pollen germination and viability and might resulted in more number of unfertile pollen than the irrigated plants. The result obtained was similar with the findings of Winkel *et al.* (1997) [17]. Among the subplot treatments, the foliar application of 1% KCl on 20 DAS and 2% PPFM on 40 DAS (S_5) with 2272 grains/earhead followed by foliar spray of 2% PPFM spray on 20 & 40 DAS (S_3) with 2152 grains/earhead whereas, the control (water spray) did not show any increase towards number of grains/earhead. The reason behind the highest number of grains in S_5 might be the combined action of Potassium on compatible osmolytes in alleviating the effect of moisture stress and the role of PPFM in synthesis of various enzymatic and non-enzymatic components during moisture stress. This finding of PPFM role was correlated with Sivakumar *et al.* (2017) [16].

3.2.3 Test weight (g)

The test weight was significantly influenced by moisture stress at critical stages and higher test weight was registered with M_4 (14.0 g) and all other treatments were statistically similar. Proper pollination and translocation of photosynthates might have resulted in increased test weight under non moisture stress conditions. The foliar treatments had no significant influence on test weight.

3.2.4 Grain yield (kg/ha)

Significantly higher grain yield was obtained in no stress plants (M_4) with 3299 kg/ha and was on par with moisture stress imposed during active tillering stage (M_1) with 3264 kg/ha. The plants exposed to moisture stress during flowering stage decreased the grain yield of crop about 2757 kg/ha (M_2) and was on par with plants experienced moisture stress during both active tillering and flowering stage (M_3) with 2705 kg/ha. The increase in grain yield might be due to increased availability of soil moisture which inturn maintained internal water status and growth of crop, whereas reduction in grain yield might due to less uptake of nutrients from the soil due to the poor filling of grains in earhead. This finding was supported by the Bhunia *et al.* (2016) [3]. The yield produced by plants suffered from moisture stress during active tillering stage was comparatively than plants suffered from moisture stress during flowering stage because on receiving watering during flowering stage, the plants got reclaimed and exhibited fast recovery from the impact of moisture stress. The finding was corroborated with Abid *et al.* (2018) (1). Significantly higher yield was produced under foliar spray of 1% KCl on 20 DAS and 2% PPFM on 40 DAS (S_5) with 3184 kg/ha which was on par with 2% PPFM on 20 & 40 DAS (S_3) and 1% KCl on 20 DAS and 100 ppm salicylic acid on 40 DAS (S_4) with grain yield of 3130 kg/ha and 3069 kg/ha respectively. This higher yield might be due to the increase in yield parameters produced by KCl and the augmented effect of PPFM in increasing the ability of plants in producing Indole acetic acid which might increase the productivity of the plant. The obtained result was confirmed with findings of Poorniammal *et al*. (2020); Ivanova *et al.* (2000) [14] [8].

3.2.5 Stover yield (kg/ha)

The moisture stress had significant effect on stover yield of the crop and higher stover yield was obtained under no moisture stress conditions (M_4) with 5162 kg/ha and it was on par with plants under moisture stress imposed during active tillering stage (M_1) with 4886 kg/ha. The stover yield got reduced in plants under moisture stress imposed during flowering stage (M_2) with 4569 kg/ha which was on par with to the plants exposed to moisture stress during both active tillering and flowering stage (M_3) with 4524 kg/ha. Poor extraction of nutrients, poor development of tillers and increased transpiration might be the reason behind low stover yield in moisture stressed plants than the no stress plants. No significant dfiference was observed in stover yield by usage of stress ameliorants. This result was confirmed with the findings of Emerson *et al.* (2014) [6].

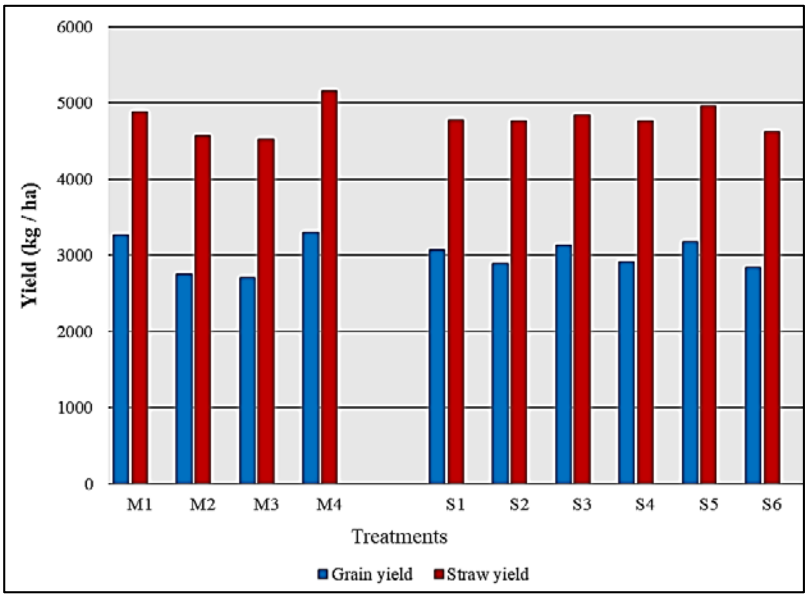

Fig 1: Effect of moisture stress and stress ameliorants on grain and stover yield

4. Conclusion

In pearl millet, the moisture stress occurred during flowering stage caused drastic reduction in growth and yield parameters, and productivity than the occurrence of moisture stress at active tillering stage of the crop and inturn have negative impact on the crop returns. Among the stress ameliorants, elucidated trend in yield parameters was obtained under the foliar application of 1% KCl on 20 DAS and 2% PPFM on 40 DAS. From the experimental results, we can suggest that if the pearl millet producer is supposed to give irrigation facility for any one of the critical growth stages for pearl millet during summer, providing irrigation at flowering stage, along with foliar spray of 1% KCl on 20 DAS and 2% PPFM on 40 DAS will be appropriate and economically advisable phenomenon to achieve higher crop productivity.

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