E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(12): 275-278
Received: 15-10-2024
Accepted: 19-11-2024

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Studies on contribution of production factors to yield and economics of pearl millet (*Pennisetum glaucum* L.)

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i12d.2144

Abstract
The field experiment entitled "Studies on contribution of production factors to yield and economics of pearl millet (*Pennisetum glaucum L.)*" was conducted on the experimental farm of the National Agricultural Research Project, Chh. Sambhajinagar, during the *Kharif* season of 2023. The field was well leveled with efficient drainage. The soil of the experimental plot was clayey, with a nutrient profile showing low available nitrogen (144.9 kg ha^{-1}), medium available phosphorus (20.16 kg ha^{-1}), high available potassium (405 kg ha^{-1}), and alkaline pH (8.29). The conditions during the experiment were conducive to normal growth and development. The field trial was designed using a Randomized Block Design, with eight treatments involving the pearl millet hybrid AHB1200 Fe and various application practices, replicated three times. The dimensions of the gross plot were 5.0 x 4.5 m^2, while the net plot measured 4.0 x 3.6 m^2. All protective measures were implemented as recommended, including seed treatment as per experiment treatment, field management, and irrigation management. Sowing was done on 28th June 2023. It was concluded from the experimental results that, the several application practices or the treatment T_1 i.e. Full package and practices of location RDF+$ZnSO_4$ @ 25kg ha^{-1}+$FeSO_4$ F@ 0.5-0.75% at 20-25DAS+ bioinoculant seed treatment of *Azospirillum*) + thinning & gap filling + weeding & hoeing (3 &5 weeks after sowing) +irrigation notably recorded the highest grain yield (2644 kg ha^{-1}), which was at par with the treatment T_3 i.e. [T_1-$ZnSO_4$ @ 25 kg ha^{-1}] at sowing (2312 kg ha^{-1}), T_4 i.e. [T_1-$FeSO_4$ F @ 0.5-0.75% at 20-25DAS] at sowing (2282 kg ha^{-1}), T_5 i.e. [T_1-Bioinoculant seed treatment (*Azospirillum*)] at sowing (2356 kg ha^{-1}). The maximum reduction that is 36.94% was observed without RDF, which was followed by without weeding & hoeing (36.42%) and thinning & gap filling (29.55%) treatments as compared to T_1. The fodder yield also recorded the similar trend with reduction between 10.2-36.0% across the treatments. The highest net monetary returns(Rs. 49503 ha^{-1}) was observed in T_1 i.e. receiving full package and practices of the location (RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @0.5-0.75% at 20-25DAS + Bioinoculant seed treatment (*Azospirillum*)+ thinning and gap filling + weeding and hoeing (3 & 5 weeks after sowing) + Irrigation) than other treatments, however, it was not par with treatment T_3 (Rs. 41451 ha^{-1}), T_4 (Rs. 40225 ha^{-1}) and T_5 (Rs. 41014 ha^{-1}). The net returns across the treatments was reduced from 16.3-53.4% as compared to full package and practices.

Keywords: Studies, production factors, economics, pearl millet (*Pennisetum glaucum* L.)

Introduction
Pearl millet is the fourth most widely grown food crop in India after rice, wheat, and maize. In 2023-24, pearl millet area in India was 7.36 million ha, with an average production of 10.67 million tons and 1449 kg ha^{-1} productivity (Anonymous, 2024) [2]. Maharashtra occupies 16.00 lakh ha area with an annual production of 14.04 lakh tonnes and productivity of 888 kg ha^{-1} as the 2023-2024 farming year (Anonymous, 2024) [2]. Marathwada region comprising Beed, Jalna and Aurangabad is the major pearl millet growing area of the state as these three districts jointly contribute more than 80% share in area and production of this crop in the state. Marathwada region occupies 1.37 lakh ha area with an annual production 1.22 lakh tonnes and productivity of 994 kg ha^{-1} (Anonymous, 2021) [1]. Plant density maintained by thinning and gap filling is another significant element influencing pearl millet output. Plants compete more for resources (moisture, light, nutrients, etc.) when there are more plants per unit space; but, when there are fewer plants, these resources are not fully utilized.

According to research, if thinning and gap filling are not done in pearl millet, it can result in a yield reduction of around 10-15%. When comparing a plot with and without gap filling and thinned areas, the plant yield has 3 improved dramatically. Pearl millet is exhaustive crop and it needs to be supplied with heavy doses of inorganic fertilizers to meet nutritional requirements of the crop which is quite uncommon in the bajra growing areas. When RDF is not applied to the pearl millet plot the yield reduction of 50-55% has been reduced as compared to applied plot. Nitrogen (N) deficiency result in 30-40% yield reduction where as Phosphorus (P) and Potassium (K) deficiency result in 25-30%. According to Kumavat *et al*. (2017) [7], over 50% of Indian soils are deficient in zinc, making it the most prevalent micronutrient deficiency in the soil worldwide. If zinc and iron are not supplied to pearl millet plants, it can result in significant yield reductions. Zinc deficiency result in 20-30% yield reduction and Iron deficiency 15-25% yield reduction as compared to normal yield of pearl millet with supply of Zinc and Iron in India. Productivity of any crop depends on many management factors such as fertilizer, thinning, gap filling, weeding, hoeing and irrigation management and every factor has its towards productivity. Non-adoption of improved package of practices recommended for specific zone by the farmers is one of the major causes of low yield of pearl millet crop. Therefore, it is necessary to find out the contribution of individual or combinations of full package of practices to the yield of pearl millet. But very less information is available regarding role of individual factor towards the productivity of pearl millet. Keeping the above points in view, the present study was conducted.

Materials and Methods

An experiment was carried out on experimental field of National agricultural Research Project, Chh. Sambhajinagar. The experimental design was RBD with eight treatments. The experimental plot, characterized by its levelled and well-drained conditions, with clay texture. The chemical composition of experimental plot soil was as follows: medium organic carbon content (0.63%), low available nitrogen (144.0 kg ha^{-1}), medium available phosphorus (20.16 kg ha^{-1}), very high accessible potassium (405 kg ha^{-1}), and alkaline pH (8.29) in reaction. Additionally, the concentrations of zinc, iron, manganese, copper, and boron in the soil were 0.39, 4.23, 4.89, 1.98, and 0.31 ppm, respectively. However, variations in monsoon patterns make crop production uncertain. The pearl millet was sown on 28th June 2023 by dibbling method and harvested at 25th September 2023.

The experiment consisted of eight treatments as detailed below (T_1) Full package and practices of location RDF+ZnSO4 @25kg ha^{-1}+FeSO4 F@ 0.5-0.75% at 20-25DAS+ bioinoculant seed treatment-*Azospirillum*) + thinning & gap filling + weeding & hoeing (3&5 weeks after sowing) +Irrigation, (T_2) T_1-RDF, (T_3) T_1-$ZnSO_4$ @ 25kg ha^{-1}, (T_4) T_1-$FeSO_4$ F @0.5-0.75% at 20-25 DAS, e) T_5=T_1-Bioinoculant Seed Treatment [*Azospirillum*], (T_6) T_1-Thinning & gap filling, (T_7) T_1-Weeding & hoeing (3& 5 weeks after sowing), (T_8) T_1-Irrigation. The gross and net plot sizes were 5.0 x 4.5 m^2 and 4.0 x 3.6 m^2 respectively.

Results and Discussion

A) Growth Studies

The plant height of pearl millet is significantly affected at all growth stages with the different levels of treatment (Table 1). Among all the treatment, the treatment T_1 recorded the highest plant height at 30, 45, 60, 75DAS and at harvest. The results followed the similar trend as Togas *et al.* (2017) [12]. At growth stages (30, 45, 60, 75 DAS and at harvest) treatment T_1 found significantly highest number of leaves plant^{-1} (5.47, 7.67, 11.67, 14.33, 5.32) over all other treatments (Table 1). Parallel results was found by Kumavat and Shekawat (2017) [7]. Impact of Full package and practices of T1 has observed significantly highest leaf area plant^{-1} i.e. 39.24 dm^2 at 30DAS, 125.40 dm^2 at 45DAS, 158.29 dm^2 at 60DAS, 163.40 dm^2 at 75 DAS and 159.47 dm^2 at harvesting stage (Table 1). Parallel outcome was recorded by Swetha *et al.* (2022) [11]. The treatment T_1 Full package and practices reported significantly highest dry matter plant^{-1} (g) over all other treatments i.e. 11.80 g at 30 DAS, 57.63g at 45DAS, 117.51g at 60 DAS, 150.11g at 75DAS and 154.00g at harvesting stage (Table 1). On the contrary, treatment (T_2) T_1-RDF reported lowest dry matter plant^{-1}. Similar results were found by Ray *et al.* (2021) [10], and Kumavat and Shekawat (2017) [7].

B) Yield contributing characters Studies

In yield contributing characters treatment T_1 (Full package and practices) recorded significantly highest number of tillers plant^{-1} (4.93) over other treatments (Table 2). However, treatment T_7 observed lowest (3.13) number of tillers plant^{-1}. Parallel results were found by Ray *et al.* (2021) [10] and Yalamati *et al.* (2019) [14]. The treatment T_1 (Full package and practices) found significantly highest number of effective tillers plant^{-1}(3.87) over all other treatments (Table 2). On contrary treatment N_1 (100% RDN) reported lowest number of effective tillers plant^{-1} (2.83). Analogous results were found by Ray *et al.* (2021) [10]. The treatment T_1 (Full package and practices) noted significantly highest grain weight earhead^{-1} (35.39g) over rest of the treatment (Table 2). On the contrary treatment T_2 (T_1-RDF) recorded lowest grain weight earhead^{-1} (28.93g). Grain weight plant^{-1} of pearl millet noted significantly highest (75.45g) in treatment T_1 (Full package and practices) over other treatments. On the other hand treatment T_2 (T_1-RDF) observed lowest grain weight plant (48.96g). Test weight of pearl millet noted significantly highest test weight 16.7g in treatment T_1 (Full package and practices) and was at par with treatment N_1 (100% RDN) and N_2 (112.5% RDN) i.e.14.37g and 15.44g respectively. Similar result reported by Arshewar *et al.* (2018) [4], G Divya *et al.* (2017), [5] (Table 2).

C) Yield Studies

From the (Table 2) it was concluded that, the treatment T_1 receiving full package and practices of the location [(RDF + $ZnSO_4$ @ 25 kg/ha + $FeSO_4$ F @ 0.5-0.75% at 20-25DAS + Bioinoculant seed treatment (*Azospirillum*) + thinning and gap filling + weeding and hoeing (3 & 5 weeks after sowing) + Irrigation recorded significantly higher grain yield (2644 kg ha^{-1}) of pearl millet than rest of the treatments, however, it was on par with treatments receiving full package and practices of the location-(T_3) $ZnSO_4$ @ 25 kg ha^{-1}, (T_4) $FeSO_4$ F@ 0.5-0.75% at 20-25DAS and (T_5) Bioinoculant seed treatment *(Azospirillum*) and found to be significantly superior over treatments such as T_6 (1863 kg ha^{-1}), T_8 (1766 kg ha^{-1}) and T_7 (1681 kg ha^{-1}) was significantly reduced by not caring out the important management operations. The perusal of the data in the (Table 2) resulted that maximum reduction of 36.94% was observed without RDF operation which was followed by without weeding & hoeing (36.42%) and thinning & gap filling (29.55%) treatments. The reduction was between 10.89-13.68% when $ZnSO_4$, $FeSO_4$, irrigation, biofertilizers were not applied. Parallel results were found by Vinay *et al.* (2019) [13].

Table 1: Growth attributes of pearl millet as influenced by different treatments and at harvest

Tr. No.	Treatment	Plant height (Cm)	Number of leaves plant^{-1}	Leaf area plant^{-1}	Dry matter plant^{-1} (g)
T_1	Full package and practices of the location (RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ F @ 0.5-0.75% at 20-25 DAS + Bioinoculant seed treatment (*Azospirillum*) + thinning & gap filling + weeding & hoeing (3 & 5 weeks after sowing) + Irrigation	198.73	5.32	159.47	154.00
T_2	T_1-RDF	183.60	3.14	131.66	127.72
T_3	T_1-$ZnSO_4$ @ 25 kg ha^{-1}	183.93	5.49	154.67	149.76
T_4	T_1-$FeSO_4$ F @ 0.5-0.75% at 20-25DAS	180.50	6.50	155.81	146.27
T_5	T_1-Bioinoculant seed treatment (Azospirillum)	184.40	5.56	155.42	148.03
T_6	T_1-Thinning & gap filling	177.87	4.39	136.80	119.70
T_7	T_1-Weeding & hoeing (3 & 5 weeks after sowing)	174.80	3.78	129.61	128.40
T_8	T_1-Irrigation	181.50	4.07	130.01	121.47
	SE$\pm$	4.09	0.40	2.03	2.89
	C.D at 5%	12.4	1.20	6.16	3.66
	G.M.	183.16	5.28	143.7	137.5

Table 2: Yield attributes and gross monetary returns (Rs ha^{-1}), net monetary returns (Rs ha^{-1}), B:C ratio and Cost of cultivation of pearl millet as influenced by various treatments

Tr. No.	Treatment	Total number of tillers Plant^{-1}	Number of effective tillers plant^{-1}	Grain Weight Ear Head^{-1} (G)	Grain Weight Plant^{-1} (G)	Test Weight (G)	Grain Yield (Kg Ha^{-1})	Fodder Yield (Kg Ha^{-1})	Harvest Index	GMR (₹.Ha-1)	NMR (₹.Ha-1)	Cost of Cultivation (₹)	B:C Ratio
T_1	Full package and practices of the location [(RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ F @ 0.5-0.75% at 20-25 DAS + Bioinoculant seed treatment (Azospirillum) + thinning & gap filling + weeding & hoeing (3 & 5 weeks after sowing) + Irrigation]	4.93	3.87	35.39	75.45	16.7	2644	6873	27.7	85703	49503	36200	2.37
T_2	T_1-RDF	3.60	2.47	28.93	48.96	14.7	1667	4340	27.7	54044	23144	30900	1.75
T_3	T_1-$ZnSO_4$ @ 25 kg ha^{-1}	3.97	3.54	33.31	71.39	15.9	2312	5813	28.5	74631	41451	33180	2.25
T_4	T_1-$FeSO_4$ F @ 0.5-0.75% at 20-25DAS	4.03	3.62	32.76	70.25	15.7	2282	5834	28.1	73825	40225	33600	2.20
T_5	T_1-Bioinoculant seed treatment (Azospirillum)	3.83	3.81	32.52	71.44	16.1	2356	5890	28.5	75994	41014	34980	2.17
T_6	T_1-Thinning & gap filling	3.57	2.93	29.67	68.78	14.7	1863	4845	27.7	60412	26732	33680	1.79
T_7	T_1-Weeding & hoeing (3 & 5 weeks after sowing)	3.13	2.67	30.47	58.53	14.5	1681	4369	27.7	54484	24904	29580	1.84
T_8	T_1-Irrigation	3.67	2.70	29.37	59.07	14.3	1766	4570	27.8	57222	23022	34200	1.67
	SE$\pm$	0.18	0.18	1.09	1.72	0.50	123.21	352.61	0.46	3916.17	3916.17	-	0.12
	C.D at 5%	0.57	0.56	3.00	5.22	1.51	373.76	1068.41	NS	11879.64	11879.64	-	0.36
	G.M.	3.32	3.18	31.55	56.55	15.03	2071	5317	28	67039	33749	33290	2.0
	C.D at 5%	0.57	0.56	3.00	5.22	1.51	373.76	1068.41	NS	11879.64	11879.64	-	0.36
	G.M.	3.32	3.18	31.55	56.55	15.03	2071	5317	28	67039	33749	33290	2.0

In fodder the highest yield (6873 kg ha^{-1}) was recorded by T_1-Full package and practices of location RDF+$ZnSO_4$ @25kg ha^{-1}+FeSO4 F@ 0.5-0.75% at 20-25DAS+ bioinoculant seed treatment-*Azospirillum*) + thinning & gap filling + weeding & hoeing (3&5 weeks after sowing) + irrigation and it was found significantly superior over treatments T_6 (4845 kg ha^{-1}), T_8 (4570 kg ha^{-1}) and T_7 (4369 kg ha^{-1}), but at par with treatment T_3 (2312 kg ha^{-1}), T_4 (5834 kg ha^{-1}) and T_5 (5890 kg ha^{-1}). The perusal of the data in the Table 2 revealed that the fodder yield was significantly reduced by not caring out the important management operations. The maximum reduction of 37.0% was observed without RDF operation which was followed by without weeding & hoeing (36.5%), thinning & gap filling (29.55%) and irrigation (33.5%) treatments. The reduction was between 10.2-15.4% when ZnSO4, FeSO4, Biofertilizer were not applkied. Similar findings have also been published by kumar *et al*. (2014), Yalamati *et al*. (2019) [14] and Vinay *et al*. (2019) [13].

D) Economic studies

From the (Table 2) the treatment T_1 i.e. receiving full package and practices of the location (RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ F @ 0.5-0.75% at 20-25DAS + Bioinoculant seed treatment (*Azospirillum*)+ thinning and gap filling + weeding and hoeing + Irrigation) recorded significantly higher gross monetary returns (Rs. 85703 ha^{-1}) than rest of the treatments, however, it was on par with treatment T_3 (Rs. 74631 ha^{-1}), T_4 (Rs. 73825 ha^{-1}) and T_5 (Rs. 75994 ha^{-1}) also it was found to be significantly superior over other treatments such as T_2 (Rs. 54044 ha^{-1}) and T_6 (Rs. 60412 ha^{-1}), T_7 (Rs. 54484 ha^{-1}), T_8 (Rs. 57222 ha^{-1}). The perusal of the data in the Table 2 revealed that the gross monetary returns was significantly reduced by not caring out the most important management operations. The maximum reduction of 36.9% was observed without RDF operation which was followed by without weeding & hoeing (36.4%), and irrigation (33.2%) treatments. The reduction was between 12.2-29.5% when ZnSO4, FeSO4, biofertilizer and thinning and gap filling were not done**.** The results are in close agreement with finding of Rathore *et al.*, (2006) [9], Kumar *et al.*, (2014) [6] and Arshewar *et al.*, (2018) [4].

The effects of various treatments have a considerable impact on pearl millet's net monetary gains. T_1 i.e. receiving full package and practices of the location [(RDF + $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @0.5-0.75% at 20-25DAS + Bioinoculant seed treatment (*Azospirillum*)+ thinning and gap filling + weeding and hoeing + Irrigation] recorded significantly higher net monetary return (Rs. 49503 ha^{-1}) than rest of the treatments, however, it was on but at par with treatment T_3 (Rs. 41451 ha^{-1}), T_4 (Rs. 40225 ha^{-1}) and T_5 (Rs. 41014 ha^{-1}) also it was discovered to be significantly superior over other treatment T_6 (Rs. 26732 ha^{-1}), T_7 (Rs. 24904 ha^{-1}), T_2 (Rs. 23144 ha^{-1}) and T_8 (Rs. 23022 ha^{-1}). Similar result of percentage reduction of gross monetary returns was found in net monetary returns. Similar results were found by Rathore *et al.*, (2006) [9], Kumar *et al.*, (2014) [6], and Togas *et al*. (2017) [12]. B: C ratio of pearl millet resulted significantly highest (2.37) in treatment T_1. However, treatment T_8 reported lowest (1.67) (Table 3). Similar results were found by Kumar *et al.*, (2014) [6] and Arshewar *et al.* (2018) [4].

Conclusion

The study demonstrates that adopting the full package of agronomic practices significantly enhances both growth character and yield character of pearl millet. Eliminating critical elements like RDF or proper weeding practices results in significant yield losses, highlighting the importance of comprehensive and integrated management practices for maximizing production. Therefore, it is recommended to implement the complete package of practices to achieve the best yields in pearl millet cultivation. The net returns reduction in percentage was 16.3-53.4% and gross returns reduction in percentage was 12.2-36.9%, respectively as compare to treatment T_1. This suggest that that adopting the full package of agronomic practices significantly enhances net and gross returns

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