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Influence of varying spacings and levels of nutrients on yield characteristics, yield and economics of barnyard millet

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Abstract
A field trial was conducted during the *kharif* season of 2024 on barnyard millet at the Agronomy Farm, College of Agriculture, Nagpur, to study the effect of spacing and fertilizer levels on growth and yield. The experimental soil was vertisol, clayey in texture, slightly alkaline in reaction with a pH of 7.65, low in available nitrogen (255.80 kg ha^{-1}), medium in available phosphorus (22.13 kg ha^{-1}), and high in available potassium (369.20 kg ha^{-1}). The experiment was laid out in a factorial randomized block design (FRBD) comprising three spacing levels and three fertilizer levels, replicated three times. The treatment combinations were randomized within each replication. The treatments consisted of three spacings viz., S_1-30 x 10 cm, S_2-45 x 5 cm and S_3-45 x 10 cm, and three nutrient levels viz., F_1-30:20:00, F_2-40:20:00 and F_3-50:20:00 kg N:P:K ha^{-1}. The result revealed that among the different sowings, number of length of panicle, panicle weight, grain and straw weight $plant^{-1}$, significantly higher with spacing S_3-45 x 10 cm. Grain yield, straw yield, biological yield, gross monetary returns, net monetary returns, and benefit-cost (B:C) ratio were significantly higher under the spacing treatment S_2 (45 × 5 cm). Among the nutrient levels, F_3 (50:20:00 kg N:P:K ha^{-1}) resulted in greater panicle length, panicle weight, grain and straw weight per plant, grain yield, straw yield, biological yield, and higher economic returns, including gross and net monetary returns as well as B:C ratio. However, the interaction between spacing and fertilizer levels was found to be non-significant for all the parameters studied.

Keywords: Barnyard millet, spacing, nutrient levels, yield attributes, yield

Introduction
Millets are among the earliest known foods consumed by humans and are likely the first cereal grains domesticated for household use. These small-grained cereal crops are highly nutritious and are typically grown in low-fertility soils with minimal input requirements. Cereals like wheat and rice have been cultivated more since the green revolution, whereas millet cultivation has sharply decreased. Millet crops hold significant potential to enhance the country's food and nutritional security.

Small millets are mainly cultivated during the *kharif* season, though several varieties also yield well in the *rabi* and summer seasons. These crops are highly nutritious and mineral-rich, and they exhibit strong resistance to drought and other environmental stresses common in rainfed agriculture. They are well adapted to diverse ecological conditions and are typically grown on shallow, less fertile soils with a depth of less than 15 cm. These crops do not require nutrient-rich soils for their growth. Barnyard millet is considered one of the fastest-growing millet species, known for its early maturity, good storage qualities, and ability to flourish in poor soil conditions (Yabuno, 1987) [15].

By implementing optimal crop arrangement, the competition among individual plants can be lessened. Furthermore, achieving an ideal plant density at the point of harvest can significantly impact the overall yield. When plants are given adequate space, they can readily access ample sunlight, water, and vital nutrients from the soil, which in turn fosters robust growth and enhances the quality of the harvested produce (Anandha Krishnaveni *et al.*, 2020) [3].

Optimizing crop geometry effectively lessens the among competition individual plants. Additionally, maintaining an optimal plant population at the point of harvest significantly impacts the overall yield output. When plants are afforded adequate spacing, they can acquire ample sunlight, water, and essential nutrients from the soil, which in turn fosters robust health and enhances key yield attributes (Anandha Krishnaveni *et al.*, 2020) [3].

Although barnyard millet has relatively low nutrient demands, improved varieties tend to perform better with supplementary nutrient inputs. Integrated nutrient management generally includes the application of 5 to 10 tons of farmyard manure (FYM) per hectare, depending on the existing soil fertility. Fertilizer requirements vary across different regions: a dose of 40:20:00 NPK is recommended for areas like Bihar, Tamil Nadu, Maharashtra, and Uttar Pradesh, while 20:20:00 NPK is suitable for Andhra Pradesh and other states (Prabhakar *et al.*, 2012) [17]. In order to maximize grain yield within sodic soils, a spacing pattern of 35 x 10 cm, coupled with an application of 125% of the prescribed fertilizer amount, is recommended (Krishnaveni, 2018) [3]

Materials and Methods

A field experiment was carried out during the 2024 kharif season at the P.G. Research Farm, College of Agriculture, Nagpur, to investigate the effects of varying fertilizer levels and plant spacings on barnyard millet. 255.80 kg ha^{-1} of accessible nitrogen, 22.13 kg ha^{-1} of available phosphorus, 369.20 kg ha^{-1} of available potassium, clayey soil, and a somewhat alkaline reaction (pH 7.65) were all present in the experimental plot. Three replications and nine treatment combinations were employed in the factorial randomized block design experiment. The three spacings were S_1-30 x 10 cm, S_2-45 x 5 cm, and S_3-45 x 10 cm, and the three fertilizer levels were F_1-(30:20:00 kg NPK ha^{-1}), F_2-(40:20:00 kg NPK ha^{-1}), and F_3-(50:20:00 kg NPK ha^{-1}). A complete dose of phosphorus and 50% nitrogen treated as a basal dressing and the remaining 50% nitrogen applied as a top dressing, the variety (DHBM-93-3) was seeded at various intervals. Data on yield qualities were collected from five randomly chosen plants from each net plot during the crop growth period (June to October), when the total rainfall was 1179.6 mm. The mean value was then calculated. The current market price of barnyard millet was used to calculate the cost of cultivation and conduct economic research. The typical procedure described for randomized block design (Gomez and Gomez, 1984) [4] was used to statistically analyze the data. Wherever the effect was significant, the crucial difference was calculated, and statistical significance was assessed using the F-value at the 0.05% level of probability.

Results and Discussion

Yield attributes

Effect of Spacing

The panicle's length, weight, grain yield plant-1, and straw yield plant-1 were significantly highest when the spacing was 45 x 10 cm (S_3), followed by 30 x 10 cm (S_1). Closer line spacing of 45 x 5 cm had the lowest stated attributes (S_2). Its effective translocation from source to sink under wider spacing and improved carbohydrate synthesis may be the cause of this. Additionally, similar outcomes were observed by Anandha *et al.* (2020) [3], Pavankumar *et al.* (2021) [6], Aghara *et al.* (2023) [1] T. Lokesh *et al.* (2023) [5].

Effect of nutrient levels

The length of panicles, panicle weight, and grain and straw weight $plant^{-1}$ were all significantly impacted by nutrient levels. The application of 50:20:00 kg N:P:K ha^{-1} (F3) produced the highest number of panicles $plant^{-1}$, panicle length, panicle weight, and grain and straw weight $plant^{-1}$. This was comparable to the treatment that received 40:20:00 kg N:P:K ha^{-1} (F_2). Using 30:20:00 kg N:P:K ha^{-1} (F_1) resulted in the smallest panicle length, panicle weight, and grain and straw weight per plant. Higher fertilizer dosages may have increased the crop's nutrient availability, which may have improved the yield characteristics, namely. number of panicles $plant^{-1}$, length of panicle and panicle weight, which might have reflected as an increased grain and straw weight $plant^{-1}$. Similar results were also reported by Anandha Krishnaveni (2018) [8], Pol *et al.* (2019) [7] and Soutade and Raundal (2022) [12].

Table 1: Mean of length of panicle (cm), panicle weight (g), grain and straw weight $plant^{-1}$ (g) as influenced by various treatments

Treatment	Length of panicle (cm)	Panicle weight (g)	Grain weight $plant^{-1}$ (g)	Straw weight $plant^{-1}$ (g)
A. Spacings				
S_1-(30 x 10cm)	15.27	2.39	4.10	10.98
S_2-(45 x 5 cm)	13.46	1.77	3.61	9.26
S_3-(45 x 10 cm)	15.77	2.39	4.62	12.29
S.E. (m)±	0.62	0.18	0.24	0.73
C.D. at 5%	1.86	0.54	0.73	2.18
B. Nutrient Levels (kg N: P: K ha^{-1})				
F_1-30:20:00	13.32	1.77	3.29	8.86
F_2-40:20:00	15.06	2.19	4.22	10.78
F_3-50:20:00	16.11	2.59	4.82	12.89
S.E. (m)±	0.62	0.18	0.24	0.73
C.D. at 5%	1.86	0.54	0.73	2.18
C. Interaction (S x F)				
S.E. (m)±	1.08	0.31	0.42	1.26
C.D. at 5%	NS	NS	NS	NS
GM	14.83	2.18	4.11	10.84

Yield

Effect of line spacing

The closer spacing of 45 x 5 cm (S_2) produced the significantly highest grain yield, straw yield, and biological yield, which was comparable to 30 x 10 cm (S_1). The crop with a larger spacing of 45 x 10 cm produced the least amount of grain and straw (S_3). Wider spacing enhanced yield-attributing characteristics, but it cannot outperform the total grain and straw yield per unit area that comes from closer crop spacing. For this crop, 45 x 5 cm may be the ideal spacing for possible growth and development given the availability of enough room and additional resources like moisture, sunlight, nutrients, etc. Wider spacing of 45 x 10 cm and 30 x 10 cm, however, may result in a higher harvest index, which could limit the amount of biomass produced per unit area and, consequently, the amount of straw produced. Similar results were also reported by Shamina *et al.* (2019) [10] Swati *et al.* (2020) [13], Siddiqui *et al.* (2020) [11], Aliveni *et al.* (2021) [2] and T Lokesh *et al.* (2023) [5].

Nutrient levels

According to the results, an increase in nutrient levels was associated with an improvement in yield. The highest grain, straw, and biological yield and harvest index were observed by applying 50:20:00 kg N:P:K ha^{-1} (F_3), which was comparable to applying 40:20:00 kg N:P:K ha^{-1} (F_2). Harvest index, grain, and straw yields were considerably reduced when a lower dose of 30:20:00 kg N:P:K ha^{-1} was applied. boosted nutrient availability and uptake may have contributed to the rise in grain, straw, and biological yields associated with increased fertilizer application. This, in turn, may have boosted metabolic efficiency and total plant production. It is possible that improved vegetative growth and more efficient photosynthesis were facilitated by the improved soil nitrogen status. Similar results were also reported by Thakur *et al.* (2019) [14], Siddiqui *et al.* (2020) [11], and Sachin *et al.* (2023) [9].

Economics

Effect of spacings

The closer spacing of 45 x 5 cm (S_2) produced the significantly largest gross monetary returns, net monetary returns, and B:C ratio, which was comparable to 30 x 10 cm (S_1). The crop grown with a wider spacing of 45 x 10 cm had the lowest grain and straw yield ha-1 (S_3). The economic yield of barnyard millet increased significantly, which led to increases in gross monetary returns, net monetary returns, and the B:C ratio.

Effect of nutrient levels

According to data on barnyard millet economics, higher fertilizer application resulted in higher gross monetary returns, net monetary returns, and the B:C ratio. Different nutritional levels caused differences in the gross monetary returns, net monetary returns, and B:C ratio, according to an evaluation of treatments based on economic features. Application of 50:20:00 kg N:P:K ha^{-1} (F_1) produced the highest gross monetary returns, net monetary returns, and B:C ratio among the various nutrient levels; these results were comparable to those obtained with application of 40:20:00 kg N:P:K ha^{-1} (F_2). The B:C ratio, net monetary returns, and gross monetary returns were all considerably reduced when 30:20:00 kg N:P:K ha^{-1} (F_3) was applied.

Table 2: Mean grain yield, straw yield, biological yield (kg ha^{-1}), Gross monetary returns (Rs. ha^{-1}), Net monetary returns (Rs. ha^{-1}) and B:C ratio of barnyard millet as influenced by various treatments

Treatment	Yield (ha^{-1} kg)		Biological yield (kg ha^{-1})	Gross monetary returns (Rs. ha^{-1})	Net monetary returns (Rs. ha^{-1})	B:C ratio
	Grain	Straw				
A. Spacings						
S_1-(30 x 10 cm)	1291	2533	3825	80012	56648	3.43
S_2-(45 x 5 cm)	1395	2723	4118	86448	63008	3.69
S_3-(45 x 10 cm)	1052	2022	3075	65178	41975	2.99
S.E. (m)±	91	137	210	5553	-	-
C.D. at 5%	272	412	631	16647	-	-
B. Nutrient Levels (kg N: P: K ha^{-1})						
F_1-30:20:00	1013	2003	3034	63872	40664	2.75
F_2-40:20:00	1245	2583	3829	77342	54017	3.31
F_3-50:20:00	1462	2692	4155	90424	66987	3.86
S.E. (m)±	91	137	210	5553	5553	-
C.D. at 5%	272	412	631	16647	16647	-
C. Interaction (S x F)						
S.E. (m)±	157	238	364	9318	9619	-
C.D. at 5%	NS	NS	NS	NS	NS	NS
GM	1246	2426	3673	77212	53889	3.31

Interaction effect

The interaction impact of spacings and nutrient levels did not significantly affect yield characteristics, yield, or economics (Table 1 and 2).

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