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Performance of proso millet (*Panicum miliaceum* L.) under different sowing periods and row spacing in arid conditions

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ABSTRACT

A field experiment was conducted at PC unit, AICRP on millets, Jodhpur during the Kharif season of 2024 to evaluate the performance of proso millet (Panicum miliaceum L.) under different sowing periods and row spacings. The experiment was laid out in a split plot design (SPD) with four sowing dates (1st week of July, 2nd week of July, 3rd week of July, and 4th week of July) and three row spacings (30 cm, 45 cm and 60 cm). The results revealed that sowing during first week of July recorded the highest plant height, number of tillers, panicle length, grain yield and straw yield, which declined progressively with delayed sowing. Among spacings, 30 cm row spacing showed significantly higher grain yield (1090 kg/ha) and yield attributes (compared to 45 cm and 60 cm). Interaction effects between sowing dates and spacing were more significant revealing that the combination of 1st week of July sowing with 30 cm row spacing recorded the maximum yield and growth performance, indicating it as the most suitable treatment combination under arid agro-climatic conditions. Thus, early sowing (1st week of July) and closer row spacing (30 cm) are recommended for optimizing productivity of proso millet in arid regions.

Keywords**:** Proso millet, sowing date, row spacing, arid condition, productivity

INTRODUCTION

Proso millet (*Panicum miliaceum* L.) is referred to as Chena in Hindi and Baragu in Kannada in India. Due to its short growing season and high nutritional content, this drought-tolerant grain is a good fit for sustainable agriculture and food security. In India, because of its remarkable resistance to abiotic stressors such drought, salt, and low soil fertility, proso millet (*Panicum miliaceum* L.) is a perfect crop for sustainable agriculture in harsh climates (Prabhakar., 2017). Because of its short growing season (60–90 days), proso millet has been adapted to marginal areas of rainfed agriculture systems that are characterized by low rainfall (100–250 mm) and high temperatures for the production of food or feed in arid and semi-arid regions of China, India, Africa, and Russia (Aishwarya *et al.,* 2022). Before cool-season crops like wheat are planted, proso millet is used as a catch crop. Because it requires few inputs, proso millet is a good choice for farmers with limited resources. With 11–12% protein, 8–9% dietary fibre, and vital vitamins and minerals, it has a high nutritional value. rendering it appropriate for use as animal feed and for human consumption (Vetriventhan *et al.,* 2020). Its nutritional profile highlights how it can help combat malnutrition and improve food security. A more robust and sustainable food system may be possible if proso millet is grown successfully. It might also lessen the need for imports and help create a more varied agricultural landscape that is less reliant on traditional crops. Finding the right proso millet sowing timing and row spacing in arid climates is essential to ensuring the best crop performance and yield in the difficult environment.

MATERIALS AND METHODS

The present field experiment was conducted during rainy season of 2024 at PC-Unit, AICRP on pearl millet, Mandor, Jodhpur (Rajasthan) in a split plot design (SPD) with 3 replications. The soil of the experimental plot was loamy sand in texture, low in available nitrogen (174.43 kg ha^{-1}) and phosphorus (20.48 kg ha^{-1}) and low in organic carbon 0.15 and moderately saline in reaction (pH 8.04). The seeds of proso millet were sown at varying row spacing 30 cm, 45 cm and 60 cm in main

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plots and at different sowing dates *viz*., 2nd July, 9th July, 16th July and 23rd July in sub plots. The nutrients were applied at a rate of 20 Kg K_2O /ha and 40 kg P_2O_5/ha. Manures of potash (60 percent K_2O) and single super phosphate (16 percent P_2O_5) were utilized as sources of potash and phosphorus. In contrast, urea (46% N) was utilized as a source of nitrogen to meet the crop's nitrogen needs. Before seeding, fertilizers containing half a dose of nitrogen, a full dose of phosphorus, and potash were drilled 8 cm deep in each plot. The remaining nitrogen dose was applied as top dressing at 25 DAS. For every character, observations were made on five randomly chosen plants in each replication. Similarly for yield and yield attributes. The number of panicles in each net row were counted from one meter row length. Length of five panicles was measured in centimetres from the cut end of the panicles to the tip of the panicle and mean was worked out and recorded plot wise. The five panicles per plot selected from randomly tagged plants at the time of light-yellow colour panicle grain were weighed with the help of digital weighing balance and recorded in grams. A composite sample of grains was collected from the produce of each net plot and 1000 grains were counted and their weight was recorded in gram by using electric digital balance. The weight of the thoroughly sun-dried harvested produce of each plot was recorded separately before threshing as biological yield and then converted into kg/ha. Before threshing, the crop harvest was kept in the respective plots for 2-3 days to lose moisture under open sun then it was threshed by beating with wooden stick to collect grain per plot and converted in to kg/ha. Grains weight per net plot (kg) was deducted from already recorded weight (kg) of biological yield to get straw yield per net plot. Finally, it was converted to kg/ha. The formula given as by Donald, 1962 was used to work out harvest index:

$$\text{Harvesting index (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

RESULTS AND DISCUSSION

Population and growth attributes

Effect of sowing dates

Different sowing dates had no discernible effects on the plant population (Table 1); however there was a decline from the beginning to the harvest stage. The decline was greatest during the final week of July (16.7%), followed by the third week (9.5%) and the second week (6.3%). The plant population decreased the least (4.6%) from the first to the last stage during the first week of July planting. Plant height increased gradually from 30 DAS to 60 DAS and finally at proso millet harvest. Numerous studies have detailed the possible effects of sowing timing on plant growth (Bello *et al.,* 2020; Bhavna *et al*., 2020; Srikanya *et al.*, 2020). Compared to W2: 9th July (37.2 cm, 100.6 cm, and 115.6 cm, respectively), W3: 16th July (29.5 cm, 88.2 cm, and 103.2 cm, respectively), and W4: 23rd July (28.4 cm, 72.8 cm, and 87.9 cm, respectively), the sowing of proso millet during the first week of July (W1: 2nd July) resulted in the highest plant height of the crop at all stages of observation (30 DAS, 60 DAS, and at harvest). Mubeena *et al.,* (2019) and Nandini and Sridhara (2019) reported similar results. Depending on when the crop was sown, different numbers of tillers were seen at the harvest stage (Table 1). The maximum number of tillers per meter row length (32.1) in the first sowing (W1: 2 July) was comparable to the second sowing (W2: 9 July), which produced 30.8 tillers per meter row length. With the third (W3: July 16) and fourth (W4: July 23) sowings, it was further decreased to 28.6 and 26.2, respectively. W1 had a substantially greater maximum total number of tillers per meter row length of proso millet than the other sowing dates, except W2. Proso millet's decreased number of tillers with delayed sowing may be the result of a less conducive microclimate, which makes it less ideal for plant growth. Jan *et al*., (2015), Yoon *et al*., (2015), and Rea ger *et al*., (2023) also reported similar findings.

Effect of row spacing

Different row spacing treatments resulted in variations in the proso millet plant population. At 30 days after planting, the

Table 1: Effect of sowing dates and row spacing on plant height and number of total tillers per metre row length of proso millet

Treatments	Plant height (cm)			No. of total tillers per meter row length	Plant population (lakh/ha)	
	30 DAS	60 DAS	At harvest	At harvest	30 DAS	At harvest
Row Spacing						
S_1: 30 cm	38.6	103.1	117.8	27.1	3.244	3.158
S_2: 45 cm	35.1	90.9	105.9	28.8	2.142	2.053
S_3: 60 cm	30.9	81.2	96.2	32.3	1.607	1.503
SEm±	0.8	3.2	3.0	0.87	0.057	0.095
CD (P=0.05)	3.2	12.7	11.8	3.4	0.222	0.373
Sowing date						
W_1: 2 July	44.3	105.4	120.1	32.1	2.363	2.317
W_2: 9 July	37.2	100.6	115.3	30.8	2.344	2.281
W_3: 16 July	29.5	88.2	103.2	28.6	2.339	2.244
W_4: 23 July	28.4	72.8	87.9	26.2	2.277	2.110
SEm±	1.1	3.4	3.5	0.79	0.025	0.067
CD (P=0.05)	3.4	10.2	10.4	2.4	NS	NS

average number of plants per hectare in S1 (30x10 cm) was 3.244 lakh, whereas in S2 (45x10 cm) and S3 (60x10 cm), the average number was 2.142 lakh and 1.607 lakh, respectively. At the harvest stage, these numbers were lowered by 2.7%, 4.2%, and 6.5%. Proso millet plant height varied significantly in the current study, according to data on plant height and number of tillers in Table 1. At 30 DAS, S1 (30 x 10 cm) had a noticeably larger plant height (38.6 cm) than S2 and S3 (35.1 cm and 30.9 cm, respectively). Likewise, it was 103.1 cm in S1 (30 x 10 cm) at 60 DAS, which was noticeably more than S2 (45 x 10 cm) at 90.9 cm and S3 (60 x 10 cm) at 81.2 cm. S2 (45 x 10 cm) and S3 (60 x 10 cm) had plant heights of 105.9 cm and 96.2 cm at harvest, respectively, which were statistically comparable but noticeably lower than S1 (117.8 cm). The taller plants seen with closer spacing may be the result of a natural predisposition to grow taller brought on by the availability of packed space. Denser populations of plants compete for sunlight by growing taller to receive it (Xiao, 2016). Maurya *et al*., (2016), Bello *et al*., (2016), Jan *et al*., (2025), and Srikanya *et al*., (2002) all verified similar findings. Because S1 (30 x 10 cm), S2 (45 x 10 cm), and S3 (60 x 10 cm) had different row spacing, there were differences in the total number of tillers per meter row length at harvest. S3 (32.3) had the most tillers overall, followed by S2 (28.8) and S1 (27.1). Plants may grow higher under dense sowing (closer spacing) to obtain light, as was previously described in the case of plant height response to plant density. However, this often comes at the expense of other growth qualities, such as stem diameter and branching (tillering) (Shibuya *et al*., 2013). There were fewer tillers in the current study when the row spacing was closer. This could be because there are more plants spaced closer together per unit area. Additionally, it may be because more horizontal resources were captured due to the increased distance between lines; Yoon *et al*., (2015), Choi *et al*., (2016), and Reager *et al*., (2023) reported similar results of fewer tillers with tighter spacing.

Yield and yield attributes

Effect of sowing dates

Yield characteristics, including panicle count, panicle length, panicle weight, and weight of 1000 grains, are shown in Table 2. The weight of 1000 grains and the number of functioning panicles have a major impact on the yield. Other important factors that influence yield include the panicles' weight and length. Grain weight is particularly important since a variety of factors influence grain development. Environmental variables have a circumlocutory effect on proso millet grain yield. The different sowing date treatments in the current study had a significant impact on all of these yield-attributing traits, and they might have contributed to increased yield; higher values were noted when sowing occurred during the first week of July. The data shows that the first

Table 2a: Effect of sowing dates and row spacing on yield attributes of proso millet

Treatments	Number of panicles per meter row length	Panicle length (cm)	Panicle weight (g)	1000 grain weight (g)
Row Spacing				
S_1: 30 cm	22.9	27.5	6.45	3.28
S_2: 45 cm	24.8	28.4	6.83	3.53
S_3: 60 cm	26.3	29.1	7.31	3.79
SEm±	0.63	0.92	0.16	0.03
CD (P=0.05)	2.5	NS	0.63	0.14
Sowing dates				
W_1: 2 July	26.8	29.8	7.75	4.31
W_2: 9 July	25.6	28.9	6.83	3.67
W_3: 16 July	23.4	27.4	6.79	3.23
W_4: 23 July	22.7	27.3	6.08	2.92
SEm±	0.71	0.77	0.23	0.04
CD (P=0.05)	2.1	NS	0.67	0.11

week of July (W1) sowing date had a significantly higher number of panicles per meter row length than the other sowing date treatments. W1 had 26.8 panicles per meter row length, W2 had 25.6, W3 had 23.4, and W4 had 22.7. With the exception of W1, which produced 4.7%, 14.5%, and 18.1% more panicles per meter row length than W2, W3, and W4, respectively, their statistical values were comparable. The panicle's longest length (29.8 cm) was measured during the first week of July (W1), followed by 28.9 cm during the second week (W2) and 27.4 cm during the third week (W3). The proso millet panicle length was comparable across all sowing date treatments (Choi *et al*., 2016). The panicle weight was significantly impacted by the sowing period as well. The crop sown on the 27th MW (W1) had the highest panicle weight statistically, followed by the crop sown on the 28th MW (W2). The crop planted on the 29th MW (W3) and 30th MW (W4) had the lowest panicle weight. Early-planted crops had longer photoperiods, which induced more assimilates to flow toward the panicle, increasing its weight, while late-planted crops (those planted in the fourth week of July) experienced relatively fewer hours of bright sunshine, resulting in less productive panicles. The crop sown on the 27th MW (W1) had the greatest 1000 grain weight (4.3 g), which was comparable to the crop sown on the 28th MW (W2). The crop planted on the 29th and 30th MW (W3 and W4) had the lowest 1000 grain weight. There were plenty of bright hours and a reasonable quantity of equally distributed rainfall for the crop that was sowed during the first week of July. This might have helped the plant grow better and produce more dry matter, which would have increased the amount of dry matter that was distributed among the grains and helped the plant develop (Maurya *et al*., 2016; Gavit *et al*., 2017 and Mubeen *et al*., 2019). A far higher grain yield was obtained by sowing during the first week of July (W1) as opposed to the second, third, and fourth weeks of July (W2, W3, and W4). A far higher grain yield was obtained by sowing during the first week of July (W1) as opposed to the second, third, and fourth weeks of July (W2, W3, and W4). Sowing in the first week of July increased the yield by 276 kg/ha compared to sowing in the second week of July, which produced 887 kg/ha. The results indicated that the first week of July was the best date to seed proso millet because subsequent sowing in the third and fourth weeks of July resulted in a significant loss in grain production of 32.6% and 35.9%, respectively.

There was a discernible decrease in grain yield from late sowing during the fourth week of July. From seeding to the vegetative stage, there was sufficient and balanced rainfall, which is associated with better nutrient availability. This, in turn, leads to effective metabolism, plenty of sunshine, and optimal temperatures, all of which may have contributed to the production of good yields. The yield was considerably lower when the crop was planted in the fourth week of July. Thus, when proso millet was sown after its optimal time, grain output was significantly decreased. These findings are in agreement with each other, as noted by Dubey *et al*., (1993), Basavarajappa and Jolli (2001),

Table 2b: Effect of sowing dates and row spacing on yield and harvest index of proso millet

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Row Spacing				
S_1: 30 cm	1090	2182	3272	33.30
S_2: 45 cm	909	1805	2715	33.28
S_3: 60 cm	684	1357	2040	34.20
SEm±	24	61	58	0.01
CD (P=0.05)	92	238	227	NS
Sowing dates				
W_1: 2 July	1163	2216	3380	34.32
W_2: 9 July	887	1719	2606	34.28
W_3: 16 July	783	1608	2391	33.22
W_4: 23 July	745	1582	2327	32.18
SEm±	33	71	74	0.01
CD (P=0.05)	98	210	221	NS

Maurya *et al*. (2016), and Gavi et al., (2017). Compared to the other sowing date treatments, the 27th MW (W1), which was sown in the first week of July, produced the highest straw yield (2216 kg/ha) and biological yield per hectare (3380 kg/ha). Proso millet yielded the least amount of straw (1582 kg/ha) when it was seeded in the last week of July in the 30th MW (W2), followed by the third week in the 29th MW (W3) (1608 kg/ha). This suggests that it is less appropriate to sow proso millet in the third and fourth weeks of July as opposed to the first week. When straw was sown in the fourth week of July (W4) as opposed to the first week of July (W1), the yield was 28.6% lower.

The biological yield was 29.7% higher in the first week of July (W1), 41.3% higher in the second week (W2), 41.3% higher in the third week (W3), and 45.2% higher in the fourth week (W4). Dimple *et al*. (2020) also noted that late sowings resulted in a lower straw yield. The increased straw and biological yield seen when the crop was sown in the first week of July may have been caused by the ideal weather conditions and the availability of bright sunshine hours during the crop. Additionally, these elements contributed to the improvement of growth characteristics, which raised the biological yield and straw, which tend to decrease with later crop sowing (Mubeena *et al*., 2019). The harvest index was not substantially impacted by the timing of sowing.

The crop sown in the first and second weeks of July (0.34) yielded an obliviously higher harvest index value than the crop sown in the third week of July (0.33). Crops seeded in the final week of July had the lowest harvest index value (0.32). This is due to proso millet's comparatively lower grain yield when compared to the biological yield from later sowing. The crop with the greatest harvest index that was sown in the first week of July might have had higher grain output. The harvest index may have declined in other sowing weeks due to lower grain and biological yield. The fact that fewer tillers were turned into panicles overall, which leads to a smaller rise in grain yield, may also be the cause of the fourth week of July's lowest harvest index. Similar results were reported by Mubeena *et al*., (2019).

Effect of row spacing

Table 2 displays yield attributes such as the number of panicles, panicle length, panicle weight, and weight of 1000 grains. Among these, the weight of 1000 grains and the quantity of panicles are essential for calculating the yield. The length and weight of the panicles are additional significant variables that affect yield. In contrast to 24.8 in S2 (45 cm) and 22.9 in S1 (30 cm), a wider row spacing of S3 (60 cm) resulted in 26.3 panicles per meter row length. Compared to closer row spacing (30 cm), a wider row spacing (60 cm) resulted in 14.8% more panicles per meter row length. More panicles were formed as a result of more tillers spaced widely apart. According to Mownika *et al*., (2021), this could be because the crop was given a favourable microclimate that allowed it to use available nutrients, moisture, and photosynthates more effectively to the reproductive portions, resulting in improved yield qualities. Since panicle length is mostly a hereditary trait, various row spacing treatments have little effect on it. Under 60 cm

(29.1 cm) row spacing (S_3), a statistically greater length of panicle was observed, followed by 45 cm (28.4 cm) row spacing (S_2). Closer row spacing of 30 cm resulted in the shortest panicle length (S_1) (27.5 cm). As row spacing decreased, a non-significant decrease in panicle length was noted. Sanjay *et al*., 2021 and Nandini and Sridhara (2019) both had the identical conclusions.

Row spacing was found to have a substantial impact on 1000 grain weight. The row-spaced crop (60 cm, S_3) had the greatest 1000 grain weight, followed by the 45 cm row-spaced crop (S_2). Wider row spacing creates a microclimate that is conducive to the crop's efficient use of available moisture and nutrients as well as improved photosynthetic partitioning to reproductive portions, which results in a higher 1000 grain weight value. Row spacing has a major impact on panicle weight. A 60 cm row spacing (S_3) produced a statistically larger panicle weight, followed by a 45 cm row spacing (S_2). Compared to wider row spacing, the panicle weight achieved from a closer row spacing of 30 cm (S1) was lower. Panicle weight is determined by the size and filling condition of the grains. Grain weight decreased with closer spacing, which in turn reduced panicle weight. Similar results were previously reported by Sujathamma and Naik., 2022 and Mownika *et al*., (2021). Changes in row spacing had a major impact on the proso millet grain output per hectare. The highest grain production (1090 kg/ha) was obtained with a closer row spacing of 30 cm as opposed to 45 cm (909 kg/ha) and 60 cm (684 kg/ha). Compared to 60 cm row spacing, grain yield under 45 cm row spacing was noticeably higher. It was found that the grain yield of proso millet decreased by 16.5% when the row spacing was raised from 30 cm to 45 cm and by 24.7% when it was extended from 45 cm to 60 cm. With an ideal plant population per unit area and a higher total number of tillers and panicles per unit base, rows spaced 30 cm apart produced more grain per hectare. These outcomes are consistent with Sujathamma and Naik's (2022) findings. Significantly, 30 cm row spacing (S1) produced the highest straw production (2128 kg/ha) and biological yield (3272 kg/ha) per hectare, followed by 45 cm row spacing (S2), which produced 1805 kg/ha and 2715 kg/ha, respectively.

Wider row spacing of 60 cm produced the lowest biological production (2040 kg/ha) and straw yield (1357 kg/ha) (S_3). The biological yield per hectare was 31% lower with a 60 cm (S_3) row spacing compared with a 30 cm row spacing. Because there were much less plants per unit area with a wider spacing, the straw and biological yield were lower than with a closer spacing. Similar results were achieved by Sujathamma and Naik (2022) in agreement with the spacing treatments. The harvest index of proso millet did not significantly change as a result of the various row spacing treatments. However, a numerically higher harvest index value was noted under 60 cm (34.30) row spacing, followed by 45 cm (33.20) and 30 cm (33.15). This is because closer spacing resulted in a higher biological yield per unit area due to the larger number of plants per unit area.

CONCLUSION

When proso millet was sown in the first week of July with a 30-cm row spacing, it showed noticeably growth attributes, yield attributes, yield with higher returns, and B:C ratio. Therefore, for increased proso millet productivity and profitability, the first week of July is a good time for sowing and 30 cm is a optimum row spacing. Since these findings are based on a single season's study, more research is necessary to get a firm conclusion.

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