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Resource Optimization through Crop Geometry and Fertilizer Management for Sustainable Productivity of Pearl Millet (*Pennisetum glaucum* L.) under Semi-Arid Conditions of Rajasthan, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Pearl millet is an important drought-tolerant cereal crop cultivated widely in semi-arid regions of India, where optimum nutrient management and crop geometry play a crucial role in improving productivity and resource-use efficiency. The present investigation was conducted during 2025-26 at the Agronomy Research Farm of Jaipur National University, Jaipur, Rajasthan to study the effect of fertilizer doses and crop spacing on growth

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and yield of pearl millet. The experiment was laid out in a randomized block design with three replications comprising twelve treatment combinations. Four fertility levels (50% RDF, 75% RDF, 100% RDF and 125% RDF) and three spacing treatments (20 cm × 15 cm, 30 cm × 15 cm and 45 cm × 15 cm) were evaluated. The findings revealed that application of 125% RDF recorded significantly higher plant height (67.16 cm at 30 DAS, 180.63 cm at 60 DAS and 210.37 cm at maturity), number of tillers plant^{-1} (3.03 at 30 DAS, 4.79 at 60 DAS and 3.78 at harvest), dry matter accumulation (8.03, 41.92 and 67.19 g plant^{-1}), crop growth rate and relative growth rate (RGR) and yield attributes including ear head length (25.12 cm), number of grains per panicle (2494.44), grain weight per ear (22.98 g) and 1000-seed weight (9.91 g) and was at par with 100% RDF but significantly higher than 50% RDF. However, plant population was not significantly affected by fertilizer doses. Among spacing treatments, 30 cm × 15 cm spacing was superior, recording higher plant population per plot (470.58 at 20 DAS and 466.00 at maturity), plant height (61.04 cm at 30 DAS, 163.39 cm at 60 DAS and 193.55 cm at maturity), tillers plant^{-1} (2.71, 4.10 and 3.17), dry matter accumulation (7.41, 35.51 and 59.82 g plant^{-1}) and yield attributes such as ear head length (22.38 cm), number of grains per panicle (2119.75), grain weight per ear (19.78 g) and 1000-seed weight (9.49 g) and was at par with 45 cm × 15 cm but significantly higher than 20 cm × 15 cm. Relative growth rate remained non-significant throughout the crop growth period. The study concludes that application of 100-125% RDF in combination with 30 cm × 15 cm spacing is most suitable for higher growth and productivity of pearl millet under the agro-climatic conditions of Jaipur.

Keywords: Pearl millet; fertility levels; crop spacing; RDF; growth; yield; productivity.

1. Introduction

Pearl millet (*Pennisetum glaucum* L.), commonly known as bajra in India is a short-duration, drought-tolerant cereal crop of the family Poaceae. It thrives in tropical and semi-arid climates with an optimum temperature of 28-33°C and completes its life cycle in 70-90 days. Due to its short duration and high adaptability, it fits well into dryland farming systems and is widely grown as a staple and fodder crop, making it an important component of sustainable farming systems in India. India accounts for a major share of global pearl millet cultivation. During 2023-24, pearl millet was grown on 7.08 million hectares with a production of 9.53 million tonnes and an average productivity of 1360 kg ha^{-1} (Anonymous, 2024). In Rajasthan, it covered about 4.2 million hectares with a productivity of 1161 kg ha^{-1}, which is lower than the national average due to marginal lands and low input use. Nutritionally, pearl millet contains 11-12% protein, high dietary fibre, essential minerals such as iron and zinc and provides about 360 kcal per 100 g grain. It is also rich in energy and micronutrients. Being a drought-tolerant cereal, it contributes to food and nutritional security under harsh climatic conditions and improves resilience of farming systems in arid regions.

Fertilizer application is crucial for enhancing pearl millet productivity. Nitrogen, phosphorus, and potassium are the major nutrients required for growth and yield improvement. Application of balanced fertilizers enhances growth, yield, nutrient uptake and grain quality under semi-arid conditions. Giri *et al*. (2024) reported that integrated application of 125% RDF combined significantly improved yield, soil fertility and nutrient uptake.

Crop geometry also plays a vital role in maximizing productivity. Optimum plant population ensures efficient use of light, nutrients and moisture, leading to better growth and yield. Both overcrowding and wider spacing can reduce yield potential, whereas proper inter- and intra-row spacing improves crop performance. Ghuraiya *et al*. (2021) found that 45 cm × 15 cm spacing significantly increased harvest index, grain weight and panicle length under rainfed conditions in eastern Rajasthan. Thus, integration of appropriate fertilizer levels, improved nutrient management and optimum crop geometry is essential for enhancing pearl millet productivity under semi-arid regions like Rajasthan (Gomez and Gomez 1984).

2. Materials and Methods

The experiment was carried out at the Agronomy Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan, India. The experimental site is situated at 26.85° N latitude and 75.87° E longitude, with an elevation of approximately 390 m above mean sea level**.**

The site falls under Agro-climatic Zone IIIa (Semi-Arid Eastern Plain Zone) of Rajasthan and experiences a hot semi-arid climate with temperatures ranging from 5°C to 45°C and an average annual rainfall of about 527 mm.

Relative humidity ranges from 20-30% during summer to 60-80% during the monsoon season with wind speeds varying from 5-15 km h^{-1} and occasional dust storms reaching up to 40 km h^{-1}. During the kharif season, temperatures ranged from 22.0°C to 43.1°C with sporadic rainfall.

The soil of the experimental field was sandy loam in texture, comprising 68.84% sand, 21.67% silt and 9.49% clay. The soil was slightly alkaline in reaction (pH 7.78), low in organic carbon (0.52%), medium in available nitrogen (149.88 kg ha^{-1}) and phosphorus (19.25 kg ha^{-1}), and high in available potassium (198.45 kg ha^{-1}). The bulk density, particle density and porosity of the soil were 1.29 Mg m^{-3}, 2.77 Mg m^{-3} and 37.16%, respectively. Soil analysis was carried out using standard procedures described by Piper (1950), Black (1950), Olsen *et al.* (1954), Richards (1954), Subbiah and Asija (1956) and Jackson (1973).

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising two factors, namely fertilizer dose and crop spacing. The fertilizer treatments consisted of four levels: **F_1** (50% RDF: 30:15:0 $N:P_2O_5:K_2O$ kg ha^{-1}), **F_2** (75% RDF: 45:22.5:0 $N:P_2O_5:K_2O$ kg ha^{-1}), **F_3** (100% RDF: 60:30:0 $N:P_2O_5:K_2O$ kg ha^{-1}) and **F_4** (125% RDF: 75:37.5:0 $N:P_2O_5:K_2O$ kg ha^{-1}). The spacing treatments included **S_1** (20 cm × 15 cm), **S_2** (30 cm × 15 cm) and **S_3** (45 cm × 15 cm). Recommended agronomic practices were followed throughout the crop growth period.

Observations on growth parameters were recorded from five randomly selected plants in each plot, while plant population was estimated on a per-plot basis and expressed as thousand ha^{-1}. Plant height (cm) was measured at different growth stages using a meter scale and the number of tillers per plant was counted from the selected plants. Dry matter accumulation (g $plant^{-1}$) was determined by oven-drying plant samples at 65 ± 5°C until constant weight was obtained. Yield attributes *viz*., ear head length, number of grains per panicle, grain weight per ear and 1000-seed weight were recorded using standard procedures. Statistical analysis of the experimental data was carried out using SPSS software following the procedure of Analysis of Variance (ANOVA) appropriate for a Factorial Randomized Block Design (FRBD). Treatment means were compared at the 5% level of significance ($P \leq 0.05$) and simple correlation coefficients (r) were computed to study the relationships among different characters (Yadav et al. 2021).

3. Results and Discussion

3.1 Effect of Fertilizer Dose

The data presented in Table 1 to 4 and Fig. 1, 2 and 3 revealed that growth parameters, growth indices and yield attributes of pearl millet were significantly influenced by different fertilizer doses. Among the fertilizer levels, application of 125% RDF (F_4) recorded maximum values for most of the observed parameters and remained statistically at par with 100% RDF (F_3) at different growth stages. The data depicted in Table 1 and Fig. 1 showed that application of 125% RDF (F_4) recorded the highest plant height at 30 DAS (67.16 cm), 60 DAS (180.63 cm) and at maturity (210.37 cm), The increase in plant height under F_3 over F_2 was 15.91%, 14.27% and 12.24% at 30 DAS, 60 DAS and at maturity, respectively. Similarly, F_3 showed 39.18%, 29.40% and 25.79% higher plant height over F_1 at 30 DAS, 60 DAS and at maturity, respectively. However, plant population of pearl millet was not significantly affected by different fertilizer doses.

Application of 125% RDF (F_4) recorded the maximum number of tillers $plant^{-1}$ at 30 DAS (3.03), 60 DAS (4.79) and at harvest (3.78). Dry matter accumulation under application of 125% RDF (F_4) was also highest with 8.03, 41.92 and 67.19 g $plant^{-1}$ at 30 DAS, 60 DAS and at harvest, respectively, which were marginally superior to application of 100% RDF (F_3). The increase under F_3 over F_2 in number of tillers $plant^{-1}$ was 25.89%, 25.64% and 27.51% at 30 DAS, 60 DAS and at harvest, respectively, while the corresponding increase in dry matter accumulation was 11.18%, 25.91% and 17.87%. Similarly, F_3 recorded 55.80%, 63.94% and 65.70% higher number of tillers $plant^{-1}$ and 24.76%, 59.63% and 40.56% greater dry matter accumulation over F_1 at 30 DAS, 60 DAS and at harvest, respectively (Table 2 and Fig. 1).

The growth indices presented in Table 3 and Fig. 2 further revealed that application of 125% RDF (F_4) recorded the highest crop growth rate (CGR) at 30 DAS (0.27 g m^{-2} day^{-1}), 60 DAS (1.13 g m^{-2} day^{-1}) and at harvest (0.84 g m^{-2} day^{-1}), showing increases of 3.85%, 10.78% and 1.20% over application of 100% RDF (F_3), respectively. Likewise, relative growth rate (RGR) under application of 125% RDF (F_4) was highest at 30 DAS (0.17 g m^{-2} day^{-1}) and 60 DAS (0.055 g m^{-2} day^{-1}), which were marginally higher than application of 100%

RDF (F_3). However, at harvest, the highest RGR was recorded under application of 50% RDF (F_1), whereas application of 125% RDF (F_4) recorded the lowest value (0.016 g m^{-2} day^{-1}).

Among fertilizer levels, application of 125% RDF (F_4) recorded the highest ear head length (25.12 cm), number of grains per panicle (2494.44), grain weight per ear (22.98 g) and 1000-seed weight (9.91 g), followed by 100% RDF (F_3). The increase in F_3 over F_2 was 16.47%, 25.80%, 25.39% and 11.63% in ear head length, number of grains per panicle, grain weight per ear and 1000-seed weight, respectively, while over F_1 the corresponding increase was 32.74%, 61.36%, 57.05% and 20.72%, respectively (Table 4 and Fig. 3).

The superior performance under the application of 125% RDF (F_4) may be attributed to the adequate and balanced supply of essential nutrients, particularly nitrogen and phosphorus, which played a key role in enhancing physiological and biochemical processes such as cell division, chlorophyll formation, enzymatic activity and overall photosynthetic efficiency. This improved nutritional environment likely promoted more vigorous vegetative growth, better canopy development and enhanced expression of yield attributes in pearl millet. Similar positive responses to increased fertilizer levels have also been reported by Yadav *et al*. (2019), Munagilwar *et al*. (2020) and Adhikari *et al*. (2021), who emphasized that higher nutrient availability supports stronger plant establishment and improved assimilate production during critical growth stages.

The increased nutrient supply under F_4 also contributed to higher dry matter accumulation and crop growth rate due to more efficient utilization of light, moisture and nutrients during active vegetative and reproductive phases. This ultimately improved source strength and supported better translocation of assimilates towards developing reproductive structures, resulting in enhanced yield components. However, the marginal differences between 125% RDF (F_4) and 100% RDF (F_3) suggest that the crop response beyond the recommended dose was limited, indicating a plateau effect in nutrient utilization efficiency. Similar findings have been reported by Babar *et al*. (2021), Reddy *et al*. (2021), Kumar *et al*. (2024), Giri *et al*. (2024) and Deepshikha *et al*. (2024), who observed that both optimal and slightly higher fertilizer levels often remain statistically at par for most growth and yield parameters in pearl millet.

3.2 Effect of Spacing

The data presented in Table 1 to 4 and Fig. 1, 2 and 3 indicated that spacing treatments significantly influenced growth and yield parameters of pearl millet, whereas their effect on relative growth rate remained non-significant at most growth stages. Among the spacing treatments, spacing of 30 cm × 15 cm (S_2) proved superior for most of the growth and yield attributes and remained statistically at par with spacing of 45 cm × 15 cm (S_3) in several cases. The data illustrated in Table 1 and Fig. 1 indicated that among the spacing treatments, spacing of 20 cm × 15 cm (S_1) recorded significantly higher plant population per plot with 470.58 plants at 20 DAS and 466.00 plants at maturity due to closer spacing. This was followed by spacing of 30 cm × 15 cm (S_2) with 320.00 and 315.42 plants, respectively, whereas the lowest plant population was recorded under spacing of 45 cm × 15 cm (S_3) with 213.00 plants at 20 DAS and 208.42 plants at maturity. However, plant height was found maximum under spacing of 30 cm × 15 cm (S_2), which recorded 61.04 cm, 163.39 cm and 193.55 cm at 30 DAS, 60 DAS and maturity, respectively. The increase in plant height under S_2 over S_3 was 5.55%, 1.71% and 2.62% at 30 DAS, 60 DAS and at maturity, respectively. Similarly, S_2 showed 10.96%, 5.97% and 6.15% higher plant height over S_1 at 30 DAS, 60 DAS and maturity, respectively.

Likewise, Table 2 and Fig. 1 revealed that spacing of 30 cm × 15 cm (S_2) recorded the maximum number of tillers $plant^{-1}$ at 30 DAS (2.71), 60 DAS (4.10) and at harvest (3.17). Dry matter accumulation under spacing of 30 cm × 15 cm (S_2) was also highest with 35.51 g $plant^{-1}$ at 60 DAS and 59.82 g $plant^{-1}$ at harvest. The increase in number of tillers $plant^{-1}$ under S_2 over S_3 was 7.97%, 3.80% and 4.28% at 30 DAS, 60 DAS and at harvest, respectively, while the increase over S_1 was 22.62%, 16.81% and 14.86%, respectively. Similarly, dry matter accumulation under S_2 was higher by 2.07%, 2.72% and 3.53% over S_3 and by 7.86%, 14.33% and 10.09% over S_1 at 30 DAS, 60 DAS and at harvest, respectively.

The growth indices presented in Table 3 and Fig. 2 showed that spacing of 30 cm × 15 cm (S_2) recorded the highest crop growth rate (CGR) at 30 DAS (0.25 g m^{-2} day^{-1}), 60 DAS (0.94 g m^{-2} day^{-1}) and at harvest (0.81 g m^{-2} day^{-1}). The increase in CGR under spacing of 30 cm × 15 cm (S_2) at 60 DAS was 3.30% over spacing of 45 cm × 15 cm (S_3). Relative growth rate (RGR) among spacing treatments varied only marginally and remained statistically non-significant throughout the crop growth period.

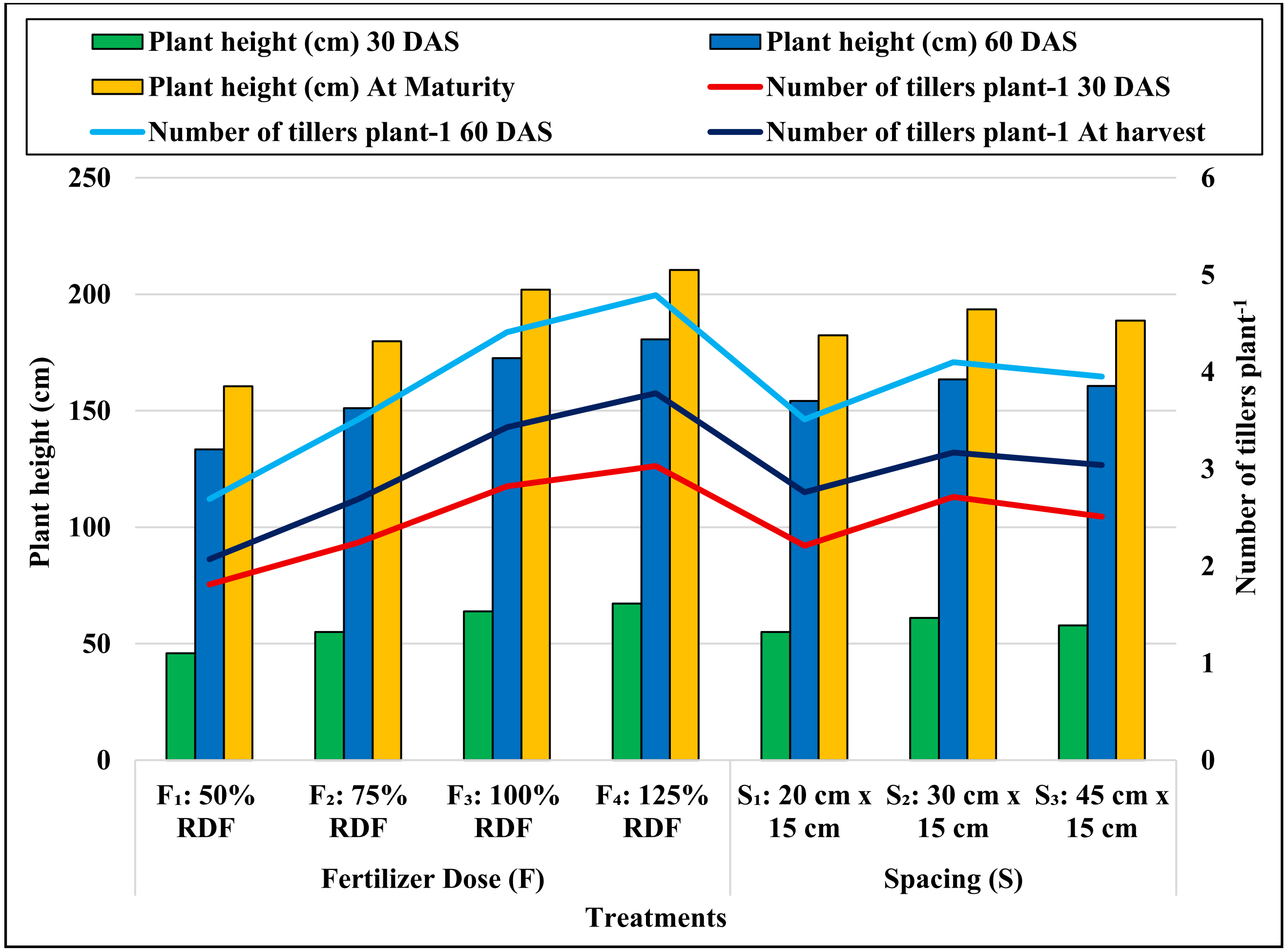

Fig. 1. Graph showing Effect of fertilizer dose and spacing on plant height (cm) and number of branches plant^{-1} of pearl millet

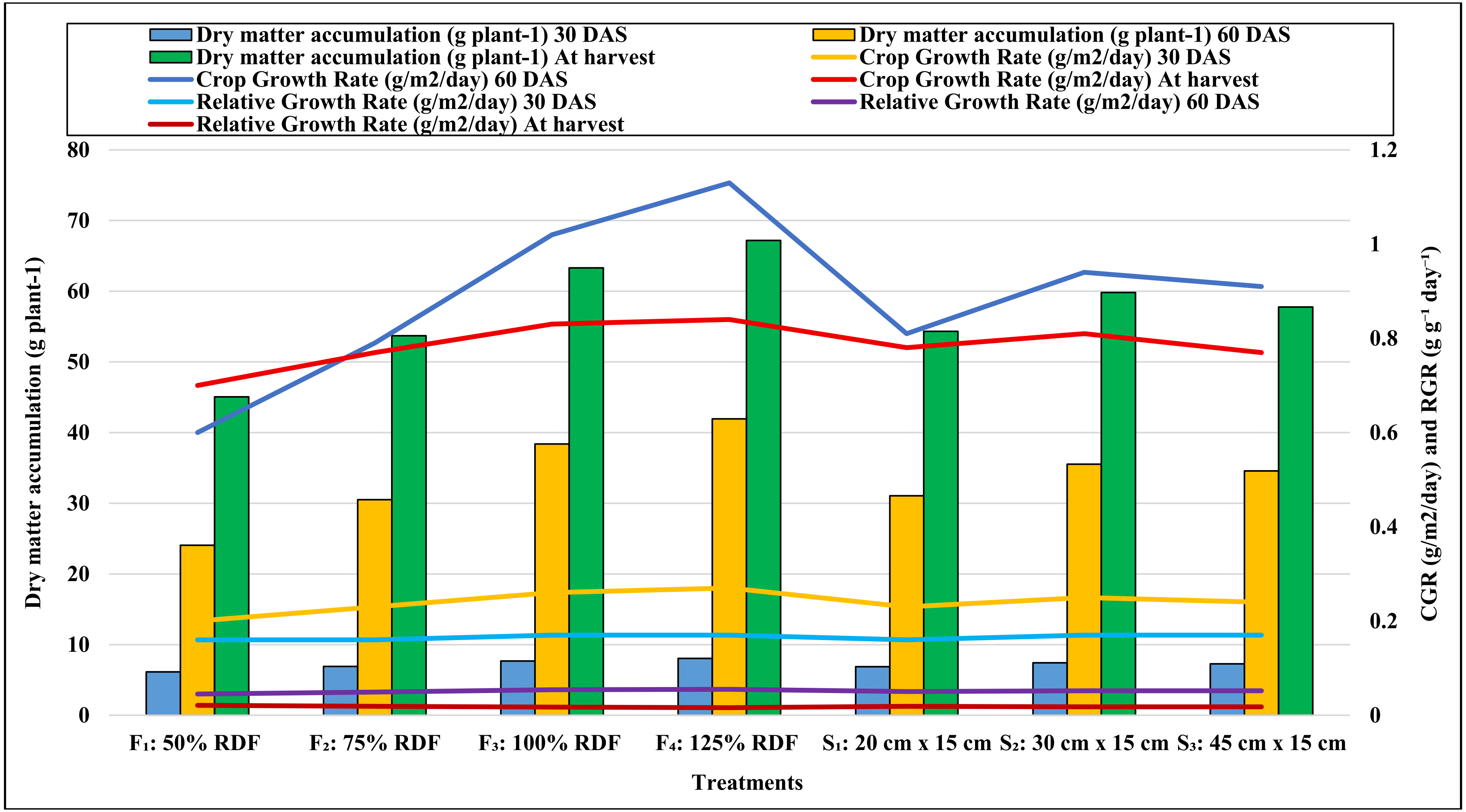

Fig. 2. Graph showing Effect of fertilizer dose and spacing on dry matter accumulation plant^{-1} (g), crop growth rate (g/m^2/day) and relative growth rate (g/m^2/day) of pearl millet

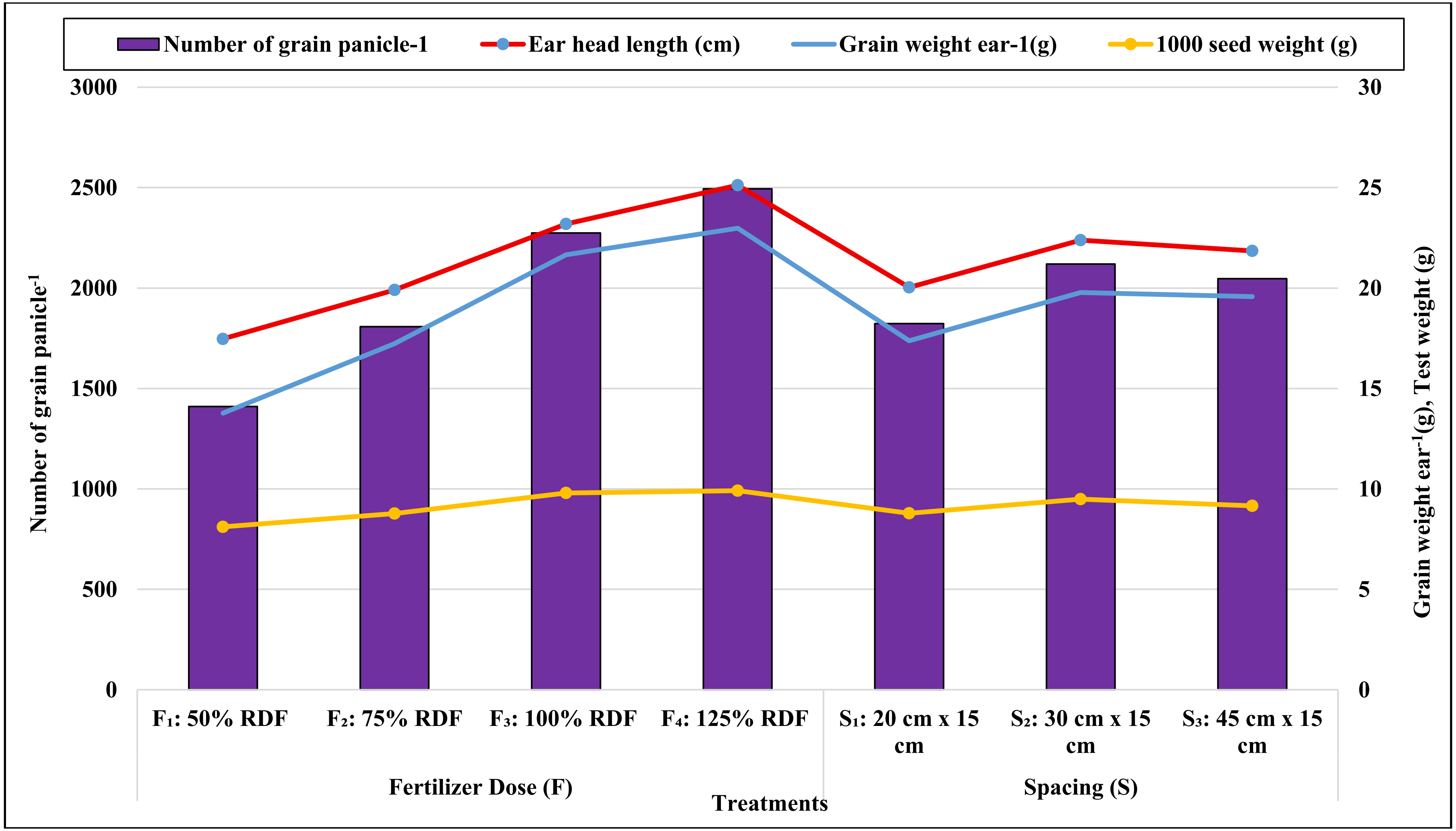

Fig. 3. Graph showing Effect of fertilizer dose and spacing on yield attributes of pearl millet

Table 1. Effect of fertilizer dose and spacing on plant population and plant height (cm) of pearl millet

Treatments	Plant Population per plot		Plant height (cm)		
	20 DAS	**At Maturity**	**30 DAS**	**60 DAS**	**At Maturity**
Fertilizer Dose (F)					
F_1: 50% RDF (30:15:00 N P_2O_5 K_2O kg/ha)	333.67	327.33	45.84	133.37	160.51
F_2: 75% RDF (45:22.5:00 N P_2O_5 K_2O kg/ha)	334.33	329.33	55.04	151.03	179.88
F_3: 100% RDF (60:30:00 N P_2O_5 K_2O kg/ha)	334.89	330.89	63.80	172.58	201.90
F_4: 125% RDF (75:37.5:00 N P_2O_5 K_2O kg/ha)	335.22	332.22	67.16	180.63	210.37
SEm±	2.59	2.61	1.60	2.86	3.03
C.D (p=0.05)	NS	NS	4.70	8.40	8.88
Spacing (S)					
S_1: 20 cm x 15 cm	470.58	466.00	55.01	154.18	182.33
S_2: 30 cm x 15 cm	320.00	315.42	61.04	163.39	193.55
S_3: 45 cm x 15 cm	213.00	208.42	57.83	160.64	188.61
SEm±	2.25	2.26	1.39	2.48	2.62
C.D (p=0.05)	6.59	6.62	4.07	7.28	7.69

Table 2. Effect of fertilizer dose and spacing on number of branches plant^{-1} and dry matter accumulation plant^{-1} (g) of pearl millet

Treatments	Number of tillers plant^{-1}			Dry matter accumulation (g plant^{-1})		
	30 DAS	**60 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**At harvest**
Fertilizer Dose (F)						
F_1: 50% RDF (30:15:00 N P_2O_5 K_2O kg/ha)	1.81	2.69	2.07	6.14	24.05	45.04
F_2: 75% RDF (45:22.5:00 N P_2O_5 K_2O kg/ha)	2.24	3.51	2.69	6.89	30.49	53.71
F_3: 100% RDF (60:30:00 N P_2O_5 K_2O kg/ha)	2.82	4.41	3.43	7.66	38.39	63.31
F_4: 125% RDF (75:37.5:00 N P_2O_5 K_2O kg/ha)	3.03	4.79	3.78	8.03	41.92	67.19
SEm±	0.14	0.17	0.12	0.39	1.28	1.72
C.D (p=0.05)	0.40	0.50	0.35	1.14	3.74	5.05
Spacing (S)						
S_1: 20 cm x 15 cm	2.21	3.51	2.76	6.87	31.06	54.34
S_2: 30 cm x 15 cm	2.71	4.10	3.17	7.41	35.51	59.82
S_3: 45 cm x 15 cm	2.51	3.95	3.04	7.26	34.57	57.78
SEm±	0.12	0.15	0.10	0.34	1.11	1.49
C.D (p=0.05)	0.35	0.44	0.31	**NS**	3.24	4.38

Similarly, in Table 4 and Fig. 3 shows that spacing of 30 cm × 15 cm (S_2) recorded the highest ear head length (22.38 cm), number of grains per panicle (2119.75), grain weight per ear (19.78 g) and 1000-seed weight (9.49 g), which were higher than S_1 and S_3 but remained statistically at par with spacing of 45 cm × 15 cm (S_3), whereas test weight was not significantly influenced by spacing treatments. The increase in S_2 over S_1 was 11.68%, 16.31%, 13.81% and 8.00%, respectively, while over S_3 it was 2.43%, 3.59%, 1.07% and 3.60%, respectively. On the other hand, spacing of 20 cm × 15 cm (S_1) recorded higher plant population but comparatively lower growth and yield attributes due to severe inter-plant competition for nutrients, moisture, space and solar radiation.

Table 3. Effect of fertilizer dose and spacing on crop growth rate (g/m^2/day) and relative growth rate (g/m^2/day) of pearl millet

Treatments	Crop Growth Rate (g/m^2/day)			Relative Growth Rate (g g^{-1} day^{-1})		
	30 DAS	**60 DAS**	**At harvest**	**30 DAS**	**60 DAS**	**At harvest**
Fertilizer Dose (F)						
F$_1$: 50% RDF (30:15:00 N P_2O_5 K_2O kg/ha)	0.20	0.60	0.70	0.16	0.045	0.021
F$_2$: 75% RDF (45:22.5:00 N P_2O_5 K_2O kg/ha)	0.23	0.79	0.77	0.16	0.049	0.019
F$_3$: 100% RDF (60:30:00 N P_2O_5 K_2O kg/ha)	0.26	1.02	0.83	0.17	0.054	0.017
F$_4$: 125% RDF (75:37.5:00 N P_2O_5 K_2O kg/ha)	0.27	1.13	0.84	0.17	0.055	0.016
SEm±	0.01	0.04	0.04	0.02	0.002	0.001
C.D (p=0.05)	0.04	0.12	0.11	0.01	0.006	0.002
Spacing (S)						
S$_1$: 20 cm x 15 cm	0.23	0.81	0.78	0.16	0.050	0.019
S$_2$: 30 cm x 15 cm	0.25	0.94	0.81	0.17	0.052	0.018
S$_3$: 45 cm x 15 cm	0.24	0.91	0.77	0.17	0.052	0.018
SEm±	0.01	0.04	0.03	0.002	0.002	0.001
C.D (p=0.05)	NS	0.11	NS	NS	NS	NS

Table 4. Effect of fertilizer dose and spacing on yield attributes of pearl millet

Treatments	Yield attributes			
	Ear head length (cm)	**Number of grain panicle^{-1}**	**Grain weight ear^{-1}(g)**	**1000 seed weight (g)**
Fertilizer Dose (F)				
F$_1$: 50% RDF (30:15:00 N P_2O_5 K_2O kg/ha)	17.47	1410.00	13.77	8.11
F$_2$: 75% RDF (45:22.5:00 N P_2O_5 K_2O kg/ha)	19.90	1807.33	17.23	8.77
F$_3$: 100% RDF (60:30:00 N P_2O_5 K_2O kg/ha)	23.19	2273.67	21.66	9.79
F$_4$: 125% RDF (75:37.5:00 N P_2O_5 K_2O kg/ha)	25.12	2494.44	22.98	9.91
SEm±	0.69	77.83	0.67	0.33
C.D (p=0.05)	2.03	228.27	1.96	0.96
Spacing (S)				
S$_1$: 20 cm x 15 cm	20.03	1822.92	17.38	8.79
S$_2$: 30 cm x 15 cm	22.38	2119.75	19.78	9.49
S$_3$: 45 cm x 15 cm	21.85	2046.42	19.57	9.16
SEm±	0.60	67.40	0.58	0.28
C.D (p=0.05)	1.75	197.69	1.70	**NS**

The better performance under spacing of 30 cm × 15 cm (S_2) may be attributed to the development of an optimum plant geometry, which ensured a balanced utilization of available growth resources and reduced intra-specific competition among plants (Kumar *et al*., 2024; Ghuraiya *et al*., 2021). Several researchers have also highlighted that appropriate spacing improves crop efficiency by optimizing plant population and resource availability (Singh *et al*., 2025; Minz *et al*., 2021, Ghaffari et al. 2011). At this spacing, the crop likely achieved a favourable equilibrium between plant population and individual plant access to light, moisture, nutrients and space, thereby avoiding both excessive competition (as in closer spacing) and underutilization of resources (as in wider spacing). This optimum configuration promoted better establishment and overall crop vigor throughout the growth period.

Adequate spacing under S_2 also improved root proliferation, soil aeration and nutrient uptake due to reduced root overlap and better soil volume exploitation per plant. Previous studies have similarly reported that intermediate spacing enhances below-ground development and improves nutrient acquisition efficiency

(Patel *et al*., 2023; Reddy *et al*., 2021). Improved canopy architecture under such conditions enhances light interception and photosynthetic efficiency, resulting in higher dry matter accumulation, crop growth rate and better expression of yield attributes. The improved physiological efficiency under this spacing ultimately strengthens source-sink relationships, leading to superior ear head development and grain formation. Consistent findings have been reported by Shubha *et al*., 2021; Arfith Lal *et al*., 2024; Giri *et al*., 2024 and Kumar *et al*., 2024, confirming that intermediate spacing consistently provides an agronomically optimum environment for higher productivity in pearl millet.

4. Conclusion

In light of the results, it can be concluded that fertilizer dose and crop spacing significantly influenced the growth and yield performance of pearl millet. Application of 125% RDF recorded superior growth and yield parameters; however, it remained statistically at par with 100% RDF. Among the spacing treatments, 30 cm × 15 cm spacing proved most effective in enhancing plant growth, yield attributes and overall productivity. Therefore, application of 100-125% RDF in combination with 30 cm × 15 cm spacing may be recommended for achieving higher productivity and better resource utilization in pearl millet under the agro-climatic conditions of Jaipur, Rajasthan.

5. Recommendation

Adopt 100% RDF with a spacing of 30 cm × 15 cm to enhance growth, vegetative development, and yield attributes of pearl millet by ensuring adequate nutrient availability, improved photosynthetic efficiency, assimilate translocation and optimal plant geometry, thereby maximizing productivity and nutrient use efficiency. The present study was conducted at a single location during one growing season; therefore, the results may be influenced by specific soil and climatic conditions and may require multi-location and multi-year validation for wider applicability for sustainable pearl millet production.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Competing Interests

Authors have declared that no competing interests exist.

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