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RESEARCH ARTICLE

Effect of land configuration and methods of establishment on pearl millet (*Pennisetum glaucam*)

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Abstract

The present study examines the impact of land configuration and establishment methods on the growth and productivity of pearl millet. The experiment was conducted using a split-plot design with three main plot treatments, flatbed planting (M_1), ridges and furrows (M_2) and raised bed paired row planting (M_3) and four subplot treatments: direct sowing (S_1), 10- day-old seedlings (DOS) (S_2), 15 DOS (dapog) (S_3) and 20 DOS (S_4). Each treatment combination was replicated three times. The results revealed that among the main plot treatments, ridges and furrows (M_2) demonstrated superior performance exhibiting greater plant height, a higher total number of tillers, and increased dry matter production (DMP) at harvest. In subplot treatments, direct sowing (S_1) resulted in better growth parameters, including greater plant height, higher DMP at harvest, and improved indices such as Leaf Area Index (LAI), Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR). In contrast, the 20 DOS in raised bed paired row planting (M_3) recorded the shortest time to heading and 50% flowering. Among the treatment combinations, direct sowing in ridges and furrows (M_2S_1) achieved the highest plant height, maximum DMP at harvest and superior grain and straw yield.

Keywords

growth; land configuration; pearl millet; seedling; soaking time

Introduction

Pearl millet (*Pennisetum glaucum* L.), a member of the Poaceae family, is one of the most extensively cultivated cereal crop. Its remarkable resilience to harsh growing conditions, such as drought, poor soil fertility and high temperature, allows it to thrive in regions where other cereal crops like maize (*Zea mays*) or wheat (*Triticum aestivum*), often fail. Over 95% of global pearl millet production and acreage is concentrated in developing countries (1). India stands as one of the top millet producers globally, with pearl millet contributing to approximately two-thirds of the nation's total millet output (2). In the 2022-2023 period, India's pearl millet cultivation covered an area of approximately 6.84 million hectares, yielding 9.7 million tonnes, with an average productivity of 1430 kg ha^{-1}. Rajasthan alone accounts for 44% of India's total pearl millet production (3).

Pearl millet is often referred to as a "poor man's food" due to its affordability and widespread consumption in developing countries across Asia and Africa. Approximately 93% of pearl millet grain is utilized as a food source, while the remaining 7% is used for animal and poultry feed. Its use in bakery products and snacks remains limited. With a texture like brown rice, pearl millet can be cooked in the same manner. It is an economical source of nutrition, providing 13% protein, 5.1% fats, 38 mg calcium, 5 mg zinc, 8.8 mg iron, 106 mg magnesium, 1.3% insoluble dietary fibres and 71% carbohydrates (4). Additionally, the dry stover of pearl millet serves as a vital livestock feed, ensuring stability in crop-livestock farming systems, particularly in water-stressed regions. In northern India, pearl millet is primarily grown for forage (5). Typically cultivated as a dryland crop for both grain and fodder, it is occasionally irrigated during the summer months when it is predominantly grown as a forage crop (1). To address poor crop establishment in semi-arid regions, practices such as seed priming and nursery management have been adopted. Seed priming, which involves soaking seeds in water before sowing, has improved establishment in crops like maize, sorghum and pearl millet (6).

However, the uncertain onset of monsoons, variable rainfall and potential soil moisture depletion often results in failed initial sowing or complete/partial crop failure. Crop establishment becomes effective only after multiple attempts, causing significant losses in seed and capital for farmers (7). In addition, dry spells during the growing period hinder rainfed cereal crops from completing their developmental cycles, negatively impacting production and yield (8).

In this context, it is essential to modify agro techniques to ensure food security, especially when climate change and variability are prevailing (9). Transplanting has recently emerged as a promising technology to boost the productivity of millets, like sorghum and pearl millet. This approach is particularly advantageous in challenging agro-climatic conditions where conventional sowing techniques are less effective (10). Studies have shown that transplanted pearl millet achieves earlier flowering, quicker maturity, and higher grain and stover yields compared to direct sowing (11).

Land configuration also plays a pivotal role in crop management practices, including nutrient application, irrigation, and weed management. Techniques such as flatbed planting, ridges and furrows and broad bed and furrow significantly influence plant height, LAI, DMP and tiller count at various growth stages of pearl millet. Among these, ridges and furrows have been particularly effective, providing improved drainage and aeration during periods of heavy rainfall (12).

Materials and Methods

Laboratory experiment

A laboratory experiment was conducted to determine the optimal soaking duration for pearl millet seeds to achieve the highest germination percentage. The treatments included soaking time of T_1-12 hour, T_2-10 hour, T_3-8 hour, T_4-6 hour and T_5- 4 hour. A total of 400 seeds per treatment were placed in 100 mL glass beakers filled with water to a level twice the height of the seeds, with four replications for each treatment. The soaked seeds were incubated in the dark for 12 hours under humid conditions. Germination percentage was assessed by counting the number of seeds exhibiting radicle emergence following incubation. The optimal soaking time identified in the experiment was subsequently used to prepare pre-germinated seeds for 15-day-old dapog seedlings.

Experimental site and weather

The experiment was conducted during summer of 2024 at the Eastern Block Farm, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore. Pearl millet hybrid COH 10 was used for the study. The experimental site is situated in the Western Agro-Climatic Zone of Tamil Nadu, with geographic co-ordinates of 11°01'00.9" N Latitude, 76°56'03.9" E Longitude and an altitude of 426.8 meters above mean sea level. During the cropping period, the mean maximum and minimum mean temperature recorded were 34.8 °C and 24.8 °C, respectively. Relative humidity was observed to be 81% at 07.22 hour and 49% at 14.22 hour. The average wind speed during the period was 5.65 km h^{-1}. The total rainfall received was 208 mm, spread over 22 days. The mean sunshine duration was 7.0 h per day, with a mean solar radiation of 351.6 Cal/cm^2/day. The average evaporation rate recorded was 6.5 mm. The data on weather parameters that prevailed during the cropping period (April to June) are presented in Fig. 1.

Field experiment

The study employed a split-plot design, biologically replicated thrice in the field. The main plot consisted of three land configurations: (M_1- flatbed, M_2- ridges and furrows and M_3- raised bed paired row planting). The subplots included four establishment methods: (S_1- direct sowing, S_2-10 DOS, S_3-15 days old dapog seedlings and S_4-20 DOS).

For the 10 and 20 DOS treatments, unsoaked seeds (300 g per bed) were sown in raised beds measuring 3 m × 1.5 m. The dapog nursery bed was prepared by covering the raised bed with a 50-60-gauge polythene sheet, perforated with 1-2 mm diameter holes to allow drainage of excess water. A mixture of soil (35 kg), well-decomposed farmyard manure (FYM) (10 kg) and vermicompost (5 kg) in a 70:20:10 ratio was thoroughly combined and spread to a height of 5 cm over the polythene sheet. The bed surface was levelled to ensure uniform water distribution. Pre-germinated seeds, soaked for 8 hours (the optimal soaking time determined from laboratory experiments), were gently broadcasted to avoid damage to the radicles.

For all establishment methods, line sowing was performed along with transplanting for 10, 15 and 20 DOS. A spacing of 45 cm × 15 cm for normal planting and 60/30 cm × 15 cm for paired row planting was adopted.

Fertilization, weeding, irrigation and pest management were conducted uniformly across all treatment plots to maintain local control. Five plants were randomly selected and tagged within each plot for subsequent measurements of growth and yield parameters, following standard procedures. Grain, stover and biological yields were calculated from net plot crops.

Statistical Analysis

The data obtained were statistically analysed using R software, with the critical difference (CD) determined at $P \le 0.05$ to identify significant differences among treatment averages.

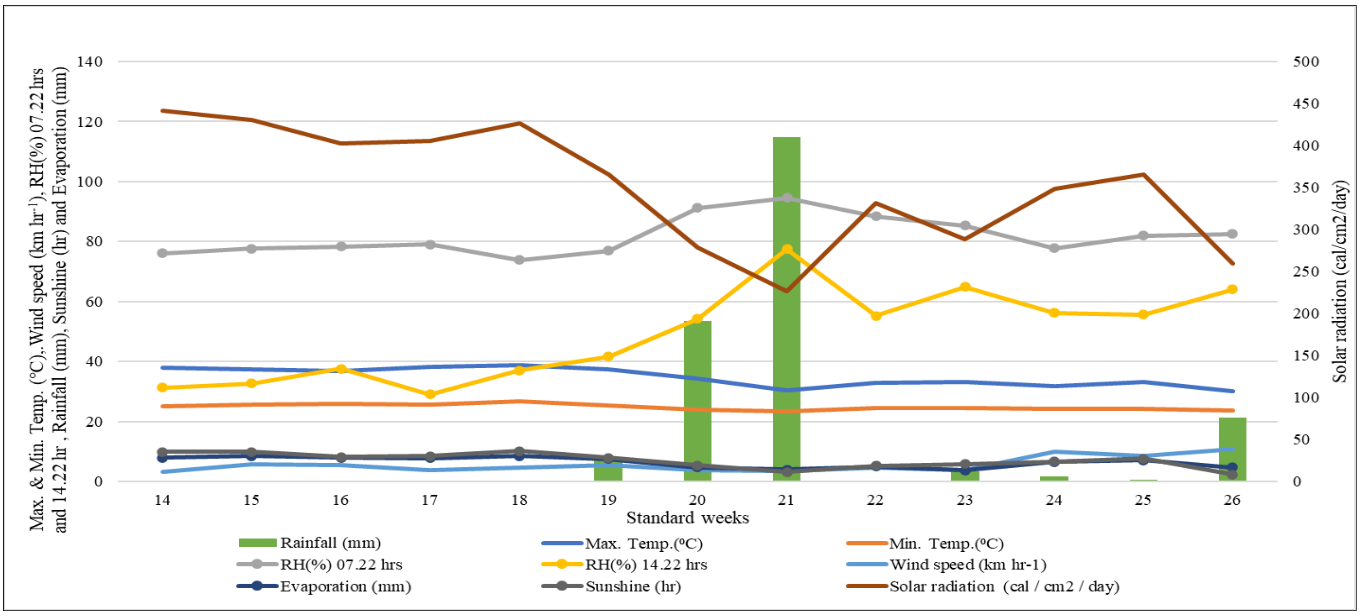

Fig.1. Weather parameters prevailing during the cropping period (Apr-Jun).

Results

Laboratory experiment

Effect of soaking time on germination percentage: The results indicated that the highest germination percentage (78.50%) in pearl millet seeds was recorded with 8 hours of soaking. This was statistically on par with 12 hour of soaking (78.06%) and 10 hour of soaking (77.75%). In contrast, the lowest germination percentage (53.43%) was observed with 4 hour of soaking (Table 1).

Table 1: Influence of different soaking hours on germination of pearl millet

Treatments	Germination (%)
T_1	77.75
T_2	78.06
T_3	78.50
T_4	69.81
T_5	53.43
SEd	**1.82**
CD (P ≤ 0.05)	**3.97**

T_1 - 12 h soaking, T_2 - 10 h soaking, T_3 - 8 h soaking, T_4 - 6 h soaking and T_5 - 4 h soaking and SEd – Standard Error of deviation and CD- Critical difference

Field experiments

Effect of land configuration: Effect of land configuration on establishment parameters of pearl millet: The experimental results demonstrated that land configuration significantly influenced the establishment and growth parameters of pearl millet. The ridges and furrows configuration recorded the highest establishment percentage (87.15%), plant population (1,29,115 ha^{-1}), dry matter production (DMP) (251.7 kg ha^{-1}) and LAI (0.110) at 20 DAS/P. These results were statistically on par with the raised bed paired row planting methods, which achieved an establishment percentage of 81.07%, plant population (1,20,713 ha^{-1}), DMP (233.9 kg ha^{-1}) and LAI (0.108) at 20 DAS/P. The flatbed recorded the lowest (77.60, 1,14,969 ha^{-1}, 195.4 kg ha^{-1} and 0.090, respectively) as indicated in Table 2.

Raised bed paired row planting exhibited higher shoot length (23.5 cm), root length (9.1 cm) and SPAD reading (39.6), which were statistically comparable to ridges and furrows

Table 2: Effect of different land configuration and establishment methods on seedling establishment (%) at 10 Days After Sowing/Planting, plant population (no.) on 10 DAS/P and shoot length (cm), root length (cm), DMP (kg/ ha^{-1}) and SPAD meter reading on 20 DAS/P.

Treatments	Seedling establishment (%) on 10 DAS/P	Plant population/ ha on 10 DAS/P	Shoot length (cm) on 20 DAS/P	Root length (cm) on 20 DAS/P	Dry matter production DMP ha^{-1} (kg ha^{-1}) on 20 DAS/P	SPAD meter reading on 20 DAS/P
M_1	77.6	114969	22.0	7.25	302.2	36.6
M_2	87.1	129115	23.5	8.27	361.1	37.8
M_3	81.5	120713	23.5	9.07	336.3	39.6
SEd	**2.2**	**3222**	**0.3**	**0.36**	**9.3**	**1.5**
CD (P ≤ 0.05)	**6.0**	**8947**	**0.8**	**NS**	**25.7**	**NS**
S_1	82.9	122942	18.2	6.18	219.8	36.9
S_2	73.1	108367	20.5	7.02	299.3	33.9
S_3	86.6	128257	27.1	9.42	405.9	40.1
S_4	86.1	127571	26.2	9.21	407.9	41.0
SEd	**1.4**	**2048**	**0.6**	**0.34**	**9.7**	**1.4**
CD (P ≤ 0.05)	**2.9**	**4302**	**1.3**	**0.72**	**20.5**	**3.0**
Interaction (M×S)						
SEd	**3.0**	**4452**	**1.0**	**0.63**	**17.3**	**2.6**
CD (P ≤ 0.05)	**6.3**	**9354**	**NS**	**1.31**	**NS**	**5.6**
Interaction (S×M)						
SEd	**2.4**	**3547**	**1.1**	**0.59**	**16.9**	**2.5**
CD (P ≤ 0.05)	**5.0**	**7452**	**NS**	**1.24**	**NS**	**5.3**

M- Main plot (different land configurations (M_1: flatbed, M_2: ridges and furrows and M_3: raised bed paired row planting)); S- Subplot (different establishment methods (S_1: direct sowing, S_2: 10 Day Old Seedlings, S_3: 15-day-old dapog seedlings and S_4: 20 DOS)); SEd -Standard error of deviation; CD- critical difference.

(23.5cm, 8.3cm and 37.8, respectively). DMP at 20 DAS/P was highest in ridges and furrows (361.1 kg ha^{-1}), followed by raised bed paired row planting (336.3 kg ha^{-1}), with the lowest recorded in the flatbed configuration (302.2 kg ha^{-1}).

Effect of land configuration on growth parameters of pearl millet: The effect of land configuration on LAI at 20, 40 and 60 DAS/P, respectively and at harvest was significant. LAI was higher in ridges and furrows (0.11, 2.93, 10.2 and 9.40, respectively) and raised bed paired row planting (0.10, 2.40, 10.53 and 9.89, respectively) at 20, 40, 60 DAS and at harvest and was comparable with each other, lowest was recorded in flatbed (0.09, 2.26, 9.60 and 8.52, respectively) (Fig. 2).

There was a significant effect of land configuration on CGR, RGR and NAR. Raised bed paired row planting registered higher CGR from 20-40 DAS/P, 40-60 DAS/P and 60 DAS/P- to harvest (12.0, 17.1 and 16.4, respectively) (Fig. 3). RGR (g g^{-1} day^{-1}) was higher in raised bed paired row planting (0.106) from 20-40 DAS/P. From 40-60 DAS/P, high RGR was recorded in flatbed (0.046) and 60 DAS/P- harvest, it was ridges and furrows (0.022) (Fig. 4). Among land configurations, from 20-40 DAS/P and 40-60 DAS/P, raised bed paired row planting (1.81 and 0.33, respectively) registered higher NAR and from 60 DAS/P- harvest it was higher in ridges and furrows (0.18) (Fig. 5). Land configuration had no significant effect on days to heading, flowering and 50% flowering.

The effect of land configuration on DMP (kg ha^{-1}) and SPAD value at harvest was significant. Ridges and furrows recorded higher plant height (cm) and DMP (kg ha^{-1}) at harvest (173.4 and 9222.4, respectively) which were comparable with raised bed paired row planting (172.7 and 9134.2, respectively) and the lowest value was found in flatbed (160.6 and 7809.9) (Table 3). Whereas, raised bed paired row planting showed a higher SPAD value (74.1) which was significantly on par with ridges and furrows (72.7) and the lowest number was observed in flatbed (72.2) (Table 3). Tiller count was significantly high in ridges and furrows and raised bed paired row planting (M_3) (5.1) over flatbed (4.8).

Effect of land configuration on grain and stover yield (kg ha^{-1}) of pearl millet: Grain and stover yield were significantly influenced by land configuration. The highest grain yield was recorded in both ridges and furrows (3315 kg ha^{-1}) and raised bed paired row planting (3315 kg ha^{-1}). The lowest grain yield was observed in the flatbed configuration (2755.4 kg ha^{-1} and 5054.6 kg ha^{-1}, respectively). Similarly, the highest stover yield was recorded in raised bed paired row planting (6125.0 kg ha^{-1}), comparable to ridges and furrows (M_2) (6124.5 kg ha^{-1}), while the lowest was observed in the flatbed configuration (5492.7 kg ha^{-1}) (Table 3).

Effect of methods of establishment: Effect of methods of establishment on establishment parameters of pearl millet: In the subplots, the establishment percentage, plant population, shoot length and root length (cm) were superior in the 15 DOS treatment (86.57%, 1,28,257 ha^{-1}, 27.1cm and 9.41cm, respectively), which was comparable to the 20 DOS treatment (86.11%, 1,27,571 ha^{-1}, 26.2cm and 9.21cm, respectively). The lowest values were observed in 10 DOS (73.14%, 1,08,367 ha^{-1},18.2cm and 6.08cm, respectively), indicating a lower plant population per unit area in 10 DOS.

DMP, LAI and SPAD reading at 20 DAS/P were higher in the 20 DOS (407.9 kg ha^{-1}, 0.127 and 41.01, respectively), which were significantly on par with the 15 DOS treatment (405.9 kg ha^{-1}, 0.121 and 40.14, respectively). The lowest DMP, LAI and SPAD readings at 20 DAS/P were recorded in direct sowing (219.8 kg ha^{-1}, 0.073 and 33.89, respectively).

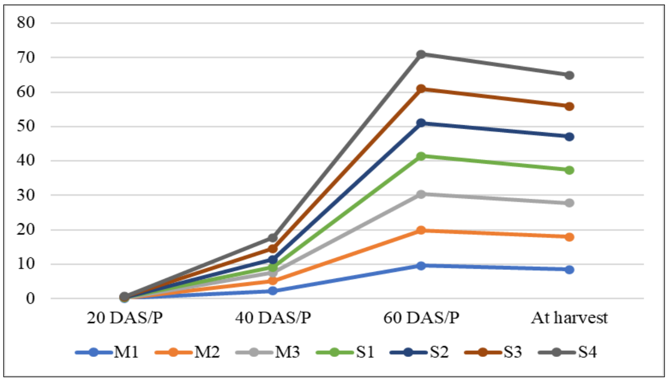

Fig.2. Effect of individual treatments on LAI.

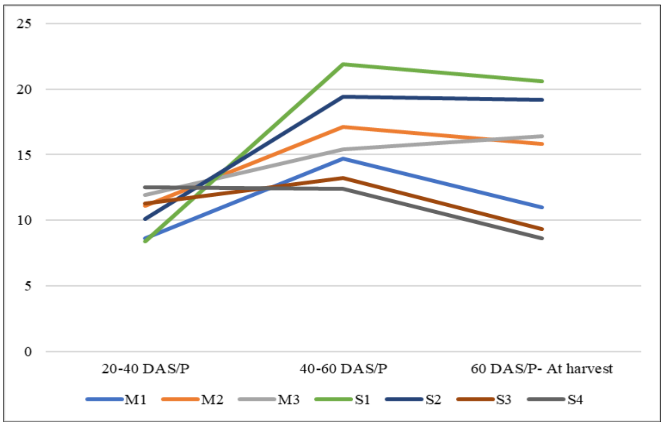

Fig.3. Effect of individual treatments on CGR.

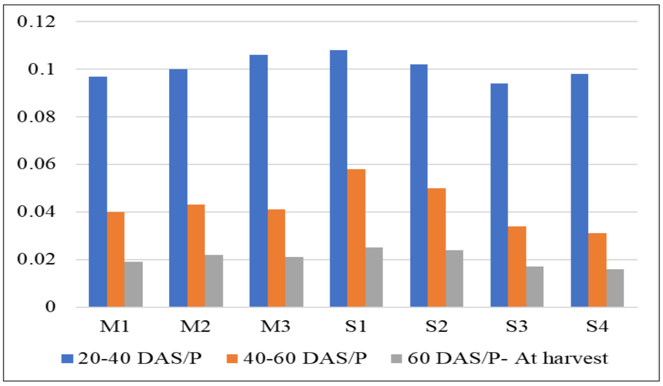

Fig.4. Effect of individual treatments on RGR.

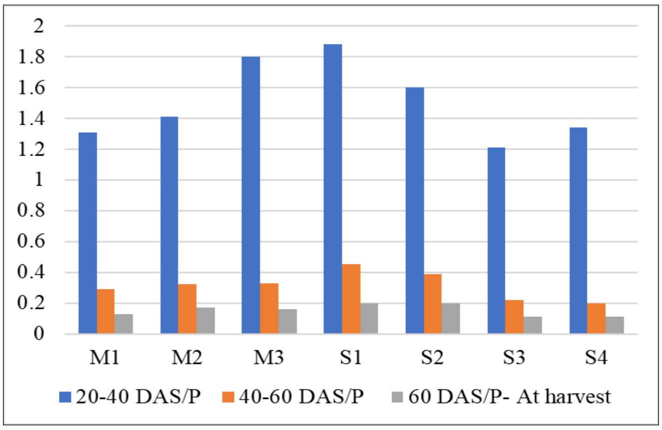

Fig.5. Effect of individual treatments on NAR.

Effect of methods of establishment on growth parameters: The method of establishment significantly influenced LAI at 20, 40 and 60 DAS/P, as well as at harvest. The 20 DOS and 15 DOS treatments recorded higher LAI values at 20 and 40 DAS/P (0.12 and 3.1, respectively), while the lowest LAI was observed in direct sowing (0.073 and 1.514, respectively). At 60 DAS/P, direct sowing achieved the higher LAI (10.9), followed by 20 DOS and 15 DOS (9.9 each), while the lowest was recorded in the 10 DOS treatment (9.6). At harvest, the 10 DOS treatment (S_2) (9.7) outshined other treatments, with the lowest LAI observed in the 15 DOS treatment (8.7) (Fig. 2).

The methods of establishment also significantly affected growth parameters, including CGR, RGR and NAR. The 20 DOS treatment recorded the highest CGR (12.5) during 20-40 DAS/P, while the lowest was observed in direct sowing (8.4) (Fig. 3). From 20-40 DAS/P, 40-60 DAS/P and 60-at harvest, RGR and NAR values were higher in direct sowing and lowest in 20 DOS treatment (Fig. 4 and 5). Additionally, days to heading, flowering and 50% flowering were significantly influenced by the methods of establishment. Early flowering was observed in the 20 DOS treatment (35.6 days), which was statistically on par with the 15 DOS treatment (36.1 days) (Plate 1).

Plant height (cm) and DMP (kg ha^{-1}) at harvest were significantly affected by the methods of establishment. Direct sowing recorded the highest plant height (191.8 cm) and DMP (10495.7 kg ha^{-1}) at harvest, followed by the 10 DOS treatment (172.7 cm and 10067.8 kg ha^{-1}, respectively). The lowest plant height and DMP were observed in the 15 DOS treatment (155.2 cm and 7177.8 kg ha^{-1}, respectively). The highest SPAD value (77.7) and tiller count (5.1) were registered higher in the 20 DOS treatment, while the lowest values were observed in the 10 DOS treatment (68.9 and 4.9, respectively) (Table 3).

Effect of methods of establishment on grain and stover yield (kg ha^{-1})

Grain yield and stover yield were significantly influenced by the methods of establishment. Direct sowing recorded the highest grain yield (3430.9 kg ha^{-1}) and stover yield (6227.4 kg ha^{-1}), followed by the 10 DOS treatment (3177.0 kg ha^{-1} and 5891.9 kg ha^{-1}, respectively). The lowest grain yield and stover yield were recorded in the 15 DOS treatment (3092 kg ha^{-1} and 5723.5 kg ha^{-1}, respectively) (Table 3) (Plate 2).

Plate 1. Early heading in 20 Day Old Seedlings of pearl millet.

Plate 2. Experimental field at 70 Days After Sowing/ Planting.

Table 3. Effect of land configuration and methods of establishment plant height (cm) (at harvest), total no. of tillers (at harvest), DMP (kg ha^{-1}) (at harvest) and SPAD value (at harvest), grain yield (kg ha^{-1}) and straw yield (kg ha^{-1})

Treatments	Plant height (cm) (at harvest)	Total no. of tillers (at harvest)	DMP (kg ha^{-1}) (at harvest)	SPAD value (at harvest)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
M_1	160.8	4.8	7809.9	72.2	3005.6	5492.7
M_2	173.4	5.1	9222.4	72.7	3315.1	6124.5
M_3	172.7	5.1	9134.2	74.1	3314.7	6125.0
SEd	**5.3**	**0.2**	**201.0**	**2.3**	**75.5**	**191.3**
CD (P ≤ 0.05)	**NS**	**NS**	**558.3**	**NS**	**209.6**	**531.1**
S_1	191.8	4.9	10495.7	70.1	3430.9	6227.4
S_2	172.7	4.9	10067.8	68.9	3177.0	5891.9
S_3	155.2	5.1	7177.8	75.1	3092.0	5723.5
S_4	156.2	5.1	7147.4	77.9	3147.3	5813.5
SEd	**5.1**	**0.2**	**436.0**	**2.4**	**120.3**	**268.1**
CD (P ≤ 0.05)	**10.7**	**NS**	**916.0**	**5.1**	**250.7**	**NS**
			Interaction (M×S)			
SEd	**9.3**	**0.4**	**684.2**	**4.3.1**	**194.2**	**445.3**
CD (P ≤ 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
			Interaction (S×M)			
SEd	**8.8**	**0.3**	**755.2**	**34.2**	**206.6**	**464.3**
CD (P ≤ 0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

M- Main plot (different land configurations (M_1: flatbed, M_2: ridges and furrows and M_3: raised bed paired row planting)); S- Subplot (different establishment methods (S_1: direct sowing, S_2: 10 Day Old Seedlings, S_3: 15-day old dapog seedlings and S_4: 20 DOS)); SEd -Standard error of deviation; CD- critical difference.

Effect of interaction of land configuration and methods of establishment

Among the interactions, planting pearl millet on ridges and furrows with 15 DOS and 20 DOS recorded significantly higher establishment percentage and population (95.13% and 1,40,946 ha^{-1}; 93.05% and 1,37,859 ha^{-1}, respectively). These values were comparable. Conversely, the lowest establishment percentage (69.44%) and population (1,02,880 ha^{-1}) were observed in flatbed planting with 10 DOS. Root length in the 15 DOS treatments on ridges and furrows was the highest (10.49 cm) among all treatment combinations, whereas the shortest root length (6.06 cm) was observed in plants establishment through direct sowing in flatbed.

In the treatment combinations, the 15 DOS (S_3) with ridges and furrows (M_2) achieved the highest SPAD reading (43.62), while the lowest SPAD reading (29.72) was observed in the 10 DOS (S_2) with flatbed planting (M_1). Shoot length and DMP at 20 DAS/P were not significantly influenced by the treatment combinations.

No significant differences were found among treatment combinations for plant height, total no. of tillers, DMP and SPAD values at harvest (Table 3). However, the interaction effect of land configuration and methods of establishment significantly influenced LAI at 20 and 40 DAS/P. Raised bed paired row planting with 20 DOS recorded the highest LAI (0.128) at 20 DAS/P, while the lowest LAI (0.061) was observed in direct sowing on flatbeds. At 40 DAS/P, 20 DOS on ridges and furrows achieved a higher LAI (3.58), whereas direct sowing in flatbed recorded the lowest (1.20) (Fig. 6).

The interaction effect of land configuration and methods of establishment did not significantly influence CGR, RGR, or NAR (Fig. 7, 8 and 9 respectively). The interaction effect of land configuration and methods of establishment on days to flowering and days to 50% flowering was presented in Fig. 10. Furthermore, grain and straw yields were not influenced by the combination of land configuration and methods of establishment. Growth parameters (plant height (cm), number of tillers, dry matter production (kg ha^{-1}), SPAD value) and yield parameters (grain and stover yield (kg ha^{-1})) were positively correlated (Fig. 11).

Discussion

Effect of land configuration

The effect of land configuration on the initial population of pearl millet was significant. A higher population was observed in ridges and furrows and raised bed paired row planting, which were comparable to each other, while the lowest population was recorded in the flatbed configuration. This outcome can be attributed to the favourable microenvironment created by

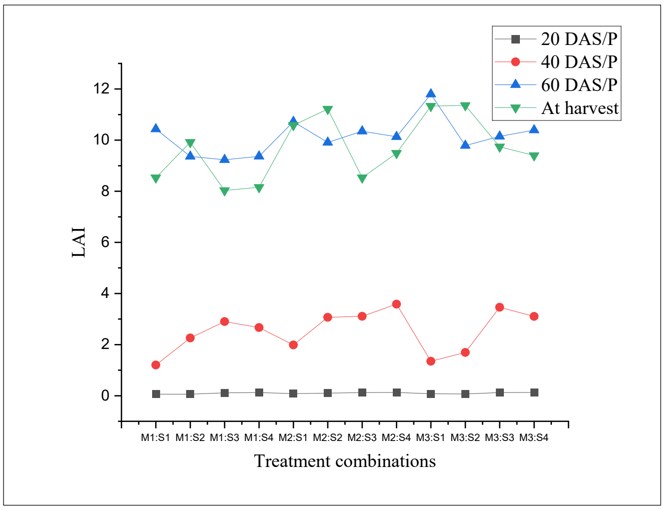

Fig. 6. Effect of land configuration and establishment methods on LAI.

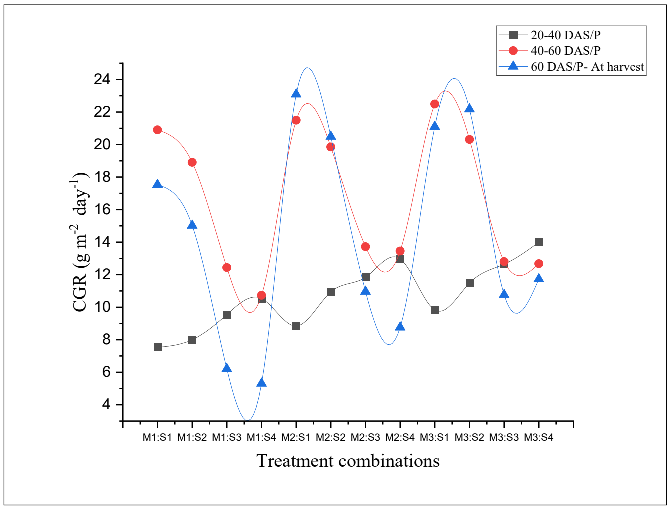

Fig. 7. Effect of land configuration and establishment methods on CGR.

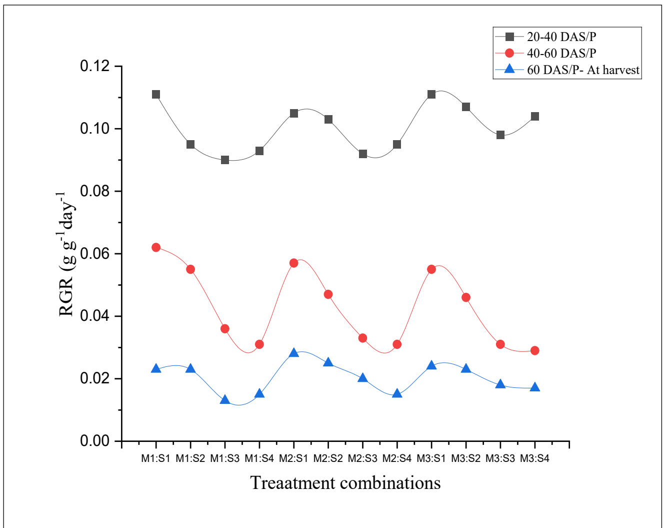

Fig. 8. Effect of land configuration and establishment methods on RGR.

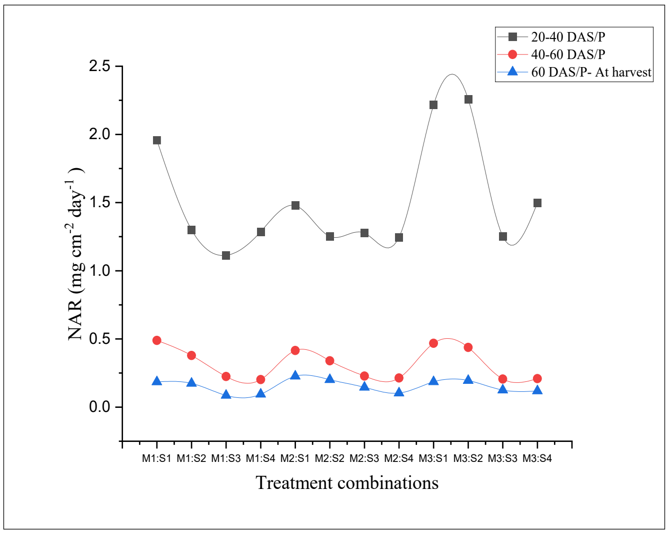

Fig. 9. Effect of land configuration and establishment methods on NAR.

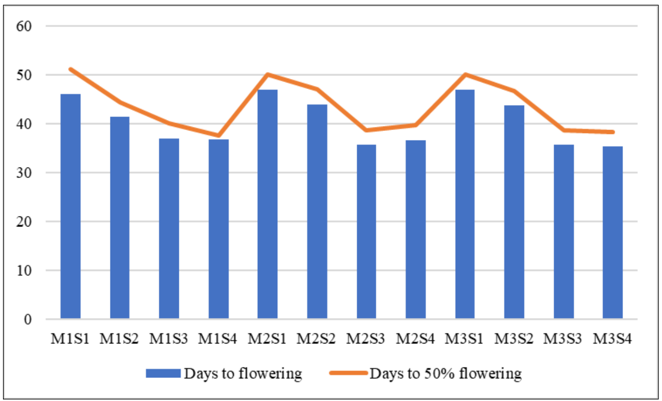

Fig.10. Effect of land configuration and establishment methods on days to flowering and days to 50% flowering.

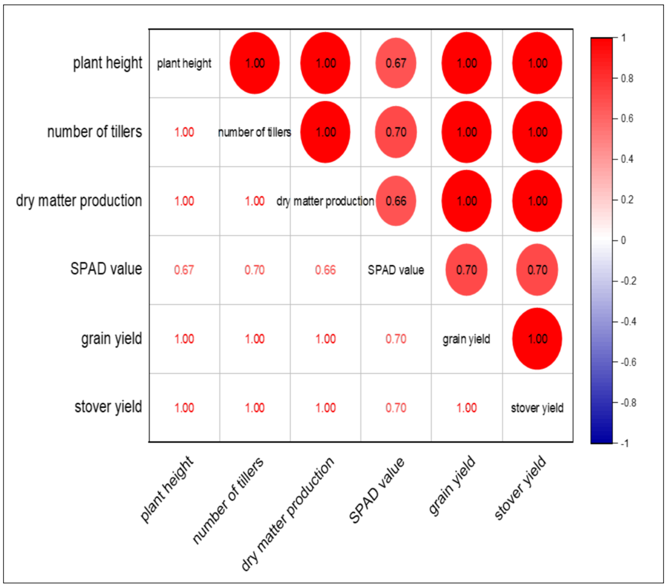

Fig. 11. Correlation graph of plant height (cm), number of tillers, dry matter production (kg ha^{-1}), SPAD value, grain and stover yield (kg ha^{-1}).

improved soil aeration, better water retention and reduced salt stress (13). In contrast, lower growth parameters in flatbeds were likely due to poor drainage, increased salt accumulation and poor root aeration (14).

Ridges and furrows, along with raised bed paired row planting, demonstrated superior performance in plant height, DMP, SPAD value and the number of tillers at harvest. This can be ascribed to the enhanced soil moisture retention associated with these land configurations, which sustained favorable moisture levels for a longer duration. Such conditions are critical for sustained plant growth and development, ultimately leading to improved growth parameters (15).

The leaf area index (LAI) was comparable between ridges and furrows and raised bed paired row planting at all stages of growth. This might be due to the efficient transfer of photosynthates to sink development, thereby increasing leaf area (16). Raised bed paired row planting consistently recorded higher crop growth rates (CGR) across all stages. However, relative growth rate (RGR) varied across different land configurations at various growth stages. Net assimilation rate (NAR) was higher in raised bed paired row planting during the initial growth stages, whereas in the final stages before harvest, ridges and furrows recorded higher NAR. These trends are likely due to the optimal soil moisture and aeration provided by these land configurations, which enhanced root development and nutrient uptake, leading to more vigorous plant growth (17).

Grain and stover yields were significantly higher in ridges and furrows and raised bed paired row planting. This improvement can be attributed to proper soil aeration and water supply, which enhanced nutrient availability and uptake, thereby increasing photosynthetic efficiency (18).

Effect of methods of establishment

In subplots, a higher population was recorded in 15 DOS (S_3), attributed to the adequate development of seedlings and reduced transplanting shock. This facilitated high vigour, enabling the plants to establish quickly in the new environment (19).

Higher plant height and DMP were recorded in direct sown plots (20). Growth parameters like LAI, RGR, CGR and NAR was also higher in direct sowing. This could be due to an extended vegetative stage, which allowed for prolonged and efficient resources utilization, ultimately resulting in enhanced growth and development (21).

Grain and stover yields were significantly higher in direct sown plots than transplanted ones. This might be due to premature heading in transplanted pearl millet crops (22). Direct sowing likely enabled early and uniform establishment, fostering vigorous growth and an extended growth phase. This facilitated greater yield and biomass accumulation.

Early flowering and maturity were observed in transplanted crops, which could be explained by reduced transplanting shock and the appropriate age of seedlings in 15 and 20 DOS treatments. Conversely, 10 DOS exhibited similar maturity timing as direct sown crops, likely due to prolonged transplanting shock (23).

Conclusion

From the experimental results, it can be concluded that under field conditions, the ridges and furrows method resulted in higher plant height, DMP and LAI, while the raised bed paired row planting demonstrated superior CGR, RGR and NAR. Grain and stover yields were increased by 10% in ridges and furrows and raised bed paired row planting compared to the flatbed method. Among the subplots, direct sown plants recorded higher plant height, DMP, LAI, CGR, RGR and NAR compared to transplanted treatments. However, transplanted plants showed fewer days to heading and flowering, indicating early maturity. Further research is needed to know the role of land configuration and nursery-raising methods on pearl millet.

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Authors' contributions

MNS carried out the experiment under the guidance of VV. SK guided the seed related studies. All authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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