



Performance of Pearl Millet (*Pennisetum glaucum* L.) as Influenced by Different Planting Techniques and Nutrient Management Practices in Arid Western Rajasthan

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Authors' contributions

This work was carried out in collaboration among all authors. Author S. Kumar designed and conducted the experiment, performed the statistical analysis under the guidance of author SMK. Authors TP and AC helped in field work. Author S. Kumar wrote the first draft of the manuscript and managed the literature searches with the help of authors S. Kumawat and PK. All authors read and approved the final manuscript.

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ABSTRACT

The productivity of arid region is much lower and resource degradation is much faster comparatively other ecosystem due to aberrant climatic conditions and anthropogenic activities. Lower production in arid region is due to lower nutrient and water holding capacity of soil, erratic rainfall pattern and inappropriate crop management practices. Therefore, present study was conducted with six planting techniques and four nutrient management practices in split plot design and replicated thrice, to find out suitable planting techniques and nutrient management practices and their influence on growth, productivity of pearl millet in arid western Rajasthan. Results of the study showed that pit planting technique treatment PT₆ noted taller plant over rest of the treatments during 2018 and 2019. Among various planting techniques, pit technique realized significantly

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higher relative growth rate (RGR) as compared ridge planting (PT₂ and PT₃) and direct seed sowing (PT₁) also. However, pit planting technique PT₄ recorded highest RGR of 1.87 & 1.77 g g⁻¹ day⁻¹ during 20 days after sowing/transplanting (DAS/DAT) to 40 DAS/DAT and 2.26 & 2.23 g g⁻¹ day⁻¹ during 40 DAS/DAT to at harvest during 2018 and 2019, respectively, which registered significantly edge over rest all treatments of sowing/transplanting. Though ridge planting techniques PT₂ and PT₃, computed significantly highest crop growth rate (CGR) as compared to rest all planting treatments yet formerly both treatment remained statistically at par with each other. Pearl millet planted by pit planting technique PT₆ recorded highest grain yield during both the years. Moreover, growth parameters and grain yield also increased with increasing dose of nutrients from nutrient management practice NMP₁ to nutrient management practice NMP₃ over control (NMP₀). Highest plant height, crop growth rate (g m⁻¹ day⁻¹) and relative growth rate (g g⁻¹ day⁻¹) at different intervals and grain yield were recorded maximum in nutrient management practice NMP₃, while minimum values of all above parameters were observed in no fertilization control (NMP₀) treatment during individual years of 2018 and 2019.

Keywords: Fertilization; flat bed; growth; pit technique; ridge and furrow.

1. INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.) popularly known as *bulrush millet*, *cattle millet*, originated in tropical Western Africa and belongs to the family *gramineae* (*poaceae*), subfamily *panicoideae*, genus *Pennisetum* and tribe *paniceae* [1,2]. Pearl millet is known as *bajrrior bajra* over large part of India, which is a low priced food grain crop, so it is also known as poor man's food. It is largely grown for grain and fodder purpose under those marginal situations where other crops generally fail, It is grown mainly in arid and semiarid environmental conditions due to its drought escaping mechanism and lower water requirement as compared to other cereals like sorghum and maize [3], that's why pearl millet is a staple food of arid and semiarid regions of India. Pearl millet grains are nutritious and are a vital component for the human diet, and its stover acts as the primary maintenance ration for ruminant livestock in the dry season [4]. Pearl millet grains have high protein content, balanced amino acid profile, and high levels of zinc, iron and are the major source of dietary carbohydrates in the human diet. In the world, it's rank sixth followed by rice, wheat, corn, barley and sorghum [5]. It is one of the most important cereal crop grown in over 40 countries, predominantly in Africa and Asia. However, in India, it is fourth most important cereal crop after rice, wheat and sorghum [1,6]. In India pearl millet is grown mainly as a rainfed crop, except in summer, where it is grown as an irrigated crop [7]. India ranks first in the area and production of pearl millet and covers an area of about 7.4 million hectares, production is 9.21 million tonnes and productivity is 1231 kg ha⁻¹, respectively [8]. In India major producing states

are Rajasthan (46%), Maharashtra (19%), Gujarat (11%), Uttar Pradesh (8%) and Haryana (6%), [9]. Rajasthan occupies 4.29 million hectares of area producing 5.11 million tonnes with productivity of pearl millet 1192 kg ha⁻¹ during 2019-20 [10]. It is conventionally grown in the district of Jodhpur, Bikaner, Barmer, Churu, Sikar, Jhunjhunu, Jaipur, Jalore and Alwar.

Pearl millet is mostly cultivated by the economically poor farmers using either less improved production technology or using it at suboptimal levels. It is adapted to drought conditions and poor soil fertility, but responds well to higher fertility level and good management. It is generally cultivated in area with rainfall ranging from 150 to 600 mm [1]. Transplanting in pearl millet is a traditional practice to compensate the crop growth period for complete crop life cycle [11]. The practice of transplanting also can be useful to optimize plant population and crop yield. 20-25 days old seedlings of pearl millet were found best for transplanting [12]. Ensuring optimum quantity of nutrients in a given soil for good plant growth and better yield is the greatest challenge of the day for arid region farmers because yield potentials vary among soils and soils of arid region of Western Rajasthan is not only thirsty but hungry also. For maintaining sustained crop production, manuring and fertilization is very essential to improve soil health and thereby better yield in this region. So, wide use of suitable planting method [13] and nutrient management comprising approach [14] are essential to make best use of limited available water. In Western Rajasthan farmers are using traditional method of sowing and unbalanced and suboptimal fertilizers application which lead to poor

establishment and productivity of pearl millet. Agronomic interventions like planting techniques/methods and site specific nutrient management may prove useful in utilization of the scarce natural resources. Hence, keeping above facts in view the present investigation was planned and carried out.

2. MATERIALS AND METHODS

The experiment was conducted at the Instructional Farm, Department of Agronomy, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University (SKRAU), Bikaner during *kharif* seasons of 2018 and 2019. According to National Planning Commission, Bikaner falls under Agro-climatic zone XIV (Western Dry Region) of India. According to "Agro-ecological region map" brought out by National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Bikaner falls under Agro-ecological region No. 2 (M9E1) under Arid ecosystem (Hot Arid Eco-region). The climate of this zone (Ic) is typically hot and arid characterized by aridity of the atmosphere and slight salinity in the *rhizosphere* with extremes of maximum and minimum temperature both in summers and winters, respectively. The average annual rainfall of the region is about 274 mm [15] which is mostly received during the rainy season from July to September. The maximum and minimum temperature ranged between 30.4 to 41.8°C and 9.9 to 29.9°C in 2018 and 25.5 to 42.3°C and 12.8 to 30.5°C in 2019, respectively. The total rainfall received during *kharif* seasons was 287.4 mm in 14 rainy days during 2018 and 246 mm in 15 rainy days during 2019. Experimental field soil was loamy sand in texture, low in organic carbon (0.12 & 0.14) and available nitrogen (87.14 & 89.15 kg ha⁻¹), medium in available phosphorus (18.8 & 20.0 kg ha⁻¹) and rich in available potassium (316.85 & 304.51 kg ha⁻¹). Also, the soil was alkaline in reaction having pH (1:2 soil water suspensions) of 8.28 and 8.14 with electrical conductivity (EC) of 0.18 and 0.20 dSm⁻¹ during 2018 and 2019, respectively.

The experiment was laid out in a Split Plot Design with twenty four treatment combinations which were replicated thrice. Each plot sized 7.2 m in width and 4.8 m in length. The treatment combinations were comprised of six planting techniques and four nutrient management practices. The details of treatment are given in Table1. The pearl millet variety MPMH-17 has been used for experimentation, which was sown

firstly in nursery using seed rate of 2 kg ha⁻¹ and for direct seed sowing in field @ 4 kg ha⁻¹. In nursery seeds were sown by broadcasting method on 25th June 2018 and 29th June 2019. Sowing in flat bed treatment (direct seed sowing) was done at 45 cm row interval by "pora" method (seeds are dropped in funnel which attached with hoe) on 20th July 2018 and 26th July 2019, respectively. Nearly three weeks old healthy seedlings were transplanted in experimental plots in sub plot, thereby making twenty four treatment combinations.

The biometric observations were recorded on five randomly selected plants from net plot of each treatment. Crop growth rate (CGR) was estimated using the formula reported by Brown [16] and expressed as g m⁻² day⁻¹. Relative growth rate (RGR) was calculated using the formula given by Radford [17] and expressed as g⁻¹ day⁻¹.

$$\text{Crop Growth Rate (g m}^{-2} \text{ day}^{-1}) = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W₁= dry matter production per unit area at time t₁

W₂=dry matter production per unit area at time t₂

t₁=days to first sampling

t₂=days to second sampling

$$\text{Relative Growth Rate (g g}^{-1} \text{ day}^{-1}) = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where,

log_e W₁ = Initial dry weight of plant (g)

log_e W₂ = Final dry weight of plant (g)

t₁ = Initial time period

t₂ = Final time period

3. RESULTS AND DISCUSSION

3.1 Plant Height

The result revealed that there was significant effect of planting techniques and nutrient management practices on plant height during both cropping seasons. Pit planting technique treatment PT₆ recorded maximum plant height of 169.47 and 167.95 cm during 2018 and 2019 crop season, respectively and closely followed by another pit planting treatment PT₅ and PT₄.

Whereas flat bed seed sowing treatment PT₁ recorded lowest plant height during both crop seasons. The lower plant height might have been due to the fact of time difference i.e., plants started growing about three weeks later in direct seeded treatment as compared to transplanted treatments. Deshmukh et al. [18] also stated that the methods of planting significantly affected plant height of the pearl millet crop at Navsari, Gujarat in black cotton soil. In pit technique with 2, 3 or 4 plants pit⁻¹ (PT₄, PT₅ and PT₆) resulted in lower plant density as compared to ridge planting PT₃, PT₂ and seed sowing PT₁ thereby increased water availability per plant and thus directly enhanced response to fertilizer and efficiency of utilization of solar radiation also. Almost similar findings were observed by researchers Payne et al. [19] and Fatondji et al. [20] in pearl millet. Among nutrient management practices highest fertilization level treatment NMP₃ recorded highest plant height during both the year of study and no fertilization control (NMP₀) noted lowest plant height. Higher plant height with increasing dose of fertilizer may be due to increase in cytokinin production, which have effect on cell wall elasticity and led to higher number of meristematic cells [21].

3.2 Crop Growth Rate (CGR)

Data presented in Table 2 revealed that ridge planting techniques PT₂ and PT₃ recorded significantly higher crop growth rate ($\text{g m}^{-1} \text{day}^{-1}$) over rest of planting technique treatments (except between 20-40 days after sowing/days after transplanting in 2018) and both the treatments (PT₂ and PT₃) remained statistically at par with each other at 0-20, 20-40 and 40 DAS/DAT-harvest. Among pit technique treatments, PT₆ (4 plants pit⁻¹) noted higher crop growth rate of 4.52 and 3.98 $\text{gm}^{-1} \text{day}^{-1}$ during day of sowing/transplanting to 20 DAS (Days after sowing)/DAT (Days after transplanting), 19.04 and 15.65 $\text{g m}^{-1} \text{day}^{-1}$ during 20-40 and 12.53 and 14.17 $\text{g m}^{-1} \text{day}^{-1}$ during 40 DAS/DAT-harvest, during 2018 and 2019, respectively. While lowest crop growth rate was realized with pit technique PT₄ followed by direct seed sowing treatment (PT₁). Data further revealed significant variations in CGR due to different nutrient management practices (NMP) and CGR improved with increasing levels of fertilization to pearl millet. Although, NMP₃ recorded the highest crop growth rate of 5.05 and 4.62 during 0-20 DAS/DAT, 20.87 and 17.90 during 20-40 DAS/DAT and 19.21 and 18.99 $\text{g m}^{-1} \text{day}^{-1}$ during 40 DAS/DAT-harvest during 2018 and 2019,

respectively which registered statistical superiority over rest of NMP treatments. Whereas, minimum crop growth rate was realized with control treatment (NMP₀) at all growth stages during both the years. The possible reason of higher CGR in ridge technique could have been due to better air circulation, light interception in wider row spacing and also more moisture availability in bunds which supported side dressed nutrients absorption by roots which culminated to higher dry matter accumulation plant⁻¹, which ultimately reflected as higher stover yield. The application of 10 ton FYM + NPK as per treatments in present investigation also improves the physico-chemical properties and hydraulic conductivity of the soil and thereby availability of nutrients which increased plant growth, dry matter accumulation plant⁻¹, crop growth rate and relative growth. Results obtained in this study are in close conformity with those of Jain and Poonia [22], Rathore and Singh [23] and Choudhary and Gautam [24].

3.3 Relative Growth Rate (RGR)

Data furnished in Table 3 revealed that planting technique of 2 plants pit⁻¹ (PT₄) significantly increased relative growth rate between 20-40 and 40 DAS-harvest over rest of all planting technique treatments. Whereas, minimum relative growth rate of 1.33 and 1.25 $\text{g g}^{-1} \text{day}^{-1}$ during 20-40 DAS and 1.77 and 1.76 $\text{g g}^{-1} \text{day}^{-1}$ during 40 DAS-harvest were observed in direct seeded treatment (PT₁) during crop season 2018 and 2019, respectively. Higher RGR in PT₄ treatment may be due to better availability of resources (space, light, water and nutrient etc.) because of lower plant density in per unit area. The relative growth rate for dry matter was increased with every increased level of nutrients. Application of NMP₃ realized maximum relative growth rate 1.74 and 1.68 $\text{g g}^{-1} \text{day}^{-1}$ during 20-40 DAS/DAT and 2.13 & 2.10 $\text{g g}^{-1} \text{day}^{-1}$ 40 DAS/DAT-harvest during 2018 and 2019 crop season, respectively, which showed significant superiority over rest of NMP treatments. Further, NMP₂ recorded significantly higher RGR over NMP₁ and NMP₁ also and registered statistically significance over NMP₀ (control) during either years of investigation.

3.4 Grain Yield (kg ha^{-1})

A thoughtful perception of the data revealed that transplanting of 4 plants pit⁻¹ (PT₆) produced maximum grain yield of 3142 and 3030 kg ha^{-1} which was significantly higher over rest of the

treatments but it was found statistically at par with PT₅ during each year 2018 and 2019, respectively. While, transplanting of 4 plants together at 30 cm interval on ridges (PT₃) obtained the lowest grain yield of 2034 and 1932 kg ha⁻¹ during 2018 and 2019, respectively, which was statistically at par with 2 plants pit⁻¹ technique PT₄ (2094 kg ha⁻¹). Though, grain yield of treatment PT₁, PT₂ and PT₄ were remained statistically at par with each other during individual year of investigation. Moreover, it is apparent from data that increasing dose of nutrients showed significant effect on grain yield of pearl millet. The highest grain yield 3374 and 3273 kg ha⁻¹ was realized in the treatment NMP₃ during the year of 2018 and 2019, respectively, which was statistically superior over lower doses of nutrients management practices (NMP₁&

NMP₂) and control (NMP₀) during both the year of study. The higher grain yield of pearl millet with planting technique treatment PT₆ and nutrient management practice NMP₃ might be due to cumulative effect of improved growth parameters and yield attributes which was boosted by adequate and increased nutrients supply. The better availability of nutrients due to applied higher dose of primary nutrients and mineralization of organics (FYM) thereby influence both shoot and root growth favored absorption of both water and nutrient. Similar results were reported by Thumar et al. [25] and Chandana et al. [26]. Singh et al. [27], Singh et al. [28], and Gautam et al. [29] in pearl millet and Prabudoss et al. [30] in kodomillet, also reported higher yields with incremental levels of nutrient application.

Table 1. Treatment detail of different planting techniques and nutrient management practices under pearl millet cultivation

Treatment details	Abbreviation
A. Planting Techniques	
1. Flat bed (45 cm x 15 cm) – Recommended practice	PT ₁
2. Ridge and furrow (90 cm x 15 cm) with 2 plants together transplanting	PT ₂
3. Ridge and furrow (90 cm x 30 cm) with 4 plants together transplanting	PT ₃
4. Pit method (80 cm x 80 cm) with 2 plants per pit	PT ₄
5. Pit method (80 cm x 80 cm) with 3 plants per pit	PT ₅
6. Pit method (80 cm x 80 cm) with 4 plants per pit	PT ₆
B. Nutrient Management Practices	
1. Control	NMP ₀
2. NPK- 60, 40, 20 + 10 t FYM	NMP ₁
3. NPK - 90, 60, 30 + 10 t FYM	NMP ₂
4. NPK - 120, 80, 40 + 10 t FYM	NMP ₃

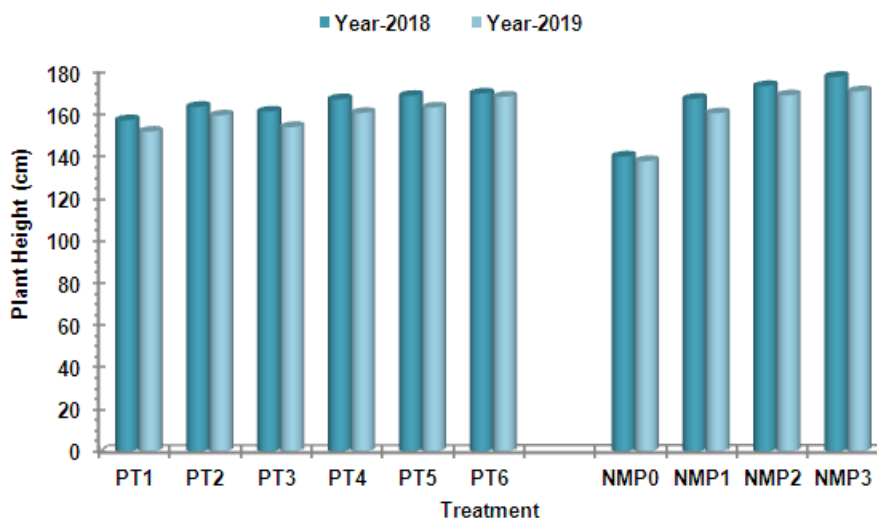


Fig. 1. Effect of planting technique and nutrient management practice on plant height (cm) of pearl millet

Table 2. Effect of planting technique and nutrient management practice on crop growth rate ($\text{g m}^{-2} \text{day}^{-1}$) of pearl millet

Treatment	0-20 DAS/DAT		20-40 DAS/DAT		40 DAS/DAT-Harvest	
	2018	2019	2018	2019	2018	2019
Planting Techniques						
PT ₁	2.28	2.13	14.69	12.09	17.09	17.06
PT ₂	6.24	5.70	21.17	16.40	20.97	19.67
PT ₃	6.57	5.84	19.14	17.04	19.16	18.64
PT ₄	2.15	2.08	12.56	9.54	10.08	10.40
PT ₅	3.35	2.76	15.25	12.44	12.18	11.78
PT ₆	4.52	3.98	19.04	15.65	12.53	14.17
S.Em \pm	0.15	0.08	0.50	0.89	1.24	0.80
CD (p=0.05)	0.46	0.25	1.56	2.80	3.92	2.53
Nutrient Management Practices						
NMP ₀	2.57	2.15	9.32	7.21	9.19	8.86
NMP ₁	4.44	4.17	17.99	14.02	15.31	15.70
NMP ₂	4.68	4.05	19.72	16.31	17.63	17.60
NMP ₃	5.05	4.62	20.87	17.90	19.21	18.99
S.Em \pm	0.13	0.06	0.52	0.39	0.67	0.57
CD (p=0.05)	0.37	0.18	1.48	1.13	1.91	1.64

Table 3. Effect of planting technique and nutrient management practice on relative growth rate ($\text{g g}^{-1} \text{day}$) of pearl millet

Treatment	20-40 DAS/DAT		40 DAS/DAT-at harvest	
	2018	2019	2018	2019
Planting Techniques				
PT ₁	1.33	1.25	1.77	1.76
PT ₂	1.51	1.42	1.90	1.85
PT ₃	1.48	1.42	1.87	1.84
PT ₄	1.87	1.77	2.26	2.23
PT ₅	1.81	1.72	2.17	2.13
PT ₆	1.78	1.71	2.10	2.09
S.Em \pm	0.01	0.02	0.02	0.01
CD (p=0.05)	0.04	0.05	0.06	0.04
Nutrient Management Practices				
NMP ₀	1.39	1.30	1.79	1.75
NMP ₁	1.68	1.59	2.04	2.01
NMP ₂	1.71	1.64	2.09	2.06
NMP ₃	1.74	1.68	2.13	2.10
S.Em \pm	0.01	0.01	0.01	0.01
CD (p=0.05)	0.03	0.02	0.03	0.03

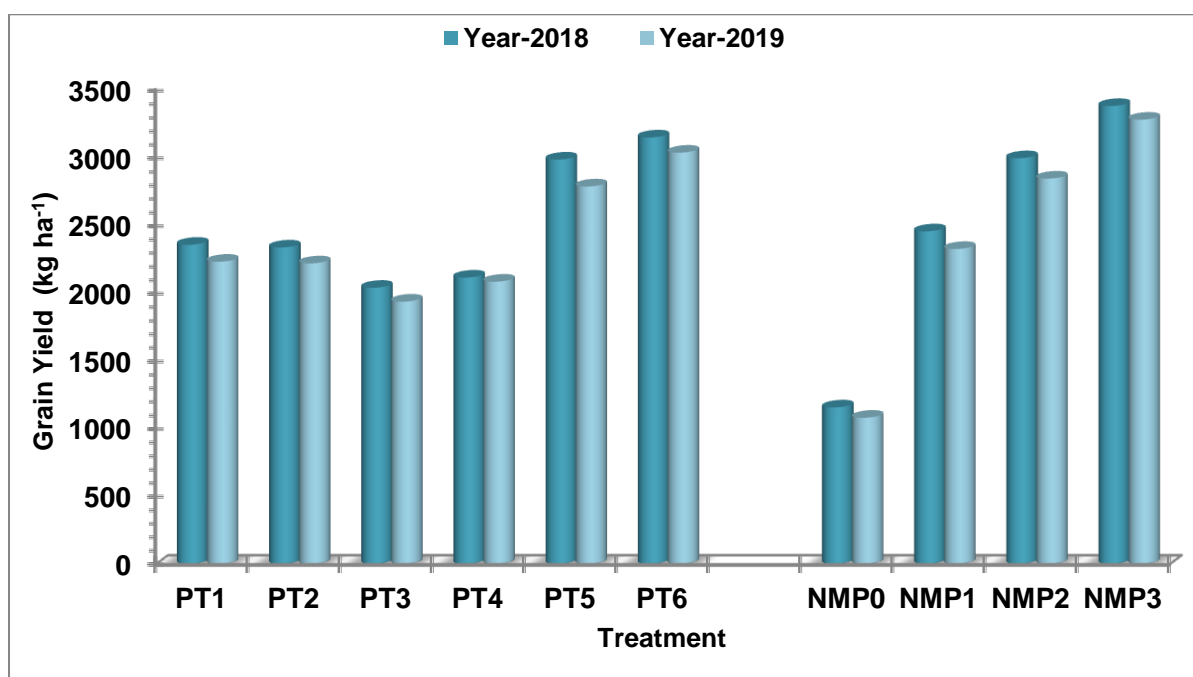


Fig 2. Effect of planting technique and nutrient management practice on grain yield (kg ha⁻¹) of pearl millet

4. CONCLUSION

Based on above results it can be concluded that pit planting technique- PT₆(4 plants per pit) helps to get higher plant height and maximum grain yield in arid environmental conditions. Further growth parameters and grain yield also increased with increasing dose of nutrients. Higher plant height, crop growth rate (g m⁻¹ day⁻¹) and relative growth rate (g g⁻¹ day⁻¹) at different intervals and grain yield were recorded maximum in nutrient management practice NMP₃.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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