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Effect of plant geometry and organic manures on growth and yield of Kodo millet (*Paspalum scrobiculatum*) under rainfed condition

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Abstract

A field experiment was conducted during *kahrif* 2019, 2020 and 2021 at Agricultural Research Station, Tiptur to study the growth and yield of Kodo millet as influenced by spacing and organic nutrient management practices. It was laid out in factorial randomized complete block design with three replication comprising of two spacing and six organic nutrient management practices. Soil of the experimental site was red sandy loam classified as *Alfisols*. Among the spacing Narrow spacing of 22.5 cm X 7.5 cm (S₁) recorded significantly higher grain yield (2655 kg/ha, 2491 kg/ha, 2619 kg/ha and 2589 kg/ha, respectively) in 2019, 2020, 2021 and pooled data as compared to wider spacing of 30 cm X 7.5 cm. Application of 125% N equivalent Vermicompost + FYM @ 7.5 t/ha (N₆) recorded significantly higher grain yield (2832 kg/ha, 2543 kg/ha, 2836 kg/ha and 2737 kg/ha) in 2019, 2020, 2021 and pooled data respectively and straw yield (3563 kg/ha, 3348 kg/ha, 3406 kg/ha and 3439 kg/ha) in 2019, 2020, 2021 and pooled data respectively as compared to other organic nutrient sources and levels. Among the interactions, growing of Kodo millet with a spacing of 22.5 cm X 7.5 cm with application of 125% N equivalent Vermicompost + FYM @ 5.0 t/ha (S₁N₆) recorded significantly higher grain yield (2842 kg/ha, 2583 kg/ha, 2842 kg/ha and 2756 kg/ha) in 2019, 2020, 2021 and pooled data respectively and straw yield (3514 kg/ha, 3500 kg/ha, 3353 kg/ha and 3456 kg/ha) in 2019, 2020, 2021 and pooled data respectively as compared to others interaction treatments. However it was at par with a spacing of 30 cm X 7.5 cm along with application of 125% N equivalent Vermicompost + FYM @ 7.5 t/ha in grain yield (2822 kg/ha, 2503 kg/ha, 2831 kg/ha and 2719 kg/ha) in 2019, 2020, 2021 and pooled data respectively.

Keywords: Vermicompost, FYM, kodo millet, organic nutrient sources and spacing

Introduction

Kodo millet (*Paspalum scrobiculatum*) is a small, seeded cereal grain and is among one of the oldest cultivated crops in India. In recent years, Kodo millet—in addition to other species of millet—have seen a sharp decline in production area due to the promotion of other staple cereals (mainly rice and wheat). Millets have been neglected from research and development, and now consequently lack the production advantages of rice and wheat, such as availability of improved varieties and knowledge of cultivation practices to maximize yields. However, due its rich nutrient profile, low input requirements, and adaptability to marginal soils and various climatic conditions, kodo millet has received renewed research interest as a method of risk management and adaptation to climate change for farmers.

Kodo millet (*Paspalum scrobiculatum* L.), is indigenous to India, and it is said to have been domesticated about 3000 years ago. (Rawat *et al.*, 2021) [11]. This cereal is well known as ‘varagu’ in Tamil and ‘kodo’ in Hindi. Throughout the world's tropics and sub tropics, the species is extensively dispersed and found in moist habitats. *Paspalum scrobiculatum* var. *scrobiculatum* is grown as a significant crop in India, while *Paspalum scrobiculatum* var.

commersonii is the wild variety native to Africa. The old-world tropical regions are home to kodo millet. (Joshi *et al.*, 2021) [5].

In India, kodo millet is primarily grown in the states of Madhya Pradesh, Chhattisgarh, Maharashtra, Tamil Nadu and Karnataka. It is grown in Arunachal Pradesh's Jhum field as well as it has good adaptation to sub tropical and tropical climates. The crop yields varying from 250 to 1000 kg/ha and matures in 4-6 months. (Cheruku *et al.*, 2023) [4]. This crop exhibits resilience to climate change and is hardy, drought-resistant, and able to grow on marginal soils. It also affected by abiotic stresses, though it is better adapted to abiotic stresses than most other cereals (Mundada *et al.*, 2022) [8]. Similar to other small millets, kodo millet is a good source of phosphorus and iron. They are nutritionally comparable to rice, wheat, and other staple cereals, and even offer higher protein content, sulfur-containing amino acids Cysteine and Methionine. Kodo millet is particularly high in B vitamins, especially niacin, pyridoxine, and folic acid, in addition to minerals such as calcium, iron, potassium, magnesium, and zinc. Kodo millet contains polyphenols, tannins, and phytic acids—antinutrients which form complexes with nutrients such as carbohydrates, proteins, iron, calcium, and zinc and

reduce their bioavailability. Fortunately, processing of kodo millet typically reduces the levels of tannins and phytates and increase the bioavailability of nutrients. For example, dehulling kodo millet can remove 40-50% of phytate. Each 100g of Kodo millet contains the following nutrients: energy (302 kcal), protein (8.03 g), carbohydrate (69.9 g), crude fibre (8.5 mg), calcium (22.0 mg) and iron (9.9 mg) (Anonymous, 2022).

Adoption of organic farming is essential to avoid chemical-based pesticides and fertilizers. In contrast to conventional farming, organic farming may increase the nutritious value of meals and food products. However, chemicals may leave residues in foods and products that could have disastrous effects on human health and the environment. Various methods that can enhance soil fertility organically, include using bio-fertilizers, organic manures, etc. Organic manures refer to natural components used by farmers to provide nutrients to crop plants. Various forms of organic manure exist, including green manures, FYM, vermicompost, compost manures and oil cakes, etc., which improves the soil's organic matter, water-holding capacity and drainage (Bhujje and Joshi., 2023) [3].

Organic manures, such as farmyard manure, compost, and vermicompost, are utilized as organic fertilizers to improve soil fertility and crop yield. However, the low nutrient content, bulkiness, less availability in the market, lack of awareness among farmers of their beneficial effects, and handling challenges of these organic manures discourage farmers from using them more frequently (Sindhu *et al.*, 2020 and Yatoo *et al.*, 2021) [14, 16]. The amendment of cow manure and organic nutrient supplements results in producing mature and nutrient-enriched vermicompost suitable for sustainable agricultural production (Yatoo *et al.*, 2022) [17]. Keeping this view, the present study was undertaken to study the "Effect of plant geometry and organic manures on growth and yield of Kodo millet (*Panicum miliaceum*) under rainfed condition".

Materials and Methods

The field study was conducted during *kharif* seasons of 2019, 2020 and 2022 at Agricultural Research Station, Tiptur. The experiment was laid out in factorial randomized complete block design in which Factor 1 comprised of two spacing (S_1 : 22.5 cm $\times$ 7.5 cm and S_2 : 30 cm $\times$ 7.5 cm) and Factor 2 comprised of Six nutrient levels through organic manures (N_1 : 75% N equivalent through FYM + FYM 5 t/ha, N_2 : 100% N equivalent through FYM + FYM 5 t/ha, N_3 : 125% N equivalent through FYM + FYM 5 t/ha, N_4 : 75% N equivalent through Vermicompost + FYM 7.5 t/ha, N_5 : 100% N equivalent through Vermicompost + FYM 7.5t/ha and N_6 : 125% N equivalent through Vermicompost + FYM 7.5t/ha). The N Equivalent organic manures supplied through FYM and Vermicompost. The Recommended N equivalent FYM, Vermicompost and recommended FYM are applied 15 days before sowing of Kodo millet. The Kodo millet sown 15 days after organic manures applied and Kodo millet was harvested at 120 to 140 days after sowing.

The initial soil available nutrient analysed by soil sampling before organic manures are applied. The observations like Plant height (cm), Grain yield (kg/ha) and straw yield (kg/ha) were recorded at harvest. The mean values were subjected to t-test analysis.

Results and Discussion

1. Grain yield (kg/ha)

Among spacing narrow spacing of 22.5 cm X 7.5 cm (S_1) found optimum for Kodo millet to get significantly higher grain yield (2655 kg/ha, 2491 kg/ha, 2619 kg/ha and 2589 kg/ha, respectively) during 2019, 2020, 2021 and pooled data respectively as compared to wider spacing of 30 cm X 7.5 cm (2454 kg/ha, 2332 kg/ha, 2500 kg/ha and 2429 kg/ha, respectively) (Table.1).

Application of 125% N equivalent Vermicompost + FYM @ 7.5 t/ha (N_6) recorded significantly higher grain yield (2832 kg/ha, 2543 kg/ha, 2836 kg/ha and 2737 kg/ha) in 2019, 2020, 2021 and pooled data respectively (Table.1) as compared to other organic nutrient sources and levels. Among the interactions, growing of Kodo millet with a spacing of 22.5 cm X 7.5 cm with application of 125% N equivalent Vermicompost + FYM @ 5.0 t/ha (S_1N_6) recorded significantly higher grain yield (2842 kg/ha, 2583 kg/ha, 2842 kg/ha and 2756 kg/ha) in 2019, 2020, 2021 and pooled data respectively (Table.1) as compared to other interaction treatments. This might be due to the fact that different organic sources influenced the physiological activity, which increased the dry matter accumulation and it was optimum at maturity stage due to diversion of food material from source to sink. These results confirm the findings of Shanmugam and Veeraputhran (2001) [13] and Bana *et al.* (2012) [2]. The application of vermicompost were effectively absorbed and translocated to the developing panicle there by producing more number of productive tillers and better filling in proso millet. These observations were also supported by the findings of Mohamed *et al.* (2016) [6]; Okee (2020) [9]; Ramveer *et al.* (2023). Application of enriched vermicompost and organic foliar nutrition were significantly influenced the growth and yield of Proso millet and the treatment T5 (100% Enriched vermicompost + sea weed extract) was found the best treatment among all the treatments and it gave the maximum growth and yield (Sangeetha S.P. and M. Anandhavalli, 2023) [12].

2. Straw yield (kg/ha)

Among spacing narrow spacing of 22.5 cm X 7.5 cm found optimum for Kodo millet to get significantly higher straw yield (3296 kg/ha, 3429 kg/ha, 3323 kg/ha and 3349 kg/ha, respectively) during 2019, 2020, 2021 and pooled data respectively as compared to wider spacing of 30 cm X 7.5 cm (2944 kg/ha, 3456 kg/ha, 2918 kg/ha and 3160 kg/ha, respectively) (Table.1).

Application of 125% N equivalent Vermicompost + FYM @ 7.5 t/ha (N_6) recorded significantly higher Straw yield (3563 kg/ha, 3348 kg/ha, 3406 kg/ha and 3439 kg/ha) in 2019, 2020, 2021 and pooled data respectively (Table.1) as compared to other organic nutrient sources and levels. Among the interactions, growing of Kodo millet with a spacing of 22.5 cm X 7.5 cm with application of 125% N equivalent Vermicompost + FYM @ 5.0 t/ha recorded significantly higher straw yield (3514 kg/ha, 3500 kg/ha, 3353 kg/ha and 3456 kg/ha) in 2019, 2020, 2021 and pooled data respectively (Table.1) as compared to other interaction treatments. This might be due to the fact that different organic sources influenced the physiological activity, which increased the dry matter accumulation and it was optimum at maturity stage due to diversion of food material from source

to sink. These results confirm the findings of Shanmugam and Veeraputhran (2001) ^[13] and Bana *et al.* (2012) ^[12]. The application of vermicompost were effectively absorbed and translocated to the developing panicle there by producing more number of productive tillers and better filling in proso millet. These observations were also supported by the findings of Mohamed *et al.* (2016) ^[6]; Okee (2020) ^[9]; Ramveer *et al.* (2023). Application of enriched vermicompost and organic foliar nutrition were significantly influenced the growth and yield of Proso millet and the treatment T5 (100% Enriched vermicompost + sea weed extract) was found the best treatment among all the treatments and it gave the maximum growth and yield (Sangeetha S.P. and M. Anandhavalli, 2023) ^[12].

3. Harvest index (HI)

Among spacing there is no significant difference in Harvest Index (HI) during 2019, 2020, 2021 and pooled data (Table.1).

Application of 125% N equivalent Vermicompost + FYM @ 7.5 t/ha (N₆) recorded significantly higher HI (0.514, 0.424, 0.486 and 0.472) in 2019, 2020, 2021 and pooled data respectively (Table.1) as compared to other organic nutrient sources and levels. Among the interactions, growing of Kodo millet with a spacing of 30 cm X 7.5 cm with application of 125% N equivalent Vermicompost + FYM @ 5.0 t/ha recorded significantly higher HI (0.538, 0.418, 0.531 and 0.492) in 2019, 2020, 2021 and pooled data respectively (Table.1) as compared to other interaction treatments.

Table 1: Effect of plant geometry and organic manures on grain yield, Straw yield and HI of Kodo millet

Treatments	Grain Yield (kg/ha)				Straw yield (kg/ha)				HI			
	2019	2020	2021	Pooled	2019	2020	2021	Pooled	2019	2020	2021	Pooled
Factor 1: Spacing (S)												
S ₁	2655	2491	2619	2589	3296	3429	3323	3349	0.456	0.403	0.450	0.435
S ₂	2454	2332	2500	2429	2944	3456	2918	3106	0.446	0.409	0.441	0.432
S.Em ±	23.55	31.75	23.71	16.92	32.42	34.24	32.42	18.79	0.004	0.004	0.004	0.002
CD @ 5%	69.06	93.11	69.53	49.63	95.07	NS	95.07	55.10	NS	NS	NS	NS
Factor 2: Nutrient levels through organic manures (N)												
N ₁	2169	2257	2135	2187	2694	3459	3056	3070	0.413	0.414	0.422	0.416
N ₂	2433	2329	2468	2410	3086	3202	2972	3087	0.453	0.411	0.449	0.436
N ₃	2729	2380	2496	2535	2979	3341	3028	3116	0.464	0.389	0.434	0.429
N ₄	2563	2450	2669	2561	3146	3736	3250	3377	0.441	0.407	0.471	0.438
N ₅	2600	2511	2753	2621	3254	3570	3011	3278	0.422	0.429	0.447	0.433
N ₆	2832	2543	2836	2737	3563	3348	3406	3439	0.514	0.424	0.486	0.472
S.Em ±	40.78	54.99	41.06	29.31	56.15	59.30	56.15	32.54	0.007	0.006	0.006	0.004
CD @ 5%	119.62	161.27	120.42	85.96	164.67	173.93	164.67	95.44	0.020	0.019	0.019	0.011
Interaction												
S ₁ N ₁	2378	2275	2308	2320	3353	3361	3514	3409	0.415	0.404	0.396	0.405
S ₁ N ₂	2558	2361	2558	2493	3458	3403	2958	3273	0.425	0.410	0.464	0.432
S ₁ N ₃	2817	2478	2489	2595	3194	3625	3194	3338	0.468	0.406	0.438	0.437
S ₁ N ₄	2637	2608	2697	2648	3203	3556	3203	3320	0.452	0.423	0.457	0.444
S ₁ N ₅	2697	2642	2822	2720	3611	3195	3458	3421	0.428	0.452	0.449	0.443
S ₁ N ₆	2842	2583	2842	2756	3514	3500	3353	3456	0.538	0.418	0.531	0.492
S ₂ N ₁	1961	2239	1961	2054	2819	3042	2431	2764	0.410	0.424	0.447	0.426
S ₂ N ₂	2308	2297	2378	2328	2431	3486	2500	2806	0.480	0.412	0.434	0.440
S ₂ N ₃	2642	2283	2503	2476	2500	3278	3097	2958	0.460	0.372	0.431	0.420
S ₂ N ₄	2489	2292	2642	2474	3306	3584	2819	3236	0.430	0.390	0.484	0.433
S ₂ N ₅	2503	2381	2683	2522	2958	3431	3611	3333	0.416	0.405	0.445	0.422
S ₂ N ₆	2822	2503	2831	2719	3097	3848	3306	3417	0.490	0.429	0.440	0.452
S.Em ±	57.68	77.76	58.07	41.45	79.40	83.87	79.40	46.02	0.010	0.009	0.009	0.005
CD @ 5%	169.17	228.07	170.31	121.57	232.88	245.98	232.88	134.98	0.029	0.027	0.027	0.016

4. Plant height (cm)

Among the spacing wider spacing of 30 cm X 7.5 cm found optimum for Kodo millet to get significantly higher Plant height (59.99 cm, 52.00 cm, 52.18 cm and 57.06 cm, respectively) during 2019, 2020, 2021 and pooled data respectively as compared to narrow spacing of 22.5 cm X 7.5 cm (52.88 cm, 52.76 cm, 53.69 cm and 53.11 cm, respectively) (Table.2).

Application of 125% N equivalent Vermicompost + FYM @ 7.5 t/ha (N₆) recorded significantly higher Plant height (60.98 cm, 51.96 cm, 60.60 cm and 57.85 cm) in 2019, 2020, 2021 and pooled data respectively (Table.2) as compared to other organic nutrient sources and levels. Among the interactions, growing of Kodo millet with a spacing of 30 cm X 7.5 cm

with application of 125% N equivalent Vermicompost + FYM @ 5.0 t/ha recorded significantly higher plant height (61.57 cm, 56.42 cm, 59.76 cm and 59.25 cm) in 2019, 2020, 2021 and pooled data respectively (Table.2) as compared to other interaction treatments. Organic manure influence both growth and yield by improving supply of plant micronutrients need and thus help to sustain crop productivity (Montaghatian *et al.* 2008). The higher number of branches due to the application of poultry manure might be due to the availability of desired and required quantity of nutrients for longer period in root zone of growing plants which helped plant cells to divide. The results were found to in correspondence with Upendranaik *et al.*, (2018) ^[15].

Table 2: Effect of plant geometry and organic manures on plant height of Kodo millet

Treatments	Plant height (cm)			
	2019	2020	2021	Pooled
Factor 1: Spacing (S)				
S ₁	52.88	52.76	53.69	53.11
S ₂	59.99	52.00	59.18	57.06
S.Em ±	0.58	1.33	0.58	0.51
CD @ 5%	1.70	3.91	1.70	1.49
Factor 2: Nutrient levels through organic manures (N)				
N ₁	54.26	51.63	54.30	53.40
N ₂	58.66	51.25	59.59	56.50
N ₃	56.96	56.42	58.48	57.28
N ₄	53.80	49.83	51.13	51.59
N ₅	53.95	53.21	54.51	53.89
N ₆	60.98	51.96	60.60	57.85
S.Em ±	1.00	2.31	1.00	0.88
CD @ 5%	2.94	6.77	2.94	2.58
Interaction				
S ₁ N ₁	49.91	52.33	48.14	50.13
S ₁ N ₂	56.85	49.25	56.85	54.32
S ₁ N ₃	52.34	56.42	57.20	55.32
S ₁ N ₄	50.40	50.00	49.91	50.10
S ₁ N ₅	59.63	53.08	59.63	57.45
S ₁ N ₆	60.46	53.25	62.33	58.68
S ₂ N ₁	48.14	55.50	50.40	51.35
S ₂ N ₂	58.61	50.92	60.46	56.66
S ₂ N ₃	62.33	50.83	61.57	58.24
S ₂ N ₄	57.20	49.67	52.34	53.07
S ₂ N ₅	59.76	50.92	58.61	56.43
S ₂ N ₆	61.57	56.42	59.76	59.25
S.Em ±	1.42	3.27	1.42	1.24
CD @ 5%	4.16	9.58	4.16	3.65

Conclusion

Sowing of Kodo millet at the spacing of 22.5 cm X 7.5 cm with application of 125% N equivalent Vermicompost + FYM @ 5.0 t/ha was found to enhance growth and yield of Kodo millet.

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