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Influence of spacing and nitrogen level on growth and yield of Kodo millet (*Paspalum scrobiculatum*) Indra Kodo-1 variety, North East plain zone

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Abstract
To evaluate the influence of spacing and nitrogen levels on growth and yield of kodo millet (*Paspalum scrobiculatum*) a field experiment was conducted in 2023 at research area of cereal and pulses section, at Agricultural Research Farm of United University, Prayagraj- 211012, Uttar Pradesh, India. During *Kharif* season of 2023-24. The experiment consisted of three doses of nitrogen (@75, @100, @125 kg/ha) and three spacing (20 x 10 cm, 30 x 10 cm, 40 x 10 cm). The experiment was arranged in a statistical design of Randomized Block Design (RBD) with three replications. Report of study indicate that, among different nitrogen levels the application of Nitrogen @125 kg/ha +20 x 10 cm spacing produced significantly superior plant height (99.75 cm) was recorded in treatment T_3. However, the application of Nitrogen @125 kg/ha + 40 x 10 cm spacing was found to be significantly maximum Number of tillers (6.67), plant dry weight (31.40 g), Number of panicles (6.14), panicle length (6.14 cm), Number of grains per panicle (165.46), No. of productive tillers/hill (5.97), test weight (5.84 g) was recorded in treatment T_9. The highest seed yield (2.16 t/ha), straw yield (6.56 t/ha), biological yield (8.72 t/ha), was produced by the application of Nitrogen @125 kg/ha + 20 x 10 cm spacing. However, application of 20 x 10 cm + Nitrogen @125 kg/ha significantly increase Cost of cultivation (24875.5 t/ha), gross return (72656.80 ha), net return (47781.3 ha) and benefit cost ratio (1.82) was recorded in treatment T_3. The spacing of 20 x 10 cm and @125 kg/ha application of nitrogen level proved significantly superior in terms of grain, straw and biological yield when compared to the rest of treatments spacing of 20 x 10 cm and nitrogen level of @125 kg/ha had higher gross return, net return, and B:C ratio of kodo millet crop. B: C ratio compared to other rest treatments of kodo millet crop, respectively. In harvest index highest shown in T_2 (25.48%) are the study's objectives. highest values were observed when applying (Spacing 20 x 10 cm + Nitrogen 100 kg/ha.) mix of treatments.

Keywords: Kodo millet, spacing, nitrogen, growth, yield and Economics

Introduction
Kodo millet (*Paspalum scrobiculatum L.*), a member of the family Poaceae, having chromosome no. 2n=40 is a highly drought resistant crop and coarsest of all food grains was domesticated in India some 3,000 years ago (Malleshi and Hadimani, 1993.) [1] and is cultivated as agricultural crop in parts of Madhya Pradesh, Maharashtra, Uttar Pradesh, Gujarat, Rajasthan and Tamil Nadu (De Wet *et al.* 1983) [2].

Kodo millet is mostly grown in hot and temperate regions. That is drought resistant and, as a result, may be grown in areas where rainfall is scarce and erratic. It's wonderful to thrive in areas where yearly precipitation is just 40 to 50 cm (Tadele 2016) [3]. Because of the nutritional and physiological benefits, they provide to customers, v. millets have become a popular food raw material alternative for major cereals in recent years (Baghele *et al.* 2021) [4].

The leading producer of millets in India includes Maharashtra, Rajasthan, and Karnataka (Agarwal *et al.*, 2018) [5]. The high consumption of millets is in rural areas of Assam (18.82 kg/hsh/m) and Bihar (18.69 kg/hsh/m). The cultivation area of minor millets was high in Madhya Pradesh (84,000 hectares) followed by Chhattisgarh (63,370 hectares) and Uttarakhand (53,000 hectares).

The most increased production was recorded in Madhya Pradesh (74,000 tons) followed by Uttarakhand (70,970 tons) and Tamil Nadu (37,340 tons). The highest productivity was recorded in Pondicherry (2274 kilograms/hectare) followed by Telangana (1711 kilograms / hectare) and Tamil Nadu (1444 kilograms / hectare) (Indiastat. 2018-19).

Grain has 98.3 percent protein, 1.4 percent fat, 65.6 percent carbs, and 2% ash. Fiber The overall fiber level of the grain is fairly high throughout. Kodo-millet has a lower Phosphorus (P) concentration than other millets, and it has a significantly higher antioxidant capacity than virtually other millets and common cereals (Ratnavathi 2017) [6]. The grain is recommended as a rice supplement for those with diabetes (Bhat 2018) [7].

Nitrogen is very important component of any fertilizer management programme. Application of only chemical fertilizers has a great effect on soil health and environment. Despite, fertilizers increase the food production but it leads to the micronutrient deficiencies. Organic manures such as poultry manure and farm yard manure not only increase the crop yield but also leads to increased quality of the produce. Integration of chemical fertilizers with organic manures has been found quite promising not only in sustaining the soil health and productivity but also in stabilizing the crop production in comparison to the use of each component, separately (Hemalatha *et al.*, 2021) [9].

The spacing of crops is a crucial factor that significantly influences their growth and yield. Proper spacing ensures that each plant receives adequate sunlight which is essential for photosynthesis. Adequate spacing allows each plant to access sufficient nutrients and water from the soil. Plants spaced too closely compete for resources which can result in stunted growth and lower yields. Sufficient space allows roots to expand and access more soil area enhancing the plant's ability to absorb water and nutrients (Jalajakshi *et al.*, 2022) [8].

Materials and Methods

A field experiment was arried out during *kharif* season 2023 at the Agronomy research field in United University, Rawatpur, Jhalwa, Prayagraj (U.P.) The soil of the experimental field was silty clay loam having pH 8.25, electrical conductivity 0.40 dS m^{-1}, organic carbon 0.24% available-N 160.25 kg ha^{-1}, available-P_2O_5 13.35 kg ha^{-1}, available-K_2O 245.63 kg ha^{-1} The experiment was laid out in randomized-block design with three replications. The treatments comprised nitrogen packages. The Indra kodo-1 variety was sown on10 August 2023, keeping different seed rate in different plots and row spacing 20, 30, 40 cm respectively and plant spacing 10 cm. The organic and inorganic sources of nutrients were applied as basal according to the specified treatments. The crop was grown under rainfed condition. The rainfall received during the crop season 2023 was 704.6 mm. The crop was harvested on 25 November in the years. The yield attributes and yield of kodo millet were recorded at harvest under each of the nitrogen and spacing treatments.

Results and Discussion

Growth parameters

Plant height (cm): Plant height: Spacing and different nitrogen levels significantly affected plant height. The highest Plant height was observed 99.75 cm with treatment combination T_3 (Spacing 20 x 10 cm + 125 kg N/ha). The lowest height observed 80.81 cm with treatment T_{10} (Control).

Number of tillers: At harvest, T_9 (6.67) produced significantly more tillers than T_8. It is also clear from the data that the number of tillers increased with the increase in the spacing and nitrogen levels for Kodo millet. Kodo millet at a wider spacing of Spacing 40 x 10 cm and highest dose of nitrogen 125 kg N/ha produced a significantly higher number of tillers Less tillers produced by T_{10} (5.00).

Plant dry Weight (g/plant): significantly highest plant dry weight (31.40 g) was recorded in the treatment with T_9 (Spacing 40 X 10 cm + Nitrogen 125 kg/ha) over all the other treatments. Among all treatment T_{10} (control) recorded lowest plant dry weight (23.71g).

Yield parameters

Number of panicles: A perusal of the data clearly indicates that the number of panicles was significantly affected due to spacing and different levels of nitrogen. Higher number of panicles with the value (6.14) were recorded in T_9 (Spacing 40 X 10 cm + Nitrogen 125 kg/ha). The smaller number of panicles was recorded in T_{10} (100% RDF control) (4.23).

Panicle length (cm): A critical examination over the data revealed that spacing and different nitrogen levels significantly influenced the length of panicle. The maximum in number of length (cm), (7.06 cm), recorded significantly higher in T_9 (Spacing 40 X 10 cm + Nitrogen 120 kg/ha). The lower panicle length was recorded in T_{10} (100% RDF control) (4.33 cm).

Number of grains per panicle: A perusal of the data indicates that number of grains/panicles was found significantly higher with treatment combination T_9 (Spacing 40 X 10 cm + Nitrogen 125 kg/ha) (165.46) of the investigation. The lower number of grains/panicles was recorded in T_{10} (100% RDF control) (128.12).

Number of productive tillers/hills: There was a significant improvement in the productive tillers/hill with T_9 (Spacing 40 X 10 cm + Nitrogen 125 kg/ha), which produced significantly higher productive tillers/hill (5.97). The lower number of productive tillers/hills was recorded in T_{10} (100% RDF control) (4.37).

Test weight (g): The highest test weight (g), (5.84 g) was recorded significantly in Spacing and different level of nitrogen treatment T_9 (Spacing 40 X 10 cm + Nitrogen 125 kg/ha). The lowest test weight was recorded in T_{10} (100% RDF control) (4.17 g).

Seed yield (t/ha): The highest seed yield (t/ha), (2.16 t/ha) was recorded significantly in spacing and different nitrogen levels treatment T_3 (Spacing 20 X 10 cm + Nitrogen 125 kg/ha) was significantly more. T_{10} Control plot produced lowest seed yield (1.43 t/ha).

Straw yield (t/ha): The highest straw yield of (6.65 t/ha) was recorded with treatment T_3 (Spacing 20 X 10 cm + Nitrogen 125 kg/ha) which was superior. T_{10} Control plot produced lowest straw yield (5.22 t/ha).

Biological Yield (t/ha): Highest biological yield (8.72 t/ha) was recorded by treatment combination of T_3 (Spacing 20 X 10 cm + Nitrogen 125 kg/ha). Least biological yield at all treatment combination was recorded by T_{10} Control (6.65 t/ha).

Harvest Index (%): Higher and lower harvest index was found

non-significantly with T_2 (Spacing 20 X 10 cm + Nitrogen 100 kg/ha) (25.48%), T_{10} Control (21.53%) respectively.

Cost of cultivation (₹/ha): Maximum cost of cultivation of (24875.5 ₹/ha) was recorded T_3 (Spacing 20 X 10 cm + Nitrogen 120 kg/ha) and being lowest (23248.0 ₹/ha) with T_{10} (Control).

Gross returns ((₹/ha): Maximum gross income of (72656.80 ₹/ha) was recorded under T_3 (Spacing 20 X 10 cm + Nitrogen 125 kg/ha) followed by and minimum under T_{10} (Control) (47339.20 ₹/ha).

Net returns (₹/ha): Maximum net return (47781.3 ₹/ha) was noted with T_3 (Spacing 20 X 10 cm + Nitrogen 125 kg/ha) and being lowest net return (24091.2 ₹/ha) under T_{10} (Control).

Benefit cost ratio: Highest benefit: cost ratio of 1.82 was noted under treatment T_3 (Spacing 20 X 10 cm + Nitrogen 125 kg/ha) and being lowest benefit: cost ratio under the T_{10} (Control) 1.03.

Table 1: Effect of spacing and nitrogen level on growth and yield of kodo millets.

Tr. No.	Treatment combination	Growth parameters			Yield parameters			
		Plant height (cm)	Number of tillers	Dry weight (g/plant)	No. of panicle	Panicle length (cm)	No. of grain / per panicle	No. of productive tillers/hill
T_1	Spacing 20 x 10 cm + Nitrogen 75 kg/ha	92.14	5.17	25.11	4.96	5.11	131.77	4.67
T_2	Spacing 20 x 10 cm + Nitrogen 100 kg/ha	97.04	5.30	25.56	5.00	5.53	132.33	4.80
T_3	Spacing 20 x 10 cm + Nitrogen 125 kg/ha	99.75	5.43	25.85	5.08	5.80	134.15	4.83
T_4	Spacing 30 x 10 cm + Nitrogen 75 kg/ha	86.74	5.63	26.82	5.11	6.04	136.44	4.93
T_5	Spacing 30 x 10 cm + Nitrogen 100 kg/ha	88.81	5.77	27.98	5.16	6.10	142.52	5.10
T_6	Spacing 30 x 10 cm + Nitrogen 125 kg/ha	88.17	5.87	27.78	5.17	6.14	144.41	5.17
T_7	Spacing 40 x 10 cm + Nitrogen 75 kg/ha	82.92	6.00	29.42	5.58	6.17	147.87	5.70
T_8	Spacing 40 x 10 cm + Nitrogen 100 kg/ha	83.26	6.20	30.04	5.46	6.21	155.62	5.77
T_9	Spacing 40 x 10 cm + Nitrogen 125 kg/ha	85.12	6.67	31.40	6.14	7.06	165.46	5.97
T_{10}	100% RDF (Control)	80.81	5.00	23.71	4.23	4.33	128.12	4.37
	F-test	S	S	S	S	S	S	S
	Sem±	3.18	0.24	1.05	0.24	0.28	5.95	0.26
	CD (p=0.05)	9.46	0.71	3.13	0.72	0.85	17.68	0.78

Table 2: Effect of spacing and nitrogen level on yield of kodo millets.

Tr. No.	Treatment combination	Yield parameters				
		Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
T_1	Spacing 20 x 10 cm + Nitrogen 75 kg/ha	4.31	1.76	6.01	7.76	22.58
T_2	Spacing 20 x 10 cm + Nitrogen 100 kg/ha	4.35	2.07	6.09	8.15	25.48
T_3	Spacing 20 x 10 cm + Nitrogen 125 kg/ha	4.54	2.16	6.56	8.72	24.74
T_4	Spacing 30 x 10 cm + Nitrogen 75 kg/ha	4.64	1.65	5.44	7.09	23.34
T_5	Spacing 30 x 10 cm + Nitrogen 100 kg/ha	4.77	1.74	5.82	7.56	23.14
T_6	Spacing 30 x 10 cm + Nitrogen 125 kg/ha	4.97	1.75	5.79	7.54	23.20
T_7	Spacing 40 x 10 cm + Nitrogen 75 kg/ha	5.56	1.60	5.30	6.90	23.14
T_8	Spacing 40 x 10 cm + Nitrogen 100 kg/ha	5.77	1.62	5.34	6.95	23.22
T_9	Spacing 40 x 10 cm + Nitrogen 125 kg/ha	5.84	1.65	5.38	7.03	23.44
T_{10}	100% RDF (Control)	4.17	1.43	5.22	6.65	21.53
	F-test	S	S	S	S	NS
	Sem±	0.27	0.07	0.20	0.22	0.96
	CD (p=0.05)	0.83	0.23	0.67	0.67	2.87

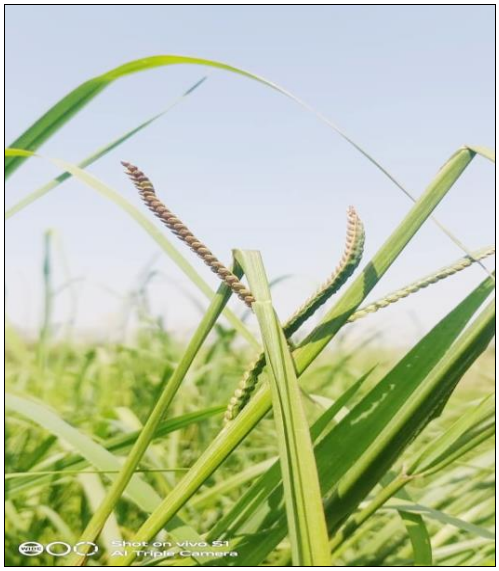
Table 3: Effect of spacing and nitrogen level on economics of kodo millets.

Tr. No.	Treatment combination	Economics			
		Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
T_1	Spacing 20 x 10 cm + Nitrogen 75 kg/ha	23790.5	59927.20	36136.7	1.73
T_2	Spacing 20 x 10 cm + Nitrogen 100 kg/ha	24333.0	69274.00	44941	1.78
T_3	Spacing 20 x 10 cm + Nitrogen 125 kg/ha	24875.5	72656.80	47781.3	1.82
T_4	Spacing 30 x 10 cm + Nitrogen 75 kg/ha	23090.5	56117.20	33026.7	1.45
T_5	Spacing 30 x 10 cm + Nitrogen 100 kg/ha	23633.0	59280.40	35647.4	1.50
T_6	Spacing 30 x 10 cm + Nitrogen 125 kg/ha	24175.5	59501.04	35325.54	1.57
T_7	Spacing 40 x 10 cm + Nitrogen 75 kg/ha	22707.5	54272.80	31565.3	1.34
T_8	Spacing 40 x 10 cm + Nitrogen 100 kg/ha	23250.0	54856.80	31606.8	1.36
T_9	Spacing 40 x 10 cm + Nitrogen 125 kg/ha	23792.5	55884.40	32091.9	1.40
T_{10}	100% RDF (Control)	23248.0	47339.20	24091.2	1.03

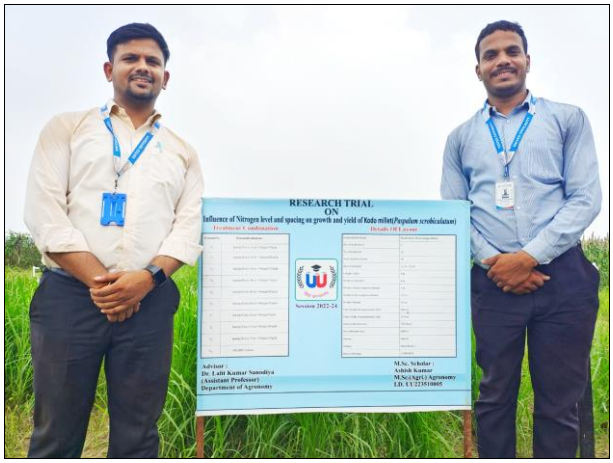
Making field layout

Field of kodo millet

Taking plant height



Panicle of kodo millet



Harvesting of kodo millet

Summary

Title: Influence of Spacing and Nitrogen Level on Growth and Yield of Kodo Millet (*Paspalum scrobiculatum*) Indra Kodo-1 Variety.

Research Location and Duration

- **Location:** Agriculture Research Farm, Faculty of Agriculture & Allied Sciences, United University, Rawatpur, Jhalwa, Prayagraj (Allahabad), Uttar Pradesh
- **Season:** Kharif season of 2023–2024

Experimental Design

- **Design:** Randomized Block Design (RBD)
- **Treatments:** 10 different combinations of spacing and nitrogen levels
- **Replications:** 3 replications for each treatment

Factors Studied

- **Spacing:** 20x10 cm, 30x10 cm, 40x10 cm
- **Nitrogen Levels:** 75 kg/ha, 100 kg/ha, 125 kg/ha

Key Observations

Treatment T9 (Spacing 40x10 cm + Nitrogen 125 kg/ha):

- **No. of Tillers:** 6.67
- **Plant Dry Weight:** 31.40 g/plant
- **No. of Panicles:** 6.14

- **Panicle Length:** 7.06 cm
- **No. of Productive Tillers per Plant:** 5.97
- **No. of Grains per Panicle:** 165.46
- **Test Weight:** 5.84 g

Treatment T3 (Spacing 20x10 cm + Nitrogen 125 kg/ha)
- **Highest Plant Height:** 99.75 cm
- **Seed Yield:** 2.16 t/ha
- **Straw Yield:** 6.56 t/ha
- **Biological Yield:** 8.72 t/ha

Treatment T2 (Spacing 20x10 cm + Nitrogen 100 kg/ha)
Highest Harvest Index: 25.48%

Economic Analysis
Treatment T3 (Spacing 20x10 cm + Nitrogen 125 kg/ha)
- **Cost of Cultivation:** Rs. 24,875.5/ha
- **Gross Returns:** Rs. 72,656.80/ha
- **Net Returns:** Rs. 47,781.3/ha
- **Benefit-Cost Ratio:** 1.82

Conclusion
- Treatment T3 (Spacing 20x10 cm + Nitrogen 125 kg/ha) resulted in the highest plant height and significant yield, making it productive and economically viable.
- Treatment T9 (Spacing 40x10 cm + Nitrogen 125 kg/ha) was better for growth parameters and yield components.
- Despite promising results, these findings are based on a single season's data. Further trials are recommended to validate the accuracy and reliability of these results.

Based on the provided context that T_{10} generally represents the lowest observed values for various parameters, here is a conceptual summary:
- **Lowest Growth Performance:** T_{10}, showed the least favorable results in terms of growth parameters such as the number of tillers, plant dry weight, number of panicles, and other yield-related traits.
- **Economic Returns:** The economic analysis for T_{10} would likely show the lowest gross returns, net returns, and benefit-cost ratio, reflecting its lower productivity and economic viability compared to other treatments.

Please refer to your detailed experimental data to extract and accurately report the specific values for each parameter under Treatment T_{10}.

Recommendations for Further Research
Multi-Season Trials
Conduct experiments over multiple seasons to account for seasonal variability.

Increased Replications
Increase the number of replications to enhance statistical reliability.

Extended Factors
Include additional factors such as soil types, irrigation, and pest control to understand their interactions with spacing and nitrogen levels.

Economic Analysis
Perform a detailed economic analysis, including input costs, labor, and market prices to validate economic viability.

Regional Trials
Implement trials in different geographical regions to ensure the findings are applicable under various local conditions.

Future line of work
Since the results are based on a four-month period of experimentation, more trials must be conducted to provide more concrete conclusions.

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