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Exploring the role of land configuration, mulching and fertilizer management in direct seeded dibbled rice to enhancing the growth and yield

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Abstract
The field experiment was carried out during *kharif* seasons of 2022 at Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli. Dist. Ratnagiri (M.S.). The soil of the experimental plot was sandy clay loam in texture, low in available nitrogen and very low in phosphorus, medium in potassium, very high in organic carbon and acidic in reaction. The field experiments were laid out in a strip plot design comprising of twelve treatment combinations replicated thrice. The vertical strips consist of four land configurations with or without mulch treatment *viz.*, M_1: Raised bed with mulch, M_2: Raised bed without mulch, M_3: Flatbed with mulch and M_4: Flatbed without mulch and horizontal strips comprised three fertilizer management practices *viz.*, F_1: RDF through straight fertilizer, F_2: Konkan Annapurna Briquettes (KAB) + Remaining N, P_2O_5 and K_2O through fertigation and F_3: RDF through fertigation. The results revealed that the among the varying land configuration with or without mulch, the treatment raised bed with mulch (M_1) showed significantly higher growth, yield attributes and yield of rice and it was found statistically at par with the treatment flat bed with mulch (M_3). Regarding the different fertilizer management practices, the combination of Konkan Annapurna Briquettes with the remaining RDF applied through fertigation (F_2) achieved significantly higher growth, yield attributes and yield. This result was found to be statistically at par to the treatment involving application of the entire RDF through fertigation (F_3) in the rice crop. Evaluating the interaction of treatment combinations, raised bed with mulch including Konkan Annapurna Briquettes plus remaining RDF through fertigation (M_1F_2) recorded a significant increase in growth, yield attributes and yield of *kharif* rice.

Keywords: Rice, fertigation, Konkan Annapurna briquettes, growth and yield

Introduction
The slogan “Rice is life” is most appropriate for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural house hold. The 85 per cent of the rice that is produced in the world is used for direct human consumption. Rice can also be found in cereals, snack foods, brewed beverages, flour, oil, syrup and religious ceremonies to name a few other uses.
Rice is the most important crop in India, grown over an area of 46.38 million hectares, with an annual rough rice production of 130.29 million tons (Anonymous, 2022) [2]. In Maharashtra rice is the second important crop of the people, which is grown over an area of 15303 hectares with an annual rough rice production of 34482 tonnes. The average productivity of the state is 2253.3 kg ha^{-1} (Anonymous, 2023-24) [3]. Maharashtra ranks 13th place in rice production in country. The average productivity of the Maharashtra state is low as compared to other rice growing states *viz.*, Panjab, Tamil Nadu, Haryana, Andhra Pradesh etc. The area (8190.60 ha) of rice crop is more in Vidarbha region. The higher productivity was observed in Konkan region *i.e.*, 2306.09 kg ha^{-1}. Marathwada region is the non-traditional rice growing area. Due to the erratic and less rainfall in Marathwada region, the average productivity of rice crop is lowest *i.e.*, 6.58 million tons (Anonymous, 2019-20) [1].
Raised beds improve surface drainage, reduce waterlogging stress and enable the cultivation of sensitive crops. Permanent raised beds further enhance efficiency by allowing direct drilling,

minimizing tillage, reducing greenhouse gas emissions and enabling rapid crop turnover. However, weed infestation poses a significant challenge in direct seeding, competing with crops for resources and reducing yields. Mulching effectively addresses this issue by conserving soil moisture, suppressing weeds and stabilizing the soil surface. Silver-black polythene mulch, in particular, modifies the microclimate, increasing soil temperature and boosting crop performance. Fertilizer management, including fertigation and use of briquette enhances nutrient efficiency, curbing losses and improving yields by up to 30 per cent, while saving time, labour and costs.

Materials and Methods

A field experiment was conducted at the Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli, Ratnagiri, during the *kharif* 2022 season using the Ratnagiri-1 variety of rice. The experiment was arranged in a strip plot design with twelve treatment combinations replicated three times, four vertical strips of land configurations with or without mulch treatment *viz.*, M_1: Raised bed with mulch, M_2: Raised bed without mulch, M_3: Flatbed with mulch and M_4: Flatbed without mulch and horizontal strips comprised three fertilizer management practices *viz.*, F_1: RDF through straight fertilizer, F_2: Konkan Annapurna Briquettes (KAB) + Remaining N, P_2O_5 and K_2O through fertigation and F_3: RDF through fertigation. The field had flat topography and sandy clay loam soil with low nitrogen and phosphorus, medium potassium and an acidic reaction. A total rainfall of 3454.6 mm was recorded over 91 rainy days during the season. Rice was dibbled at a spacing of 15 cm × 15 cm and the recommended dose of straight fertilizer (100:50:50 NPK kg ha^{-1}) was applied using urea, single superphosphate and muricate of potash similarly fertigation by Sujla (19:19:19) and Sulphate of Potash (SOP) also briquettes through Konkan Annapurna Briquette (KAB) as nutrient sources. Fertigation was provided in 10 equal splits at 7 day's intervals starting after 30 DAS to treatment F_3, while briquettes were applied at 15 DAS for treatment F_2. Growth parameters such as plant height (cm), number of functional leaves, tillers $hill^{-1}$ and dry matter production $hill^{-1}$ (g) were recorded at 30, 60, 90 DAS and at harvest. Yield and yield attributes, including panicle length (cm), weight of grains $panicle^{-1}$ (g), number of filled and unfilled grains $panicle^{-1}$ and grain and straw yield (kg ha^{-1}) were assessed at harvest.

Results and Discussion

Effect of varying land configuration with or without mulch

Growth attributes

The significantly maximum plant height was recorded under flat bed with mulch and it was found statistically at par with raised bed with mulch in all the growth stages of crop *i.e.*, from 30 DAS to till at harvest (Table 1). Improved nutrient absorption, facilitated by a higher concentration of foraging roots, likely results from reduced weed competition on flat and raised beds covered with polyethylene mulch. This mulch enhances growth by retaining soil moisture, lowering soil temperatures, and minimizing evaporation, while also improving photosynthetic capacity. The restricted competition in narrow row strips allows rice crops to better access soil moisture and conserved nutrients, fostering vigorous growth and increased plant height. Similar findings were reported by Iqbal *et al.*, (2014) [5] and Patil *et al.*, (2018) [8] in rice crop.

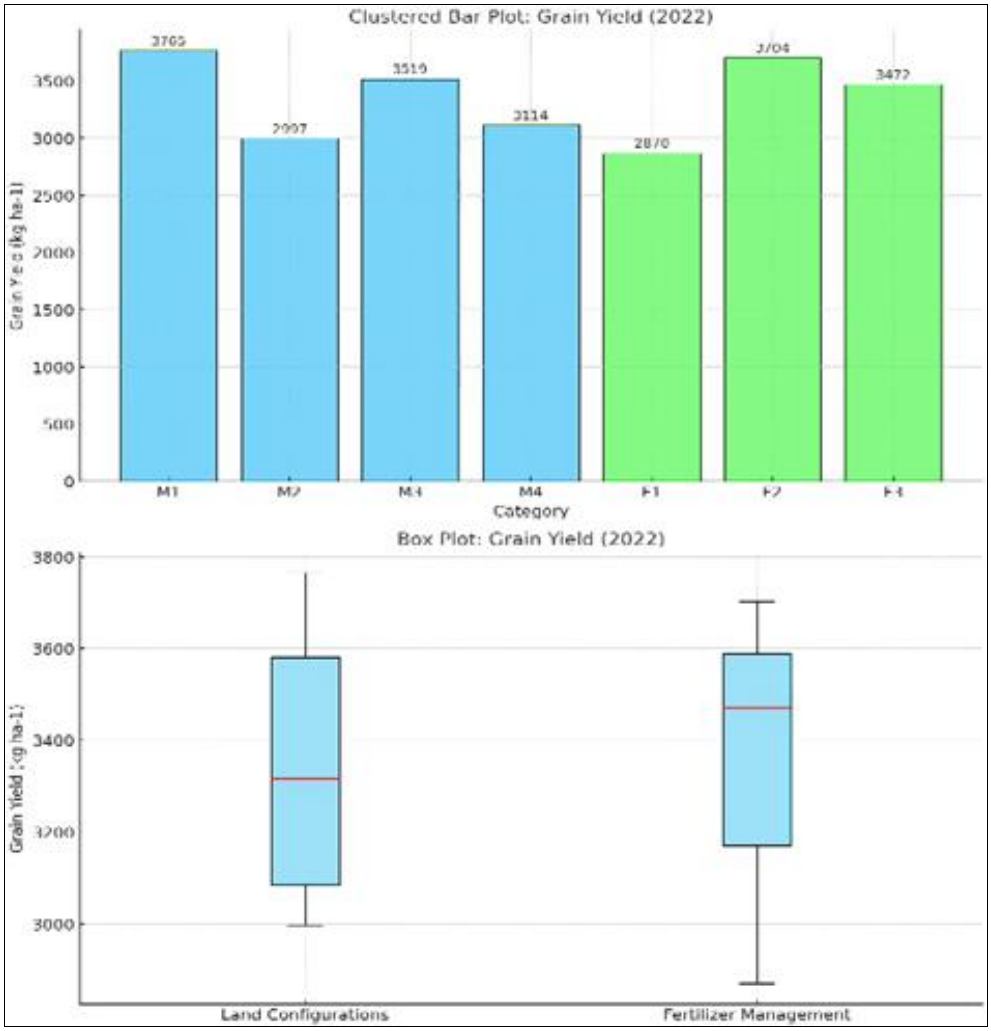
The sowing of rice crop with a raised bed with mulch consistently led to a significantly higher number of functional leaves $hill^{-1}$, total number of tillers $hill^{-1}$ and dry matter accumulation $hill^{-1}$ from initial growth stage till harvest. However, the treatment involving a flat bed with mulch found at par with the treatment raised bed with mulch. This effect can likely be attributed to the favourable moisture regime provided by the land configuration combined with mulch throughout the crop growth period. This setup promoted the development of more leaves in the mulched treatments. Enhanced soil moisture availability and proper root aeration under the raised bed with mulch likely facilitated cell elongation and Department, which, in turn, improved the tillering capacity of aerobic rice by conserving both moisture and nutrients. Additionally, the higher dry matter accumulation in plants may be due to the effective utilization of soil moisture during the peak growth period in the mulched treatment. The present results are inconsonance with those of Iqbal *et al.*, (2014) [5] in rice crop and Reddy *et al.*, (2021) [9] in sorghum crop.

Yield attributes

The grain yield of rice per unit area is contributed by yield attributes *viz.*, length of panicle (cm), weight of grains $panicle^{-1}$ (g), number of filled grains $panicle^{-1}$ and ultimately the grain and straw yield (kg ha^{-1}) obtained from the crop. The results revealed that used of raised bed with mulch remained at par with flat bed with mulch and both the treatments significantly increased almost all the yield attributes (Table 2) as compared to remaining practices of land configuration with or without mulch. The higher grain yield in raised bed planting system is due to its ability to manage water drainage, maintain aeration during heavy rainfall and conserve moisture. Mulching further boosts yield by regulating soil temperature, reducing evaporation, and minimizing thermal diffusion. These factors enhance growth parameters, leading to improved panicle length, grain weight and the number of filled grains $plant^{-1}$, ultimately increasing grain and straw yield. Similar findings were reported by Choudhary (2020) [4] in ginger crop and Singh *et al.*, (2021) [10] in wheat crop (Fig.1)

Here are two additional visualization types:

1. **Clustered Bar Plot:** Combines land configurations (M_1–M_4) and fertilizer management (F_1–F_3) to compare yields across all categories.
2. **Box Plot:** Summarizes the distribution of grain yields for land configurations and fertilizer management, showing medians and variability.



Effect of different fertilizer management practices

Growth attributes

It is evident from the data presented in (Table 1) that the remarkable influence of different fertilizer management practices on growth characters of rice *viz.*, plant height (cm), number of functional leaves hill^{-1}, number of tillers hill^{-1}and dry matter accumulation hill^{-1} (g) recorded significantly maximum under application of Konkan Annapurna Briquettes plus remaining N, P_2O_5 and K_2O through fertigation over rest of the fertilizer management treatments and was statistically at par with treatment RDF through fertigation. This might be due to release of sufficient amount of nutrients by mineralization at a constant level and readily available by application of NPK through briquettes (Jadhav M. S. 2016) [6].

The application of Konkan Annapurna Briquettes plus remaining N, P_2O_5 and K_2O through fertigation enhanced nutrient absorption, leading to vigorous growth through increased leaf production at all growth stages of crop. The higher number of tillers due to briquette application promoted greater photosynthetic activity, allowing rice plants to synthesize more photosynthate. Nutrients play a crucial role in crop physiology, essential for carbohydrate transformation, sugar utilization and enzyme activation. Applying macronutrients along with fertigation at recommended rates significantly improved crop growth, as reflected in dry matter production per plant due to positive impacts on morphological and photosynthetic traits. The briquettes, placed at a depth of 5-6 cm in the reduced soil zone, released essential nutrients slowly, benefiting rice crops under aerobic conditions. Consequently, maximum plant height was recorded with briquettes and fertigation, attributed to enhanced nutrient availability compared to other fertilizer management practices. These findings are consistent with those of Patil *et al.*, (2018) [8] in rice crop.

Yield attributes

The grain yield of rice per unit area is contributed by yield attributes *viz.*, length of panicle (cm), weight of grains panicle^{-1} (g), number of filled grains panicle^{-1} and ultimately the grain and straw yield (kg ha^{-1}) obtained from the crop. The results revealed that (Table 2) application of RDF through fertigation remained at par with the application of Konkan Annapurna Briquettes plus remaining N, P_2O_5 and K_2O through fertigation and both the treatments significantly increased almost all yield attributes as compared to RDF through straight fertilizer. This might be due to better nutrition especially quick availability of nitrogen, phosphorus and potassium to the crop. Similar results were also reported by Jadhav (2016) [6] in sugarcane crop.

The increase in grain yield can be attributed to the enhanced root growth enabled by nutrient application, which allows plants to access soil moisture from deeper layers. Additionally, proper fertilizer application promotes canopy development, which covers the soil, intercepts more solar radiation and reduces evaporation. This effect is primarily due to the greater and more consistent availability of soil moisture and nutrients, resulting in improved crop growth, yield attributes and ultimately higher grain yield. Similar conclusions were drawn by Kumar *et al.*, (2018) in summer squash crop and Patil[8] *et al.*, (2018) [7] in rice crop.

Interaction effect on growth attributes

The interaction effect of land configuration with or without mulch and fertilizer management on plant height, number of functional leaves hill^{-1}, total number of tillers hill^{-1} and dry matter accumulation hill^{-1} of rice were found to be significant at 60 and 90 DAS and it was enumerated in (Table 3).

The treatment combination of raised bed with mulch and Konkan Annapurna Briquettes plus remaining N, P_2O_5 and K_2O through fertigation (M_1F_2) recorded significantly higher growth attributes and were at par with treatment combinations raised bed with mulch and RDF through fertigation (M_1F_3) and flat bed with mulch and Konkan Annapurna Briquettes plus remaining N, P_2O_5 and K_2O through fertigation (M_3F_2) at 60 and 90 DAS.

Interaction effect on yield attributes

The interaction effect between various techniques of land configuration with or without mulch and different fertilizer management practices were found to be significant with respect to length of panicle, weight of grains panicle^{-1}, number of filled grains panicle^{-1}, grain and straw yield of rice are presented in (Table 4).

The data presented in Table 4 indicated that, interaction effect between raised bed with mulch and Konkan Annapurna Briquettes plus remaining N, P_2O_5 and K_2O through fertigation (M_1F_2) recorded significantly maximum yield attributes and yield of rice and it was found at par with treatment combinations of raised bed with mulch and RDF through fertigation (M_1F_3), flat bed with mulch and Konkan Annapurna Briquettes plus remaining N, P_2O_5 and K_2O through fertigation (M_3F_2) and flat bed with mulch and RDF through fertigation (M_3F_3) respectively.

Table 1: Growth parameters of rice as influenced periodically by different treatments

Treatments	Plat height (cm)				Number of leaves hill^{-1}				Number of tillers hill^{-1}				Dry matter hill^{-1} (g)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Vertical strips: Land configuration with or without mulch (M)																
M_1: Raised bed with mulch	16.86	39.13	55.94	71.88	33.06	53.28	44.87	41.14	6.13	13.81	12.02	11.81	8.73	27.58	40.75	41.82
M_2: Raised bed without mulch	15.73	36.79	53.37	70.12	29.37	49.35	41.88	35.05	4.99	12.31	11.19	10.42	7.83	23.28	36.55	39.08
M_3: Flat bed with mulch	17.13	40.01	57.40	73.10	32.20	51.74	42.98	39.75	5.50	13.42	11.73	11.55	8.17	25.22	38.96	40.38
M_4: Flatbed without mulch	15.14	35.85	53.33	68.31	28.61	48.98	40.94	32.46	4.52	11.60	10.88	10.03	6.93	22.31	35.75	36.62
S.Em.±	0.19	0.71	0.70	0.65	0.77	0.60	0.74	1.19	0.11	0.12	0.11	0.17	0.25	0.69	0.77	0.58
C.D. at 5%	0.67	2.44	2.43	2.25	2.67	2.09	2.55	4.13	0.38	0.42	0.39	0.60	0.87	2.40	2.67	2.01
Horizontal strips: Fertilizer Management (F)																
F_1: RDF through straight fertilizer	15.03	34.23	51.75	67.26	26.89	47.51	39.09	33.56	4.80	12.23	10.94	10.30	7.40	21.42	34.44	36.98
F_2: KAB + Remaining N, P_2O_5 and K_2O through fertigation	17.05	40.29	57.58	73.93	33.77	53.54	45.15	39.74	5.65	13.25	11.85	11.53	8.41	27.27	40.66	41.37
F_3: RDF through fertigation	16.58	39.32	55.70	71.38	31.77	51.46	43.77	38.00	5.40	12.87	11.58	11.02	7.93	25.10	38.91	40.07
S.Em.±	0.20	0.64	0.58	0.74	0.99	0.63	0.68	1.07	0.08	0.19	0.09	0.14	0.15	0.58	0.60	0.34
C.D. at 5%	0.78	2.53	2.28	2.92	3.87	2.49	2.66	4.21	0.33	0.76	0.34	0.54	0.60	2.28	2.34	1.32
Interaction (M×F)																
S.Em.±	1.12	1.04	1.89	2.08	3.35	1.86	0.92	4.05	0.47	0.25	0.12	1.13	0.29	1.00	0.86	0.76
C.D. at 5%	N.S.	3.22	5.81	N.S.	N.S.	5.73	2.84	N.S.	N.S.	0.76	0.37	N.S.	N.S.	3.08	2.66	N.S.

Table 2: Yield attributes and yield of rice as influenced by different treatments at harvest

Treatments	Length of panicles (cm)	Wt. of grains panicle^{-1} (g)	No. of filled grains panicle^{-1}	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Vertical strips: Land configuration with or without mulch (M)					
M_1: Raised bed with mulch	21.36	4.31	99.10	3765.43	4876.54
M_2: Raised bed without mulch	17.06	3.20	93.21	2997.26	4189.99
M_3: Flat bed with mulch	19.00	4.00	98.03	3518.52	4685.19
M_4: Flat bed without mulch	16.17	3.36	94.28	3113.85	4292.87
S.Em.±	0.68	0.16	0.80	111.79	96.80
C.D. at 5%	2.34	0.54	2.76	386.85	334.96
Horizontal strips: Fertilizer Management (F)					
F_1: RDF through straight fertilizer	15.20	3.15	92.02	2870.37	4161.52
F_2: KAB + Remaining N, P_2O_5 and K_2O through fertigation	21.05	4.22	99.66	3703.70	4820.99
F_3: RDF through fertigation	18.94	3.78	96.78	3472.22	4550.93
S.Em.±	0.57	0.12	1.16	18.55	72.52
C.D. at 5%	2.25	0.46	4.57	72.82	284.76
Interaction (M×F)					
S.Em.±	0.94	0.39	2.29	176.37	243.74
C.D. at 5%	2.90	1.22	7.05	543.45	751.05

Table 3: Interaction effect of land configuration with or without mulch and fertilizer management on growth attributes of *kharif* rice at 60 DAS and 90 DAS

Vertical strips / Horizontal strips	Plat height (cm)				Number of leaves hill^{-1}				Number of tillers hill^{-1}				Dry matter hill^{-1} (g)			
	M_1	M_2	M_3	M_4	M_1	M_2	M_3	M_4	M_1	M_2	M_3	M_4	M_1	M_2	M_3	M_4
At 60 DAS																
F_1	34.75	32.56	35.93	33.67	47.99	47.47	47.02	47.58	12.95	11.86	12.78	11.32	23.87	20.11	21.20	20.49
F_2	41.52	39.21	42.17	38.24	56.31	51.42	54.70	51.71	14.30	12.80	13.87	12.02	30.12	25.93	27.98	25.07
F_3	41.13	38.58	41.91	35.65	55.56	49.15	53.49	47.65	14.19	12.26	13.61	11.44	28.74	23.80	26.49	21.37
S.Em.±	1.04				1.86				0.25				1.00			
C.D. at 5%	3.22				5.73				0.76				3.08			
At 90 DAS																
F_1	51.22	51.67	52.19	51.93	41.02	37.65	38.93	38.76	11.43	10.64	11.13	10.57	36.82	32.75	34.70	33.51
F_2	58.90	55.08	60.26	56.06	47.26	44.30	45.70	43.33	12.43	11.59	12.15	11.22	43.71	39.04	41.65	38.24
F_3	57.69	53.35	59.76	52.00	46.33	43.67	44.31	40.74	12.19	11.35	11.90	10.85	41.74	37.85	40.54	35.52
S.Em.±	1.89				0.92				0.12				0.86			
C.D. at 5%	5.81				2.84				0.37				2.66			

Table 4: Interaction effect of land configuration with or without mulch and fertilizer management on yield attributes, grain and straw yield of *kharif* rice

Vertical strips / Horizontal strips	Length of panicles (cm)				Wt. of grains panicle^{-1} (g)				No. of filled grains panicle^{-1}				Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
	M_1	M_2	M_3	M_4	M_1	M_2	M_3	M_4	M_1	M_2	M_3	M_4	M_1	M_2	M_3	M_4	M_1	M_2	M_3	M_4
F_1	17.65	13.89	14.98	14.27	3.76	2.94	3.02	2.89	93.30	89.61	93.25	91.94	3292.18	2674.90	2777.78	2736.63	4537.04	4028.81	4080.25	4000.00
F_2	23.90	19.71	21.76	18.85	5.09	3.34	4.93	3.52	105.67	94.09	102.18	96.72	4012.35	3333.33	4032.92	3436.21	5355.97	4275.72	5261.32	4390.95
F_3	22.52	17.58	20.27	15.40	4.08	3.32	4.05	3.68	98.33	95.93	98.67	94.18	3991.77	2983.54	3744.86	3168.72	4736.63	4265.43	4713.99	4487.65
S.Em.±	0.94				0.39				2.29				176.37				243.74			
C.D. at 5%	2.90				1.22				7.05				543.45				751.05			

Conclusion

The study concludes that the use of raised or flat beds with polyethylene mulch significantly improves the growth and yield attributes of rice by enhancing soil moisture retention, nutrient availability and root aeration. Among fertilizer management practices, the application of Konkan Annapurna Briquettes combined with remaining N, P_2O_5 and K_2O through fertigation showed the best results for growth and yield, attributed to sustained nutrient release and effective utilization. The interaction of raised bed with mulch and Konkan Annapurna Briquettes plus remaining N, P_2O_5 and K_2O through fertigation (M_1F_2) consistently demonstrated superior performance in growth and yield parameters, providing an efficient strategy for aerobic rice cultivation.

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