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Effect of spacing and biofertilizers on the yield of ginger (*Zingiber officinale* Rosc) cv Mahima planted by pro tray seedling method

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Abstract
The study, conducted in 2021-2022 at AICRP on spices, Central Experiment Station, Wakavali, investigated the impact of spacing and biofertilizers on ginger *(Zingiber officinale* Rosc) cv Mahima using the pro tray seedling method. Spacing S3 consistently exhibited maximum growth and developmental characteristics, while S1 recorded the highest plant height. S3B3 emerged as the most effective combination, showing superior attributes in primary and secondary rhizomes and yield per plant. However, S1B3 excelled in yield per plot and yield per hectare. Biofertilizer treatment B3 consistently outperformed B4 in various growth parameters. The interaction between spacings and biofertilizer treatments emphasized S3B3 as the most favorable combination, except for plant height where S1B3 excelled. In conclusion, for higher yield per hectare, it is recommended to cultivate ginger with S1 spacing (30 x 20 cm) and B3 biofertilizer (Vesicular arbuscular mycorrhizae at a rate of 25 kg/h).

Keywords: Biofertilizers, spacing, ginger

Introduction

Ginger (*Zingiber officinale* Rosc) holds significant economic importance as a major cash crop and a principal spice globally, particularly in India. India stands out as the largest producer, consumer, and exporter of ginger worldwide. The commercial ginger is derived from the dried rhizome, prepared from fresh rhizomes. Its cultivation plays a crucial role in contributing to India's foreign exchange earnings. With over 50% of the world's ginger production, India not only caters to domestic consumption but also exports to more than 50 countries, with a notable focus on Middle Eastern nations.

Spacing is an important criteria for cultivation of ginger crop. In cultivation with wider spacing the planting material requirement is less and ultimately cost of cultivation is reduced. On other hand with closer spacing the land and nutrients use efficiency is increased and also increases the yield.

Biofertilizers, which utilize the mass of living organisms as a nutrient source for crops, play a crucial role in enhancing crop productivity. Various biofertilizers, including PSB, Azospirillium, and VAM (vesicular arbuscular mycorrhizae), are employed to augment nutrient availability in ginger crops, leading to increased yields. This research aims to identify the optimal spacing and the most effective biofertilizer, utilizing the pro tray seedling method, to achieve maximum ginger yield in terms of both quantity and quality. The goal is to enhance overall productivity and meet the demands for a successful harvest.

Materials and Methods

A research investigation was conducted during the Kharif season in the Konkan region at the All India Co-ordinated Research Project on Spices, Asund Block, Central Experiment Station, Wakavali. The study, focusing on the impact of spacing and biofertilizers on the yield of ginger (*Zingiber officinale Rosc*) cv Mahima using the pro tray seedling method, was arranged in a FRBD (Factorial Randomized Block Design) with 16 treatments replicated twice. The details of the treatments are outlined in Table 1.

The recommended fertilizer dose (75:50:50 kg N, P2O5, and K_2O per hectare) and other prescribed agricultural practices for ginger were uniformly applied across all treatments, including control treatments.

Table 1: Treatment details of the field experiment Main plot: Spacing

Sr. No.	Spacing Code		Spacing details
1)	S1	:	30 cm X 20 cm
2)	S2	:	30 cm X 30 cm
3)	S3	:	30 cm X 45 cm
4)	S4	:	25 cm X 25 cm

Subplot: Biofertilizers

Sr.no	Biofertilizer	Biofertilizer details
1	B1	PSB (Phosphate solubilizing bacteria)+ RDF
2	B2	Azospirillium+ RDF
3	B3	VAM(Vesicular arbuscular mycorrhizae)+ RDF
4	B4	Control (RDF only)

Results and Discussion

The yield characteristics of ginger (*Zingiber officinale* Rosc.) cv Mahima were impacted by the application of diverse biofertilizers and variations in spacing. Crop yield, primarily determined by the genetic makeup of the plant, represents the conversion of solar energy into chemically useful forms. While the genetic composition is a key factor, the efficiency of solar energy utilization for yield can be improved through genetic modifications or agronomic adjustments. Among agronomic manipulations, plant spacing is a method that ensures an optimal plant population, contributing to enhanced efficiency in solar energy utilization and overall crop yield.

Yield per plant (g)

Effect of spacing

The analysis of Table 2 reveals that the significantly highest yield per plant (278.38 g) was achieved with the much wider spacing S3 (30 x 45 cm), while the closest spacing S1 (30 x 20 cm) resulted in the lowest yield per plant (261.40 g). The overall trend indicates an improvement in average yield per plant with increasing spacing. Wider spacing consistently outperformed closer spacing, delivering the best yield per plant. Notably, wider spacing led to a proportionally larger rhizome weight, contributing to the overall maximum yield per plant. This finding aligns with Bahadur *et al*.'s (2000) [3] report, which observed that wider spacing (50 x 40 cm) generated the highest yield per plant (189.35 g).

Effect of biofertilizers

VAM treatment (B3) resulted in the highest yield per plant at 288.22 g, surpassing all other treatments. In contrast, the control treatment (B4) exhibited the lowest yield per plant at 256.46 g. This aligns with Yunus *et al*.'s (2014) [17] observations, where mycorrhizal treatment at a dose of 15 g/plant significantly increased the fresh weight of ginger rhizome without affecting the fresh weight and dry weight of the plants.

Effect of interaction

The interaction S3B3 yielded the significantly highest per plant yield at 293.00 g, comparable to S2B3 (291.90 g) and S3B2 (287.75 g). In contrast, the interaction S1B4 produced a lower yield per plant at 248.00 g.

The joint impact of spacing and biofertilizers suggests that the heightened yield per plant can be attributed to increased availability of space, nutrients, and moisture, facilitating better rhizome development in wider spacing. Additionally, the superior yields in the VAM treatment may be attributed to enhanced stem size and a greater number of rhizomes per plant, likely stemming from an increase in the number of leaves per plant. This, in turn, could lead to elevated levels of photosynthesis.

Yield per plot (kg)

Effect of spacing

The highest yield per plot (13.07 kg) was achieved at S1 spacing, on par with S4, which yielded 12.84 kg. Wider spacing S3 resulted in the lowest yield per plot at 6.12 kg. This could be attributed to the increased plant population or the accommodation of more plants per unit area with closer spacing compared to medium and wider spacing, leading to the highest yield per plot. These findings align with Wakhare (2001) [18], who reported the highest yield per plot (7.76 kg) at a spacing of 45 x 15 cm. Similar results were observed by Shashidhar (1995) [19], where the highest yield per plot (7.73 kg) was recorded at a spacing of 45 x 22.5 cm.

Effect of biofertilizers

The data indicates that the B3 biofertilizer (VAM @ 25 kg/ha) resulted in the highest yield per plot at 10.97 kg, while the B4 (control) treatment yielded the lowest at 9.74 kg. The elevated values for rhizome attributes may be attributed to the enhanced growth parameters influenced by the VAM biofertilizer. These parameters contribute to an improved photosynthesis process, coupled with the production of food material.

This aligns with Yunus *et al*.'s (2014) [17] findings, which reported that mycorrhizal treatment at a dose of 15 g/plant significantly increased the fresh weight of ginger rhizome, without affecting the fresh weight and dry weight of the plants.

Effect of interaction

The S1B3 interaction demonstrated the highest yield per plot at 14.08 kg, comparable to S4B3 (13.74 kg), while the S3B4 interaction yielded the lowest at 5.74 kg.

These findings indicate that factors contributing to yield, such as primary rhizome, secondary rhizome, and yield per plant, were optimized per unit area with wider plant spacing and VAM biofertilizer treatment, outperforming other treatment combinations. This observation aligns with Wakhare (2001) [18], who reported a peak yield per plot (7.76 kg) at a spacing of 45 x 15 cm in *Curcuma longa* L. cv. Kesar. Similarly, Shashidhar (1995) [19] documented the highest yield per plot (7.73 kg) at a spacing of 45 x 22.5 cm in various turmeric varieties.

Yield per hectare (t)

Effect of spacing

The yield per hectare data indicates that S1, with a closer spacing compared to S2, S3, and S4, achieved the highest yield per hectare at 43.56 t. The increased yield per hectare in tighter spacing is attributed to the higher plant density per unit area, a naturally expected outcome. These findings align closely with the observations of Ramchandra and Muthuswami (1984) [20], who reported that a spacing of 30 x 15 cm demonstrated superiority over others, yielding the highest rhizome yield of 47.43 t/ha in turmeric. Additionally, Rajput *et al*. (1980) [21] noted that a closer spacing of 30 x 45 cm resulted in a significantly better yield in turmeric compared to other spacings, with 45 x 45 cm and 45 x 60 cm following in yield performance.

Effect of biofertilizers

The B3 biofertilizer resulted in the highest yield per hectare at 36.58 t, surpassing all other treatments. Conversely, the B4 treatment recorded the lowest yield per hectare at 32.48 t. The enhanced yield per hectare with the application of VAM compared to its control treatment can be attributed to increased assimilation of food in the rhizome, facilitated by the root colonization of arbuscular mycorrhizal fungi. This, in turn, enhances nutrient uptake by the plants.

This could be attributed to the influence of VAM bioinoculant, which led to increased plant height, a higher number of leaves per tiller, and an increased leaf count, resulting in elevated carbohydrate production in the plants. Consequently, more resources were directed towards rhizome accumulation, leading to an increased number of primary and secondary rhizomes per plant and an overall higher yield per hectare.

Similar observations were reported by Pescador *et al*. (2010) [22], where the rhizome biomass production was significantly larger in plants treated with AMF, P, and AMF+P, compared to control plants, in micropropagated ginger.

Effect of interaction

The interaction effects between spacing and biofertilizer were notably influential in the data concerning yield per hectare. The data presented in Table 2 revealed that the S1B3 treatment combination exhibited a significantly higher maximum yield per hectare at 46.93 t, surpassing all other combinations. Conversely, the S3B4 combination reported the lowest production per hectare at 19.14 t.

Chattopadhyay *et al*. (1993) [7] observed a reduction in turmeric yield as spacing increased, identifying 20 x 30 cm as the optimum spacing, which yielded significantly higher at 25.72 t/ha. This finding is consistent with the results of Medhi and Bora (1993) [23], who investigated various spacings in turmeric and found that a closer spacing of 45 x 20 cm resulted in a higher yield at 23.40 t/ha compared to wider spacings (45 x 30 and 45 x 40 cm).

Dry powder recovery (%)

Effect of spacing

The findings concerning dry powder recovery indicated no discernible variation across different spacings. These results align with the observations of Yadav *et al*. (2013) [24], who noted that, among various spacings, wider spacing (35 × 25 cm) resulted in the highest dry recovery. It was also observed that spacing did not exert a significant impact on quality attributes such as oil and crude fiber content in ginger.

Effect of biofertilizers

The results regarding ginger dry powder recovery indicated no discernible difference among the various biofertilizer treatments. This aligns with the findings reported by Datta *et al*. (2018) [13], who concluded that there is no significant effect of biofertilizers on the quality attributing characters of the ginger plant.

Effect of interaction

None of the interactions exhibited a significant difference in dry recovery. This lack of significance might be attributed to the fact that dry recovery is likely influenced primarily by varietal variations. Varieties with thinner outer skin are expected to demonstrate higher dry recovery.

Table 2: Effect of spacing, biofertilizers and their interaction on yield per plant of ginger (cv. Mahima) planted by pro tray method

Yield per plant (g)					
	S_1	S_2	S_3	S_4	Mean
B_1	247.00	265.50	271.75	259.90	261.03
B_2	267.00	278.70	287.75	274.30	276.93
B_3	281.60	291.90	293.00	286.40	288.22
B_4	248.00	265.00	261.05	249.80	256.46
Mean	261.40	275.27	278.38	267.60	
	S.Em±		CD @ 5%		
S	1.00		3.05		SIG
B	1.00		3.05		SIG
S X B	2.01		6.11		SIG

Table 3: Effect of spacing, biofertilizers and their interaction on yield per plot of ginger (cv. Mahima) planted by pro traymethod

Yield per plot (kg)					
	S_1	S_2	S_3	S_4	Mean
B_1	12.35	8.76	5.97	12.47	9.89
B_2	13.35	9.19	6.33	13.16	10.51
B_3	14.08	9.63	6.44	13.74	10.97
B_4	12.50	8.74	5.74	11.99	9.74
Mean	13.07	9.08	6.12	12.84	
	S.Em±		CD @ 5%		
S	0.11		0.32		SIG
B	0.11		0.32		SIG
S X B	0.21		0.65		SIG

Table 4: Effect of spacing, biofertilizers and their interaction on yield per hectareof ginger (cv. Mahima) planted by pro tray method

Yield per hectare (t)					
	S_1	S_2	S_3	S_4	Mean
B_1	41.16	29.20	19.92	41.58	32.97
B_2	44.50	30.65	21.10	43.88	35.03
B_3	46.93	32.10	21.48	45.82	36.58
B_4	41.66	29.15	19.14	39.96	32.48
Mean	43.56	30.28	20.41	42.81	
	S.Em±		CD @5%		
S	0.17		0.54		SIG
B	0.17		0.54		SIG
S X B	0.35		1.08		SIG

Table 5: Effect of spacing, biofertilizers and their interaction on dry powder recovery of ginger (cv. Mahima) planted by pro tray method

Dry powder recovery (%)					
	S_1	S_2	S_3	S_4	Mean
B_1	22.70	24.05	23.35	23.75	23.46
B_2	23.70	23.70	25.55	23.30	24.06
B_3	22.75	25.35	25.70	26.10	24.97
B_4	23.10	23.75	25.85	22.75	23.86
Mean	23.06	24.21	25.11	23.97	
	S.Em±		CD @ 5%		
S	1.34		-		NS
B	2.68		-		NS
S X B	1.34		-		NS

Conclusion
Based on the outcomes of a one-year experiment, it is deduced that the spacing S1 (30 x 20 cm), biofertilizer B3 (VAM), and the interaction S1B3 (S1 - 30 x 15 cm; B3 - VAM @ 25 kg/ha) are potential recommendations for achieving maximum fresh ginger yield per hectare in the agro-climatic conditions of the Konkan region. However, as this experiment was conducted for the first time in this location, it is advisable to conduct further investigations over the next 2-3 years to provide more precise recommendations.

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