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Growth and yield of turmeric (*Curcuma longa* L.) cultivated under different mulching materials

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Abstract In agricultural systems, mulching is important in soil conservation, moisture retention, and weed suppression, influencing crop growth and yield. This study investigates the efficacy of utilizing diverse mulching materials such as albizia sawdust, banana pseudo-stems, sunflower lopping, and gliricidia lopping in turmeric cultivation by evaluating their impact on crop yield and vegetative growth. Turmeric yield was significantly increased by gliricidia lopping (1928.4 g/plant) and albizia sawdust (1664.6 g/plant) compared to sunflower lopping (1212.8 g/plant), banana pseudo-stem (1061.9 g/plant), and the control (977.7 g/plant). All treatments showed significant positive correlations between fresh yield and the number of mother rhizomes, the number of primary and secondary fingers, and fresh canopy biomass. Only albizia sawdust did not increase plant height, but it increased the number of tillers significantly. Any mulching material did not affect the number of leaves and leaf width. The leaf blade length was significantly higher in the gliricidia lopping (64.4 cm) and banana pseudo-stem (62.2 cm). Petiole length was significantly different ($p<0.05$) between banana pseudo-stem mulch (41. 6 cm) and albizia sawdust mulch (37.5 cm). The number of mother rhizomes was significantly different in all treatments compared to controls. Banana pseudo-stem mulch indicated its ineffectiveness in promoting mother rhizome production and plant elongation. All mulching materials except sunflower mulch increased the number of primary fingers, secondary fingers, canopy biomass, and fresh yield per plant. In all treatments, including the control, the number of primary and secondary fingers per plant and canopy biomass were positively and significantly correlated with fresh yield ($p=0.01$). For optimal fresh turmeric yield, it is recommended to prioritize the use of gliricidia lopping as a mulching material, given its ability to produce the highest yield and exhibit strong positive correlations with critical growth parameters such as plant height and leaf width. Albizia sawdust mulching is an effective alternative, as it resulted in comparatively high fresh yield, with no significant difference observed between its yield and that of gliricidia lopping. This indicates flexibility for farmers based on availability and cost considerations of mulching materials.

Keywords: Albizia, banana pseudo-stem, gliricidia, mulching, sunflower, turmeric

1 Introduction

Turmeric (*Curcuma longa* L.) is an herbaceous spice crop (Order: Zingiberales, Family: Zingiberaceae). Due to its anti-inflammatory and antioxidant properties, it has an important medicinal value (Osawa *et al*. 1995, Cousins *et al*. 2007). Recent statistics on turmeric production Sri Lanka in 2020 reported a growth of 17.9% (Vidanapathirana *et al*. 2022). Still, turmeric production in the country remains inefficient and insufficient (Abeynayake *et al.* (2020).

Because turmeric is a high water-demanding crop, it is crucial to maintain sufficient soil moisture, especially during the dry season to support optimal growth and yield (Choudhary and Kumar 2019, Ramos *et al*. 2024). 'Mulching' is a management strategy to cover topsoil, reduce soil evaporation, and conserve moisture in the soil (Jayakumar *et al.* 2024). In moisture controlling, farmers use different types of mulching materials, including organic, such as paddy straw mulch, dry grasses, wood chips, farm residues, nutshell, and inorganic, such as pearlite, pumice stone, oyster shell and shattered plastic, polythene (Kumar *et al*. 2018, Santosh *et al*. 2021). Organic mulches conserve soil moisture, suppress weeds, reduce erosion and nutrient loss, and add organic matter to the soil, while being environmentally friendly and their overall effect is improved root growth and, ultimately, higher yield (Chakraborthy *et al*. 2008, Kumar *et al*. 2018, Choudhary and Kumar 2019, Syahrinudin *et al*. 2020). Furthermore, organic mulching materials effectively reduce nitrate leaching, regulate soil temperature, improve soil physical properties, and enhance soil biological activity (Bhardwaj *et al*. 2011, Iqbal *et al*. 2020). Mulching materials and their effect on plant production have been studied by many researchers (Gerhards 2018, Choudhary and Kumar 2019, Jayakumar *et al*. 2024). Further, mulching has been shown to increase yield by 44 - 46% compared to non-mulched fields, reporting the highest turmeric yield under straw mulch, followed by dry-grass mulch (Verma and Sarnaik 2006).

The cultivation of turmeric in India using Sal leaves and Sesbania leaves as mulching showed promising results with higher fresh and dry rhizome yields (Sahoo *et al*. 2015). Dry leaf mulching with N and P at 120 kg per ha and 160 kg per ha, respectively, increased the plant height and rhizome weight per plant (Sanyal and Dhar 2006). Sidhu *et al*. (2016) observed a 3.91 benefit-cost ratio in turmeric as affected by mulching over the control with no mulching. Santos *et al*. (2020) reported that an increase in growth and yield of the corn plants as affected by mulching is a result of a reduction in weed growth. Yield after two weeding rounds was similarly achieved by mulching. Manan *et al*. (2019) recommended the use of mulching material at 6 t/ha together with fertilizer to improve the yield of turmeric.

Identifying different mulching materials for turmeric cultivation is worthy of optimizing their yield while promoting soil health and sustainability. Gliricidia (*Gliricidia sepium*) is a fast-growing nitrogen-fixing leguminous tree that can provide abundant biomass for mulching (Quee *et al*. 2017, Alamu *et al.* 2023), and gliricidia leaves have allelopathic effects (Santos *et al*. 2020). Wild sunflower (*Tithonia diversifolia*) leaf biomass releases high N content by rapid decomposition (Jama *et al*. 2000, Mustonen *et al*. 2014). Further, the wild sunflower is a material that can control soil free-living nematodes (Amulu *et al*. 2021). Banana pseudo-stem mulching has been used by Gas and Yo (2024). It decomposes gradually, releasing nutrients such as potassium, nitrogen, and phosphorus into the soil, which are essential for turmeric growth and development (Anandaraj 2008, Gas and Yo 2024). Banana leaf and stem mulch showed higher yield performances (1.6 t/ha) in garlic (Ridwan and Syam 2023). Khoso *et al*. (2021) concluded that banana leaf mulching (12 t/ha) increases cotton yield and physiological parameters by suppressing weeds.

In areas like Embilitipita and Hambantota in dry zone Sri Lanka, banana pseudo-stems are highly available as a crop residue and, thus, can be used as a mulching material in turmeric cultivation. Sawdust has been tested by several researchers as a mulching material for a variety of crops, which protects from temperature fluctuations while providing organic matter to the soil (Raman *et al*. 2004, Strik *et al.* 2017a, 2019, 2020a, Solgi *et al*. 2023, Jayaweera *et al*. 2024). Sønsteby *et al.* (2004) stated that a substantial amount of K and P increase in crop leaves due to sawdust mulching. Al-Amin *et al.* (2020) have used sawdust as an organic mulching in turmeric cultivation. Further, Islam *et al*. (2019) have mentioned that soft-wood sawdust at 3 t/ha has reduced weed density. The advantages of utilizing sawdust are its ability to retain for a long period of time as a soil cover and the high amount of C, making it less decomposable (Meas *et al*. 2024). Turmeric cultivation with straw mulch yielded 125.2 % compared to that without mulching materials (Kaur and Brar 2016). According to Indulekha and Thomas (2018), fields mulched with jack leaves had lower weeding than coconut leaves. Mulching materials such as gliricidia, wild sunflower, sawdust, and banana pseudo-stems must be tested in turmeric cultivation to investigate their efficacy in local conditions since they are abundant in different locations in Sri Lanka but have not been comparatively studied. The present study evaluated their effectiveness as mulching materials in turmeric cultivation.

Crop growth is directed by genetic components and environmental conditions (Sivakumar *et al*. 2019). Sometimes, the lowest length and the girth of rhizomes were obtained due to heritability and vigour (Kumari *et al.* 2014, Kumar 2018). The greater number of leaves has increased the tiller production and horizontal growth of rhizomes (Nandini *et al*. 2023). Rao *et al.* (2006) have reported that the high leaf area index and long-duration genotypes produced higher fresh rhizome yield over medium and short-duration genotypes (Kumar *et al.* 2015, Nandini *et al*. 2023). Gill *et al.* (1999) and Khaskheli *et al*. (2021) have mentioned that soil moisture conservation and lower soil temperature reduction by straw mulch emerge quickly and obtain taller plants having many leaves, tillers and fingers and increased germination. The present study investigated the effects of different mulching materials on the final yield of turmeric.

2 Material and Methods

2.1 Experimental location

This experiment was conducted at the Faculty of Technology, University of Ruhuna, Sri Lanka between 2021 and 2022. The field was located at 6°03'46.8" N and 80°32'29.2" E with favourable soil conditions including pH between 5.5 and 6.5, EC <4 mS/cm, and silt loam texture in Ultisol. The field belongs to low country wet zone of Sri Lanka in which annual rainfall is >2500 mm and temperature around 30 ^{0}C.

2.2 Field preparation and planting

The land was cleared, and raised beds were prepared to be 30 cm in height and the block size is 120 cm X 90 cm. A 15 cm width drainage system was installed surrounding the beds, and wooden piles were used to separate the beds, avoiding the mixing of mulching materials. Turmeric rhizome of 35-45 g, as per the recommendation of the Department of Export Agriculture, Sri Lanka, was used as the seed rhizomes. The spacing arrangement between rows and plants was 30 × 30 cm, as recommended. Fertilization was done using basal and top dressing according to the recommendation of the Department of Agriculture, Sri Lanka (20 MT/ha compost with 100 Kg/ha TSP was added before the planting as the basal dressing. The top dressing was split into two, providing 45 days and 90 days after planting. Urea at 65 Kg/ha and MOP at 100 Kg/ha). Weeding and earthing up were continued manually whenever necessary. A sprinkler system was installed, and the field was irrigated frequently.

2.3 Experimental design

This experiment consists of 4 treatments: gliricida lopping (T1), banana pseudo-stem (T2), wild sunflower lopping (T3), and albizia sawdust (T4). The control experiment was carried out without mulch (T0). Treatments were applied in a randomized complete block design with three replicates in the field, and mulching was applied as a 10 cm thick layer (Legba *et al*. 2024) in each bed immediately after planting the rhizomes. Gliricidia lopping, banana pseudo-stems, and wild sunflower lopping were collected from the Faculty of Technology field, and albizia sawdust was collected from a nearby sawmill.

2.4 Data collection and analysis

Plant growth data (plant height, number of leaves per plant, number of tillers per plant, leaf blade length, leaf width, and leaf petiole length, were collected when plants started yellowing ten months after planting (Ponnusamy 2019). Yield components (number of mother rhizomes per plant, number of primary fingers per plant, number of secondary fingers per plant, canopy biomass and fresh yield per plant) were collected at maturity when all leaves were dried eleven months after planting.

The collected data were analyzed using ANOVA, and mean separation was conducted using Duncan's Multiple Range Test (DMRT) with SPSS statistical software (SPSS Inc. 2012). Further, a Pearson’s correlation analysis was conducted to investigate the relationship of each parameter with the yield.

3 Results and Discussion

The present study evaluated the effect of (gliricidia lopping, banana pseudo-stem, wild sunflower lopping, and albizia sawdust) mulching materials on turmeric yield and plant growth parameters.

3.1 Plant growth parameters

According to the results, plant height, number of tillers, leaf blade length, leaf petiole length, and canopy biomass per plant showed significant differences ($p<0.05$) among the treatments as affected by the mulching material. However, the number of leaves and leaf width were not significantly affected by the mulching material (Table 1).

Table 1: Mean values of the turmeric growth parameters and differences between the treatments as analyzed by one-way ANOVA.

	Treatments				
Parameter*	Control (T0)	Gliricidia lopping (T1)	Banana pseudo-stem (T2)	Wild sunflower lopping (T3)	Albizia Sawdust (T4)
PH (cm)	150.6±14.7 [b]	164.8±11.5 [a]	165.4±12.3 [a]	162.3±10.30 [a]	155.7±10.9 [b]
LVS	21.6±5.1[a]	24.6±10.4 [a]	24.4±4.1 [a]	24.1±8.33 [a]	25.7±7.8 [a]
NT	4.8±2.1[b]	5.8±1.4 [ab]	5.7±2.9 [ab]	5.7±2.22 [ab]	6.1±1.9 [a]
LBL (cm)	59.7±7.7 [bc]	64.4±7.1 [a]	62.2±6.8 [ab]	57.8±4.60 [c]	59.2±8.0 [bc]
LW (cm)	13.2±2.1[a]	14.2±2.4 [a]	14.4±2.6 [a]	13.4±2.87 [a]	14.0±2.2 [a]
LPL (cm)	41.6±4.9 [ab]	42.5±7.4 [ab]	43.0±4.7 [a]	38.0±5.6 [ab]	37.5±6.4 [b]
CBM	246.0±22.8 [bc]	331.5±40.2 [a]	439.2±62.0 [a]	183.8±40.0 [c]	432.5±44.4 [a]

The data are the means ± SD of three replications. Based on the DMRT, data with similar letters on the same row are not significantly different at the 5% level.
*PH: Plant Height, LVS: Number of leaves per plant, NT: Number of tillers per plant, LBL: Leaf blade length, LW: Leaf width, LPL: Leaf petiole length, CBM: Canopy biomass.

3.2 Plant height

Plant height was significantly higher in all mulching treatments compared to the control, except albizia sawdust mulch, which showed a comparatively lower effect. Among the treatments, gliricidia lopping, banana pseudo-stem, and wild sunflower lopping resulted in the most notable increases in plant height, due to their high amount of organic matter content and faster decomposition rates, which enhance nutrient availability. Several studies have found the same effect (Sanyal and Dhar 2006, Sengupta *et al*. 2009, Thankamani *et al*. 2016, Bhardwaj *et al*. 2017, Kaur and Bons 2017). Further, the effect of treatment groups of gliricidia lopping mulching (164.8 cm), banana pseudo-stem mulching (165.4 cm), and wild sunflower lopping (162.3 cm) was found to be not significantly different from each other. Quee *et al*. (2017) have suggested that the rate of leaf decomposition as the cause of plant height increase with gliricidia lopping mulching. Banana leaves and stem mulch appeared to be the best mulch type on plant height of garlic (Ridwan and Syam 2023).

3.3 Number of leaves per plant

Results of this study showed that there was no significant effect of mulching on the number of leaves per plant in turmeric ($p>0.05$). Contrast findings have been reported that number of leaves per plant has been affected by mulching application (Sengupta *et* *al*. 2009, Manhas *et al*. 2011, Kumar *et al*. 2015, Bhardwaj *et al*. 2017, Kaur and Bons 2017). Mathew and Sreekala (2019) observed the same in ginger plants and Ridwan and Syam (2023) supported this for garlic.

3.4 Number of tillers per plant

The average number of tillers per plant was significantly affected by the mulching materials tested in this study ($p<0.05$). The effect of albizia sawdust mulching on the number of tillers per plant (6.1) was significantly higher than the control group (4.8), and it was not significantly different from other treatment groups. However, gliricidia lopping (5.8), banana pseudo-stem (5.7), and wild sunflower lopping (5.7) did not show a significant effect on the number of tillers per plant compared to the control.

3.5 Leaf blade length

This study shows that mulching can significantly affect the leaf blade length of turmeric plants ($p<0.05$). The effect was significantly higher in the gliricidia lopping (64.4 cm) and banana pseudo-stem (62.2 cm) mulching group compared to the other groups and the control (59.7 cm). All other mulching had no significant effect on leaf blade length compared to the control group. Further, the effect was insignificant among the treatments of wild sunflower lopping mulching (57.8 cm), and albizia sawdust mulching (59.2 cm). Bhardwaj *et al*. (2017) reported similar results.

3.6 Leaf width

The average leaf width of the turmeric plants was not affected by the mulching materials used in this study ($p>0.05$). However, Bhardwaj *et al*. (2017) reported a significant mulching effect on leaf width.

3.7 Leaf petiole length

According to the findings of this study, mulching materials significantly affected the leaf petiole length of turmeric plants ($p>0.05$). The effect was significantly different in banana pseudo-stem mulch (43.0 cm) compared to albizia sawdust mulch (37.5 cm), and it did not show any significant difference from other treatments. All the treatments were not significantly different compared to the control group (41.6 cm).

3.8 Canopy biomass

The average canopy biomass was significantly affected by the mulching materials in the present study ($p<0.05$). It was significantly higher in gliricidia lopping (331.5 g/plant), banana pseudo-stem (439.2 g/plant), and albizia sawdust (432.5 g/plant) mulching groups compared to the wild sunflower lopping and the control group. Plots mulched with poplar leaves significantly increased leaf, stem, and root dry biomass (Kumar *et* *al*. 2015). According to the data by Kaur *et al*. (2019), straw mulch produced higher dry matter accumulation (stem plus leaves) compared to no mulch.

3.9 Yield components and final yield per plant

As presented in Table 2, mulching treatments significantly influenced key yield components of turmeric such as the number of mother rhizomes, primary fingers, and secondary fingers per plant, with notable variations observed among the different mulching materials.

Table 2: Mean values of the turmeric yield components and final yield differences between the treatments as analyzed by one-way ANOVA.

Parameter	Treatments				
	Control (T0)	Gliricidia lopping (T1)	Banana pseudo-stem (T2)	Wild sunflower lopping (T3)	Albizia Sawdust (T4)
NMR	4.3±2.0 ^{b}	6.3±1.4 ^{a}	6.3±1.1 ^{a}	5.8±0.9 ^{a}	6.0±1. 7^{a}
NPF	19.9±8.6 ^{b}	33.9±5.2 ^{a}	28.8±4.3 ^{a}	21.7±4.70^{b}	28.2±2.4 ^{a}
NSF	63.1±17.3 ^{d}	131.4±19.7 ^{a}	115.8±17.8 ^{ab}	86.2±5.7 ^{cd}	102.8±4.7 ^{bc}
FYP	977.7±33.6^{c}	1928.4±93.8^{a}	1061.9±56.5^{b}	1212.8±86.2^{c}	1664.6±36.2^{a}

The data are the means ± SD of three replications. Based on the DMRT, data with similar letters on the same row are not significantly different at the 5% level.
NMR: Number of mother rhizomes per plant, NPF: Number of primary fingers per plant, NSF: Number of secondary fingers per plant, FYP: Fresh yield per plant

3.10 Number of mother rhizomes per plant

The number of mother rhizomes per turmeric plant was significantly impacted by the mulching materials ($p<0.05$). The effect was significantly different in all groups of treatments compared to the control group (4.3), and they were statistically equivalent to each other. More potato tubers were recorded under plastic mulch over albizia sawdust, paddy straw, paddy husk, and no mulching (Bharati *et al*. 2020).

3.11 Number of primary fingers per plant

The average number of primary fingers per plant was significantly higher in all treatment groups compared to the control (19.9) as affected by the mulching materials ($p<0.05$), except wild sunflower lopping (21.7). However, the effect was not significantly different among the treatments of gliricidia lopping (33.9), banana pseudo-stem (28.8), and albizia sawdust (28.2) mulching groups. Primary rhizome yield increased with mulch and farmyard manure (Manhas *et al*. 2011).

3.12 Number of secondary fingers per plant

The number of secondary fingers per plant was significantly higher ($p<0.05$) in all treatment groups except the wild sunflower (86.2) lopping group compared to the control group (63.1). The maximum number of secondary fingers per plant was recorded during the treatments of gliricidia lopping (131.4) and banana pseudo-stem mulching (115.8), and they were not significantly different. The number of secondary fingers per plant in the banana pseudo-stem mulching group and albizia sawdust (102.8) mulching group was not significantly different from each other. Further, wild sunflower lopping did not show a significant effect compared to albizia, which sawdust mulching.

3.13 Fresh yield per plant

Fresh yield per plant was significantly higher ($p<0.05$) in gliricidia lopping (1928.4 g/plant), banana pseudo-stem (1061.9 g/plant), and albizia sawdust (1664.6 g/plant) mulching groups compared to the control (977.7 g/plant) and wild sunflower (1212.8 g/plant) lopping mulching groups. Further, they were not significantly different in banana pseudo-stem, and albizia sawdust mulching groups. However, giliricidia and albizia sawdust mulching recorded significantly equal fresh yield per plant. Therefore, it indicates that gliricidia lopping and albizia sawdust mulching are effective in increasing turmeric yield. The mulching materials significantly affected the average fresh yield per plant ($p < 0.05$), and similar findings have been reported for turmeric in other studies (Nwokocha *et al*. 2009, Lakshmi and John 2015, Manan *et al*. 2019, Santos *et al*. 2020, Davis *et al*. 2024). Mathew and Sreekala (2019) reported the same for ginger and Santos *et al*. (2020) reported the same for corn.

Table 3. Pearson correlation values between the fresh plant yield and other parameters in all treatments.

Treatment	Control	Gliricidia lopping	Banana pseudo-stem	Wild sunflower lopping	Albizia sawdust
PH	0.145	0.397*	-0.464**	-0.109	0.178
LVS	0.258	0.121	-0.136	0.326	0.125
NT	0.154	0.152	-0.135	0.366*	-0.004
LBL	0.129	0.317	-0.293	0.06	0.193
LW	0.126	0.460*	-0.243	-0.277	0.251
LPL	0.081	-0.119	-0.029	0.04	-0.089
NMR	0.727**	0.727**	0.349	0.684**	0.664**
NPF	0.755**	0.653**	0.194	0.578**	0.675**
NSF	0.771**	0.863**	0.683**	0.751**	0.869**
CBM	0.581**	0.496**	0.468**	0.542**	0.535**

PH: Plant Height, LVS: Number of leaves per plant, NT: Number of tillers per plant, LBL: Leaf blade length, LW: Leaf width, LPL: Leaf petiole length, NMR: Number of mother rhizomes per plant, NPF: Number of primary fingers per plant, NSF: Number of secondary fingers per plant, CBM: Canopy biomass.
*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

3.14 Correlations

The fresh yield per plant was significantly and positively correlated with the number of mother rhizomes per plant in control, gliricidia lopping, wild sunflower lopping, and albizia sawdust mulches at α=0.01 significant level, but not in banana pseudo-stem mulch. Further, plant height showed a significant negative correlation (r=-0.464, α=0.01) with fresh yield in banana pseudo-stem mulching. Mother rhizome production and plant elongation were not induced by banana pseudo-stem. The number of primary fingers per plant, secondary fingers per plant, and canopy biomass were positively and significantly correlated with the yield in all mulches and control plants at α=0.01 significant level (Table 3). Further, the fresh yield in gliricidia lopping showed a significant positive correlation between leaf width at α=0.05. It shows that the leaf expansion has been induced in turmeric by gliricidia looping. Further, the number of tillers per plant in wild sunflower lopping mulching exhibited a significant positive correlation with the fresh yield of the plant (r=0.366, α=0.05) (Table 3). Singh *et al.* (2018) reported significant correlations between plant height and fresh rhizome yield (r = 0.89) as affected by organic and inorganic sources of nitrogen in turmeric. Further, they observed positive but non-significant correlations of a number of rhizomes with all other studied parameters. However, they reported that plant height and total number of rhizomes have a non-significant correlation (r = 0.35).

4 Conclusions

The study demonstrated that turmeric yield was significantly enhanced by the application of gliricidia lopping and albizia sawdust, which emerged as highly effective mulching materials, whereas sunflower lopping was found to be less effective. Among these, gliricidia lopping was the most effective, and the yield increase under this treatment was strongly attributed to specific growth parameters and yield components. Under gliricidia lopping, the number of mother rhizomes, primary fingers, secondary fingers, and canopy biomass showed strong positive correlations with fresh yield, indicating that these were the most significantly contributing yield components. Additionally, leaf width and canopy biomass were the most influential growth parameters, as gliricidia mulch notably enhanced leaf expansion and aboveground biomass accumulation. This was supported by a significant positive correlation between leaf width and fresh yield (α=0.05). Across all treatments, including the control, fresh yield consistently showed a strong positive correlation (α=0.01) with the number of mother rhizomes, primary and secondary fingers, and canopy biomass. A particularly strong correlation between fresh yield and the number of mother rhizomes per plant was observed under gliricidia, albizia sawdust, wild sunflower, and control treatments (α=0.01), while no such correlation was evident under banana pseudo-stem mulch. Interestingly, plant height exhibited a significant negative correlation (r = -0.464, α = 0.05) with fresh yield under banana pseudo-stem mulch, suggesting its ineffectiveness in promoting productive growth. These findings emphasize that the choice of mulching material significantly influences turmeric yield by affecting key physiological traits. Therefore, incorporating gliricidia lopping and albizia sawdust as mulching materials is recommended for enhancing turmeric cultivation through their positive effects on critical growth and yield parameters.

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