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Research Article

GROWTH AND YIELD RESPONSE OF SEEDLESS AND KAGOJI LEMON CULTIVARS TO DIFFERENT AGRONOMIC MANAGEMENT PRACTICES UNDER SYLHET CONDITIONS OF BANGLADESH

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Abstract

The experiment was conducted at the Citrus Germplasm Centre, Sylhet Agricultural University, from December 2020 to November 2021 to identify suitable agronomic management practices for improving growth, yield, and profitability of two lemon varieties under the agro-ecological conditions of Sylhet. The experiment included two lemon cultivars, Seedless and Kagoji, and four agronomic management practices: poultry manure, chemical fertilizer, mulching, and a control (no management). Four replications of a Randomized Complete Block Design (RCBD) were used in the experiment and 5% level of significance ($P \leq 0.05$) was used to examine the data. The findings showed that the plants with the highest fruit yield was Seedless lemon due to its highest fruit weight, fruit length and fruit breadth while the highest total number of fruit/plants were recorded in Kagoji lemon. Considering the effect of agronomic management practices, poultry manure performed better and had the highest yield contributing characteristics of the seedlings viz. number of leaves/plant (543.88), number of fruit/plant (189.96), number of flower/plant (345.63) and fruit breadth (4.52 cm). The interaction effect among the cultivars and agronomic management practices indicated that, Seedless lemon with poultry manure and chemical fertilizer produced statistically similar result in terms of yield and other attributes. But the highest yield (19.29 kg/plant) was recorded in Seedless lemon with poultry manure. The result suggested that Seedless lemon along with poultry manure can be the best combination for optimizing lemon production in the agro-ecological conditions of the Sylhet region. The findings also demonstrate the potential of poultry manure as a sustainable and eco-friendly source of nutrients that can lessen reliance on chemical fertilizers while preserving high production and raising lemon cultivation profitability.

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Introduction

Citrus is one of the most commercially significant fruit crops in the world and is essential to both global fruit production and human nutrition (Liu et al., 2022; Deng et al., 2020). Northeast India, Myanmar and Yunnan province in China are considered as the hotspot of Citrus (Deng et al., 2020). Citrus fruits are widely recognized for their exceptional nutritional quality and health-promoting properties. Vitamin C, dietary fiber, flavonoids, carotenoids, and other bioactive substances with antioxidant, antibacterial, and anti-inflammatory qualities are abundant in citrus fruits (Zahr et al., 2023). The physiologically active, non-nutrient chemicals contained in citrus can reduce the incidence of several chronic diseases. As a result, citrus fruits are increasingly recognized as functional foods because of their abundant bioactive compounds, including flavonoids, carotenoids, vitamin C, and phenolic acids, which play important roles in promoting human health and reducing the risk of chronic diseases (Liu et al., 2022).

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Citrus fruits, particularly lime and lemon (*Citrus limon*) are grown across Bangladesh and is particularly abundant in the districts of Sylhet, Chittagong, the Chittagong Hill Tracts, Rajshahi, and Maulavibazar. According to several research studies, over 93 percent of Bangladeshi's are vitamin C deficient, and the body is unable to keep vitamin C, in contrast to other vitamins. (Sayem *et al.*, 2015). Thus, lemon and lime could significantly contribute to lessen the issue with vitamin C in developing countries like Bangladesh. When compared to other citrus-producing nations worldwide, Bangladesh ranks quite low in terms of citrus fruit production, despite the huge health advantages of citrus. According to BBS (2020), the total land used for growing citrus in Bangladesh was about 156,440 acres, and the total production was about 58,552 metric tons during 2019–20.

The quality of the soil and proper supply of plant nutrients has a major impact on the growth and productivity of lemon and lime. Citrus production and fruit quality must be maintained through appropriate nutrient management and integrated soil fertility management (Zekri and Obreza, 2019; Kadyampakeni *et al.*, 2022). This kind of fertilizer management with some special agronomic management is gaining popularity day by day. Commercial cultivation is also increased countrywide like that kind of management.

Although many studies have reported the effects of individual nutrient sources or agronomic practices on citrus production, information on their combined effects on lemon growth and yield under the agro ecological conditions of Sylhet, Bangladesh, is limited. The region's high rainfall, acidic soils, and unique climate require location-specific management practices rather than recommendations developed elsewhere. Therefore, this study evaluated the effects of different agronomic management practices on the growth, yield attributes, and fruit yield of lemon to identify an effective and sustainable production strategy for Sylhet, Bangladesh.

Materials And Method

The research was conducted throughout the time frame of December 2020 to November 2021 on four years old lemon cultivars at Citrus Germplasm Centre of Sylhet Agricultural University, Sylhet (Figure 1). It is located at 24.89°N and 91.88°E in the Sylhet Division in the north eastern part of Bangladesh. The sandy loam soil utilized in the experiment had a low to medium fertility condition and belongs to Khadim Nagar soil series under Eastern Surma-Kushiyara Flood Plain Agro-Ecological Zone (AEZ 20). The pH of the soil in Sylhet is below 6.5 and the amount of organic matter varies between 0.55 and 2.45%. (Urmi, 2020). Through the period of experiment, the average maximum and minimum temperature was recorded 34.4°C and 21.4°C respectively in the month of April. Additionally, the highest rainfall was found in the month of April (326mm), but the highest relative humidity was 71% in November.

For the study, four-year-old that were healthy and consistently vigorous lemon trees were chosen. The trees were placed 4 m × 5 m apart. Prior to the experiment's start, the orchard was maintained in accordance with the Citrus Germplasm Center's conventional cultural methods, which included routine irrigation, pruning, and pest and disease control. To reduce experimental variance, every tree that was chosen had almost the same canopy size, trunk girth, and growth habit.

There were two treatment factor, factor A: Lemon cultivar (V_1 - Seedless lemon, V_2 - Kagoji lemon) and factor B: Different nutrient and agronomic management (T_1 - Poultry manure, T_2 - chemical fertilizer T_3 - mulching, T_4 - No agronomic management practices). Factorial Randomized Complete Block Design (RCBD) with four replications was used to set up the experiment. Each treatment was replicated four times, with four plants in each treatment plot. Thus, a total of 128 experimental plants were used in the study. In treatment T_1 , 20 kg composted poultry manure was applied per plant during March and May in two equal portions (just after last

year's fruit harvest). After sparing 50–100 cm from the tree base to the canopy spread, poultry manure was carefully mixed with the soil and then irrigated. In treatment T_2 , Chemical fertilizers (Urea: 400 gm/plant, TSP: 300 gm/plant, MOP: 300 gm/plant, H_3BO_3 : 15 gm/plant) were sprayed 50–100 cm from the tree base, all the way up to the canopy spread following dibbling method and then irrigated after being gently combined with the soil. In March, May and September three equal portions of fertilizer doses were applied (immediately after fruit harvest). In treatment T_3 , Mulching was applied before the first flower initiation. Rice straw and plant wastes were used as mulching within the tree basin, a homogeneous layer of mulch, about 8 to 10 cm thick, was spread from 50 cm from the trunk to the canopy drip line and it was renewed anytime the mulch's thickness decreased due to displacement or decomposition during the trial. In treatment T_4 , plants were grown without any agronomic and nutrient management practices i.e. No weeding, no chemical fertilizer but irrigation was given with native soil fertility level. The poultry manure rate (20 kg plant^{-1}) and the recommended doses of urea, TSP, MOP, and boric acid were selected according to the Fertilizer Recommendation Guide (BARC, 2018). Light irrigation was done immediately after fertilizer application. For the best soil moisture, irrigation was applied twice a month till maturity. Bordeaux mixture and insecticide Karate (Lambda-Cyhalothrin) was used to manage citrus canker and leaf miner.

Total number of leaves, flowers and number of fruits per plant was determined by counting the average number of new leaves, flowers and fruits per plant according to replication, treatment and cultivar. The number of leaves, flowers and fruits was counted in every 15 days. According to replication, treatment and cultivar each of the harvested fruits were weighted (gm) by electric balance. Every fruit length (cm) of the sampled fruits was taken by using slide calipers. Fruit breadth (cm) was taken at the middle portion of the fruits by using slide calipers according to replication, treatment and cultivar. Plant girth (cm) was taken at a marked portion of the base of the plants by using slide calipers according to replication, treatment and cultivar. Total number of fruits per plant was calculated by counting the average number of new fruits per plant according to replication, treatment and cultivar. The weight of total harvested fruit per plant was counted and converted to kg per plant. Maturity of the crops was determined when 50-70% of the fruits became matured at the end of July. Harvesting of the fruits was done three times to obtain a more accurate yield character. Five fruits from each plant were harvested for recording data viz. length, breadth, weight etc. of fruits in case of each treatment. Prior to analysis of variance (ANOVA), the homogeneity of variance and normality of residuals were evaluated. Since the ANOVA's assumptions were satisfied, the data was analyzed using R software (version 3.5.0) using a 5% significance level for the LSD test.

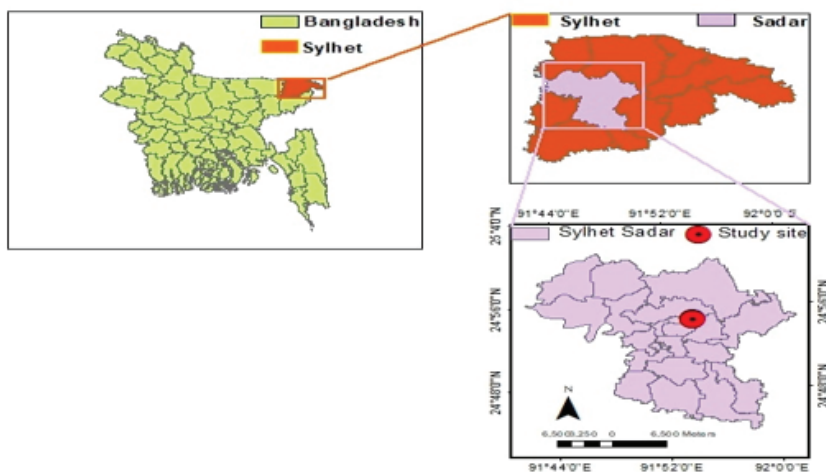


Figure 1. Study place Sylhet Agricultural University on a map of Sylhet Sadar Upazila (Bangladesh, 2025).

Results & Discussion

3.1 Leaf, flower and fruit production pattern trend of lemon under different agronomic management

Leaf, flower and fruit production pattern is graphically represented below just to observe the trend of their growth that's why it was not statistically analyzed.

3.1.1 Leaf Production Pattern

Generally, leaf production is initiated from December and continues irregularly until June. The first new leaf initiation was recorded on 5th January in Seedless lemon cultivar. On the other hand, the first new leaf initiation was recorded on 20 December in Kagoji lemon cultivar. In the first week of March, the maximum number of new leaves per plant was noted in case of Seedless lemon cultivar (62.25) and first week of January in case of Kagoji lemon cultivar (116.06) respectively which reduced irregularly to month of June irrespective of lemon cultivar (Figure 2).

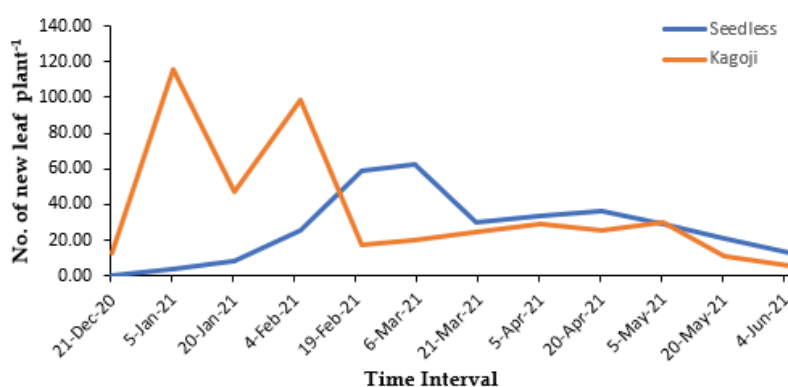


Figure 2. Effect of agronomic management practices on total number of leaves per plant of Seedless and Kagoji lemon under Sylhet conditions.

3.1.2 Flower Production Pattern

The flower flush started to bloom in the first week of January which proliferated to the first week of March. Then it gradually decreased and stopped in the starting of June. Maximum number of flowers was recorded in Seedless lemon cultivar (59.31) and in Kagoji lemon cultivar (53.69) in the middle of March. Minimum number of flowers were recorded in Seedless lemon cultivar (0.44) and in Kagoji lemon cultivar (0.50) at the start of June (Figure 3).

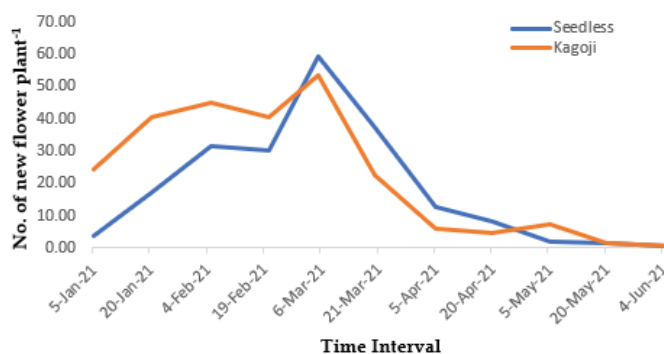


Figure 3. Effect of agronomic management practices on total number of flower per plant of Seedless and Kagoji lemon under Sylhet conditions.

3.1.3 Fruit Production Pattern

The initiation of fruits started in the first week of February which proliferated to the middle of March then gradually decreased and stopped at the starting of June. Maximum number of fruits were recorded in Seedless lemon cultivar (35.19) and in Kagoji lemon cultivar (45.50) in March. Minimum number of fruits were recorded in Seedless lemon cultivar (1.38) and in Kagoji lemon cultivar (4.56) in June (Figure 4).

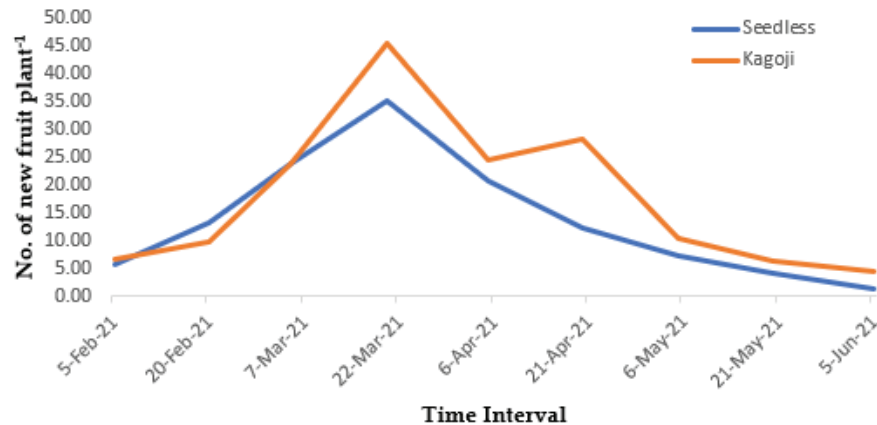


Figure 4. Effect of agronomic management practices on total fruits per plant of Seedless and Kagoji lemon under Sylhet conditions.

3.2 Impact of lemon cultivar (V) on yield and yield characteristics.

There was a significant variation observed among the cultivars in case of the yield and yield related characteristics except girth (Table 1). Kagoji lemon (V₂) produced significantly more leaves (436.38 plant⁻¹), flowers (246.31 plant⁻¹), and fruits (130.87 plant⁻¹) than Seedless lemon (V₁), which produced 321.88 leaves, 204.19 flowers, and 97.96 fruits plant⁻¹ respectively. Kagoji's innate genetic traits that support canopy development and reproductive capability may be responsible for its higher vegetative growth and flowering. On the other hand, compared to Kagoji lemon, seedless lemon yielded much larger fruits.

While Kagoji produced smaller fruits with an average weight of 50.70 g, length of 5.35 cm, and breadth of 3.63 cm, Seedless recorded greater individual fruit weight (114.38 g), fruit length (7.41 cm), and fruit breadth (4.76 cm) (Table 1). Citrus fruit size and weight vary significantly due to cultivar-dependent genetic variations that affect assimilate partitioning and sink strength throughout fruit growth (Lado *et al.*, 2014). Seedless achieved a much greater fruit output (12.03 kg plant⁻¹) than Kagoji (7.26 kg plant⁻¹), despite Kagoji producing significantly more fruits per plant. This result suggests that individual fruit size and weight had a greater influence on overall fruit yield than fruit quantity alone. Similar cultivar-dependent variations in fruit size and yield have been shown in citrus, where yield depends on both fruit weight and number rather than just one of them (Pasdaran *et al.*, 2023; Dhuique-Mayer and Servent, 2025). Seedless lemon yielded more than Kagoji lemon due to its larger fruits, indicating its greater potential for commercial cultivation in Sylhet, Bangladesh.

Table 1. Effect of yield attributes of Lemon cultivar affected by different variety

Treatment	Total no. of leaf plant ⁻¹	Total no. of flower plant ⁻¹	Individual fruit weight (g)	Fruit length (cm)	Fruit Breadth (cm)	Girth of plant (cm)	Total no. of fruit plant ⁻¹	Yield plant ⁻¹ (kg)
V ₁	321.88 b	204.19 b	114.38 a	7.41 a	4.76 a	1.81 a	97.96 b	12.03 a
V ₂	436.38 a	246.31 a	50.7 b	5.35 b	3.63 b	1.90 a	130.87 a	7.26 b
LSD _(0.05)	34.43	21.14	2.33	0.10	0.10	0.22	4.29	0.47
CV (%)	12.35	12.77	3.83	2.22	3.20	16.31	5.10	6.56

V₁ = Seedless Cultivar; V₂ = Kagoji Cultivar.

3.3 Impact of agronomic management practices (T) on lemon cultivar yield and yield characteristics.

All lemon output and yield-related characteristics were greatly impacted by agronomic management techniques (Table 2). The highest number of leaves (543.88 plant⁻¹), flowers (345.63 plant⁻¹), and fruits (189.96 plant⁻¹) were generated by poultry manure (T₁), closely followed by chemical fertilizer (T₂), while the lowest values were recorded by the control (T₄). According to Bhunia *et al.*, (2021) and Gross & Glaser (2021), applying poultry manure enhances soil organic matter, nutrient availability, microbial activity, and soil physical properties. This improves nutrient uptake and photosynthetic performance, which in turn encourages vegetative growth and reproductive development. During crucial phases of blooming and fruit set, the slow release of nutrients from poultry manures also provides a steady supply of nutrients. The highest individual fruit weight (95.79 g), fruit length (6.88 cm), plant girth (2.09 cm), and fruit yield (16.29 kg plant⁻¹) were produced by chemical fertilizer (T₂), though these results were statistically similar to those obtained with poultry manure (T₁), which produced 91.59 g fruit weight, 6.79 cm fruit length, 2.07 cm plant girth, and 15.91 kg plant⁻¹ fruit yield (Table 2). In citrus, balanced nutrient treatment has been shown to enhance photosynthesis, assimilate translocation, and fruit development (Zhang *et al.*, 2020; Pasdaran *et al.*, 2023). Poultry manure has extra agronomic and environmental benefits, even though fruit output under chemical fertilizer and poultry manure was statistically identical. Poultry manure promotes sustainable nutrient management by enhancing soil health and nutrient-use efficiency and lowering dependency on synthetic fertilizers (Lal, 2020; Chen *et al.*, 2023). Poultry manure is widely available and reasonably priced in Bangladesh, which might lower production costs and boost commercial lemon cultivation's profitability.

Table 2. Yield and yield attributes of lemon affected by Agronomic Management

Treatment	Total no. of leaf plant ⁻¹	Total no. of flower plant ⁻¹	Fruit weight (g)	Fruit length (cm)	Fruit Breadth (cm)	Girth (cm)	Total no. of fruit plant ⁻¹	Yield plant ⁻¹ (kg)
T ₁	543.88 a	345.63 a	91.59 b	6.79 a	4.52 a	2.07 a	189.96 a	15.91 a
T ₂	518.88 a	332.38 a	95.79 a	6.88 a	4.49 a	2.09 a	185.78 a	16.29 a
T ₃	292.00 b	137.00 b	75.77 c	6.12 b	4.03 b	1.74 b	55.63 b	4.41 b
T ₄	161.75 c	86.00 c	67.05 d	5.74 c	3.74 c	1.52 b	26.28 c	1.99 c
LSD _(0.05)	48.69	29.90	3.29	0.15	0.14	0.32	6.06	0.66
CV (%)	12.35	12.77	3.83	2.22	3.20	16.31	5.10	6.56

T₁ = Poultry Manure; T₂ = Chemical Fertilizer; T₃ = Mulching; T₄ = Controlled Condition.

3.4 Combined impact of agronomic management practices (T) and variety (V) on lemon cultivar yield and yield characteristics.

The total number of leaves, flowers, fruits per plant, individual fruit weight, and fruit production were all substantially impacted by the interaction between lemon cultivar and agronomic management; however, fruit length, fruit breadth, and plant girth were not significantly influenced (Table 3). V_2T_1 (Kagoji $\times$ poultry manure) had the highest leaves ($634.75 \text{ plant}^{-1}$) and flowers ($437.75 \text{ plant}^{-1}$), while V_2T_4 (Kagoji $\times$ control) had the fewest. Srivastava *et al.*, (2023) supported this study where higher microbial activity, prolonged nitrogen release, and better soil fertility all contribute to improved vegetative development and blooming under poultry manure. V_1T_2 (Seedless $\times$ chemical fertilizer) had the largest individual fruit weight (132.48 g), closely followed by V_1T_1 (Seedless $\times$ poultry manure) (128.65 g), while V_2T_4 (39.43 g) had the lowest fruit weight. Chemical fertilizers' quick nutrient availability probably encouraged fruit growth and biomass buildup, while poultry manure's slower nutrient release prolonged plant growth and fruit development (Li *et al.*, 2022; Bhunia *et al.*, 2021). V_2T_1 produced the highest fruits ($230.06 \text{ plant}^{-1}$), while V_1T_1 produced the highest fruit yield ($19.29 \text{ kg plant}^{-1}$), closely followed by V_1T_2 ($19.17 \text{ kg plant}^{-1}$). Because of its larger fruit size and higher individual fruit weight, Seedless mixed with poultry manure produced the maximum yield, even though Kagoji produced more fruits. Similar positive impacts of integrated nutrient management on fruit set, yield, and soil fertility have been documented in perennial fruit crops (Srivastava *et al.*, 2021). The results show that incorporating the Seedless cultivar with poultry manure offers an efficient, economical and sustainable production method. These findings support the adoption of integrated nutrient management for sustainable citrus production under the agro-ecological conditions of Sylhet, Bangladesh.

Table 3. Yield and yield attributes of Lemon affected by lemon Cultivar and Agronomic Management

Treat	Total No leaf plant^{-1}	Total no. of flower plant^{-1}	Fruit weight (gm)	Fruit length (cm)	Fruit Breadth (cm)	Girth (cm)	Total fruit plant^{-1}	Yield plant^{-1} (kg)
V_1T_1	453.00 b	253.50 c	128.65 a	7.82 a	5.12 a	2.08 a	149.86 b	19.29 a
V_1T_2	426.00 b	275.00 c	132.48 a	8.01 a	5.09 a	2.08 a	144.64 b	19.17 a
V_1T_3	237.50 d	169.50 d	101.73 b	7.06 b	4.55 b	1.60 b	63.09 c	6.43 c
V_1T_4	171.00 de	118.75 e	94.66 c	6.77 c	4.27 c	1.48 b	34.25 e	3.25 d
V_2T_1	634.75 a	437.75 a	54.53 d	5.77 d	3.92 d	2.06 a	230.06 a	12.54 b
V_2T_2	611.75 a	389.75 b	59.11 d	5.76 d	3.89 d	2.10 a	226.91 a	13.41 b
V_2T_3	346.50 c	104.50 e	49.81 e	5.19 e	3.50 e	1.88 ab	48.18 d	2.39 d
V_2T_4	152.50 e	53.25 f	39.43 f	4.70 f	3.21 f	1.55 b	18.30 f	0.72 e
LSD _(0.05)	68.86	42.29	4.65	0.21	0.20	0.44	8.57	0.93
CV (%)	12.35	12.77	3.83	2.22	3.20	16.31	5.10	6.56

V_1 = Seedless Cultivar; V_2 = Kagoji Cultivar | T_1 = Poultry Manure; T_2 = Chemical Fertilizer; T_3 = Mulching; T_4 = Controlled Condition

Conclusion

Considering overall performances, Seedless lemon was found the best performer in most of the yield attributes followed by Kagoji lemon. Among the agronomic management practices, Poultry manure showed a favorable impact on the majority of the yield-contributing attributes.

The interaction effect among the cultivars and agronomic management practices indicated that, Seedless lemon with poultry manure can be the best combination for maximum profitable yield.

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Conflicting Interests

There are no conflicting interests, according to the authors.

Contributions of the Authors

All of the authors equally contributed to this work.

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