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Effects of alternative production system on the growth performances of two varieties of tomato (Solanum lycopersicum l.)

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ABSTRACT

This paper examines the effect of an alternative production system on the growth performances of two varieties of tomatoes. Alternative farming systems provide a process for crop production using materials of natural origin to enrich soil and protect crops, thereby reducing the use of agrochemicals. Padma 108 F1 and Platinum 701 F1 tomato varieties were cultivated using both conventional and alternative farming methods in a completely randomized design. On the alternative farming method plot, cured cow dung manure was used for soil enrichment, and manual weeding was employed. In addition, insect pests' control was achieved with a concoction of garlic (6 g/l), ginger (10 g/l), clove (5 g/l), onions (10 g/l), and dried capsicum pepper (4 g/l). Fungicidal treatment was by an infusion of leaves from Siam weed, neem, and bitter leaf (5 g/l each). Plant height, numbers of leaves, flowers, and fruits produced were determined manually for twelve weeks of observation on both plots. The highest height of 107.5 cm was observed in Padma tomato plants, while the least height (103.5 cm) was obtained for Platinum variety, at week 12. However, there was no significant difference ($P<0.05$) in the heights of the two tomato varieties at full maturity and in between the farming systems. The same trend was observed for number of leaves, flowers, and fruits produced. The alternative farming model in this study produced similar growth performances in the two tomatoes varieties, and exhibits the potential to be a substitute for the conventional farming system of tomato as practiced by the smallholder farmers. Further studies on the bioactive components of the botanical materials used would be encouraged.

Contribution/Originality: This study provides a specific focus on the use of an indigenous knowledge systems of utilizing plant-based products as pesticides in combination with manure fertilization system, for cropping tomato plants, in the southern part of Nigeria, known for heavy rainfall with high endemic rate of tomato fungal pathogens.

1. INTRODUCTION

Agricultural chemicals, also known as agrochemicals, are chemicals used in agricultural practices to boost farm production and control pests and diseases [1]. These agrochemicals include synthetic fertilizers, pesticides (e.g., insecticides, fungicides, anti-helminthic substances, and rodenticides), plant growth regulators, and herbicides [2]. Agrochemicals aid in conditioning the soil, regulating soil acidic level, and unlocking nutrients in the soil, boosting growth of plants, and protecting the crops from rodents, parasitic worms, fungi, bacteria, and viruses that are pathogenic. In addition, they help to control weeds that compete with the crops for nutrients and other growth factors. A combination of these activities helps boost agricultural production to meet the ever-increasing demands arising from the growing human population. According to Oerke, et al. [3], the use of agrochemicals has greatly contributed to increased crop and animal yields and reduced post-harvest losses, which has caused wide acceptance of their uses across the world. However, the rapid expansion of agricultural sector in many countries has stimulated an increased demand for agrochemicals worldwide [4] while the uncontrolled increase in human population, which could not be matched by food production, has led to indiscriminate, excessive, and unguarded use of agrochemicals to support the quest to boost production of agricultural products [5]. Also, conventional modern agricultural systems are intensive, with high dependence on non-renewable resources, fuels, and chemicals [6]. Agrochemicals have been reported to persist in the ecosystem, causing deterioration of soil health, environmental pollution, degradation of the agricultural ecosystem, contamination of groundwater, and development of pesticide resistance in the pathogens in the environment [7]. The challenges caused by this excessive and indiscriminate use of agrochemicals have resulted in researchers and agriculturists developing an alternative system of agricultural practice called organic agriculture.

Organic agriculture is a production management system that is holistic in practice that promotes and supports agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. This system prioritizes management practices over off-farm inputs [8]. In farming practices, organic systems are also known as ecological or biological farming [9]. Organic farming employs the use of compost manure, green manure, and bone meal in place of synthetic fertilizers, and emphasizes farm management practices such as crop rotation and companion planting to control weeds and pests [10]. Organic farming began in the 20th century. According to Paull [11] organic agriculture covers over 70 million hectares of cultivated land globally, and more than half of that is located in Australia. The use of naturally occurring substances is the main feature of organic farming practice, while use of synthetic inputs is generally disapproved or restricted Paull [12]. USDA [13] supported the prohibition of the use of genetically modified organisms, human sewage, nanomaterials, and plant growth regulators in farming and in livestock production, as well as the use of antibiotics and hormones, in the practice of organic agriculture. The concept of organic agriculture relies firmly on employing good farm management principles and natural resources in improving production and ensuring protection of agricultural products from pests and other adverse factors, while aiding to preserve the ecosystem and maintaining the order of nature. In the light of the above, Coleman [14] opined that organic farming claims advantages of food safety, sustainability, food security, self-sufficiency, and openness. Further, in addition to the merit of operating a closed system of agricultural production, organic farming pays attention to the environment from the production stage through to handling and processing [15]. As a result of the growing consumer awareness for naturally grown food items, the practice of organic farming has increased globally as demands for products of organic farming increase.

Organic farming systems are generally observed by researchers to be safer for the environment and consumers of the products because of their non-dependence on chemicals and synthetic substances that are known to leave persistent residues in the environment and products, where they cause pollution and risks to public health [16]. In comparing the products of organic farming and conventional farming, Popa, et al. [17] claimed that organic produce possesses superior quality in terms of vitamin and mineral content, and the produce displayed longer shelf life. However, Giampieri, et al. [18] noted that reports on the dry matter contents (organic and nutritive compounds) in conventional and organic plant food are inconsistent. The major limitations of organic agriculture are high cost of labour leading to high cost of agricultural products and involvement of laborious activities.

A tomato is a vegetable that is cultivated globally. The vegetable is an important part of the human diet, supplying nutrients such as vitamin C, minerals (calcium, potassium), and organic acids [19, 20]. Tomatoes cultivated organically are reported to possess higher vitamin C, antioxidants, and reduced nitrates than the ones grown conventionally [21].

Reports on plant-specific approaches to comparison of conventional and alternative farming systems on plant performance are scarce, especially mostly in plants of agricultural importance in Nigeria. This study was embarked on to provide a plant-specific investigation into the effects of farming systems on tomato (*Solanum lycopersicum* L.), using an indigenous knowledge system of protecting plants against insects, pests, and pathogenic fungi. The specific objective is to compare the growth performances of two varieties of tomato (*Solanum lycopersicum* L.) cultivated under conventional and alternative systems.

2. MATERIALS AND METHODS

The tomato plant varieties used for the study were Platinum 701 F1 and Padma 108 F1, whose seeds were obtained from a commercial agro-based materials store at Akure, Southwest Nigeria. The farm location was at the Federal College of Agriculture, Akure, Ondo State, Nigeria. It lies within latitude 6.895929^0N, and longitude 4.893563^0 E. Tomato cultivation was carried out from October 2022 to January 2023. The experiment was set up in a completely randomized design.

2.1. Preparation of Nursery

Cocoa peat was used as the substrate for nursing the seedlings in seed trays. The cocoa peat was soaked in water for 24 hours, after which it was mixed with cured poultry droppings at a ratio of 2:1. This mixture was placed in the holes of the seed trays, and one seed of tomato is placed inside each hole. The seeds were hydrated lightly in the morning and evenings for 21 days. The seedlings were placed in the sun during the day and kept safe from reptiles and rodents. Both tomato varieties in the two farming systems used the same nursery method.

2.2. Transplanting Seedlings for Conventional Farming System

Beds were treated with a copper (I) oxide fungicide. Holes of 0.2 m depth were made in the beds with a spacing of 30 cm. The holes were filled with cured poultry droppings. A seedling is placed in each hole, ensuring to keep the topmost leaves above the ground and pressing the soil firmly around the base. Following that, the seedlings were irrigated.

2.3. Transplanting Seedlings for Alternative Farming System

This was carried out on a fallow plot of land located at about 300 m away from any cultivated plot. The procedure for transplanting was same as with the conventional farming method, except for a few modifications. Beds were made and treated with a fungicidal infusion made from a combination of crushed leaves of siam - *Chromolaena odorata* (5 g/l), neem - *Azardirachta indica* (5 g/l), and bitter leaf - *Vernonia amygdalina* (5 g/l), in water. Holes of 0.2m depth were made in the beds with a spacing of 30 cm. The holes were filled with cured poultry droppings, and a seedling is placed in each hole, ensuring to keep the topmost leaves above the ground and pressing the soil firmly around the base. Following that, the seedlings were irrigated.

2.4. Crop Management

Each experimental plot was set up with beds consisting of fifteen stands of tomato per bed, having a total of 150 stands per plot per variety. Mulching of the beds was done on week 3 after transplanting, as the plants began to produce flowers. The flowers attracted dangerous insects such as whiteflies, prompting foliar treatment with an insecticide (a methyl oxalate compound). Similar treatment was applied on the alternative farming plot by using a domestically developed insecticide containing garlic (6 g/l), ginger (10 g/l), clove (5 g/l), onions (10 g/l), and dried powder of capsicum pepper (4 g/l), all ground and mixed together before steeping in clean water for 48 hr. After steeping, the mixture was filtered through a mesh and the filtrate sprayed on the flowers and leaves of plants. Treatment against insect pests was repeated on weeks 5, 7, 9, and 11. Foliar fungicidal treatment was performed on both plots on weeks 4, 6, 7, 8, and 10, respectively. The fungicide used in treating the conventional farming plot was Saaf (a carbendazim compound), while the above-described infusions of leaves from siam, neem, and bitter leaf applied for soil treatment were used on the alternative farming plot. Weed control on both plots was by manual method. For soil fertilization, Nitrogen-Phosphorus-Potassium commercial synthetic fertilizer (NPK 15:15:15) was applied on week 4, and NPK (11:46:14) on week 6, while this was achieved on the alternative farming plot by weekly application of cured cow dung. Irrigation was carried out manually throughout the period of the experiment twice in a day, in the morning and evening.

At the fruiting stage, from immature to mature fruits were treated weekly with another insecticide that is active against caterpillars (emamectin benzoate), and the alternative farming plot was sprayed with the concoction made from garlic, ginger, cloves, onions, and dried powder of capsicum pepper.

2.5. Data Collection

Ten (10) stands of tomato plants per bed and five beds per variety were selected for collection of data. The data collected were plant height, number of leaves, number of flowers, and number of fruits per week throughout the duration of the experiment. The height was measured using a metre tape, while the number of leaves, number of flowers, and number of fruits were counted manually. Data were collected for each variety for both treatments, and the means were compared using Analysis of Variance (ANOVA) at $p < 0.05$ with Minitab 1 software package.

3. RESULTS

Growth parameters measured were plant height, number of leaves, number of flowers produced, and number of fruits produced per plant per variety in 12 weeks of cultivation.

Table 1. Heights (cm) of Padma and platinum varieties of tomato plants.

Weeks after planting						
Treatments	**2**	**4**	**6**	**8**	**10**	**12**
PD_{nf}	16.9^a	49.9^a	73.2^a	88.0^a	101.8^a	107^a
PT_{nf}	13.9^b	40.0^a	65.2^a	83.4^a	101.3^a	105.4^a
PD_0	15.2^a	44.8^a	71.1^a	85.2^a	100.2^a	107.2^a
PT_0	13.5^a	40.1^a	63.0^b	79.6^a	97.7^a	103.5^a
F test	*	NS	*	NS	NS	NS

Note: Means followed by the same letter (a or b) are not significantly different from one another based on Tukey's test at $P < 0.05$ *= Significant, NS = Not significant, PDnf= Padma alternative, PTnf= Platinum alternative, PD0= Padma conventional, PT0= Platinum conventional.

Table 1 shows the heights of the two varieties of tomato plants. The heights of the two varieties of tomato increased from week 2 to 12, with the highest (107.2 cm) obtained for the Padma variety grown by conventional method, while the least height of 103.5 cm was observed in the Platinum variety cultivated by conventional method at week 12. However, there was no observable statistically significant difference in the heights of all the plants through the period of observation except on weeks 2 and 6, in which the platinum tomato on the alternative farming plot and that planted on the conventional method plot respectively, showed significant differences in heights at 13.9 cm and 63.0 cm. Bettiol, et al. [22] reported similar findings in comparing plant heights of Debora and Santa Clara varieties of tomatoes grown by both conventional and organic farming systems, where the heights showed no statistical difference but the plant development was generally better in tomatoes cultivated by conventional methods. In this study, Padma variety exhibited higher heights than Platinum variety all through the observation period.

Table 2. Number of leaves on Padma and platinum tomato plants.

Weeks after planting						
Treatments	**2**	**4**	**6**	**8**	**10**	**12**
PD_{nf}	6.9^a	9.9^b	21.0^b	30.9^b	41.5^b	42.6^b
PT_{nf}	4.1^b	14.2^a	24.6^a	45.2^a	59.4^a	61.3^a
PD_0	4.9^b	9.9^b	21.1^b	30.9^b	40.1^b	45.0^b
PT_0	6.1^a	14.2^a	24.3^a	45.1^a	59.4^a	61.3^a
F test	*	*	*	*	*	*

Note: Means followed by the same letter (a or b) are not significantly different from one another based on Tukey's test at P < 0.05 *= Significant, NS = Not significant, PDnf= Padma alternative, PTnf= Platinum alternative, PD0= Padma conventional, PT0= Platinum conventional.

Table 2 presents the number of leaves on the two varieties of tomato. Throughout the observation period, the number of leaves on both tomato varieties increased. However, platinum tomatoes exhibited higher number of leaves, with the highest mean figure obtained on week 12 at 61.3 for both grown alternatively and conventionally. The number of leaves varies significantly between the varieties. This probably indicated that production of leaves in tomatoes is variety-dependent but independent of the farming system. The trend of foliar developments in both varieties was similar in the two farming systems. Same insect pest attacks were observed on the two plots, and the respective treatments on both plots produced similar corrective results.

Table 3. Number of flowers on Padma and platinum tomato plants.

Weeks after planting					
Treatments	**4**	**6**	**8**	**10**	**12**
PD_{nf}	0.4^a	8.8^b	6.2^a	4.0^a	2.2^a
PT_{nf}	0.8^a	12.2^a	7.0^a	3.8^a	3.0^a
PD_0	3.6^a	7.00^b	6.4^a	5.2^a	3.4^a
PT_0	4.8^a	9.00^a	6.5^a	5.4^a	4.0^a
F(Test)	NS	*	NS	NS	NS

Note: Means followed by the same letter (a or b) are not significantly different from one another based on Tukey's test at P < 0.05 *= Significant, NS = Not significant, PDnf= Padma alternative, PTnf= Platinum alternative, PD0= Padma conventional, PT0= Platinum conventional.

According to Table 3, the number of flowers produced on the plants increased initially and dropped after, with the peak observed on week 6. This occurred because some of the flowers had already developed into fruits by week 6. The highest number of flowers was observed in Platinum variety cultivated on the alternative plot with a mean value of 12.2, while the least number was produced on week 4 on both varieties on the same plot. Flower development rate appeared slower in the two tomato varieties grown by the alternative farming system than in the conventional procedure, though, the numbers of flowers are not statistically different between the farming systems on week 4. Generally, the conventional farming system supported flower production more than the alternative system, as indicated by higher mean figures in Table 3. However, except for 6 weeks, there was no statistically significant difference in the number of flowers produced by the varieties or between the two farming systems. At this particular week 6, a significant difference in number of flowers was observed between the two tomato varieties. Similarly, Bettiol, et al. [22] reported differences in the numbers of flower clusters between Debora and Santa Clara tomato varieties as the days of planting increased, showing a more conspicuous difference in the plants grown organically. However, these workers reported slightly higher number of flower clusters in the tomatoes grown conventionally than the organically cultivated plants. Flower production in tomatoes is highly influenced by an adequate supply of Nitrogen and Potassium [23]. The better flower production observed in the conventionally cultivated tomatoes could be as a result of the use of NPK fertilizer, which probably has a higher nitrogen and potassium quantity than the animal manure.

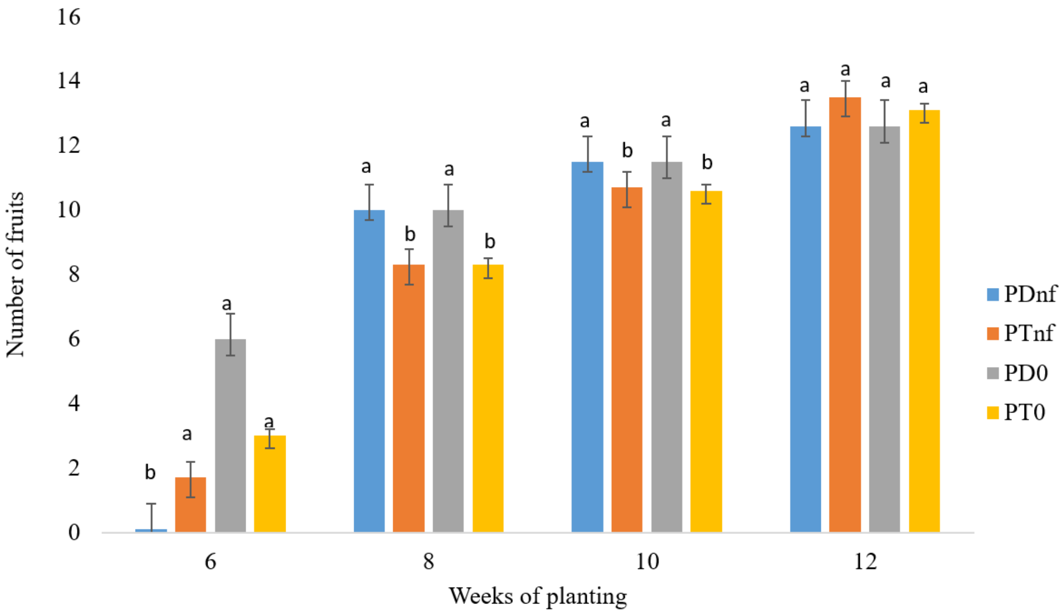

Figure 1. Number of fruits produced by Padma and platinum tomato plants.

Note: Means followed by the same letter (a or b) are not significantly different from one another based on Tukey's test at P < 0.05, PD_{nf} = Padma alternative, PT_{nf} = Platinum alternative, PD_0 = Padma conventional, PT_0 = Platinum conventional.

Figure 1 shows the mean number of fruits produced in both Padma and Platinum tomato fruits under the two farming systems. There was no significant difference in fruit production between farming systems, but between the varieties, there were significant differences until week 10. At the end of observation in week 12, there was no difference in the number of fruits produced between the varieties of tomatoes and between the farming systems. The highest mean figure of 13.5 was observed in Platinum tomato grown on the alternative farming plot at week 12, while the least mean value (0.1) was obtained at week 6 in Padma tomato grown on the alternative farming plot. Rate of fruit development appeared to be faster in the Padma tomato, irrespective of the farming system, but at the end, Platinum tomato produced higher number of fruits (Figure 1). This study observed that the farming systems did not influence the number of fruits produced per variety. Adhikari, et al. [24] concluded that organic farming systems aided tomato plants to utilize carbon and nitrogen efficiently, which impacts fruit formation. Similarly, Zoran, et al. [25] noted that tomatoes grown by organic agricultural methods possessed more carotenoids, more minerals (P, Mg, K, and Ca), and contained far fewer heavy metals (Pb, Zn, Cu, and Ni) and nitrates than the tomatoes grown by conventional method.

4. CONCLUSION

The use of an alternative farming system exhibited good growth performances in the two varieties of tomatoes cultivated. All the growth factors measured for the tomatoes cultivated by alternative farming system showed no significant difference from cultivation by the conventional system; hence, the alternative farming system as described in this study could be promoted in cropping tomatoes among smallholder farmers to help mitigate against the risks associated with the use of agrochemicals.

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