Source–Sink Relationship on the Growth and Yield Parameters of Tomato (*Solanum Lycopersicum L.*) as Influenced by Organic and Inorganic Fertilizers

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Abstract

Tomato *(Solanum lycopersicum L.)* production is highly influenced by soil fertility management and the efficiency of assimilate distribution within the plant. Thus, this study evaluated the source–sink relationship on the growth and yield parameters of tomato as influenced by organic and inorganic fertilizers. Specifically, the study aimed to: assess the effects of organic and inorganic fertilizers on the vegetative growth parameters of tomato, and determine the influence of fertilizer sources on the yield and yield components of tomato. The experiment was conducted using a randomized complete block design (RCBD) with three replications. Treatments consisted of organic fertilizer (cow dung), inorganic fertilizer (NPK 15:15:15 and Miracle-Gro), and a control. Data were collected on plant height, number of leaves, leaf area, stem girth, days to flowering, fruit weight, number of fruits per plant, and total yield. Soil and plant samples were analyzed using standard laboratory procedures, while data were subjected to analysis of variance at 5% level of significance. Results showed that fertilizer application significantly influenced vegetative growth and yield parameters of tomato. Plants treated with Miracle-Gro recorded the highest plant height, leaf production, and early flowering, while NPK and cow dung improved fruit weight and soil nutrient status. The combined use of organic and inorganic fertilizers enhanced nutrient availability and improved the source–sink efficiency of tomato plants. The study concludes that integrated nutrient management improves tomato growth and productivity and contributes to sustainable soil fertility management.

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Keywords: Tomato *(Solanum lycopersicum L.)*, source–sink relationship, organic fertilizer, inorganic fertilizer, soil fertility

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most extensively cultivated vegetable crops worldwide, valued for its nutritional, economic, and industrial importance as well as its contribution to global food and nutritional security. As a member of the Solanaceae family, tomato serves as a significant source of essential nutrients and income for farmers, particularly in developing countries such as Nigeria (Akanbi *et al*., 2020) [4]. The fruit is rich in vitamins A, C, and E, along with important minerals such as potassium, magnesium, and phosphorus. It also contains bioactive compounds like lycopene, beta-carotene, and flavonoids, which act as antioxidants and are associated with reduced risks of cardiovascular diseases and certain types of cancer (Heuvelink, 2018; FAO, 2022) [9, 7]. Owing to these health benefits, tomatoes are widely consumed both fresh and in processed forms such as sauces, juices, and pastes.

Despite the suitability of tropical climates for tomato cultivation, yields in many regions remain low. One of the major factors responsible for this is declining soil fertility, coupled with inadequate nutrient management practices. Crop productivity is largely dependent on the plant's capacity to absorb nutrients and convert them into biomass and reproductive structures. This process is influenced by the source–sink relationship in plants, where leaves act as sources by producing assimilates through photosynthesis, while fruits serve as sinks by utilizing these assimilates for growth and development (Taiz *et al*., 2015) [13].

Efficient
production and distribution of assimilates are therefore critical for achieving optimal crop yields.

Soil fertility is central to maintaining this physiological balance. However, in many tropical regions, soils have become increasingly degraded due to continuous cultivation, erosion, and nutrient leaching (Lal, 2015) [11]. To address nutrient deficiencies, farmers often rely heavily on inorganic fertilizers, which provide nutrients in readily available forms that promote rapid plant growth. Nitrogen enhances vegetative growth by supporting chlorophyll formation and protein synthesis, phosphorus aids energy transfer and root development, and potassium regulates water balance, enzyme activity, and carbohydrate transport within plants (Marschner, 2012) [12]. While these fertilizers are effective in boosting short-term productivity, their excessive or improper use can lead to soil degradation, nutrient imbalances, and environmental pollution (Gupta *et al*., 2017) [8].

In contrast, organic fertilizers such as farmyard manure, compost, and cow dung offer a more sustainable approach to soil fertility management. These organic inputs improve soil structure, increase organic matter content, enhance water-holding capacity, and stimulate beneficial microbial activity. Additionally, they release nutrients gradually, ensuring a more sustained supply to crops over time (Adekiya *et al*., 2020). However, organic fertilizers alone may not always meet the nutrient demands of high-yielding crops due to their relatively low nutrient concentrations.

To address the limitations of both fertilizer types, integrated nutrient management has been widely recommended. This approach combines organic and inorganic fertilizers to optimize nutrient availability, enhance soil fertility, and improve crop productivity. It ensures immediate nutrient supply from inorganic sources while maintaining long-term soil health through organic inputs (Lal, 2020). Research has shown that this integrated approach improves yield, increases nutrient use efficiency, and enhances soil microbial activity compared to the use of either fertilizer type alone. Beyond nutrient management, plant physiological processes such as the source–sink relationship play a vital role in determining crop performance. In tomato plants, leaves function as the primary source organs by synthesizing carbohydrates through photosynthesis, while developing fruits act as major sink organs that accumulate these assimilates for growth and maturation (Taiz *et al*., 2018). The efficiency of this relationship directly influences fruit yield and quality.

Another important factor affecting tomato growth is the type of growing substrate or soil medium. Different substrates, including topsoil, cocopeat, and river sand, vary in their physical and chemical properties such as nutrient content, aeration, and water-holding capacity. For example, cocopeat is known for its high moisture retention and good aeration, while river sand provides excellent drainage and supports root development (Abad *et al*., 2005) [1]. These characteristics significantly influence root growth, nutrient uptake, and overall plant performance, (Rabot, 2022) [15].

In Nigeria, although tomato production is widespread, yields remain below global standards. This is largely due to factors such as poor soil fertility, inadequate nutrient management, pest and disease pressures, and limited access to improved agricultural technologies (Zhang *et al*., 2020) [14]. Among these, soil nutrient depletion remains a major challenge, as continuous cropping without adequate replenishment has reduced the availability of essential nutrients such as nitrogen, phosphorus, and potassium. Tropical soils are often inherently low in organic matter, further exacerbating this problem (Lal, 2020).

Given these challenges, there is a need for effective nutrient management strategies that enhance both soil fertility and plant physiological efficiency. Understanding how different fertilizer sources and growth substrates influence the source–sink relationship in tomato plants is essential for improving productivity. Therefore, this study focuses on evaluating the effects of organic and inorganic fertilizers on the growth, reproductive development, and yield of tomato, with particular attention to how these factors interact to influence assimilate distribution and overall crop performance. Hence, the objectives is to evaluate the effect of organic and inorganic fertilizers on source–sink dynamics on tomato growth and yield under Delta State conditions.

Materials and Methods

Experimental Location: The experiment was conducted at the Teaching and Research Farm of the Department of Agronomy, Delta State University, Abraka, under controlled environmental conditions suitable for tomato production. Abraka lies within the humid tropical rainforest zone and the climatic conditions of the region are characterized by high rainfall ranging from 2000–2500 mm, average temperatures between 25°C and 32°C and moderately fertile soils suitable for vegetable production. The relative humidity is generally high throughout the year and the soils of the area are predominantly sandy loam and are typically characterized by low organic matter content and moderate nutrient availability, which makes them suitable for evaluating fertilizer effects on crop performance. The natural vegetation is tropical rainforest, characterized by a multi-layered canopy of tall, evergreen and semi-deciduous trees. However, significant portions have been converted to secondary forest and farmland. Soils in the Abraka area are highly weathered and acidic, predominantly classified as Ferralsols or Ultisols. The major agricultural systems revolve around tree crops (oil palm, rubber), root and tuber crops (cassava, yam), and plantain. The primary constraints include high leaching potential, soil acidity, and challenges with soil erosion and drainage in steeper areas.

Experimental Materials: The experimental materials used in this study included tomato (Solanum lycopersicum L.) seeds, organic manure (cow dung), inorganic fertilizers (NPK 15:15:15 fertilizer and Miracle-Gro fertilizer), and different growth substrates. The substrates used in the experiment included topsoil, cocopeat, and river sand. Cow dung was used as the organic fertilizer due to its availability and its potential to improve soil fertility through the addition of organic matter and essential nutrients. Miracle-Gro fertilizer was used as a soluble inorganic fertilizer known for its rapid nutrient availability. NPK fertilizer served as a conventional inorganic fertilizer providing balanced macronutrients required for plant growth.

Experimental Design and Treatments

The experiment was arranged in a Randomized Complete Block Design (RCBD) with four treatments and three replications to minimize the effects of environmental variability. The treatments consisted of different nutrient sources and substrate types such as: Miracle-Gro fertilizer, Cow dung manure, NPK 15:15:15 fertilizer and Control (no fertilizer application). The substrate treatments included: Cocopeat, River sand and Topsoil. Each treatment was replicated three times to ensure reliability and accuracy of the results. The experimental units consisted of containers filled with the respective substrates and planted with tomato seedlings. These treatments were applied to evaluate their effects on the vegetative growth and yield performance of tomato plants. This design minimized experimental error and ensured reliable comparison of treatment effects.

Crop Establishment: Tomato seeds were first raised in a nursery to ensure uniform seedling establishment before transplanting to the experimental plots. The nursery bed was prepared using sterilized soil to reduce the risk of pest and disease infestation. Seeds were sown evenly in the nursery and lightly covered with soil. Adequate watering was carried out regularly to maintain optimum soil moisture conditions for germination and seedling growth. Seedlings were maintained in the nursery for approximately three weeks until they reached a suitable stage for transplanting. Healthy and uniform seedlings were then carefully transplanted into containers filled with the designated substrates according to the experimental design. Transplanting was carried out in the early morning to minimize transplant shock. This was done when seedlings reached approximately four weeks of age. Fertilizers were applied according to the treatment requirements and routine agronomic practices including irrigation, weed control, and pest management were carried out throughout the experimental period to ensure optimal plant growth.

Fertilizer Application: Organic and inorganic fertilizers were applied according to the treatment specifications. Cow dung manure was applied and thoroughly mixed with the substrate before transplanting to allow partial decomposition and nutrient release. NPK fertilizer and Miracle-Gro fertilizer were applied according to recommended application rates for tomato production. Miracle-Gro fertilizer was dissolved in water and applied as a nutrient solution to ensure uniform distribution of nutrients in the growth medium. The control treatment did not receive any fertilizer application. Fertilizer applications were carried out at appropriate growth stages to support both vegetative and reproductive development of the plants.

Soil and Fertilizer Analysis: Prior to planting, samples of the substrates and fertilizers were collected and analyzed to determine their chemical properties. Soil samples were air-dried, crushed, and sieved using a 2 mm sieve before laboratory analysis.

Soil pH was determined using a glass electrode pH meter in a soil-water suspension at a ratio of 1:2.5. Organic carbon content was determined using the Walkley–Black wet oxidation method.

Total nitrogen content was determined using the Kjeldahl digestion method. Available phosphorus was determined using the Bray-1 extraction method, while exchangeable bases such as calcium, magnesium, potassium, and sodium were determined using atomic absorption spectrophotometry. Particle size distribution of the soil samples was determined using the hydrometer method in order to classify the soil texture.

Data Collection and Statistical Analysis

Data were collected on both vegetative and reproductive growth parameters throughout the growth period on plant height (cm), Number of leaves, Leaf area (cm²), Number of branches, Days to flowering, Number of fruits per plant, Fruit weight (g), and Total fruit yield per plant. Leaf area measurement provided an estimate of photosynthetic capacity, which directly influenced assimilate production in plants (Taiz *et al*., 2023). Soil samples were also analyzed to determine physicochemical properties before and after fertilizer application.

Plant Height: was measured from the base of the plant to the tip of the apical meristem using a measuring tape. Measurements were taken at 2, 4, 6, and 8 weeks after transplanting (WAT).

Number of Leaves: was determined by counting the fully expanded leaves on each plant. Observations were recorded at 2, 4, 6, and 8 weeks after transplanting.

Number of Branches: was determined by counting the total branches produced by each plant during the growth period. Measurements were taken at 2, 4, 6, and 8 weeks after transplanting.

Leaf Area: was determined using the leaf length and leaf width method. Leaf length and width were measured using a ruler, and leaf area was estimated using the formula:
Leaf Area = Length × Width × Correction Factor

Days to 50% Flowering: were recorded as the number of days from transplanting to the time when approximately half of the plants in each treatment produced flowers.

Days to Fruiting: Days to fruiting were recorded as the number of days from transplanting to the appearance of the first fruits on the plants.

Fruit Weight: was determined by harvesting mature fruits from each plant and weighing them using a digital weighing balance. The average fruit weight was calculated for each treatment.

Number of Fruits per Plant: The total number of fruits produced per plant was counted during the harvesting period to determine yield performance.

Soil and Plant Analysis: Soil samples were collected before planting and after harvest for laboratory analysis. Soil pH was determined using a pH meter, organic carbon was determined by the Walkley–Black method, total nitrogen by the Kjeldahl method, and available phosphorus by Bray-1 extraction (Anderson & Ingram, 2021). Plant tissues were analyzed for nutrient concentrations to assess nutrient uptake by tomato plants. Data collected were subjected to analysis of variance (ANOVA) appropriate for a randomized complete block design. The ANOVA was used to determine whether significant differences existed among the treatment means. Where significant differences were observed, treatment means were separated using the Least Significant Difference (LSD) test at the 5% probability level. Statistical analysis was performed using standard statistical software to ensure accuracy and reliability of the results.

Results

Table 1: Effects of Organic and Inorganic Nutrient Sources on the Height and Branches of Tomato

Treatment	**Plant height (cm)**			**Number of branches**		
	Weeks after Transplanting			**Weeks after Transplanting**		
	4	**6**	**8**	**4**	**6**	**8**
MIRACLEGRO	22.46a	45.28a	79.33a	7.06a	12.28a	20.50a
COWDUNG	22.26a	36.82b	59.50b	7.22a	10.56b	14.50b
NPK	16.25b	22.78c	50.89b	6.44a	9.39b	14.39b
LSD (0.05)	5.37	7.58	9.78	0.95	1.25	2.33
SE	1.87	2.64	3.41	0.33	0.44	0.81
Treatments X substrates	91.21ns	122.41ns	156.91ns	0.63ns	3.69ns	46.47*
Treatment X season	45.60ns	42.47ns	139.02ns	2.91ns	4.57ns	22.72ns
Substrate X season	18.31ns	157.83ns	301.79ns	1.19ns	13.57*	15.39ns
Treatment X substrate X season	104.76ns	89.08ns	192.63ns	2.96ns	1.29ns	22.03ns

PH- Plant height; NOB- Number of branches; LSD- Least significant difference

The data presented in Table 1, revealed that at 4 weeks after transplanting (WAT), the tallest plant was recorded in the miracle-gro treatment (22.46±1.87) which was significantly taller than the NPK treatment (16.25±1.87), then at 6 WAT the tallest plants was recorded in the miracle-gro treatment (45.25±2.64) which was significantly taller than the rest treatments, while at the 8th WAT, the height of the plants in miracle-gro treatments (79.33±3.41) was significantly taller than the rest treatments. There were gradual increase in the number of branches recorded from the 4 the WAT to the 8th WAT. At the 6th (12.28±0.44) and 8th (20.50±0.81) WAT, the number of branches recorded in the miracle-gro treatment was significantly higher than the rest nutrient treatments. The interaction between the nutrients and substrate was significant for the number of branches at 8 WAT, while the interaction between substrate and season of cultivation was significant for the number of branches at 6 WAT.

Table 2: Effect of Nutrient Types on The Days to Fruiting and Fruit Yield of Tomato

Treatment	**DTFLOW**	**DTFRUIT**	**FW (G)**	**NOFPP**	**DTRIP**
MIRACLEGRO	31.33b	35.39b	35.31b	7.33a	62.72b
COWDUNG	41.39a	51.22a	40.17ab	2.83b	73.39a
NPK	43.11a	51.89a	42.38a	2.67b	69.67a
LSD (0.05)	6.7	7.09	5.86	1.48	6.43
SE	2.34	2.47	2.04	0.52	2.24
Treatments X substrates	227.64ns	204.42ns	126.53ns	11.83ns	129.38ns
Treatment X season	142.24ns	150.24ns	50.74ns	3.72ns	39.02ns
Substrate X season	400.52ns	297.91ns	7.87ns	10.50ns	204.57ns
Treatment X substrate X season	82.99ns	31.27ns	208.52ns	8.06ns	41.82ns

DT-Days to flowering; DT- Days to fruiting; NOF-Number of fruit per plant; DT-Days to Ripening. Means with the same elements down the groups are not significantly different from each other at 5% level of significance. SE: Standard error. LSD: Least significance differences. FW: Fruit weight

Data in Table 2 showed that the number of days to form fruits in the NPK treatment (51.89±2.47) was significantly higher than the miracle-gro (35.39±2.47). The average fruit weight observed in the NPK fertilizer (42.38±2.04) was significantly heavier than the miracle-gro treatment (35.31±2.04). The number of days to flowering observed in the NPK treatment (43.11±2.34) was significantly higher than the miracle-gro fertilized treatment (31.33±2.34). However, the miracle-gro nutrient treatment produced the highest number of fruits (7.33±0.51) which was significantly higher than the rest nutrient treatments. Also, the miracle-gro nutrient treatment took the shortest number of days to ripe (62.72±2.24) was significantly lower than the rest nutrient treatments.

Table 3: Effect of Substrate Types and Season Types on Days of Fruiting and Fruit Yield of Tomato

Substrate	DTFLOWER	DTFRUITING	FW (G)	NOFPP	DTRIPE
COCOPEAT	39.83a	46.78a	44.19a	3.33b	68.28a
RIVERSAND	38.17a	46.44a	42.04a	5.17a	68.22a
TOPSOIL	37.83a	45.28a	31.62b	4.33ab	69.28a
LSD (0.05)	6.7	7.09	5.86	1.48	6.43
SE	2.34	2.47	2.04	0.52	2.24
SEASON					
DRY	38.96a	45.93a	41.85a	4.00a	67.74a
RAINY	38.26a	46.41a	36.72b	4.56a	69.44a
LSD (0.05)	5.47	5.79	4.78	1.21	5.25
SE	1.91	2.02	1.67	0.42	1.83

Means with the same elements down the groups are not significantly different from each other at 5% level of significance. SE: Standard error. LSD: Least significance differences. FW: Fruit weight

On the seasons of cultivation, the fruit weight harvested in the dry season (41.85±1.67) was significantly heavier than the rainy season grown plants (36.72±1.67). However, on the substrates used in this study, the Cocopeat grown plants produced the heaviest fruit weight (44.19±2.04) which was significantly heavier than the topsoil (31.62±2.04) g, whereas, the highest number of fruit per plant was observed in the riversand substrate (5.17±0.52) and it was significantly higher than the Cocopeat substrate gown plants (3.33±0.52)

Table 4: Effects of Substrate Types and Season on Height and Branches of Tomato

Treatment	Plant height			Number of branches		
	Weeks after Transplanting			Weeks after Transplanting		
	4	6	8	4	6	8
COCOPEAT	20.09a	29.68b	58.00a	6.83a	9.67b	14.17b
RIVERSAND	20.50a	38.50a	63.94a	6.94a	11.17a	17.83a
TOPSOIL	20.37a	36.69ab	67.78a	6.94a	11.39a	17.33a
LSD (0.05)	5.37	7.58	9.78	0.95	1.25	2.33
SE	1.87	2.64	3.41	0.33	0.44	0.81
SEASON						
DRY	21.18a	34.96a	63.93a	7.00a	10.59a	16.22a
RAINY	19.46a	34.95a	62.56a	6.81a	10.89a	16.67a
LSD (0.05)	4.39	6.19	7.99	0.78	1.02	1.9
SE	1.53	2.16	2.79	0.27	0.36	0.66

PH-Plant Height; NOB-Number of branches. Means with the same elements down the groups are not significantly different from each other at 5% level of significance. SE: Standard error. LSD: Least significance differences.

Data in Table 4 showed a gradual increase in the plant height from the 4th to 8th WAT, while at the 6th WAT in all the substrates used, and the tallest plant was recorded in the riversand (38.50±2.64) which was significantly taller than the Cocopeat grown plants (29.68±2.64). Also, there were gradual increase in the number of branches from the 4th to 8th WAT, while at the 6th WAT, the number of branches observed (11.39±0.44) was significantly higher than the Cocopeat grown plants (9.67±0.44) and at 8th WAT, the number of branches recorded (17.83±0.81) in the riversand grown plants was significantly higher than the Cocopeat grown plants (14.17±0.81). On the season of cultivation, there were gradual increase in the plant height and number of branches with increase on the weeks after transplanting across the two seasons, however, the plant height and number of branches were statistically similar across the two seasons. There were gradual increase in the number of leaves and leaves area from the 4th to 8th WAT.

In Table 5, at the 4th (32.94±2.82), 6th (114.94±7.64), and 8th (263.22±12.01) WAT, the number of leaves observed in the miracle-gro treatment were significantly higher than the rest treatments. At 8 WAT, the leaf area observed in the miracle-gro treatment (36.30±1.87) was significantly higher than the rest nutrient treatments. Also, the interaction between the nutrients and substrates was significant in the number of leaves and leaf area at 8 WAT.

Table 5: Effects of Organic and Inorganic Nutrient Sources on Tomato Leaf Development

Treatment	Number of Leaves			Leaf Area		
	Weeks after Transplanting			Weeks after Transplanting		
	4	6	8	4	6	8
MIRACLEGRO	32.94a	114.94a	263.22a	12.59a	43.01a	36.30a
COWDUNG	32.22a	80.22b	149.50b	12.89a	30.14a	22.23c
NPK	22.94b	55.28c	144.17b	9.49a	14.06a	30.57b
LSD (0.05)	8.08	21.92	34.44	3.61	29.07	5.38
SE	2.82	7.64	12.01	1.26	10.13	1.87
Treatments X substrates	129.29ns	1895.96ns	9813.91*	14.68ns	3586.21ns	274.82*
Treatment X season	138.57ns	1355.13ns	3902.79ns	15.01ns	1359.25ns	0.07ns
Substrate X season	22.69ns	2121.24ns	3950.68ns	44.48ns	1118.16ns	21.37ns
Treatment X substrate X season	195.35ns	493.74ns	3518.68ns	21.13ns	2576.23ns	108.42ns

NOL-Number of leaf; LA-Leaf area; LSD- Least significant difference. Means with the same elements down the groups are not significantly different from each other at 5% level of significance. SE: Standard error. LSD: Least significance differences.

Table 6: Effects of Substrate Types and Season on Leaf Production in Tomato

Substrates	Number of leaves			Leaf area (cm^2)		
	Weeks after transplanting			Weeks after transplanting		
	4	6	8	4	6	8
COCOPEAT	29.83a	62.11b	149.67b	11.63a	17.37a	27.49a
RIVERSAND	29.44a	94.06a	211.50a	11.67a	34.87a	29.75a
TOPSOIL	28.83a	94.28a	195.72a	11.66a	34.96a	31.85a
LSD (0.05)	8.08	21.92	34.44	3.61	29.07	5.38
SE	2.82	7.64	12.01	1.26	10.13	1.87
SEASON						
DRY	30.00a	81.07a	183.89a	11.94a	19.40a	27.74a
RAINY	28.74a	85.89a	187.37a	11.37a	38.74a	31.66a
LSD (0.05)	6.59	17.89	28.12	2.95	23.73	4.39
SE	2.3	6.24	9.8	1.03	8.27	1.53

NOL-Number of leaf; LA-Leaf area. Means with the same elements down the groups are not significantly different from each other at 5% level of significance. SE: Standard error. LSD: Least significance differences.

As presented in Table 6, **c**onsidering the substrates and season of cultivation, there were gradual increase in the number of leaves and leave area from the 4th WAT to 8th WAT. At 6 WAT, the number of leaves observed in the riversand substrate (94.28±7.64) was significantly higher than the Cocopeat substrate (62.11±7.64), while at 8 WAT, the number of leaves obtained in the riversand substrate (211.50±12.01) was significantly higher than the Cocopeat substrate (149.67±12.01).

Discussion

Results revealed that there was significant superior vegetative growth after treatment between 4 to 6 weeks. The significantly superior vegetative growth observed under miracle-gro treatment at 4, 6, and 8 weeks after transplanting this can be attributed to its high and readily available nitrogen and potassium contents. Nitrogen promotes rapid leaf expansion and chlorophyll synthesis, while potassium enhances photosynthetic efficiency and assimilates translocation (Marschner, 2012; Zörb *et al*., 2014) [12]. This finding agrees with the reports of Adekiya *et al*. (2020), who observed enhanced tomato vegetative growth under inorganic fertilizer application due to immediate nutrient availability. Cow dung and NPK treatments also improved vegetative growth but at a slower rate, the delayed response under cow dung is consistent with the slow mineralization pattern of organic manures, which release nutrients gradually over time. This supports the rejection of the null hypothesis that fertilizer type has no significant effect on vegetative growth of tomato.

The second objective examined the influence of fertilizer sources on reproductive growth and yield parameters, which define sink strength and sink size. Miracle-gro significantly reduced days to flowering and fruiting, indicating accelerated transition from vegetative to reproductive phase. This is consistent with findings by Fageria (2016) [6], who reported that adequate phosphorus availability hastens flowering and reproductive development in solanaceous crops. Miracle-gro-treated plants produced the highest number of fruits per plant, reflecting increased sink number. However, average fruit weight was significantly lower compared to NPK and cow dung treatments. This suggests assimilate dilution were increased sink number results in reduced assimilate allocation per fruit. In contrast, NPK and cow dung treatments produced fewer but heavier fruits, indicating stronger individual sink capacity. Similar observations were reported by Akanbi *et al*. (2020) [4], who noted that organic fertilizers improve fruit size due to balanced nutrient supply and enhanced carbohydrate partitioning. These findings lead to the rejection of the null hypothesis that fertilizer source does not significantly influence tomato yield parameters.

On influence of Substrates on tomato growth and yield**,** Riversand promoted taller plants and higher branch numbers, particularly at later growth stages. This may be due to improved aeration and reduced root resistance, which enhance root elongation (Brady & Weil, 2017) [5]. However, cocopeat consistently supported higher fruit weight and superior leaf nutrient composition. Cocopeat is known for its high water-holding capacity, cation exchange capacity, and nutrient buffering ability, which ensure sustained nutrient supply during critical fruit development stages (Abad *et al*., 2005) [1]. This finding aligns with Koomson and Zemede (2020) [10], who reported improved tomato fruit quality in cocopeat-based substrates. The significant substrate effects observed indicate rejection of the null hypothesis that substrates have no significant influence on tomato growth and yield.

The significant interaction effects recorded between fertilizer sources and substrates, particularly at 8 WAT and for yield parameters, indicated that fertilizer efficiency is strongly influenced by the rooting medium. This interaction supports the principle that nutrient availability alone does not guarantee optimal growth unless the substrate supports nutrient retention and uptake (Marschner, 2012) [12]. The miracle-gro versus riversand interaction enhanced vegetative growth and fruit number, whereas cow dung or NPK combined with Cocopeat improved fruit weight and nutrient accumulation. Similar interaction effects were reported by Adeoye *et al*. (2019) [3], who emphasized the importance of integrated nutrient and substrate management for sustainable vegetable production.

Conclusion

The study demonstrated that fertilizer sources significantly influence the growth and yield parameters of tomato. Miracle-Gro fertilizer enhanced vegetative growth and early flowering due to its rapid nutrient availability, while NPK fertilizer improved fruit weight and yield quality. Cow dung contributed to improved soil fertility and sustained nutrient release. The integration of organic and inorganic fertilizers improved both vegetative and reproductive performance of tomato plants by enhancing the source–sink relationship and assimilate distribution.

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