Int.J.Curr.Res.Aca.Rev.2026; 14(10): 1-15

EXCELLENT PUBLISHERS

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 14 Number 10 (October-2026)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2026.1410.001

Comparative Assessment of Different Types of Organic and Mineral Fertilizers on the Performance of Tomato (*Solanum lycopersicum* L.) in the Senegal River Delta

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Abstract

Tomato (*Solanum lycopersicum* L.) production often relies on synthetic fertilizers, which are effective but expensive and may have adverse environmental impacts. This study was conducted to evaluate the effects of organo-mineral fertilization on soil fertility, plant growth, yield, and population dynamics of tomato insect pests compared to the recommended mineral fertilization under the pedoclimatic conditions of northern Senegal. The experiment was conducted at the ISRA experimental station in Ndiol during the cold dry season of 2026. The Cobra 26 tomato variety was used. A completely randomized block design was adopted with one factor (fertilization) and five treatments, repeated four times: F1 (recommended fertilization), F2 and F3 (BF2 + Lithovit at two application rates), and F4 and F5 (50% F1 + F2 and 50% F1 + F3, respectively). Soil analyses revealed a moderate increase in nitrogen, phosphorus, and potassium contents after the experiment, while soil pH remained strongly alkaline. Agronomic results showed that the best growth and yield performances were obtained with treatments F1, F4, and F5. The highest yield reached 18.74 t ha^{-1} with F1, whereas F2 and F3, based solely on biofertilizers, produced only 2.5 t ha^{-1}, indicating their limited short-term effectiveness. According to entomological constraint, the species *Bemisia tabaci* was the predominant pest recorded, with higher infestation levels in treatments under mineral fertilization. Overall, the results suggest that combined organo-mineral fertilization can sustain high tomato productivity while reducing the use of chemical fertilizers. Therefore, treatment F5 represent promising alternative for the sustainable management of soil fertility in tomato production.

Article Info

Received: 01 July 2026
Accepted: 28 September 2026
Available Online:20 October 2026

Keywords

Fertilization, Tomato, productivity, soil fertility, Senegal River Delta

Introduction

In Senegal, the tomato (*Solanum lycopersicum* L.) is one of the most important horticultural crops, contributing significantly to the improvement of rural household incomes. (Dramé *et al.,* 2021). It accounts for 22.5% of total vegetable production, estimated at 710,000 tonnes (Diouf *et al.,* 2022). However, despite its importance, national production remains insufficient to meet domestic demand, estimated at more than 140,000 tonnes per year, resulting in a dependence on imports of tomato paste (MAERSA, 2024; ARM, 2023). One of the major constraints to tomato production is the progressive degradation of soil fertility, which is a critical issue. At

the national level, approximately 34% of the land is degraded, corresponding to nearly 6.8 million hectares (CNULD & MEDD, 2015). This degradation is largely caused by human activities, particularly conventional agricultural practices. It is mainly manifested by a decline in soil fertility, closely associated with a reduction in soil organic matter content, resulting in lower agricultural yields (DyTAES, 2023). Although mineral fertilization can improve yields in the short term, the intensive use of mineral fertilizers leads to chemical pollution and negative environmental impacts, thereby limiting its sustainability (Diaité *et al.,* 2020; Lawani *et al.,* 2017). Indeed, the improper use of these chemical products contributes to the contamination of drinking water and the eutrophication of freshwater systems. In addition, some fertilizers may also have adverse effects on human health (UNEP, 2021).

In response to this soil fertility problem, chemical fertilizers alone are not sufficient to restore soil productivity (Diaité *et al.,* 2020). To meet future food requirements, it is therefore necessary to promote more appropriate and resilient technologies that enable sustainable and environmentally friendly production (Mounirou *et al.,* 2024). Studies by Kotaix *et al.,* (2019) and Yolou *et al.,* (2016) have shown that the combination of organic and mineral fertilizers improves soil organic matter content as well as crop yields. This approach therefore contributes to reducing the use of chemical fertilizers while maintaining or even improving crop productivity. Furthermore, organic amendments improve soil fertility, stimulate microbial activity, enhance soil structure, and reduce water losses (Agegnehu *et al.,* 2016). However, access to traditional sources of organic matter, such as manure and compost, remains limited in both quantity and quality (Lompo *et al.,* 2009). This constraint has encouraged the development and use of alternative and innovative inputs, including certain highly effective mineral and organo-mineral amendments.

Moreover, the use of fertilizers based on nanoscale calcium carbonate (NCC) improves plant photosynthetic performance by increasing antioxidant enzyme activity, photosynthetic pigment content, Rubisco activity, stomatal conductance, and the activity of the photosynthesis (PS) II reaction center (Gao *et al.,* 2023). In response to this constraint, companies have become involved in the production and marketing of biofertilizers, such as BF2 Universel and Lithovit, in order to provide alternative solutions adapted to farmers' needs. Nevertheless, their agronomic effectiveness under local soil and climatic conditions remains insufficiently documented.

In this context, the present study was conducted and aim at contributing to the improvement of soil fertility and tomato productivity in the Senegal River Delta. Specifically, it is to: (i) assess the effects of different rates of organic and mineral fertilizers on soil fertility, tomato growth and yield; (ii) determine the incidence and severity of main insect pests of tomato; and (iii) identify the most effective fertilization strategy for optimal tomato production.

Material and Methods

Experimental site

The field trial was conducted at the Sergine Moustapha Bassirou Mbacké Agricultural Experimental Station in Ndiol (16.14° N latitude, 16.32° W longitude), located approximately 28 km from the Saint-Louis region, in the Dagana Department, Gandon Municipality, in the Senegal River Delta (Figure 1). The climate is typically Sahelian and is characterized by three distinct seasons. The rainy season extends from July to September and is hot and humid. The cool dry season occurs from mid-november to February, with minimum temperatures of approximately 15°C and very low relative humidity. The hot dry season extends from March to June (Tégaye *et al.,* 2019). The Diéri *(Foondé)* soils, which are among the most common soils along the Senegal River, are characterized by a low clay content, ranging from 10 to 30%. These soils are suitable for horticultural and fruit crops.

Plant Material

The tomato variety Cobra 26 was used in this study. It is a determinate-growth variety tolerant to Tomato Yellow Leaf Curl Virus (TYLCV) and bacterial wilt. It is well adapted to Sahelian and tropical regions, where it provides good productivity. Its fruits are abundant and uniform, with a square shape and high firmness, ensuring good post-harvest shelf life (Technisem, 2024).

Studied Factor and experimental design

The studied factor was the rate of organic and mineral fertilization, with five treatment levels:

- F1 (reference control): 200–300 kg/100 m² of manure + 4 kg/100 m² of 10N–10P–20K mineral fertilizer as

basal fertilizer + 4 kg/100 m² of 10N–10P–20K mineral fertilizer applied in four split applications at 15, 30, 50, and 80 days after transplanting (DAT) as topdressing fertilizer;

- F2: 1 tonne/ha of BF2 Universel as basal fertilizer + 1 kg/ha of Lithovit applied at 15, 30, 50, and 80 DAT as topdressing fertilizer;
- F3: 2 tonnes/ha of BF2 Universel as basal fertilizer + 1 kg/ha of Lithovit applied at 15, 30, 50, and 80 DAT as topdressing fertilizer;
- F4: 50% F1 + F2;
- F5: 50% F1 + F3.

The treatments were arranged in randomized complete block design with four replications. The area of each experimental plot was 12 m². The distances between plots and between blocks were 1 m and 2 m, respectively.

Crop Management

The seedlings were transplanted at a rate of one seedling per hole, with a spacing of 50 cm between rows and between seedlings, for a density of 48 seedlings per plot. The organic fertilizer BF2 Universel, manure, and mineral NPK (10-10-20) fertilizer were incorporated into the soil during land preparation as basal fertilizers. BF2 Universel was applied at rates of 2 t/ha and 1 t/ha for treatments F3 and F2, respectively, and for the combined treatments F4 and F5. Manure and NPK were applied at rates of 200 kg/100 m² and 4 kg/100 m², respectively, for treatment F1, and at 100 kg/100 m² of manure and 2 kg/100 m² of NPK for treatments F4 and F5.

The foliar fertilizer Lithovit and mineral NPK (10-10-20) fertilizer were applied in four split applications at 15, 30, 50, and 80 days after transplanting (DAT). Lithovit was applied at a rate of 1 kg/ha as a 0.5% suspension in 100 L of water for treatments F2, F3, F4, and F5. NPK fertilizer was applied at rates of 4 kg/100 m² for F1 and 2 kg/100 m² for F4 and F5. Other crop management practices, including weeding, staking, irrigation, and harvesting, were carried out according to recommended technical practices.

Data collection

The chemical characterization of the soil was carried out before the establishment of the experiment and after harvest to determine the concentrations of nitrogen (N), phosphorus (P), and potassium (K), as well as soil pH and electrical conductivity (EC).

Plant survival rate per elementary plot was assessed using the following formula:

$$\text{PSR (\%)} = \frac{\text{Total number of plants transplanted}}{\text{Number of plants surviving after transplanting}} X\ 100$$

Plant height and stem diameter were measured in each experimental plot on ten (10) randomly selected plants, before treatment application and then every ten (10) days after application (DAA).

Number of branches per plant was determined by direct counting on the same planting hills used for plant height measurements.

Number of leaves per plant was assessed at 80 days after transplanting (DAT) on ten (10) planting hills per elementary plot by direct counting.

Incidence and Severity of *Bemesia tabaci*

The incidence of *Bemisia tabaci* was calculated using the following formula:

$$Incidence\ (\%) = \frac{Number\ of\ infested\ plants}{Total\ number\ of\ plants\ observed} X\ 100$$

The severity of damage caused by *Bemisia tabaci* was assessed using a rating scale from 0 to 5, where 0 = no damage and 5 = more than 75% damage. The severity index was then calculated using the following formula:

$$Sévérity\ (\%) = \frac{\sum(Ni * Si)}{(Nt * 5)} X\ 100$$

Where:

- Ni: number of plants belonging to severity class *i*;
- Si: severity class score;
- Nt: total number of plants observed.

Incidence and yield losses due to *Helicoverpa armigera*
The incidence of *Helicoverpa armigera* and the resulting fruit losses were calculated using the following formulas (1) and (2):

$$\text{Incidence } H.armigera\ (\%) = \frac{\text{Number of infested fruits}}{\text{Total number of fruits per plant}} X100. \quad (1)$$

$$\text{Fruit yield loss}(\%) = \frac{\text{Weight of Damaged Fruits}}{\text{Total Weight of Harvested Fruits}} X100 \quad (2)$$

- **Yield**

The Yield was calculated using the following formula:

$$Yield\ \left(\frac{t}{ha}\right) = \frac{Total\ fruit\ weight\ (kg)}{area\ (m^2)}\ X\ 100$$

Statistical Analysis

The data were entered and processed using Microsoft Excel, and an analysis of variance (ANOVA) was performed using R software version 4.5.2. Tukey's test was used for mean comparisons at the 5% significance level. A principal component analysis was performed to determine the degree of correlation between the different treatments and the parameters studied.

Results and Discussion

Effect of fertilization on soil chemical properties

Table 1 presents the results of the soil chemical analysis conducted before fertilizer application and after harvest. Before fertilizer application, the soil had a basic pH (8.95) and very low concentrations of N, P, and K (2, 2, and 2.5 mg/kg, respectively) indicating a soil poor in essential nutrients. After harvest, no significant differences among treatments were observed for the variables studied. The soil pH remained strongly alkaline, ranging from 9.05 to 9.20. Nitrogen (2.00-2.62 mg/kg), phosphorus (2.25-2.62 mg/kg), and potassium (2.75-3.50 mg/kg) concentrations showed slight variations among treatments, with mean values of 2.30, 2.42, and 3.18 mg/kg, respectively, indicating generally low nutrient levels.

Effect of fertilization on tomato plant survival

Figure 2 presents the survival rate of tomato plants according to the different treatments. A significant difference (P = 0.0001) was observed among treatments. Treatments F1, F3, F4, and F5 showed high and statistically similar survival rates, belonging to the same statistical group, with values close to or above 90%. In contrast, treatment F2 exhibited a significantly lower survival rate (81%), clearly differing from the other treatments. Overall, plant survival remained high for most treatments, except for F2.

Effect of fertilization on growth parameters

Figure 3 shows the evolution of the number of branches over time under the different treatments. A gradual increase was observed across all treatments throughout the study period. The analysis of variance revealed significant differences among the treatments throughout the observation period.

Before fertilizer application (0 DAA), numerical differences were observed, with higher values recorded for F1 (approximately 3 branches), followed by F5 and F4 (approximately 2 branches). From 30 DAA onward, a clearer differentiation among the treatments was observed. Treatments F1 and F5 showed a rapid increase and reached values clearly higher than those of the other treatments. Treatment F4 followed a similar trend, but with slightly lower values, whereas F2 and F3 showed a slower increase and recorded the lowest values.

This trend persisted until 60 DAA, with approximately 10 branches for F1, 9 for F5 and F4, 5 for F2, and 3 for F3, indicating distinct growth trajectories among the treatments.

The distribution of the number of leaves according to the treatments is presented in Figure 4. Statistical analysis revealed highly significant differences among the treatments (p = 0.0013). Treatment F1 recorded the highest number of leaves, with 34 leaves, followed by treatments F4 and F5, both with 28 leaves, which showed relatively similar values. Treatments F2 and F3 recorded the lowest numbers of leaves, with 14 and 12 leaves, respectively. Greater variability was observed particularly in treatments F1 and F4.

The results concerning the changes in tomato plant height at different days after fertilizer application (DAA) are presented in Table 2. Before fertilizer application (0 days before application, DBA), the analysis of variance showed no significant difference among treatments (P = 0.0613). Mean values ranged from 16.75 to 24.70 cm depending on the treatment.

At 10 and 20 DAA, the differences among treatments remained non-significant (P > 0.05). However, the mean values tended to be higher for treatments F1 (41.10 ± 7.15 cm at 10 DAA and 45.70 ± 7.85 cm at 20 DAA) and F5 (35.30 ± 8.26 cm at 10 DAA and 41.40 ± 7.65 cm at 20 DAA). Treatments F2 and F3 recorded the lowest values at these dates. For F2, mean plant height was 24.80 ± 11.72 cm at 10 DAA and 27.00 ± 12.55 cm at 20

DAA, while for F3, the values were 22.65 ± 11.64 cm at 10 DAA and 26.05 ± 13.80 cm at 20 DAA.

From 30 DAA onwards, a significant difference was observed among treatments (P = 0.01845). Treatments F1 and F5 recorded significantly higher values (57.20 ± 5.44 cm and 53.15 ± 8.49 cm, respectively) than those observed with F2 (34.60 ± 13.30 cm) and F3 (34.65 ± 13.52 cm), while treatment F4 showed intermediate values (47.30 ± 7.92 cm).

This trend was maintained and became more pronounced at the subsequent stages (40, 50, and 60 DAA). At 60 DAA, the highest values were recorded for treatment F1 (63.60 ± 4.39 cm), followed by F5 (59.55 ± 4.16 cm), whereas treatments F2 and F3 remained significantly lower, with values of 43.45 ± 16.36 cm and 39.70 ± 11.85 cm, respectively. Treatment F4 remained intermediate (56.55 ± 6.12 cm). Overall mean plant height increased progressively from 19.94 to 52.57 cm between 0 and 60 DAA, reflecting a temporal increase in tomato plant height.

Table 3 illustrates the variation in tomato plant stem diameter over time under the different fertilizer treatments. A progressive increase in stem diameter was observed across all treatments throughout the experimental period. Before fertilizer application (0 DBA) and at 10 DAA, no significant differences were observed among treatments. From 20 DAA onwards, differences among treatments gradually emerged and became statistically significant. At 30 DAA, treatments F1 and F5 recorded the highest stem diameter values, followed by F4, whereas F2 and F3 exhibited the smallest diameters. This ranking among treatments was maintained through to 60 DAA. At 60 DAA, F1 recorded the highest stem diameter (10.0 mm), followed by F4 (9.3 mm) and F5 (8.5 mm), while F2 and F3 recorded lower values of 6.8 mm and 6.3 mm, respectively. Overall, the results indicate that fertilizer treatments progressively influenced tomato stem development as plant growth advanced, with F1 producing the greatest stem diameter at the end of the experimental period.

Effect of fertilization on yield and components

Table 4 presents the effects of the different fertilizer treatments on the total number of fruits (TNF), total fruit weight (TFW), and yield. Welch's analysis of variance (ANOVA) revealed a significant effect of fertilizer treatments on mean fruit weight, fruit number, and yield (P < 0.05). The Games–Howell post-hoc test showed a significant difference between treatments F5 and F2, whereas no other significant differences were observed among the treatments.

The total number of fruits (TNF) varied considerably among treatments, with the highest value recorded under F1 (662 ± 223), followed by F5 (419 ± 70) and F4 (308 ± 85). Treatments F2 (69 ± 33) and F3 (85 ± 58) recorded the lowest values.

A similar trend was observed for total fruit weight (TFW), which reached its highest value under F1 (22.49 ± 8.09 kg), followed by F5 (14.68 ± 2.52 kg) and F4 (10.35 ± 3.12 kg). The lowest total fruit weights were recorded under F2 (2.25 ± 1.11 kg) and F3 (2.66 ± 1.88 kg).

Yield followed the same pattern, with the highest value recorded under F1 (18.74 ± 6.74 t ha^{-1}), followed by F5 (12.23 ± 2.10 t ha^{-1}) and F4 (8.62 ± 2.60 t ha^{-1}). Treatments F2 (1.88 ± 0.93 t ha^{-1}) and F3 (2.22 ± 1.56 t ha^{-1}) resulted in the lowest yields. Overall, the results indicate that F1 produced the highest fruit number, total fruit weight, and yield, followed by F5 and F4, whereas F2 and F3 consistently showed the lowest performance across all yield-related parameters.

Taxonomic composition and abundance of insect pests observed in tomato plots

Table 5 presents the taxonomic composition of insect pests recorded on the tomato plots during this study. A total of three orders and four families of insect pests were recorded. The order Hemiptera was the most represented, including the piercing-sucking species *Bemisia tabaci* (whitefly) and *Aphis gossypii* (Aphididae), which were mainly observed on tomato plants. *Helicoverpa armigera* (Noctuidae) was the only lepidopteran species recorded; it is known to cause defoliation and fruit-boring damage. The order Diptera was represented by *Liriomyza* spp. Overall, piercing-sucking insects were the most abundant, with *B. tabaci* being predominant, accounting for 436 individuals.

Incidence of the whitefly (*Bemisia tabaci*)

Figure 5 shows the incidence (%) of *Bemisia tabaci* under the different treatments. The analysis of variance showed that the treatments had no significant effect on the incidence of *Bemisia tabaci* (p = 0.876). The highest incidences of *B. tabaci* were recorded in treatments F1 and F5, with infestation levels of 33.3%. Treatment F4

showed an intermediate incidence (28.3%), followed by F2 (26.7%). Treatment F3 exhibited the lowest incidence, with a value of approximately 21.7%, indicating the lowest level of infestation.

Effect of fertilization on the density of the whitefly (*Bemisia tabaci*)

Figure 6 presents the changes in the density of *Bemisia tabaci* (individuals/plant) at the floral initiation (35 DAT), flowering (50 DAT), and maturation (65 DAT) stages under the different treatments. A progressive decrease in the number of individuals per plant was observed across all treatments throughout the crop developpement. However, despite the numerical variations observed among treatments, no significant differences were detected ($p > 0.05$).

At 35 DAT, the highest densities were recorded for treatments F1 and F5 with approximately 5 individuals/plant. Treatments F2 and F4 showed intermediate densities, ranging from 3 to 3.5 individuals/plant, whereas the lowest density was observed for F3, with approximately 2 individuals/plant.

At 50 DAT, a marked decrease in *B. tabaci* density was observed across all treatments, with values below 1 individual/plant. Treatments F1 and F4 showed slightly higher densities than the other treatments, while F3 recorded the lowest density.

At 65 DAT, *B. tabaci* densities became very low across all treatments, approaching 0 individuals/plant. Overall, this trend indicates a progressive decline in the *B. tabaci* population as the crop progressed through its phenological stages, although no significant treatment effect was detected.

Severity of *Bemisia tabaci* Damage on Tomato According to the Fertilization Regime

Figure 7 presents the severity of *Bemisia tabaci* damage on tomato leaves as a function of fertilization. The treatments applied had no significant effect on the severity of *Bemisia tabaci* infestation ($p = 0.7224$). The severity of damage was observed in treatments F1, F4, and F5 with higher value in treatment F1 (2.3% of damaged leaves plant), followed by F5 (1.3% of leaves damaged). The treatment F4 recorded a lower severity with approximately 0.6% of damage recorded. No leaf damage caused by *B. tabaci* was observed in treatments F2 and F3.

Correlation between treatment and measured variables

Figure 8 presents the factorial map of the principal component analysis (PCA). The first two axes explain 90.6% of the total variance, with PC1 accounting for 76.5% and PC2 for 14.1%. PC1 is strongly associated with growth and yield parameters (plant height, collar diameter, number of branches, number of leaves, fruit weight, number of fruits, and yield), reflecting an agronomic performance gradient.

Treatments F1 and F5 are positively correlated with these variables, indicating better agronomic performance, whereas F2 and F3 are associated with lower levels of these variables, while F4 occupies an intermediate position. PC2 is mainly structured by pest densities, reflecting variability related to pest presence independently of growth and yield parameters. Overall, the PCA highlights a clear separation of the treatments according to their agronomic performance and their association with pest densities.

Effect of fertilization on soil chemical properties

The results obtained show that fertilizer applications did not lead to a significant improvement in soil chemical fertility. Analysis of the chemical parameters after the experiment indicated that nitrogen, phosphorus, and potassium contents remained low, despite a slight increase.

This suggests that the rates applied and/or the nature of the treatments were not sufficient to effectively correct the initial soil nutrient deficiencies during the experimental period. The combined treatments, particularly F4 and F5, showed slightly higher values, indicating a positive but limited effect of combining organic and mineral inputs.

This weak soil response may be explained by the highly alkaline nature of the soil, which limits the availability of certain nutrients, particularly phosphorus. Indeed, in soils with high pH, nutrients may be present but occur in forms that are less readily available for plant uptake (Brady and Weil, 2016). Furthermore, the relatively short duration of the experiment may have limited the full expression of the effects of the amendments, particularly organic amendments, whose mineralization and influence on soil properties generally occur gradually.

Figure.1 Location of the experimental site (Source: Tégaye et al., 2019)

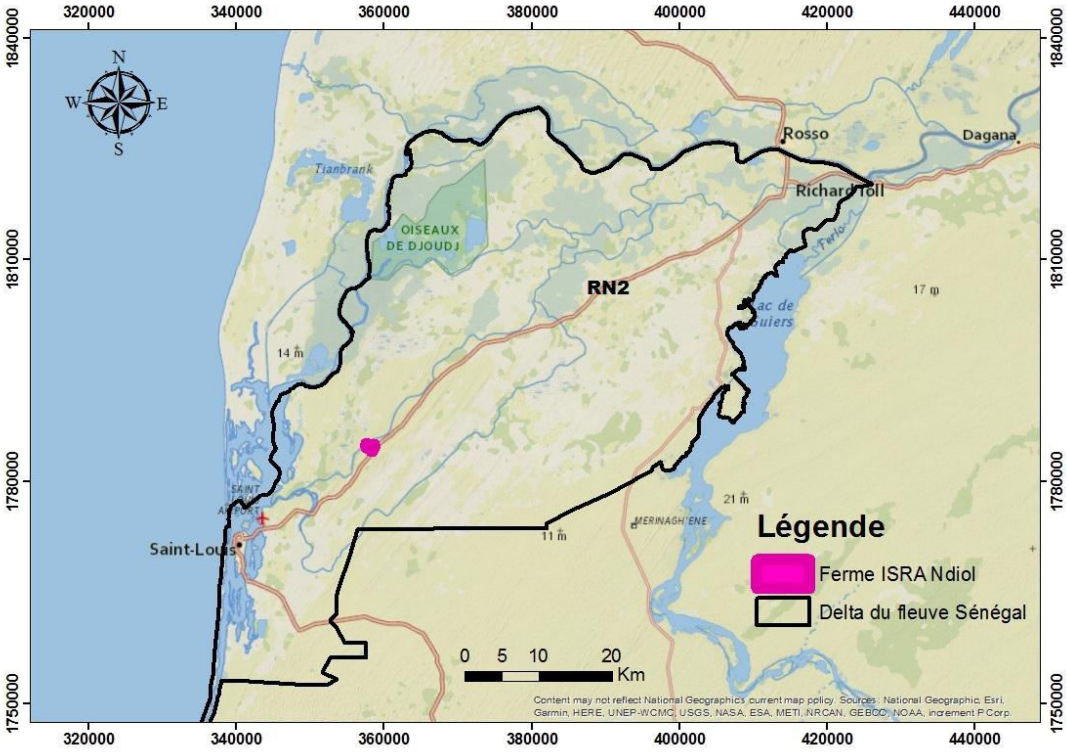
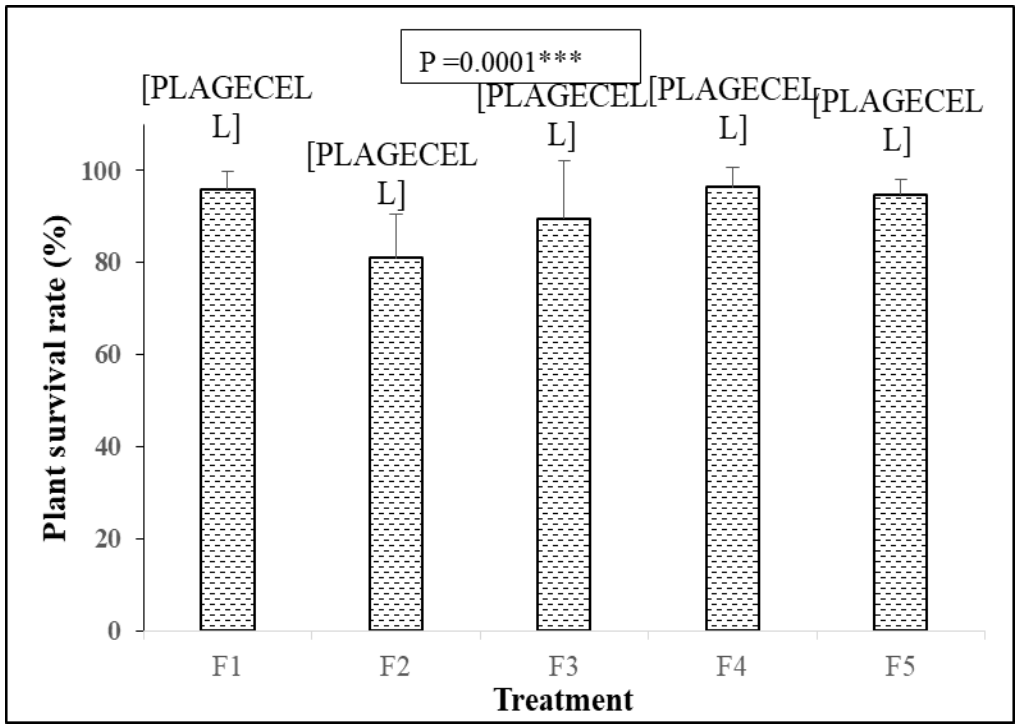
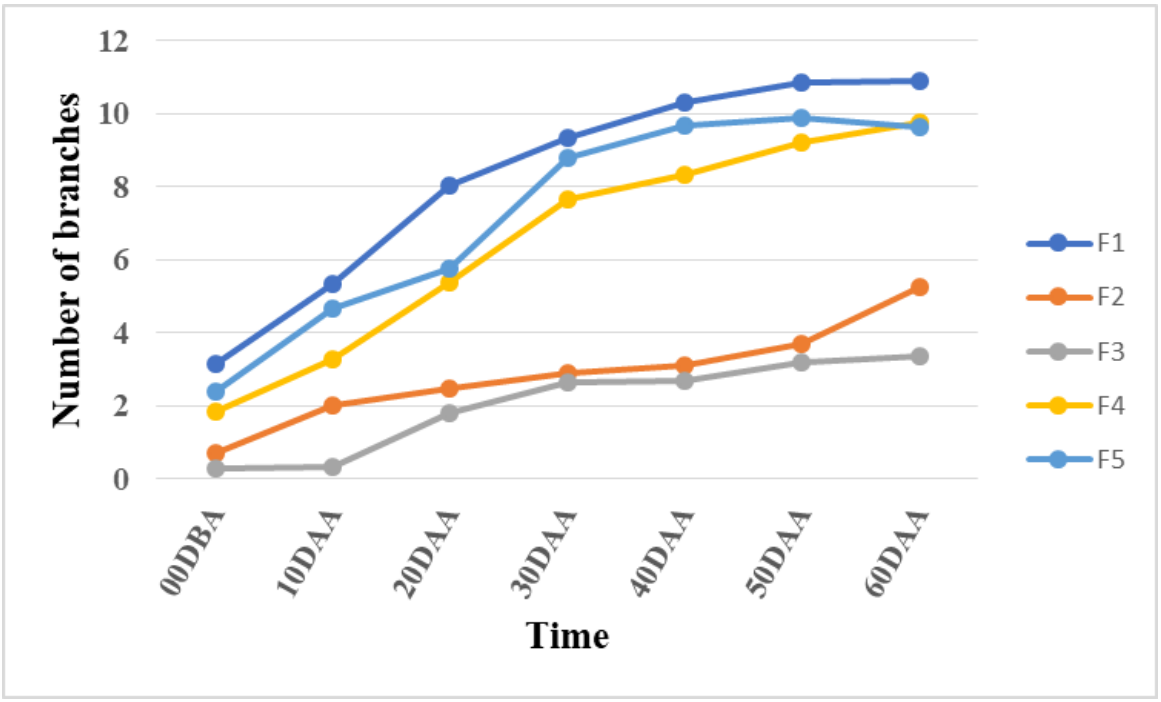


Figure.2 Effect of the treatments on the survival rate of tomato plants.



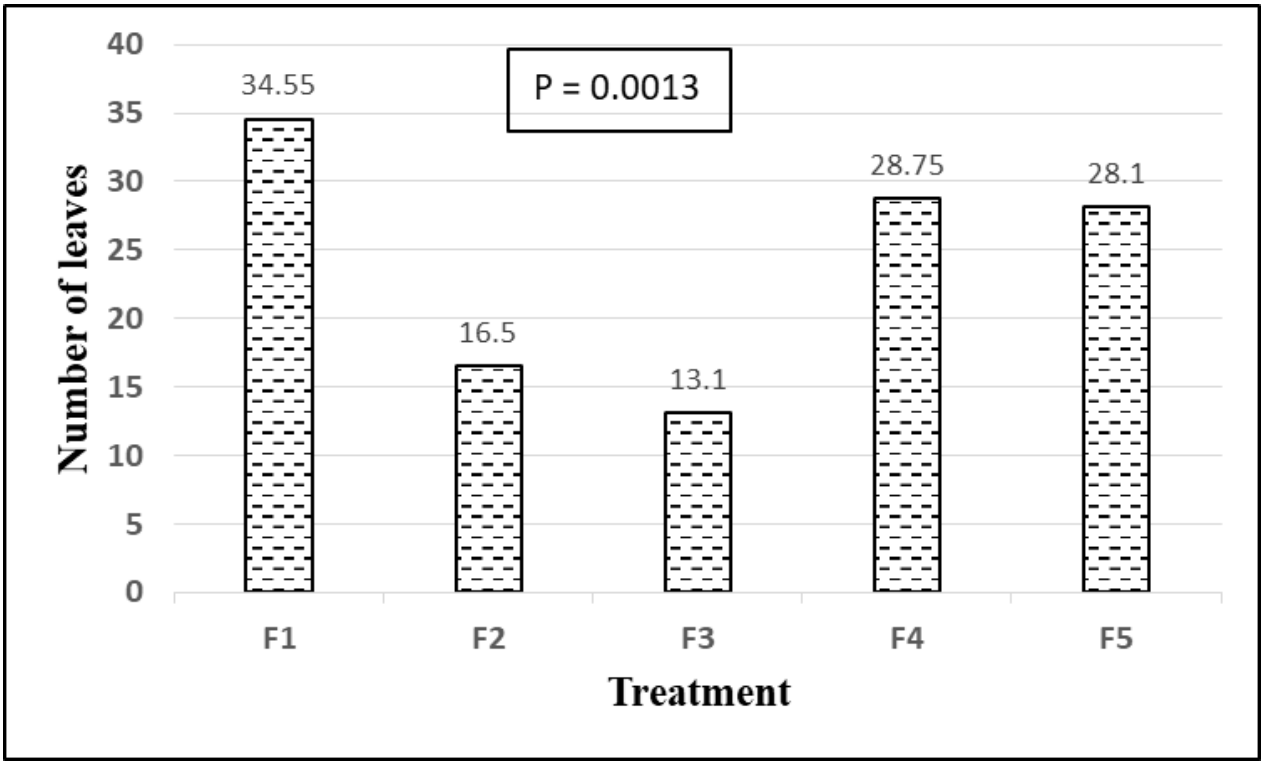
The values with same letters are not significantly different at probability level P=0.05. F1: Control; F2: BF2 Universel Min + Lithovit; F3: BF2 Universel Max + Lithovit; F4: 50% F1 + F2; F5: 50% F1 + F3.

Figure.3 Evolution of the number of branches according to the treatments



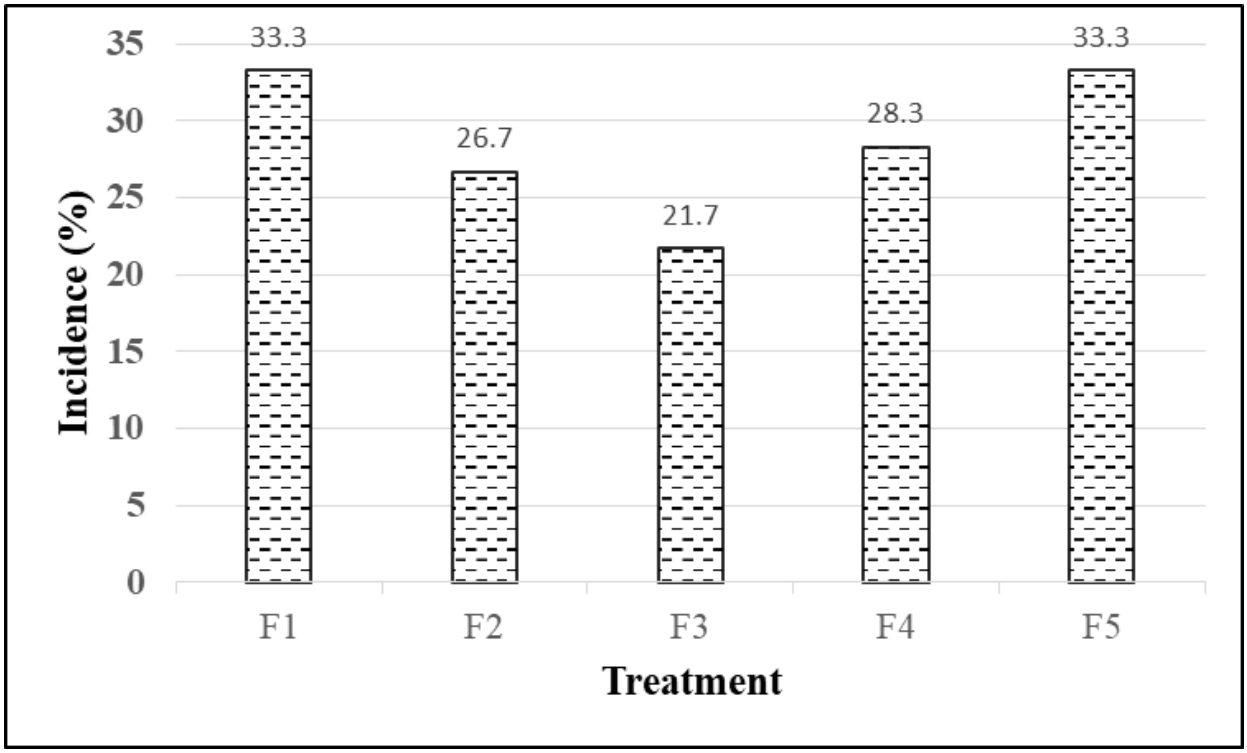
F1: Reference control; F2: BF2 Universal + Lithovit; F3: BF2 Universal Max + Lithovit; F4: 50% F1 + F2; F5: 50% F1 + F3.

Figure.4 Distribution of the number of leaves at 80 days after transplanting according to the treatments



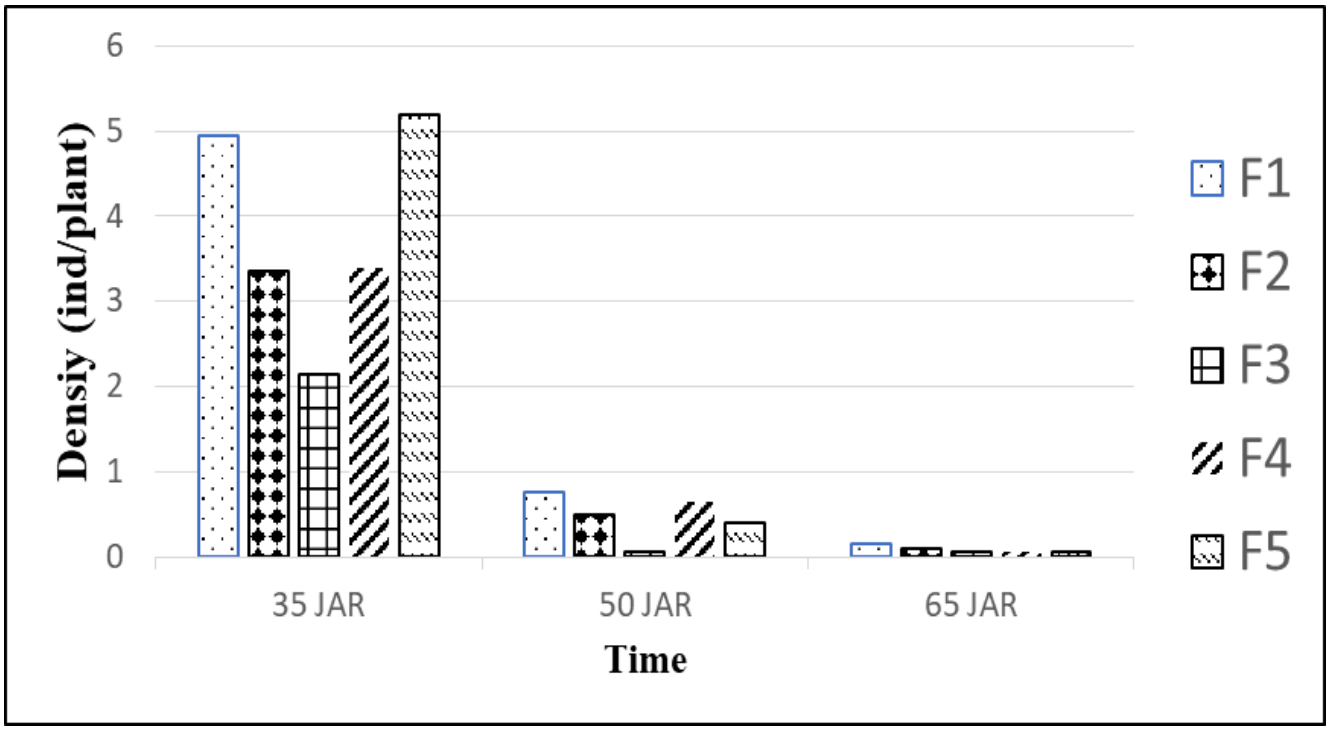
F1: Reference control; F2: BF2 Universal Min + Lithovit; F3: BF2 Universal Max + Lithovit; F4: 50% F1 + F2; F5: 50% F1 + F3.

Figure.5 Incidence of leaf damage caused by Bemisia tabaci according to the treatments



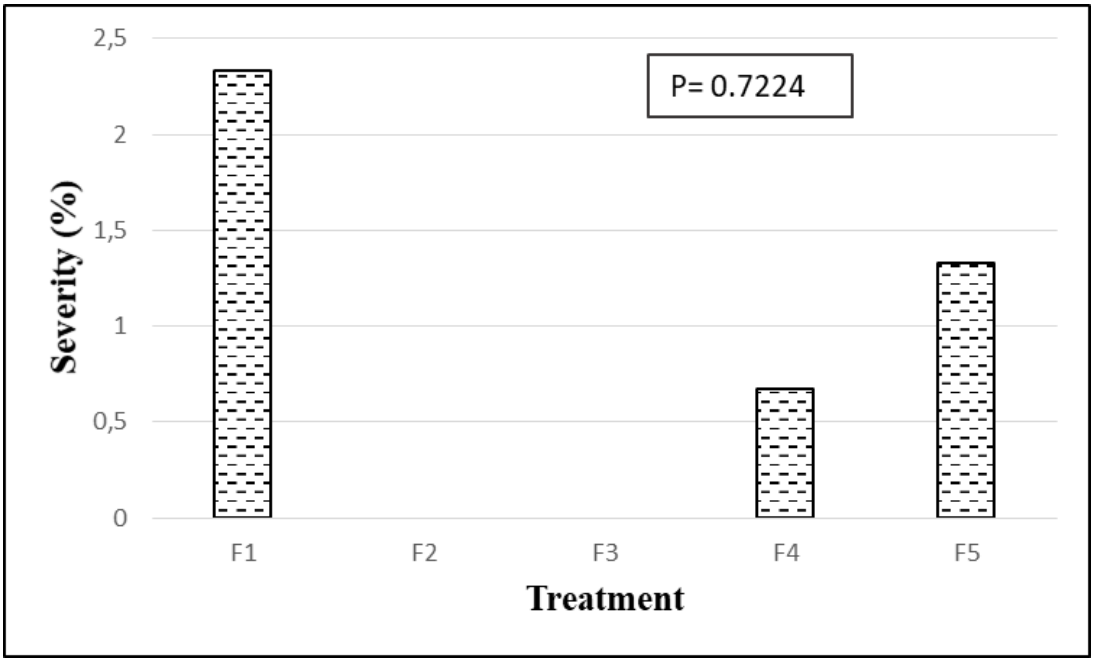
F1: Reference control; F2: BF2 Universal Min + Lithovit; F3: BF2 Universal Max + Lithovit; F4: 50% F1 + F2; F5: 50% F1 + F3

Figure.6 Temporal dynamics of Bemisia tabaci density under the different treatments.



F1: Reference control; F2: BF2 Universel Min+ Lithovit; F3: BF2 Universel Max + Lithovit; F4: 50% F1 + F2; F5: 50% F1 + F3.

Figure.7 Severity (%) of leaf damage caused by Bemisia tabaci according to the treatments



F1: Reference control; F2: BF2 Universal Min + Lithovit; F3: BF2 Universal Max + Lithovit; F4: 50% F1 + F2; F5: 50% F1 + F3.

Figure.8 Principal component analysis of the agro-morphological, production, and entomological variables according to the fertilization treatments

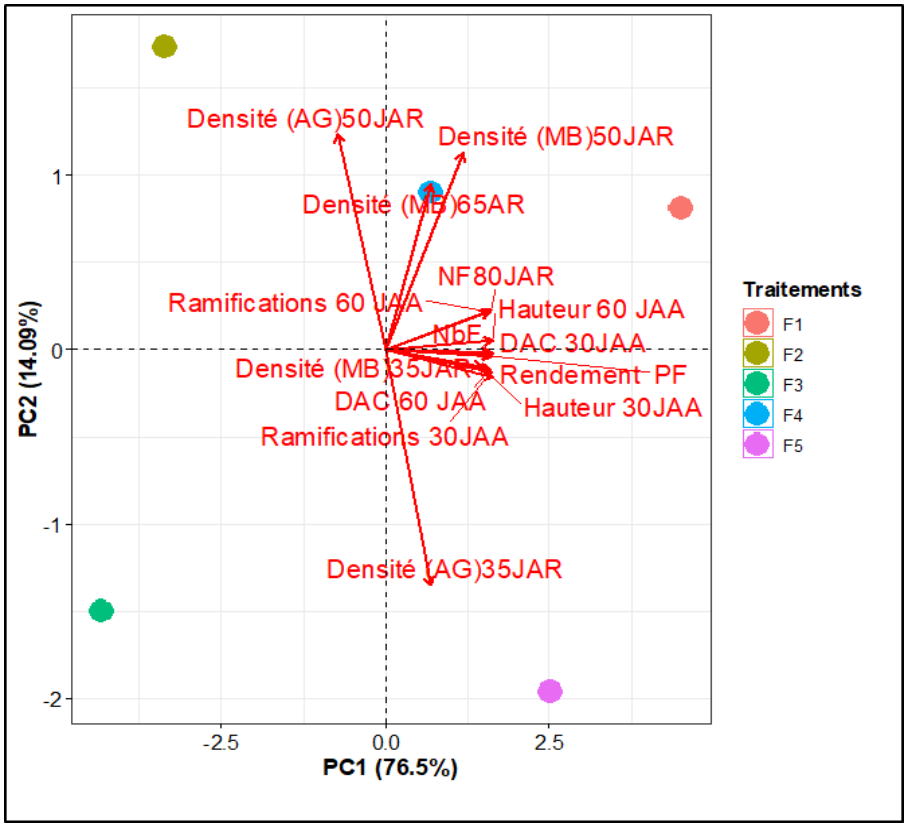


Table.1 Soil chemical analysis before transplanting and after harvest

Treatment	pH	N (mg/kg)	P (mg/kg)	K (mg/kg)
Initial soil	8.95	2.00	2.00	2.50
F1	9.15 ± 0.12[a]	2.50 ± 0.20[a]	2.62 ± 0.31[a]	3.25 ± 0.63[a]
F2	9.20 ± 0.19[a]	2.25 ± 0.43[a]	2.25 ± 0.43[a]	3.12 ± 0.55[a]
F3	9.05 ± 0.07[a]	2.12 ± 0.12[a]	2.25 ± 0.14[a]	2.75 ± 0.43[a]
F4	9.06 ± 0.10[a]	2.00 ± 0.54[a]	2.38 ± 0.77[a]	3.50 ± 1.14[a]
F5	9.15 ± 0.02[a]	2.62 ± 0.24[a]	2.62 ± 0.24[a]	3.25 ± 0.25[a]
General mean	9.12 ± 0.05	2.30 ± 0.15	2.42 ± 0.18	3.18 ± 0.27
p-value	0.713 ns	0.938 ns	0.531 ns	0.713 ns

Means followed by the same letter within a column are not significantly different according to Tukey's test at the 5% significance level. ns: not significant.

Table.2 Effect of fertilization on tomato plant height at different days before and after fertilizer application

Treatment	0 DBA	10 DAA	20 DAA	30 DAA	40 DAA	50 DAA	60 DAA
F1	24.70 ± 1.88a	41.10 ± 3.57a	45.70 ± 3.92a	57.20 ± 2.72b	61.05 ± 1.69c	62.85 ± 2.52b	63.60 ± 2.20b
F2	16.75 ± 1.62a	24.85 ± 5.86a	27.00 ± 6.28a	34.60 ± 6.65a	38.45 ± 7.37ab	42.65 ± 8.31ab	43.45 ± 8.18ab
F3	17.25 ± 2.15a	22.65 ± 5.82a	26.05 ± 6.90a	34.65 ± 6.76a	36.60 ± 6.10a	38.50 ± 5.63a	39.70 ± 5.93a
F4	19.65 ± 2.15a	31.20 ± 3.27a	35.45 ± 5.01a	47.30 ± 3.96ab	52.30 ± 3.34abc	54.60 ± 3.03ab	56.55 ± 3.06ab
F5	21.35 ± 1.76a	35.30 ± 4.13a	41.40 ± 3.82a	53.15 ± 4.25ab	58.85 ± 2.87bc	59.15 ± 2.04ab	59.55 ± 2.08ab
Grand mean	19.94 ± 1.91	31.02 ± 4.53	35.12 ± 5.19	45.38 ± 4.87	49.45 ± 4.27	51.55 ± 4.30	52.57 ± 4.29
P-value	0.0613 ns	0.0767 ns	0.0756 ns	0.0185*	0.0055**	0.0125*	0.0136*

Values are presented as mean ± standard error. Means followed by different lowercase letters within the same column are significantly different according to the statistical test used ($P < 0.05$). ns = not significant; * = significant at $P < 0.05$; ** = highly significant at $P < 0.01$. DBA = days before fertilizer application; DAA = days after fertilizer application.
F1: Reference control; F2: BF2 Universel Min + Lithovit; F3: BF2 Universel Max + Lithovit; F4: 50% F1 + F2; F5: 50% F1 + F3

Table.3 Variation in tomato plant stem diameter under the different fertilizer treatments.

Traitement	00DBA	10DAA	20DAA	30DAA	40DAA	50DAA	60DAA
F1	5.60 ± 0.57a	6.50 ± 0.70a	8.40 ± 0.56b	9.45 ± 0.61c	9.60 ± 0.63b	9.80 ± 0.55b	10.00 ± 0.54b
F2	3.35 ± 0.62a	4.45 ± 1.20a	5.20 ± 1.07a	5.65 ± 1.00ab	6.10 ± 0.90a	6.70 ± 1.15ab	6.80 ± 1.12ab
F3	4.05 ± 0.88a	4.10 ± 0.86a	4.75 ± 0.64a	5.05 ± 1.14a	5.85 ± 0.90a	6.10 ± 0.73a	6.35 ± 0.77a
F4	4.35 ± 0.56a	5.60 ± 0.54a	6.75 ± 0.54ab	7.85 ± 0.46abc	8.10 ± 0.50ab	8.70 ± 0.70ab	9.35 ± 0.74ab
F5	5.25 ± 0.55a	6.35 ± 0.79a	7.75 ± 0.43ab	8.80 ± 0.36bc	9.30 ± 0.31b	9.30 ± 0.41ab	10.05 ± 0.33b
General mean	4.52 ± 0.64	5.40 ± 0.82	6.57 ± 0.65	7.36 ± 0.72	7.79 ± 0.65	8.12 ± 0.71	8.51 ± 0.70
P-value	0.1507 ns	0.2140 ns	0.0074 **	0.0039 **	0.0031 **	0.0114 *	0.0050 **

Values are presented as mean ± standard error. Means followed by different lowercase letters within the same column are significantly different according to the statistical test used ($P < 0.05$). ns = not significant; * = significant at $P < 0.05$; ** = highly significant at $P < 0.01$. DBA = days before fertilizer application; DAA = days after fertilizer application.
F1: Reference control; F2: BF2 Universal Min+ Lithovit; F3: BF2 Universal Max + Lithovit; F4: 50% F1 + F2; F5: 50% F1 + F3.

Table.4 Variation in tomato yield parameters under the different fertilizer treatments

Treatment	Total fruit number/12 m²	Total fruit weight/12 m² (kg)	Yield (t ha⁻¹)
F1: Reference control	662 ± 223ab	22.49 ± 8.09ab	18.74 ± 6.74ab
F2: BF2 Universal Min + Lithovit	69 ± 33a	2.25 ± 1.11a	1.88 ± 0.93a
F3: BF2 Universal Max + Lithovit	85 ± 58ab	2.66 ± 1.88ab	2.22 ± 1.56ab
F4: 50% F1 + F2	308 ± 85ab	10.35 ± 3.12ab	8.62 ± 2.60ab
F5: 50% F1 + F3	419 ± 70b	14.68 ± 2.52b	12.23 ± 2.10b
General Mean	309 ± 68	10.48 ± 2.41	8.74 ± 2.00
P-value	0.0211*	0.0219*	0.0219*

Values are presented as mean ± SE. Values followed by the same letter within a column are not significantly different at the 5%; * = significant at $P < 0.05$

Table.5 Inventory of pest insects and their abundance

Order	Family	Species	Type	Abundance
Hemiptera	Aleyrodidae	*Bemisia tabaci*	Piercing-sucking insect	436
Hemiptera	Aphididae	*Aphis gossypii* spp.	Piercing-sucking insect	6
Lepidoptera	Noctuidae	*Helicoverpa armigera*	Fruit borer	1
Diptera	Agromyzidae	*Liriomyza spp.*	Leaf miner	*

**abundance could not be determined; the presence of Liriomyza spp. was confirmed based on characteristic leaf damage.*

These results are consistent with those of Kouakou *et al.,* (2025), who also observed limited changes in the physicochemical properties of soil following the application of organic and organo-mineral fertilizers in tomato cultivation. In contrast, Mounirou *et al.,* (2024) reported a more pronounced improvement in certain soil physicochemical characteristics following the application of organic and mineral fertilizers. This discrepancy may be related to differences in soil and climatic conditions, the nature of the amendments used, the application rates, and/or the initial characteristics of the soils studied.

Effect of fertilization on tomato plant survival

The plant survival rate was generally high across all treatments, indicating favorable conditions for crop establishment. This may be attributed not only to the selection of vigorous seedlings prior to transplanting but also to nursery production in plug trays. Several studies, including those by Kimuni *et al.,* (2014), Mimouni *et al.,* (2019), and Musas (2012), have shown that the establishment rates of Chinese cabbage, spinach, onion, and argan seedlings were similar in soils fertilized with NPK and various types of manure.

However, a decrease in survival was observed under treatment F2, which corresponded to the application of organic fertilizer alone at the lowest rate. This may be explained by the slower availability of nutrients supplied through organic fertilization alone, which could have limited the initial vigor of the plants, particularly following transplanting.

Effect of fertilization on growth and yield

The results obtained show a consistent response of the plants to the different treatments, both in terms of vegetative growth parameters and yield components. For all variables (plant height, collar diameter, number of branches, number of leaves, number of fruits per plant (NFP), fruit weight per plant (FWP), and yield), the same treatment ranking was observed. The highest values were recorded under treatment F1 (reference control), followed by the combined treatments F4 and F5, whereas treatments combining BF2 and Lithovit (F2 and F3) showed the lowest performance. This consistency indicates a close relationship between vegetative vigor and final productivity. The superiority of treatment F1 (reference control) can be explained by the immediate and balanced availability of nutrients readily assimilable by the roots, supplied by mineral fertilizers, particularly nitrogen, phosphorus, and potassium. Nitrogen plays an essential role in protein synthesis and cell division, thereby promoting stem elongation, leaf development, and branch formation. It rapidly stimulates aboveground growth, leaf expansion, and fruit set. The higher collar

diameter observed under F1 also reflects greater plant vigor and an increased ability to support a high fruit load, as reflected in the higher values for fruit number and fruit weight. These results are consistent with those of Kouakou *et al.,* (2025), Coulibaly *et al.,* (2022), who demonstrated the significant effect of mineral fertilization on tomato growth and productivity. Similarly, Alla *et al.,* (2021) showed that mineral fertilization resulted in the highest yields. However, these results do not agree with those of Boa *et al.,* (2022), who reported that, for growth parameters, mixed fertilizers produced higher values than compost and mineral fertilizers applied separately. The low performance observed under F2 (BF2 Min + Lithovit) and F3 (BF2 Max + Lithovit) confirms the limitations of predominantly organic fertilization in the short term. On the one hand, the gradual mineralization of organic matter supplied by BF2 does not always meet crop nutrient requirements during critical growth and fruiting stages, thereby limiting the expression of yield potential (Diacono & Montemurro, 2010; FAO, 2003). Increasing the organic fertilizer rate in F3 did not fully compensate for this limitation, suggesting that nutrient availability remained a limiting factor. On the other hand, Lithovit has a primarily physiological rather than nutritional role, as it does not constitute a significant source of major nutrients such as nitrogen, phosphorus, and potassium.

Although foliar fertilization can contribute to the improvement of certain physiological processes, it cannot replace balanced fertilization. The studies by Kouakou *et al.,* (2025) and Diaité *et al.,* (2020) support these findings, showing that organic fertilizers have limited effects on tomato growth. Furthermore, several studies have shown that Lithovit is generally used as a supplement to mineral or micronutrient fertilization rather than as a primary nutrient source (Soliman *et al.,* 2018). The combined treatments F4 and F5 produced intermediate results but were clearly superior to treatments F3 and F2. The combination of mineral and organic fertilization makes it possible to benefit from both the rapid effect of mineral fertilizers and the gradual effect of organic amendments. This approach contributes to improving plant growth and yield while reducing dependence on mineral fertilizers, representing an interesting compromise from the perspective of sustainability and rational input management (FAO, 2019; Vanlauwe *et al.,* 2010). These results are consistent with those of Soro (2022) and Yolou *et al.,* (2016), who reported that the application of combined fertilizers significantly improved tomato yield.

Effect of Fertilization on pests

The results show that fertilization differentially influenced the dynamics of insect pests. The piercing-sucking species *Bemisia tabaci* appeared to be more sensitive to the type of fertilization applied. The density, incidence, and severity of *Bemisia tabaci* were higher in treatments incorporating mineral fertilization (F1, F4, and F5). This trend may be explained by more vigorous vegetative growth and higher nitrogen content in plant tissues, making the plants more attractive to piercing-sucking insects (Altieri and Nicholls, 2003). Studies by Bi *et al.,* (2001), and Jauset *et al.,* (2000) have shown that high nitrogen inputs can promote the development of whitefly populations on tomato plants, due to improvements in the nutritional quality of the host plant (sap), on which piercing-sucking insects such as *Bemisia tabaci* strongly depend. The low impact of *B. tabaci* in treatments F2 and F3, which consisted of biofertilizers alone, could be related to the slower release of nutrients and more moderate vegetative growth, thereby limiting the attractiveness of the plants to this pest. Similar results have been reported in organic farming systems, where a reduction in the pressure of piercing-sucking pests has been observed (Bengtsson *et al.,* 2005).

In conclusion, this study aimed to evaluate the effect of biofertilizers, applied alone or in combination with mineral fertilization, on tomato growth, yield, and pest incidence, in comparison with the reference fertilization treatment. Soil analyses showed a moderate improvement in nutrient contents after the experiment, but also an increase in salinity, while soil pH remained high. This indicates that fertilization improved soil fertility but must be carefully managed to avoid negative effects in the long term. The agronomic results showed that fertilization had a significant effect on crop performance. The reference treatment (F1) produced the highest growth and yield values, followed by the combined treatments (F4 and F5), whereas the treatments consisting of biofertilizers alone (F2 and F3) showed the lowest performance. This confirms the close relationship between vegetative growth and productivity. Regarding pests, the whitefly *Bemisia tabaci* was more prevalent in the mineral and combined fertilization treatments, particularly at the beginning of the crop cycle.Overall, the reference fertilization treatment remained the most effective, but the combined fertilization systems (F5) appeared to be a promising alternative for reducing the use of chemical fertilizers while maintaining good crop performance. These findings highlight the potential of

integrated fertilization as a strategy for more sustainable agriculture.

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How to cite this article:

Baboucar Bamba; Maurice Dasylva; Aminata Tall; Rahimi Mballo and Mame Fatoumata Goudiaby. 2026. Comparative Assessment of Different Types of Organic and Mineral Fertilizers on the Performance of Tomato (*Solanum lycopersicum* L.) in the Senegal River Delta. *Int.J.Curr.Res.Aca.Rev.* 14(10), 1-15.
doi: https://doi.org/10.20546/ijcrar.2026.1410.001