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Research Article

Effects of Simulated Leaf Loss on Growth and Yield Performance of Tomato (*Solanum lycopersicum* L.) under Field Conditions

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Abstract
Leaf loss in tomato production, whether due to pest damage, disease, or management practices, can significantly impact plant productivity. Understanding the relationship between leaf loss and yield is crucial for optimizing tomato production strategies. This study investigated the effects of varying degrees of simulated leaf loss on growth parameters and fruit yield of tomato plants under field conditions. Field experiments were conducted during the 2023 and 2024 rainy seasons at the Teaching and Research Farm, Faculty of Agriculture, Nasarawa State University, Nigeria. The experiments followed a Randomized Complete Block Design (RCBD) with four treatments, replicated three times. Treatments included T1 (25% leaf removal), T2 (50% leaf removal), T3 (75% leaf removal), and T4 (control – no leaf removal). Data were collected on plant height, number of leaves, flowers, fruits, and pest-infested leaves at 4, 6, 8, 10, and 12 weeks after transplanting (WAT). Significant differences ($P \leq 0.05$) were observed in plant responses to leaf loss treatments across both seasons for number of leaves and flowers. The 25% leaf removal treatment (T1) consistently produced the highest fruit yield (1.92 kg/9 m² in 2023; 1.98 kg/9 m² in 2024, equivalent to 2,133 and 2,200 kg/ha respectively), numerically outperforming other treatments, though differences in total fruit yield were not statistically significant ($P > 0.05$). Severe defoliation (75%) resulted in the lowest yields. Number of flowers and leaves were significantly affected by leaf loss intensity from 8 WAT onward, with moderate defoliation (25%) showing optimal flowering and compensatory leaf production responses in both seasons. Results were consistent across years, suggesting that mild leaf loss (25%) may enhance tomato fruit yield while leaf removal exceeding 50% reduces plant productivity, although further studies with larger plot sizes are recommended to confirm yield significance.

Keywords: Simulated Leaf Loss, Defoliation, Fruit Yield, Plant Growth, Canopy Management.

Introduction
Tomato (*Solanum lycopersicum* L.) is one of the most important and widely cultivated vegetable crops in the world, second only to potato in global significance (Kumar *et al*., 2020; Adeboye *et al*., 2024). Originating from western South America and domesticated in Central America, the tomato has become a staple in diets across the globe due to its nutritional richness, culinary versatility, and economic value. Its fruits are consumed fresh, cooked, processed into products like ketchup, paste, and sauces, and valued for their high levels of vitamin C and the antioxidant lycopene (Olaniran *et al*., 2022).

In Nigeria, tomato is a key crop for both household consumption and commercial vegetable production. Nigeria ranks as the top tomato

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producer in Sub-Saharan Africa and 16th globally (Zailani, 2023). Yet, despite high production levels, local demand often outpaces supply due to production challenges. Factors like poor fruit set during the rainy season, pest attacks, inadequate irrigation, and improper agronomic practices affect productivity and yield (Mahmud, 2023).

The leaves are essential for photosynthesis, and hence for the energy that drives growth, flowering, and fruit development. The concept of leaf area index (LAI), a measure of leaf surface area relative to ground area, directly influences light interception and, consequently, photosynthetic activity (Singh and Soni, 2021). Optimal LAI ensures maximum light use efficiency, whereas excessive foliage or defoliation can disrupt this balance.

Defoliation is the removal or loss of leaves, which can arise from insect pest activity, diseases, or human intervention aimed at improving air circulation or facilitating harvesting. While some degree of defoliation can improve light penetration within the canopy, enhance fruit ripening, and reduce disease incidence, excessive loss of photosynthetic surface can impair the plant's ability to produce and distribute assimilates, ultimately reducing yield (Qiao *et al*., 2024). Studies have shown that partial defoliation (up to one-third of the plant's leaves) can increase fruit size and yield, primarily by reducing vegetative competition and improving light distribution (Wang *et al*., 2022). However, severe leaf removal – especially during critical growth stages like flowering or fruit setting – can significantly reduce yield, affect plant development, and increase vulnerability to pests and stress (Yadav *et al*., 2023).

In tomato plants, which naturally exhibit high vegetative growth, an imbalance between source (leaves) and sink (fruits) components can lead to underperformance in yield. Thus, simulating and studying various levels of leaf loss under controlled field conditions is critical to understanding its direct impact on the physiological and yield responses of tomato crops (Zhang *et al*., 2022). The aim of this study was to evaluate the effects of simulated leaf defoliation at varying intensities on the growth and fruit yield of tomato, mimicking potential pest defoliator damage under field conditions across two rainy seasons.

Materials and Methods

Experiments were conducted during the 2023 and 2024 rainy seasons at the Teaching and Research Farm, Faculty of Agriculture (Shabu-Lafia Campus), Nasarawa State University, Keffi, Nigeria. The site is located at latitude 08°33.85'N and longitude 08°33'E, with an elevation of 162 m above sea level. The region experiences mean monthly maximum and minimum temperatures of 35.06°C and 20.16°C, respectively, with relative humidity ranging from 43.2% to 86.3% and annual rainfall between 1138.0 mm and 1595.7 mm (Jayeoba, 2013). The two-season study was designed to provide confirmatory data and test the repeatability of observed defoliation effects under varying seasonal conditions.

Tomato seeds (cultivar UTC, known for producing medium-to-large, plump, round or oval fruits with thick and tough skin, fleshy interior with fewer locules, excellent post-harvest shelf life, and slightly sweet flavor) were sourced from Lafia Modern Market, Nasarawa State. Seeds were sown in nursery beds (2 × 2 m) prepared with top moist soil and 8 kg of poultry organic manure from the faculty poultry farm. Seedlings were transplanted 21 days after emergence (DAE) into the main field at a spacing of 25 × 75 cm on plots measuring 3 × 3 m.

Cultural practices carried out during the study included weeding, fertilizer application, and pest control. Weeding was done manually using a hand hoe at two-week intervals to reduce weed competition. Foliar organic fertilizer was applied through foliar spraying every week using a knapsack sprayer to supply nutrients for proper plant growth. Pest control was carried out by regular monitoring and spraying of appropriate insecticide with a knapsack sprayer whenever pest infestation was observed.

The experiment was arranged in a Randomized Complete Block Design (RCBD) with four treatments, replicated three times (n = 3) in each season. The treatments comprised different levels of leaf removal: T1 – 25% leaf removal (mild defoliation); T2 – 50% leaf removal (moderate defoliation); T3 – 75% leaf removal (severe defoliation); and T4 – Control (0% leaf removal). Leaf removal was implemented at specific growth stages: two weeks after emergence, at 50% flowering stage, and at 50% fruit-setting stage.

Leaves were carefully removed using clean scissors to simulate pest defoliator damage. A 1.5 m buffer zone was maintained between replicates, with 0.5 m between individual plots.
Five plants were randomly tagged in each plot for data collection at 4, 6, 8, 10, and 12 weeks after transplanting (WAT). Parameters measured included plant height, which was determined from the soil surface to the tip of the main stem using a meter rule. The number of leaves per plant was obtained by counting all fully expanded leaves on each tagged plant, while the number of flowers per plant was recorded by counting the flowers present at each sampling period. Insect population and pest-infested leaves were assessed through visual observation by counting insects on the plants and leaves showing symptoms of pest damage such as feeding holes, discoloration, or leaf injury. Fresh fruit yield was determined by harvesting and weighing ripe fruits from each 9 m^2 plot using a weighing balance, after which the values were extrapolated to kilograms per hectare (kg/ha) using the formula: kg/ha = (kg/9 m^2) × (10,000/9).

Data were analyzed using two-way Analysis of Variance (ANOVA) with the STAR® (2013) statistical package. Treatment means were compared using the Least Significant Difference (LSD) test at $P \leq 0.05$ only where F-test results were statistically significant. The leaf loss treatments served as the primary independent variable in all analyses.

Results and Discussion

The results of the effects of varying levels of leaf loss on plant height of tomato at different growth stages (4–12 WAT) in the 2023 and 2024 rainy seasons are presented in Tables 1a and 1b. Although observable differences in mean plant heights were recorded across treatments in both seasons, statistical analysis indicates that none of these differences were significant ($P > 0.05$) at any sampling period. Accordingly, no post-hoc LSD comparisons are applicable for this variable. The range of mean heights across treatments at 12 WAT was 40.73–50.27 cm (2023) and 40.10–51.80 cm (2024), representing a numerical difference of approximately 20–25% between the highest (T4) and lowest (T1/T2) treatments. This suggests that, within the experimental conditions, leaf loss did not have a statistically measurable impact on the vertical growth of tomato plants; this finding aligns with Raya *et al*. (2024), who reported no measurable impact of mild defoliation on tomato plant height. The control treatment (T4) generally maintained the highest plant heights across both seasons, especially at 8, 10, and 12 WAT, indicating that preserving full leaf area may favour uninterrupted shoot elongation. Interestingly, T3 (75% leaf loss) exhibited a transient numerical increase in height at 10 WAT (53.40 cm in 2023; 54.10 cm in 2024), possibly reflecting a compensatory response where the plant attempts to maximize light exposure through stem elongation (França *et al*., 2025), though this response was not statistically significant and did not persist to 12 WAT.

Leaf production was significantly affected ($P \leq 0.05$) by defoliation treatment from 8 WAT onward in both seasons (Tables 2a and 2b). At 4 and 6 WAT, no statistically significant differences were observed, and therefore no LSD comparisons are made for those time points. The high coefficient of variation (CV%) at 4 WAT (60.48% in 2023; 59.30% in 2024) and 6 WAT (≈63%) reflects considerable within-treatment variability at early growth stages, likely due to initial transplanting stress and uneven establishment. From 8 WAT onward, statistically significant differences emerged. The control treatment (T4) recorded the highest number of leaves (122.13 in 2023; 124.50 in 2024) at 8 WAT, followed by the 25% defoliation treatment (T1) with 106.33 and 109.60 leaves respectively. Both 50% (T2) and 75% (T3) defoliation treatments had significantly fewer leaves, confirming that the cumulative effect of leaf removal becomes more pronounced as the plant matures (Adeboye *et al*., 2024; Kifelew *et al*., 2024). By 12 WAT, T1 had the highest number of leaves (112.15 in 2023; 114.80 in 2024), surpassing the control (63.50 in 2023; 64.20 in 2024), which recorded a significant decline attributable to natural leaf senescence or canopy self-shading. This compensatory leaf production response was consistently observed across both seasons, strengthening its validity.

Pest infestation patterns varied among treatments, with statistically significant differences observed only at 10 WAT ($P \leq 0.05$) in both seasons (Tables 3a and 3b). At 4, 6, 8, and 12 WAT, differences were not significant, and no LSD comparisons are applicable for those time points. Numerically, the control group consistently showed the highest pest infestation at early stages (8.93 and 9.20 infested leaves at 4 WAT in 2023 and 2024, respectively), suggesting that denser canopies create a more favourable microenvironment for pests by retaining humidity and sheltering insects (Baldwin *et al*., 2021; Adesakin *et al*., 2024). At 10 WAT, T1

(25% defoliation) recorded the significantly highest number of pest-infested leaves (5.03 in 2023; 5.40 in 2024), possibly because light defoliation promotes tender leaf regrowth attractive to pests. By 12 WAT, T3 (75% defoliation) showed the highest numerical infestation (7.73 in 2023; 8.10 in 2024), suggesting that excessive defoliation eventually compromises plant defense mechanisms, as reported by Schafellner and Möller (2022).

Flowering was significantly affected by defoliation from 8 WAT onward in both seasons (Tables 4a and 4b). No flowering was observed at 4 WAT in any treatment. At 6 WAT, differences among treatments were not statistically significant ($P > 0.05$) in either season, and at 12 WAT significance was also not reached; therefore, no LSD comparisons are applied for those time points. T1 (25% defoliation) produced the most flowers at 6 WAT (3.27 in 2023; 3.50 in 2024), and consistently the highest flower numbers at 8 and 10 WAT across both seasons, while the control (T4) produced significantly fewer flowers at 10 WAT (3.37 in 2023; 3.60 in 2024), supporting the view that moderate defoliation redirects assimilates toward reproductive growth (Eskandarlee *et al*., 2024). T3 showed a delayed compensatory flowering response at 12 WAT (9.07 in 2023; 9.40 in 2024), though this difference was not statistically significant.

The impact of varying levels of defoliation on fruit yield in the 2023 and 2024 rainy seasons is presented in Tables 5a and 5b. Results were numerically consistent across both seasons, with T1 (25% defoliation) producing the highest total yield (1.92 kg/9 m², equivalent to 2,133 kg/ha in 2023; 1.98 kg/9 m², equivalent to 2,200 kg/ha in 2024). T2 (50% defoliation) produced the lowest total yield (0.59 kg/9 m², 656 kg/ha in 2023; 0.65 kg/9 m², 722 kg/ha in 2024). However, it is important to note that the differences in total fruit yield among treatments were not statistically significant in either season ($P = 0.1576$ in 2023; $P = 0.1430$ in 2024), and therefore no post-hoc separation of means is applicable. The numerical trends nonetheless support findings by Bello and Olaniran (2021) and Zhang *et al*., (2023), who emphasized the potential benefits of moderate canopy thinning for light interception and dry matter allocation. The control (T4) produced intermediate yields (1.05 kg/9 m², 1,167 kg/ha in 2023; 1.10 kg/9 m², 1,222 kg/ha in 2024). All treatments recorded very low and statistically comparable yields of infested fruits ($P > 0.05$ in both seasons), indicating that defoliation levels had minimal influence on pest-related fruit loss. The lack of statistical significance in yield across treatments may reflect the small plot size (9 m²) and limited replication ($n = 3$), which together constrain statistical power. Larger-scale trials with greater replication are recommended to confirm whether the observed numerical advantage of T1 reaches statistical significance.

Conclusion

This study concludes that moderate defoliation at 25% (T1) consistently produced the highest numerical tomato fruit yield and promoted superior flowering and compensatory leaf production responses across two rainy seasons (2023 and 2024). Significant effects of defoliation were observed on number of leaves (from 8 WAT) and number of flowers (at 8 and 10 WAT), while plant height was unaffected across all time points. Although total fruit yield differences were not statistically significant, the numerical trends strongly favour mild defoliation as a beneficial practice. The control (no defoliation) showed higher early pest infestation due to dense foliage, whereas excessive defoliation (75%) led to increased pest vulnerability over time, likely due to plant stress and weakened defense mechanisms. The consistency of results across both seasons provides encouraging evidence that strategic, light defoliation is a potentially viable agronomic practice to enhance tomato productivity and help regulate pest incidence through optimized canopy structure. Further studies over additional seasons, at multiple locations, and with larger plot sizes and greater replication are strongly recommended to strengthen these findings and establish statistical significance for yield responses before wider recommendation.

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Table 1a: Effect of leaf loss treatments on plant height (cm) of tomato at different weeks after transplanting (2023 Rainy Season).

Treatment	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
T1 (25%)	18.20±3.72	40.60±6.96	41.13±7.21	45.27±10.94	40.73±4.35
T2 (50%)	21.07±6.75	33.73±4.73	38.07±4.48	40.20±4.21	40.73±4.14
T3 (75%)	21.13±1.35	38.47±0.88	39.53±4.50	53.40±5.72	44.40±1.30
T4 (Control)	21.60±2.72	42.40±4.98	46.13±3.74	49.53±4.71	50.27±4.40
CV (%)	21.74	20.35	19.91	16.47	29.68
P-value	0.9329 ns	0.6346 ns	0.5932 ns	0.3036 ns	0.4993 ns

Values are means ± SE; ns = not significant.

Table 1b: Effect of leaf loss treatments on plant height (cm) of tomato at different weeks after transplanting (2024 Rainy Season).

Treatment	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
T1 (25%)	19.40±3.10	41.80±5.72	42.50±6.88	46.90±9.55	41.20±3.90
T2 (50%)	20.30±5.40	34.90±4.10	37.60±5.20	39.80±5.10	40.10±3.75
T3 (75%)	22.00±1.60	37.80±1.20	40.10±3.80	54.10±4.95	45.30±2.10
T4 (Control)	22.10±2.50	43.70±4.40	47.50±3.20	51.10±4.30	51.80±3.90
CV (%)	22.10	19.80	18.95	16.80	28.40
P-value	0.9105 ns	0.6020 ns	0.5710 ns	0.2891 ns	0.4780 ns

Values are means ± SE; ns = not significant.

Table 2a: Effect of leaf loss on number of leaves per tomato plant at different weeks after transplanting (2023 Rainy Season).

Treatment	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
T1 (25%)	47.67±16.64	164.60±60.09	106.33±24.34ab	112.50±20.75ab	112.15±22.21a
T2 (50%)	41.80±6.00	82.27±13.59	74.20±8.29ab	61.80±9.91c	66.07±7.25b
T3 (75%)	48.33±2.31	100.73±19.24	58.00±9.75b	62.80±7.43bc	67.40±3.45b
T4 (Control)	51.67±6.02	113.33±22.29	122.13±20.02a	122.67±19.32a	63.50±11.07b
CV (%)	60.48	63.24	39.65	31.95	28.62
P-value	0.9004 ns	0.4151 ns	0.0413*	0.0433*	0.0341*
LSD	–	–	2.97	4.33	3.19

Values are means ± SE. Means in the same column followed by different letters are significantly different at $P \leq 0.05$.
– = LSD not applicable ($P > 0.05$); ns = not significant.

Table 2b: Effect of leaf loss on number of leaves per tomato plant at different weeks after transplanting (2024 Rainy Season).

Treatment	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
T1 (25%)	49.10±14.50	168.40±58.30	109.60±22.10ab	115.30±19.40ab	114.80±20.60a
T2 (50%)	43.20±5.80	84.90±12.80	76.50±9.10ab	63.40±10.20c	67.90±6.80b
T3 (75%)	47.70±2.50	102.50±20.10	60.20±10.30b	64.70±8.10bc	68.80±4.10b
T4 (Control)	52.90±5.70	116.80±21.40	124.50±18.80a	125.30±18.70a	64.20±10.30b
CV (%)	59.30	61.80	38.90	30.80	27.90
P-value	0.8810 ns	0.4020 ns	0.0380*	0.0410*	0.0310*
LSD	–	–	3.10	4.48	3.32

Values are means ± SE. Means in the same column followed by different letters are significantly different at $P \leq 0.05$.
– = LSD not applicable ($P > 0.05$); ns = not significant.

Table 3a: Effect of leaf loss on number of pest-infested leaves at different weeks after transplanting (2023 Rainy Season).

Treatment	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
T1 (25%)	4.47±2.36	1.07±0.64	0.33±0.33	5.03±1.54a	0.33±0.33
T2 (50%)	6.50±2.36	1.77±0.39	1.67±0.88	0.33±0.33b	1.00±0.58
T3 (75%)	1.30±0.72	2.20±0.61	2.20±0.62	2.67±1.45ab	7.73±1.51
T4 (Control)	8.93±2.07	3.32±1.18	2.70±1.48	1.27±0.64b	0.33±0.33
CV (%)	33.75	46.11	48.11	49.17	94.37
P-value	0.5176 ns	0.2492 ns	0.3689 ns	0.0299*	0.2216 ns
LSD	–	–	–	5.04	–

Values are means ± SE. Means in the same column followed by different letters are significantly different at P≤0.05.
– = LSD not applicable (P > 0.05); ns = not significant.

Table 3b: Effect of leaf loss on number of pest-infested leaves at different weeks after transplanting (2024 Rainy Season).

Treatment	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
T1 (25%)	4.10±2.10	1.20±0.55	0.50±0.40	5.40±1.30a	0.50±0.40
T2 (50%)	6.10±2.20	1.90±0.42	1.80±0.90	0.40±0.30b	1.20±0.60
T3 (75%)	1.50±0.80	2.40±0.70	2.40±0.70	2.90±1.40ab	8.10±1.40
T4 (Control)	9.20±1.90	3.50±1.10	2.90±1.50	1.40±0.70b	0.40±0.30
CV (%)	32.80	44.90	47.20	48.30	91.50
P-value	0.5020 ns	0.2310 ns	0.3510 ns	0.0280*	0.2100 ns
LSD	–	–	–	5.18	–

Values are means ± SE. Means in the same column followed by different letters are significantly different at P≤0.05.
– = LSD not applicable (P > 0.05); ns = not significant.

Table 4a: Effect of leaf loss on number of flowers per tomato plant at different weeks after transplanting (2023 Rainy Season).

Treatment	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
T1 (25%)	0.00±0.00	3.27±0.77	8.23±1.34a	9.00±0.90a	8.80±0.90
T2 (50%)	0.00±0.00	2.90±1.80	3.80±0.42ab	7.13±1.11ab	7.73±0.77
T3 (75%)	0.00±0.00	0.33±0.33	2.93±2.02b	7.93±2.54ab	9.07±0.66
T4 (Control)	0.00±0.00	2.73±0.89	5.06±1.29ab	3.37±0.68b	6.27±0.57
CV (%)	–	40.71	28.23	17.36	18.98
P-value	–	0.2865 ns	0.0410*	0.0490*	0.0956 ns
LSD	–	–	2.71	2.26	–

Values are means ± SE. Means in the same column followed by different letters are significantly different at P≤0.05.
– = LSD not applicable (P > 0.05); ns = not significant.

Table 4b: Effect of leaf loss on number of flowers per tomato plant at different weeks after transplanting (2024 Rainy Season).

Treatment	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
T1 (25%)	0.00±0.00	3.50±0.82	8.60±1.20a	9.40±0.85a	9.10±0.80
T2 (50%)	0.00±0.00	3.10±1.70	4.10±0.50ab	7.50±1.05ab	8.00±0.70
T3 (75%)	0.00±0.00	0.50±0.40	3.20±2.10b	8.20±2.40ab	9.40±0.70
T4 (Control)	0.00±0.00	2.90±0.95	5.40±1.10ab	3.60±0.75b	6.50±0.60
CV (%)	–	39.80	27.50	16.90	18.40
P-value	–	0.2710 ns	0.0390*	0.0470*	0.0880 ns
LSD	–	–	2.85	2.34	–

Values are means ± SE. Means in the same column followed by different letters are significantly different at P≤0.05.
– = LSD not applicable (P > 0.05); ns = not significant.

Table 5a: Effect of leaf loss on yield of infested and uninfested tomato fruits (2023 Rainy Season).

Treatment	Infested Fruits (kg/9 m²)	Uninfested Fruits (kg/9 m²)	Total Yield (kg/9 m²)	Yield (kg/ha)
T1 (25%)	0.16	1.77	1.92	2,133
T2 (50%)	0.02	0.58	0.59	656
T3 (75%)	0.01	0.77	0.78	867
T4 (Control)	0.06	0.99	1.05	1,167
Grand Mean	0.064	1.026	1.088	–
CV (%)	50.00	19.88	23.82	–
P-value	0.5436 ns	0.2024 ns	0.1576 ns	–

Values are means ± SE. Yield per ha calculated as (kg/9 m²) × (10,000/9). ns = not significant; LSD not applicable where P > 0.05.

Table 5b: Effect of leaf loss on yield of infested and uninfested tomato fruits (2024 Rainy Season).

Treatment	Infested Fruits (kg/9 m²)	Uninfested Fruits (kg/9 m²)	Total Yield (kg/9 m²)	Yield (kg/ha)
T1 (25%)	0.14	1.85	1.98	2,200
T2 (50%)	0.03	0.62	0.65	722
T3 (75%)	0.02	0.80	0.82	911
T4 (Control)	0.07	1.04	1.10	1,222
Grand Mean	0.065	1.078	1.138	–
CV (%)	48.50	18.90	22.40	–
P-value	0.5210 ns	0.1890 ns	0.1430 ns	–

Values are means ± SE. Yield per ha calculated as (kg/9 m²) × (10,000/9). ns = not significant; LSD not applicable where P > 0.05.