Effect of Leaf Extracts of Selected Fallow Tree Species (*Gliricidia sepium, Leucaena leucocephala* and *Moringa oleifera*) on Growth and Yield Performance of Tomato (*Solanum lycopersicum* L.) in Jalingo, Taraba State, Nigeria

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DOI: https://doi.org/10.51244/IJRSI.2026.1311000109

Received: 08 November 2026; Accepted: 13 November 2026; Published: 25 November 2026

ABSTRACT

Tomato remains a staple vegetable and a major income crop in Taraba State, yet its yield in Nigeria, about 8.0 t/ha, is far below the global potential of 40-50 t/ha. Farmers in Jalingo cite two constraints: soils that have lost fertility after years of continuous cropping, and inorganic fertiliser that has become unaffordable, selling above ₦45,000 per bag in 2026. This preliminary, single-season trial examined whether a single crude aqueous leaf extract from three fallow tree species *Gliricidia sepium, Leucaena leucocephala* and *Moringa oleifera* could act as a foliar bio-stimulant for tomato, and which species showed the most promising response under local conditions. The experiment was conducted in the 2026 wet season at the Teaching and Research Farm, College of Agriculture, Science and Technology, Jalingo (08°53' N, 11°21' E). It was laid out in a Randomized Complete Block Design with three replications and four treatments: Tomato + Moringa (TM), Tomato + Gliricidia (TG), Tomato + Leucaena (TL) and Tomato + Control, water only (TC). One extract preparation (2 kg fresh leaves in 4 litres water) and one application rate (50 ml per plant every two weeks from 2 Weeks After Transplanting) were tested. Tomato variety Dan-Eka was used. No mineral-fertiliser treatment was included. Data were subjected to ANOVA for RCBD, and means were separated by Fisher's LSD at 5% where the overall F-test was significant. Differences were not significant at 2 WAT ($p = 0.119$) but were significant from 4 WAT onward ($p < 0.001$). At 12 WAT, the ranking was consistent: Moringa > Gliricidia > Leucaena > Control. Moringa gave 130.00 leaves, 3.14 cm stem girth, 17,090 cm² leaf area, earliest flowering (21.33 days), 43.67 fruits and 2,880 g fruit weight per plant, against 91.67 leaves, 2.42 cm girth, 13,750 cm² leaf area, 28.00 days to flowering, 23.67 fruits and 1,003 g in the control, an increase of about 187% in fruit weight. Gliricidia was tallest (168.60 cm), not significantly different from Moringa (155.10 cm). Leucaena was still better than control but consistently weakest. Post-harvest soil values differed numerically among plots, but these are reported descriptively and are not interpreted as a direct effect of foliar spraying on soil, since sprays were not applied to soil. The results suggest that, under these specific conditions and compared only with a water control, aqueous Moringa leaf extract showed the most promising bio-stimulant response. The study does not demonstrate that extracts can replace mineral fertiliser, and does not support a recommended concentration. Multi-season, multi-location, multi-rate trials including an NPK comparison and economic analysis are required before any recommendation.

Keywords: Bio-stimulant; Fallow species, Moringa oleifera, Foliar spray, Tomato, Preliminary trial

1. INTRODUCTION

Tomato (*Solanum lycopersicum L.*) is not a luxury crop in Taraba State. It is a daily soup, it is market income, and for many households in Jalingo, Zing, Takum, Ussa, Bali and Gassol, it is the difference between getting by and falling behind. Nutritionally, it is valued for lycopene, vitamins A and C, potassium and folate (1). Yet

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue XI November 2026

the average yield in Nigeria remains around 8.0 t/ha, while Egypt records about 45 t/ha and the United States up to 80 t/ha (2).

Any farmer in Jalingo can explain the gap without a textbook. The soil is tired. Years of continuous cropping, removal of residues and erosion have left the sandy loam soils acidic and low in organic matter, nitrogen and phosphorus. The obvious remedy, NPK fertiliser, has moved out of reach for most smallholders. When this work was conceived, a bag sold for more than ₦45,000. Attention therefore turned to what is already around us. Fallow lands in Taraba are colonised by woody perennials that farmers usually cut and burn without a second thought. Three dominate: Gliricidia sepium, Leucaena leucocephala and Moringa oleifera.

The literature paints them very differently. Moringa is now widely recognised as a natural bio-stimulant, rich in zeatin, a cytokinin, plus auxins, ascorbate, minerals and protein (3,4). Recent work confirms this: Bari et al. (5) found that 6% Moringa leaf extract significantly increased tomato leaf number, height, fruit size and chlorophyll content, while 9% increased branching; Ngcobo et al. (6) showed that all forms of Moringa leaf extract, especially hot-water extract, significantly enhanced growth, yield, lycopene and β-carotene in tomato; and Abdelhameed et al. (7) demonstrated in 2025 that aqueous Moringa extract not only promoted tomato seedling growth but also reduced oxidative damage under salt stress. Mashamaite et al. (12) reviewed Moringa leaf extract as a bio-stimulant to supplement synthetic fertilisers, and concluded that it shows promise but that evidence on optimal rates and mechanisms remains incomplete.

Gliricidia is a nitrogen-fixing legume. A recent review by Alamu and Adesokan (8) confirms that it improves soil fertility indicators through nitrogen fixation and rapid litter decomposition, and that its biomass, especially when combined with manure, releases mineral nitrogen quickly. Earlier field work in Ghana also showed that 50% Gliricidia biomass + 50% NPK gave 22.4 t/ha of tomato against 12.1 t/ha in control (9). That study included NPK. The present study did not.

Leucaena is the complicated one. It is high in protein and nitrogen, but it is also listed among the world's 100 worst invasive alien species (10). Its leaves, seeds and roots accumulate mimosine (0.11–6.4% dry weight), phenolic acids and flavonoids (10). Mimosine blocks cell division between G1 and S phases and disturbs peroxidase, catalase and IAA oxidase activity (10). Pires et al. (11) showed its seed leachate reduced tomato radicle growth by 90%. Yet at low dose, other workers found it stimulatory. This dose-dependence is at the heart of the present study, but it cannot be resolved with a single dose.

Most earlier Nigerian studies worked with biomass incorporation, not with a simple water extract that a farmer can prepare at home. None, to our knowledge, had compared these three species side-by-side under the same conditions in North-Eastern Nigeria, using the same preparation and application method.

Objectives:

1. Determine the effect of Gliricidia, Leucaena and Moringa leaf extracts on vegetative growth of tomato (plant height, number of leaves, stem girth, leaf area and leaf area index) under the conditions tested.

2. Evaluate their effect on reproductive and yield traits (days to flowering, number of fruits, fruit weight and relative growth rate) compared with a water control.

3. Compare their stimulatory or inhibitory effects and identify the most promising species for Jalingo, as a basis for further trials.

Hypotheses:

H_0: Leaf extracts have no significant effect on growth and yield of tomato.

H_1: Leaf extracts have significant effect on growth and yield of tomato.

Scope: This is a preliminary trial limited to one location, one wet season (2026), one tomato variety (Dan-Eka), one extract preparation, one application rate, and three replications. No mineral-fertiliser treatment was applied. Results are therefore site- and season-specific.

2. MATERIALS AND METHODS

2.1 Study Area and Dates

The trial was conducted in the 2026 wet season at the Teaching and Research Farm, College of Agriculture, Science and Technology, Jalingo, Taraba State. Jalingo lies in the Northern Guinea Savanna (08°53' N, 11°21' E, 349 m above sea level), with a wet season from July to November, mean annual rainfall of 800-1,500 mm, mean temperature of 27–35°C, and sandy loam soil that is moderately acidic (pH 5.5-6.5) and low in organic matter.

Seeds of tomato variety Dan-Eka, sourced from the National Horticultural Research Institute (NIHORT), Ibadan, were sown in nursery on 13 July 2026. Germination was observed after 7 days, on 20 July 2026.s The tomato seedlings were transplanted on 3 August 2026, that is, two weeks after germination. Final harvest was completed by late October 2026, at 12 Weeks After Transplanting (12 WAT). Rainfall during the trial period was within the long-term range for Jalingo (800-1,500 mm), and the trial was rain-fed.

2.2 Experimental Design, Randomisation and Experimental Unit

A Randomized Complete Block Design (RCBD) with three replications was used. There were 12 plots, each 2 m × 3 m, separated by 0.5 m within blocks and 1 m between blocks. Each plot had 24 stands at 50 cm × 50 cm, giving 288 plants in total.

Treatments were randomly assigned independently within each block by lottery method. Blocks were laid perpendicular to the observed fertility / drainage gradient.

Five plants in the net plot were tagged for measurement to avoid border effects. The experimental unit was the plot, not the plant. The plot mean of the five tagged plants was used as one observation in ANOVA. Plants within a plot are subsamples, not replications.

Treatments: TG = Tomato + *Gliricidia sepium* extract; TL = Tomato + *Leucaena leucocephala* extract; TM = Tomato + *Moringa oleifera* extract; TC = Tomato + Control.

2.3 Preparation and Application of Extracts

Fresh leaves were collected from fallow lands in Jalingo LGA. For each species, 2 kg of fresh leaves were pounded, soaked in 4 litres of clean water, stirred for about 25 minutes and filtered through muslin cloth. The filtrate, the crude extract, was used within five hours of preparation as a precaution by the authors to limit fermentation.

It was sprayed to foliage only (whole plant) at 50 ml per plant every two weeks, starting from 2 WAT until fruiting, using a knapsack sprayer in the early morning (7:00-9:00 am) to reduce evaporation and drift.

No extract was applied directly to soil. Any spray reaching soil was incidental drift/drip-off only. The control (TC) was sprayed with water only, at the same volume, timing and method, to control for the effect of wetting.

This is a single-dose comparative study. Only one extract preparation and one application rate were tested. A graded dose-response trial was not part of this phase. Therefore no dose-response curve, no optimal concentration and no concentration recommendation can be made.

No mineral fertiliser was applied to any plot. Therefore this trial cannot compare extracts with fertiliser, and cannot support claims about extracts supplanting or replacing fertiliser.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue XI November 2026

2.4 Planting and Management

The field was ploughed and harrowed with a tractor before layout. Weeding was manual every two weeks. The nursery was watered with a watering can; the field trial was rain-fed. The field was monitored for pests and diseases throughout. No pesticide was applied.

2.5 Data Collection

Soil samples (0-20 cm) were collected before planting and after harvest and analysed for texture (Bouyoucos, 1951), pH (1:2.5 soil/water), organic carbon (Walkley & Black, 1934), total nitrogen (micro-Kjeldahl), available phosphorus (Olsen et al., 1954), exchangeable bases (AAS/flame photometry) and micronutrients (AAS).

Soil sampling: Before planting, one composite sample was taken from 12 cores across the experimental area. After harvest, one composite sample was taken per treatment from 3 cores per plot bulked by treatment. Soil data therefore have no replication at treatment level and are reported descriptively only, with no ANOVA or LSD.

Growth and yield traits: plant height (tape, base to tip), number of leaves (count), stem girth (vernier caliper at 5 cm above soil), leaf area (length × width × 0.75), leaf area index (LAI = leaf area × number of leaves / ground area), days to first and 50% flowering, number of fruits, fresh fruit weight (g), and relative growth rate RGR = (lnW2 – lnW1) / (t2 – t1) after Williams (13).

2.6 Statistical Analysis

Data were subjected to ANOVA for RCBD: $Xij = \mu + Ti + \beta j + \varepsilon ij$, where Xij = observation, μ = overall mean, Ti = treatment effect, βj = block effect and εij = error.

Means were separated by Fisher's LSD at 5% only where the overall F-test was significant. Results are reported as Mean ± Standard Error (SE) with exact p-values. SE was calculated as $\sqrt{(MSE / r)}$, where r = 3 replications. Block effect was not significant for any trait ($p > 0.05$) and is therefore not presented in detail; full block statistics are available on request.

ANOVA summary of main traits (Treatment df = 3, Error df = 6, Block df=2, Total df = 11):

Trait	MS Treatment	Block df	MS Error	F-value	p-value
Plant height 12 WAT (cm)	1,985.28	2	61.83	32.11	< 0.001
Number of leaves 12 WAT	868.93	2	0.15	5,792.87	< 0.001
Stem girth 12 WAT (cm)	0.33	2	0.001	330	< 0.001
Leaf area 12 WAT (cm²)	6,791,594.00	2	25,493.88	266.4	< 0.001
Days to first flowering	24.36	2	0.08	289.01	< 0.001
Days to 50% flowering	39.7	2	0.67	59.64	< 0.001
Number of fruits/plant	232	2	–	–	< 0.001
Fruit weight (g/plant)	2,376,209.00	2	16.85	141,059.49	< 0.001
RGR 10–12 WAT	0.00004	2	0.0000002	179.62	< 0.001

MS= Mean square. F=MS treatment/MS error. Total df (11) = treatment df (3) +Block df (2) +Error df (6)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue XI November 2026

3. RESULTS

3.1 Soil Response Descriptive and Qualified

After one season, the control plot was numerically worse than at the start: pH fell from 5.4 to 5.2, organic carbon from 0.82% to 0.78%, nitrogen from 0.08% to 0.07%. All extract plots showed numerically higher values than the control. Moringa plots showed the highest numerical values: moisture 12.8%, pH 6.1, organic carbon 1.24%, organic matter 2.13%, total N 0.15%, available P 11.20 mg/kg and ECEC 5.21 cmol/kg. Gliricidia and Leucaena followed in that order. Texture remained sandy loam in all plots.

Interpretation: These differences must not be presented as proof that foliar spraying improved soil. Foliar sprays were not applied to soil. The amount of material applied was also far too small to explain the soil differences by direct addition alone. About "150 g" of crude extract per plant in total over a season, equivalent to about "1.5 t/ha" of dilute extract, whereas raising soil organic carbon by 0.42 percentage points in the top "20 cm" would require about "19 t/ha" of dry organic matter. Plausible indirect pathways incidental drip-off/drift, fallen leaves, root turnover may have contributed, but were not measured. Differences may also reflect pre-existing spatial variation. Soil results are therefore associative and descriptive.

Table 1: Pre-planting and post-harvest soil properties (descriptive, single composite per treatment)

Parameter	Initial	Control	Moringa	Gliricidia	Leucaena
Moisture (%)	8.6	9.2	12.8	11.9	11.3
pH (H_2O)	5.4	5.2	6.1	5.9	5.7
Organic carbon (%)	0.82	0.78	1.24	1.15	1.08
Organic matter (%)	1.41	1.34	2.13	1.98	1.86
Total N (%)	0.08	0.07	0.15	0.13	0.12
Available P (mg/kg)	6.45	5.8	11.2	10.05	9.1
K (cmol/kg)	0.18	0.16	0.29	0.26	0.24
Ca (cmol/kg)	2.45	2.3	3.1	2.95	2.8
Mg (cmol/kg)	0.84	0.79	1.12	1.05	0.99
ECEC (cmol/kg)	4.21	3.98	5.21	4.96	4.73
Fe (mg/kg)	28.4	27.9	32.5	31.2	30.4
Zn (mg/kg)	0.45	0.42	0.68	0.62	0.57

Source: Experimental data, 2026. Note: Descriptive only no replication, no statistical test.

3.2 Vegetative Growth

At 2 WAT, plant height was statistically similar (18.53-18.67 cm, $p = 0.119$ ns). From 4 WAT onward, differences were significant ($p < 0.001$). At 12 WAT, Gliricidia (168.60 cm) was tallest, not significantly different from Moringa (155.10 cm), which was also not significantly different from Leucaena (152.33 cm); Gliricidia was significantly taller than Leucaena. Control (109.23 cm) was significantly shortest.

Table 2: Plant height (cm) Mean ± SE

WAT	Control Moringa	Gliricidia	Leucaena	LSD (0.05)	p-value
2	18.53a ± 0.03	18.57a ± 0.03	18.67a ± 0.03 18.57a ± 0.03	0.12	0.117 ns
4	32.53d ± 0.09	34.70a ± 0.09	33.90b ± 0.09 32.90c ± 0.09	0.31	< 0.001
6	46.67d ± 0.16	52.77a ± 0.16	51.27b ± 0.16	0.54	< 0.001

			48.37c ± 0.16		
8	75.70d ± 0.28	90.17a ± 0.28	86.77b ± 0.28 78.80c ± 0.28	0.97	< 0.001
10	81.80c ± 6.82	143.57a ± 6.82 139.37a ± 6.82	114.07b ± 6.82	23.59	0.002
12	109.23c ± 4.54	155.10ab ± 4.54 168.60a ± 4.54	152.33b ± 4.54	15.71	< 0.001

Source: Experimental data, 2026. Means followed by same letter(s) within a row are not significantly different at 5% by Fisher's LSD. ns = not significant (p > 0.05).

Note on 10 WAT: The larger LSD and SE at 10 WAT reflect increased variability at later growth stages.

Number of leaves: Moringa 130.00 > Gliricidia 120.00 > Leucaena 103.67 > Control 91.67 at 12 WAT. Stem girth: Moringa (3.14 cm) > Gliricidia (3.00 cm) > Leucaena (2.64 cm) > Control (2.42 cm). Leaf area and LAI at 12 WAT: Moringa 17,090 cm² / 6.80 > Gliricidia 16,083 / 6.39 > Leucaena 14,533 / 5.75 > Control 13,750 / 5.47.

Table 3: Number of leaves, stem girth, leaf area and LAI at 12 WAT-Mean ± SE

Treatment	No. of Leaves	Stem Girth (cm)	Leaf Area (cm²)	LAI
Control	91.67d ± 0.23	2.42d ± 0.02	13,750d ± 92.18	5.47d ± 0.01
Moringa	130.00a ± 0.23	3.14a ± 0.02	17,090a ± 92.18	6.80a ± 0.01
Gliricidia	120.00b ± 0.23	3.00b ± 0.02	16,083b ± 92.18	6.39b ± 0.01
Leucaena	103.67c ± 0.23	2.64c ± 0.02	14,533c ± 92.18	5.75c ± 0.01
LSD (0.05)	0.78	0.07	319	0.03
F-value	5792.87	330	266.40	3643.33
CV (%)	0.35	1.13	1.04	0.28
p-value	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

Source: Experimental data, 2026. Means followed by same letter(s) within a column are not significantly different at 5% by Fisher's LSD. CV= Coefficient of variation

3.3 Reproductive and Yield Traits

Moringa flowered earliest: 21.33 days to first flowering and 27.33 days to 50% flowering, against 28.00 and 36.00 days in control. At 12 WAT, Moringa gave 43.67 fruits and 2,880 g per plant, Gliricidia 37.67 fruits and 2,763 g, Leucaena 29.67 fruits and 2,684 g, while control gave 23.67 fruits and 1,003 g. Relative growth rate declined with age in all treatments, but Moringa maintained the highest RGR at every interval (0.126 at 2-4 WAT to 0.018 at 10-12 WAT, vs 0.009 in control).

Table 4: Flowering, fruit number, fruit weight and RGR Mean ± SE

Treatment	Days to First Flowering	Days to 50% Flowering	No. of Fruits/Plot	Fruit Weight (g/Plant)	RGR (10–12 WAT)
Control	28.00d ± 0.17	36.00d ± 0.47	23.67d ± 0.53	1,003d ± 2.37	0.009d ± 0.0003

Moringa	21.33a ± 0.17	27.33a ± 0.47	43.67a ± 0.53	2,880a ± 2.37	0.018a ± 0.0003
Gliricidia	23.33b ± 0.17	30.33b ± 0.47	37.67b ± 0.53	2,763b ± 2.37	0.015b ± 0.0003
Leucaena	25.33c ± 0.17	32.33c ± 0.47	29.67c ± 0.53	2,684c ± 2.37	0.012c ± 0.0003
LSD (0.05)	0.58	1.63	–	8.2	0.001
p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Source: Experimental data, 2026. Means followed by same letter(s) within a column are not significantly different at 5% by Fisher's LSD.

4. DISCUSSION

4.1 Why the Soil Values Differed A Qualified Interpretation

The numerically higher soil values cannot be explained by the amount of material applied, however, this is not evidence that foliar spraying improved soil. Sprays were not applied to soil, soil was not replicated at baseline per plot, and indirect pathways were not measured. The soil data are therefore presented as associative, not causal.

4.2 Why Growth Improved and Why There Was a Lag

The non-significant result at 2 WAT ($p = 0.119$) is physiologically plausible. Seedlings at that stage depend more on seed reserves than on external sprays. From 4 WAT, the bio-stimulant effect became pronounced. The zeatin in Moringa is reported to promote cell division and elongation and delay senescence by retaining chlorophyll (3,4). This is supported by Bari et al. (5) and Ngcobo et al. (6), who both reported significant increases in leaf number, height and chlorophyll with Moringa extract. Gliricidia's superiority in height at 12 WAT is consistent with its high nitrogen content and fast mineralisation (8,9).

Qualification: Zeatin, auxin and mimosine were not measured in this study. Physiological explanations are therefore inferential from literature, not demonstrated by this trial.

Stem girth matters in Jalingo, where wind and heavy rain cause lodging. That Gliricidia tallest (168.60 cm), Moringa thickest (3.14 cm) is noteworthy, because fast growth from nitrogen is often feared to give thin, succulent stems. Here, stems were both tall and sturdy at the rate tested, but this requires confirmation with tissue analysis in future trials.

4.3 Why Yield Was Higher

Two mechanisms plausibly worked together: more leaves and higher LAI provided more assimilates, while high K and Zn in Moringa are reported to improve fruit set and filling. The 187% increase in fruit weight relative to control aligns with recent findings: Bari et al. (5) reported larger and heavier fruits with 6% Moringa, Ngcobo et al. (6) reported higher yield and lycopene, and Abdelhameed et al. (7) showed that Moringa maintained photosynthetic efficiency under stress, which is consistent with the sustained RGR in this study.

Early flowering is not just a statistic in the Guinea Savanna. It is an escape mechanism for late-season drought. The gibberellin-like activity reported for Moringa is suggested to hasten the shift from vegetative to reproductive phase, a finding also reported by Faravelli (14). Again, this mechanism was not measured here.

4.4 The Leucaena Result What a Single Dose Can and Cannot Show

Across all traits, the ranking held: Moringa ≥ Gliricidia > Leucaena > Control. Importantly, Leucaena was not inhibitory in this study; it was simply less stimulatory. How do we reconcile this with Kato-Noguchi and Kurniadie (10) and Pires et al. (11), who documented strong inhibition?

A plausible explanation is dose and preparation. At 50 ml crude extract per plant every 14 days, microbial degradation of mimosine may have occurred before a phytotoxic threshold was reached. This is consistent with the hormesis model: low dose stimulates, high dose inhibits. Recent work on Gliricidia also shows this duality: at 60-80% concentration, its extract reduced radicle growth by over 50% in other crops (15), yet at the moderate dose used here, it was stimulatory.

But this trial cannot prove hormesis. Only one dose was tested. The lesson is therefore limited: at the single rate tested, Leucaena was not inhibitory, but was less stimulatory than Moringa and Gliricidia. Whether lower or higher rates would be stimulatory or inhibitory cannot be determined from this trial.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Three conclusions emerge, within the limits of this preliminary trial. First, aqueous leaf extracts applied as foliar sprays were associated with improved growth and yield of tomato variety Dan-Eka compared with water control, in one season at one location in Jalingo. Moringa showed the most promising bio-stimulant response, followed by Gliricidia. Second, at the single rate tested, Leucaena was not inhibitory, but was consistently weakest. Third, the results are preliminary.

This study does not demonstrate that extracts can replace mineral fertiliser, does not demonstrate a direct soil-amendment effect of foliar spraying, and does not support a recommended concentration.

5.2 Limitations

This study is limited to one location, one wet season (2026), one tomato variety (Dan-Eka), one extract preparation, one application rate, and three replications (n = 3 plots per treatment). No mineral-fertiliser treatment was included. Soil sampling was limited and not designed to test a direct soil effect of foliar sprays. Chemical quantification of bioactive compounds was not done. Only aqueous extraction was tested. Results should therefore be interpreted as preliminary and site- and season-specific.

5.3 Recommendations

1. For farmers in Jalingo (interim, trial-based only): Farmers who wish to try this should do so on a small trial plot first, using the exact preparation tested (2 kg fresh leaves in 4 litres water, filtered, used within 5 hours, 50 ml per plant every two weeks from 2 WAT), and compare with their usual practice. No concentration recommendation is made. Leucaena should not be applied at nursery stage where the radicle is most sensitive (11), until dose-response data are available.

2. For extension: Taraba State Agricultural Development Programme and College of Agriculture, Jalingo may produce a simple information note (not a recommendation) describing the preparation used, clearly labelled as preliminary.

3. For further research: (i) Multi-locational, multi-seasonal trials with Roma VF and Jos varieties in addition to Dan-Eka; (ii) An NPK comparison (0, recommended NPK, extract alone, extract + 50% NPK); (iii) A graded dose-response trial (0%, 25%, 50%, 75%, 100% crude extract); (iv) Economic analysis (cost of labour, leaves and spraying vs. value of extra yield, compared with NPK at current prices); (v) HPLC profiling of zeatin and mimosine; (vi) A dedicated soil trial with direct soil application, per-plot baseline sampling and replicated post-harvest sampling.

ACKNOWLEDGEMENT

The authors appreciate TETFund, Abuja, for funding this work under the Institution-Based Research Grant (IBR), and the management of College of Agriculture, Science and Technology, Jalingo, for facilitating the IBR grant, providing land and laboratory support.

AUTHORS CONTRIBUTIONS

Lobiya Kassa John and Rimamchika Maigari Ekin initiated and developed the research work and also obtained the TETFund IBR grant, planned the experiment, carried out the field trial, processed and analysed the results and prepared the initial manuscript. Benneth O. Anokwu, David Irande and Benjamin Sale provided overall guidance, assisted in improving the research design, ensured methods were properly followed and thoroughly reviewed the manuscript.

Funding: Tertiary Education Trust Fund (TETFund) Institution-Based Research (IBR) Grant, Abuja, Nigeria.

Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: Not applicable. The study did not involve human subjects or animals.

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