E-ISSN 2599-2872; P-ISSN 2549-8150

J-PEN Borneo: Jurnal Ilmu Pertanian

journal homepage: https://jurnal.ubt.ac.id/index.php/jpen

Research Paper 9(2) (2026) 25 – 30

Early Maize Growth In Rhizoboxes Under Ageratum Conyzoides Leaf Extract And Chicken Manure

Nurul Chairiyah[1]*, Mardhiana[1], Aditya Murtilaksono[1] and Siti Maisurah[1]

[1] *Agrotechnology Study Program, Faculty of Agriculture, Universitas Borneo Tarakan, Tarakan, North Kalimantan, Indonesia*

* Corresponding author. E-mail address: nchairiyah@borneo.ac.id

Submitted/Received: October 2026 ; Accepted: October 2026

ARTICLE INFO

Keywords:
Ageratum conyzoides
Chicken manure
Leaf extract
Maize
Rhizobox
Vegetative growth

ABSTRACT

Maize requires adequate nutrients during vegetative growth, and organic fertilizers can serve as an alternative nutrient source to inorganic fertilizers. Babadotan (*Ageratum conyzoides* L.) leaves contain nitrogen, phosphorus, and potassium and may therefore be used as a aqueous leaf extract. This study evaluated the effect of babadotan leaf extract and chicken manure on the vegetative growth of maize (Zea mays L.) grown in rhizoboxes. The experiment was conducted from March to April 2018 in a screen house at the Faculty of Agriculture, Universitas Borneo Tarakan, using a randomized block design with six treatments and four replications: control (P0), 15 mL babadotan leaf extract (P1), 30 mL babadotan leaf extract (P2), chicken manure 4 g (P3), 15 mL babadotan leaf extract + chicken manure 4 g (P4), and 30 mL babadotan leaf extract + chicken manure 4 g (P5). Eleven shoot and root parameters were observed at four weeks after planting and analyzed by ANOVA followed by Duncan's test at the 5% level. The treatments significantly affected the number of leaves, shoot fresh weight, and shoot dry weight, whereas no statistically significant differences were detected for plant height or the root parameters. P5 gave the highest means for the three significant parameters (6.75 leaves, 6.37 g, and 0.55 g), which were comparable to P4 and significantly higher than the control. Within the conditions of this study, the combined application of babadotan leaf extract and chicken manure mainly promoted shoot growth of maize, while no statistically significant root response was detected.

INTRODUCTION

Maize (*Zea mays* L.) is a cereal of the family Poaceae whose growth, development, and yield are strongly regulated by the acquisition of nutrients, particularly nitrogen, phosphorus, and potassium [1,2,3]. Among these, nitrogen is one of the most limiting: omitting it reduced leaf area, chlorophyll content, biomass, and root length and volume of maize, and these growth attributes were positively correlated with final yield [3,4]. The vegetative phase is therefore a critical period for nutrient supply [2,3].

Soil alone can supply only limited amounts of nutrients, so fertilization is needed to increase nutrient availability and maize yield [5]. Organic fertilizers, whether solid or liquid and derived from plants or animals, are an alternative to inorganic fertilizers because they improve the physical, chemical, and biological properties of soil and can reduce reliance on costly inorganic fertilizers [5-7]. Chicken manure is a common solid organic fertilizer [5]; in sweet maize, the highest rate of chicken manure gave the best root and shoot biomass and increased nitrogen accumulation in roots [8]. Liquid organic fertilizers (LOF) prepared from local plants have also supported maize growth, for example LOF derived from Tithonia diversifolia and Ageratum conyzoides in sweet maize in the field [9]. Combining a solid fertilizer applied before planting with a plant-based LOF applied during growth may therefore provide both a nutrient base and a supplementary supply during vegetative growth.

Babadotan (Ageratum conyzoides L.; Asteraceae) is a widespread tropical weed found in many regions of Indonesia, including North Kalimantan, and may represent an underutilized resource for agricultural applications [10]. Its biomass contains nutrients such as nitrogen (N), phosphorus (P), and potassium (K), which are essential for plant growth, root development, and physiological functions [11]. Laboratory analysis conducted at the Soil Science Laboratory, Faculty of Agriculture, Universitas Borneo Tarakan, revealed that babadotan leaves contained 0.17% total N, 31.660 mg 100 g^{-1} P_2O_5, and 22.715 mg 100 g^{-1} K. These leaf values do not establish the composition or nutrient dose of the applied extract. Supporting its potential as an organic fertilizer resource, previous research found that vermicomposting A. conyzoides biomass could enhance nutrient content, including N, P, and K, while the resulting vermicompost showed no apparent phytotoxicity under the conditions tested [12]. Nevertheless, A. conyzoides also exhibits allelopathic activity that may inhibit the germination and growth of other plant species [13]. Recent research further demonstrated that its allelopathic effects varied among Bidens pilosa, rice (Oryza sativa), and cucumber (Cucumis sativus), indicating that plant responses depend on the species and experimental conditions [14]. These findings suggest that the nutritional potential of babadotan biomass should be considered alongside its possible biological effects when evaluating its agricultural use. Therefore, direct experimental assessment is necessary to determine how babadotan leaf extract, particularly at different application volumes, affects maize growth.

Root system development is an important determinant of nutrient acquisition and plant growth in maize. Root traits, including root length, branching, and root hair development, contribute to soil exploration and nutrient uptake, while their responses are influenced by the spatial distribution of nutrients in the soil [15]. In particular, phosphorus placement depth can affect root physiological

adaptations, nutrient use efficiency, and grain yield in maize [16]. These findings highlight the importance of evaluating root responses, in addition to above-ground growth, when assessing the effectiveness of nutrient inputs.

Babadotan (*Ageratum conyzoides* L.) has potential as a raw material for liquid organic fertilizer (LOF), but its effects on maize root development, particularly when applied in combination with chicken manure, remain insufficiently documented. Previous research on babadotan leaf extract in hanjeli (Coix lacryma-jobi) reported growth responses associated with application rate, suggesting that its effects may vary among crop species [17]. The combination of plant-derived organic inputs and animal manure also warrants investigation because organic amendments can differ in nutrient contributions and effects on soil biological properties [18]. Evaluating these materials in combination may therefore provide useful information on their potential to support early maize growth, although any benefits of combined application need to be established experimentally.

Assessing root development presents a methodological challenge because roots are largely concealed within the soil matrix. Rhizoboxes provide a practical approach for non-destructive observation of root growth over time and for evaluating root responses to localized nutrient availability [19]. However, observations made through a transparent surface provide only a partial representation of root system architecture and may not fully capture its three-dimensional distribution. Imaging-based approaches have therefore been developed to improve root visualization and quantify root architecture in soil-grown plants [20]. Although rhizoboxes offer advantages for monitoring root development, their geometry and dimensions should be considered when interpreting experimental results. Mašková and Klimeš [21] found no significant differences in total plant biomass or root-to-shoot biomass allocation between flat rhizoboxes and conventional pots of comparable volume across the species they tested. Thus, rhizoboxes can be useful for comparative root studies, but the suitability of a particular design depends on the research objectives, observation period, and root traits being assessed.

This study evaluated two application volumes of babadotan leaf extract, applied alone and in combination with chicken manure, using babadotan biomass obtained from the local environment of Tarakan, North Kalimantan. The study assessed above-ground growth and root development simultaneously using a rhizobox system during the early vegetative stage of maize. Accordingly, this study aimed to determine the effects of babadotan leaf extract and chicken manure, applied individually and in combination, on the shoot and root growth of maize cultivated in rhizoboxes. The findings are expected to provide baseline information on the early vegetative responses of maize to these organic inputs.

MATERIALS AND METHODS

Research site and experimental period

The study was conducted from March to April 2018 in a screen house at the Faculty of Agriculture, Universitas Borneo Tarakan, Tarakan, North Kalimantan, Indonesia. The experiment evaluated differences in early vegetative shoot and root traits among six organic-amendment treatments.

Tools and materials

The tools used in this study included Petri dishes, an analytical balance, a blender, a sieve, filter paper, a measuring cylinder, a hoe, a tarpaulin, and a measuring tape. Additional equipment consisted of sacks, wood, plywood, nails, a hammer, a ruler, label paper, stationery, and a camera. The materials used were babadotan (Ageratum conyzoides) leaves, water, chicken manure, and maize seeds.

Experimental design

The study used a randomized block design with six treatment combinations and four replications (Table 1), giving 24 experimental units. Twenty-four rhizoboxes were prepared, and seedlings were thinned to one plant per rhizobox one week after planting. Babadotan leaf extract was applied weekly, while chicken manure was applied before planting. The experimental layout is shown in Figure 1.

Table 1. Treatments of babadotan leaf extract and chicken manure on maize

Code	Treatment
P0	Control
P1	15 mL babadotan leaf extract
P2	30 mL babadotan leaf extract
P3	Chicken manure 4 g
P4	15 mL babadotan leaf extract + chicken manure 4 g
P5	30 mL babadotan leaf extract + chicken manure 4 g

The six treatments comprise three babadotan leaf-extract application volumes (0, 15, and 30 mL) crossed with two chicken manure rates (0 and 4 g). They therefore constitute a complete 3 × 2 factorial treatment structure. The statistical results presented here compare the six combinations as a single treatment factor; separate main effects and the extract × manure interaction are not reported.



Figure 1. Experimental layout using rhizoboxes

Procedures

Rhizobox construction

Twenty-four clear glass panels (30 × 21 cm, 2 mm thick) and 24 plywood boards (6 mm thick) of the same size were prepared. The plywood was assembled into a rectangular box measuring 21 × 2 × 30 cm (l × w × h), with its inner walls lined with plastic. The front side was covered with a glass panel that served as a door (Figure 2).



Figure 2. Rhizobox construction

Preparation of babadotan leaf extract

Fresh babadotan leaves were prepared one day before application. Fifty grams of leaves were blended with 250 mL of water to obtain a uniform mixture. The mixture was measured according to the assigned treatment volume. This plant-based amendment is described as babadotan leaf extract to distinguish the aqueous preparation from a chemically characterized or fermented fertilizer.



Figure 3. Harvesting maize in rhizoboxes

Soil collection and growing medium preparation

Soil was collected from the research field of the Faculty of Agriculture, Universitas Borneo Tarakan, at four points corresponding to the number of replications, at a depth of 20–30 cm using a hoe, and placed in separate sacks for each point. One replication consisted of six rhizoboxes, so four replications consisted of 24 rhizoboxes, each containing 1 kg of air-dried soil. The amount of soil collected was twice the requirement (48 kg) to allow for shrinkage after drying. The soil was air-dried on a tarpaulin indoors, away from sunlight, for one week, crushed to break up large clods, weighed to 1 kg, placed in each rhizobox, and watered to field capacity.

Planting

Two maize seeds were planted at a depth of about 2 cm in each rhizobox. One week after planting, if both seeds had germinated, one seedling was removed and the other was kept for further observation. The plants were harvested at 4 weeks after planting (WAP) (Figure 3).

Observation parameters and data analysis

The observed parameters included plant height, number of leaves, shoot fresh weight, and shoot dry weight. Root parameters consisted of root fresh weight, root dry weight, number of roots, root length, number of root hairs, and root volume, in addition to the shoot-root ratio. All parameters were measured at 4 WAP. The data were analyzed using analysis of variance (ANOVA) at the 95% confidence level, and significant differences were further tested with Duncan's multiple range test at the 5% level.

RESULTS

At four weeks after planting, treatment differences were significant for leaf number, shoot fresh weight, and shoot dry weight (Table 2). No statistically significant differences were detected for plant height, root fresh or dry weight, root length, root number, root-hair number, root volume, or the shoot–root ratio. These nonsignificant tests do not establish equivalence among treatments.

Table 2. Summary of analysis of variance (F test) for the effect of babadotan (Ageratum conyzoides) liquid organic fertilizer (LOF) and chicken manure on maize growth at 4 WAP

No.	Parameter	F test
1	Plant height (cm)	ns
2	Number of leaves	*
3	Shoot fresh weight (g)	*
4	Shoot dry weight (g)	*
5	Root fresh weight (g)	ns
6	Root dry weight (g)	ns
7	Root length (cm)	ns
8	Number of roots	ns
9	Number of root hairs	ns
10	Root volume (mL)	ns
11	Shoot-root ratio	ns

Note: ns = not significant; * = significant (F test, 5% level).

Table 3 presents the treatment means. P5 had the highest means for leaf number and shoot biomass but did not differ significantly from P4. For traits with nonsignificant overall tests, treatment means are descriptive.

Table 3. Mean values of maize growth parameters at 4 WAP under babadotan leaf extract and chicken manure treatments

Panel A. Shoot traits and root biomass

Treatment	Plant height (cm)	Leaves	Shoot FW (g)	Shoot DW (g)	Root FW (g)	Root DW (g)
P0	38.60	4.75 a	1.63 a	0.18 a	0.21	0.06
P1	50.08	5.50 a	2.69 ab	0.27 ab	0.27	0.07
P2	52.13	5.25 ab	3.23 ab	0.32 ab	0.33	0.09
P3	49.25	5.00 a	3.09 ab	0.31 ab	0.35	0.08
P4	56.18	6.00 bc	4.57 bc	0.40 bc	0.37	0.28
P5	59.13	6.75 c	6.37 c	0.55 c	0.52	0.11

Panel B. Root morphology and biomass allocation

Treatment	Root length (cm)	Roots	Root hairs	Root volume (mL)	Shoot-root ratio
P0	24.63	8.50	112.50	0.20	2.62
P1	21.50	9.50	132.75	0.25	4.60
P2	32.53	12.00	125.00	0.38	3.38
P3	20.15	10.75	137.00	0.30	5.65
P4	24.73	10.75	140.25	0.30	4.63
P5	29.03	10.00	166.75	0.33	5.10

Note: P0 = control; P1 = 15 mL babadotan leaf extract; P2 = 30 mL babadotan leaf extract; P3 = chicken manure 4 g; P4 = 15 mL babadotan leaf extract + chicken manure 4 g; P5 = 30 mL babadotan leaf extract + chicken manure 4 g. FW = fresh weight; DW = dry weight. Values are treatment means of four replications. Means sharing no letter within a column differ significantly (Duncan's multiple range test, 5%). Columns without letters showed no significant difference (F test, 5%).

Plant height ranged from 38.60 cm in P0 to 59.13 cm in P5, but treatment differences were not significant (Figure 4A). Leaf number differed significantly among treatments (Figure 4B). P5 produced 6.75 leaves, compared with 4.75 in P0, a descriptive increase of approximately 42%. P5 (c) differed significantly from P0 (a), P1 (a), P2 (ab), and P3 (a), but not from P4 (bc). P4 also did not differ significantly from P2 because they shared the letter b.

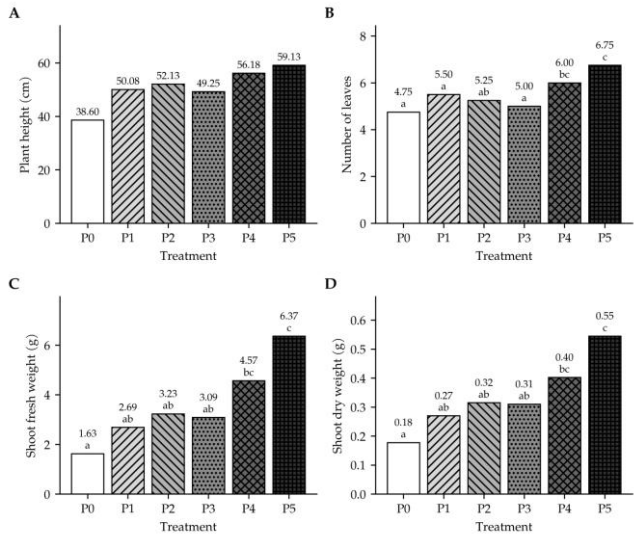


Figure 4. Shoot growth of maize at 4 WAP under babadotan leaf extract and chicken manure treatments: (A) plant height, (B) number of leaves, (C) shoot fresh weight, and (D) shoot dry weight. Bars show treatment means (n = 4); values above the bars are the means. Different letters indicate significant differences according to Duncan's multiple range test at 5%; panel A shows no letters because the F test was not significant. P0 = control; P1 = 15 mL babadotan leaf extract; P2 = 30 mL babadotan leaf extract; P3 = chicken manure 4 g; P4 = 15 mL babadotan leaf extract + chicken manure 4 g; P5 = 30 mL babadotan leaf extract + chicken manure 4 g.

Shoot fresh weight was 1.63 g in P0 and 6.37 g in P5, while shoot dry weight was 0.18 and 0.55 g, respectively (Figures 4C and 4D). These means correspond to descriptive increases of approximately 291% and 206% relative to P0. For both traits, P5 (c) differed significantly from P0 (a) and the single-input treatments P1–P3 (ab), but not from P4 (bc). P4 did not differ significantly from P1–P3 because they shared the letter b. Thus, the higher extract volume in the combined treatment did not demonstrate a statistically significant advantage over the lower volume.

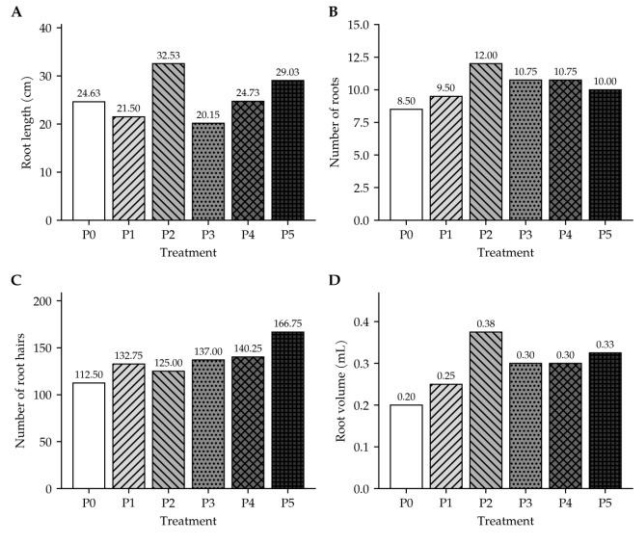


Figure 5. Root morphology of maize at 4 WAP under babadotan leaf extract and chicken manure treatments: (A) root length, (B) number of roots, (C) number of root hairs, and (D) root volume. Bars show treatment means (n = 4); values above the bars are the means. No letters are shown because the F test was not significant for any parameter. P0 = control; P1 = 15 mL babadotan leaf extract; P2 = 30 mL babadotan leaf extract; P3 = chicken manure 4 g; P4 = 15 mL babadotan leaf extract + chicken manure 4 g; P5 = 30 mL babadotan leaf extract + chicken manure 4 g.

No statistically significant treatment differences were detected for the root morphological traits (Figure 5). Mean root length ranged from 20.15 cm in P3 to 32.53 cm in P2, root number from 8.50 in P0 to 12.00 in P2, root-hair number from 112.50 in P0 to 166.75 in P5, and root volume from 0.20 mL in P0 to 0.38 mL in P2. These ranges describe the observed means and do not establish treatment superiority or a dose-related response.

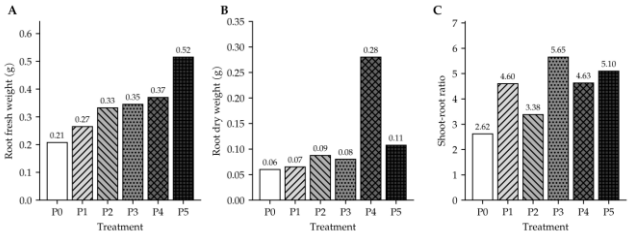


Figure 6. Root biomass and shoot-root ratio of maize at 4 WAP under babadotan leaf extract and chicken manure treatments: (A) root fresh weight, (B) root dry weight, and (C) shoot-root ratio (dimensionless). Bars show treatment means (n = 4); values above the bars are the means. No letters are shown because the F test was not significant. P0 = control; P1 = 15 mL babadotan leaf extract; P2 = 30 mL babadotan leaf extract; P3 = chicken manure 4 g; P4 = 15 mL babadotan leaf extract + chicken manure 4 g; P5 = 30 mL babadotan leaf extract + chicken manure 4 g.

Root biomass and the shoot–root ratio did not differ significantly among treatments (Figure 6). Mean root fresh weight ranged from 0.21 g in P0 to 0.52 g in P5. Mean root dry weight was 0.06–0.09 g in P0–P3, 0.28 g in P4, and 0.11 g in P5. The shoot–root ratio ranged from 2.62 in P0 to 5.65 in P3. Because the ratio did not differ significantly, these results do not demonstrate a treatment-induced change in biomass allocation.

Taken together, Figures 4–6 show statistically detectable responses in leaf number and shoot biomass, with no statistically detectable treatment differences in the root traits or plant height during the four-week experiment.

DISCUSSION

The clearest treatment responses occurred in shoot growth. P5 had significantly higher leaf number and shoot biomass than the control and single-input treatments, while P4 and P5 were statistically similar. Previous studies reported growth responses to babadotan-based organic inputs [17,22] and chicken manure in water spinach (Ipomoea reptans) [23]. These comparisons support investigating both materials as organic amendments, but differences in crops, amendment preparation, and experimental conditions limit direct comparison of application rates.

A nutritional explanation is plausible because nitrogen contributes to chlorophyll synthesis, phosphorus to energy metabolism, and potassium to enzyme activity and water relations [24-26]. Responses to nutrient availability are also species dependent [27], and liquid organic fertilizer performance varies with material and concentration [28]. However, amendment composition, soil nutrient availability, and plant nutrient uptake were not measured. Improved nutrient supply, uptake, or photosynthesis therefore cannot be established as the mechanism underlying the shoot responses.

Muktamar et al. [29] reported increased nutrient uptake and growth in sweet maize receiving vermicompost supplemented with liquid organic fertilizer. In contrast, Murtilaksono et al. [17] described trait-dependent root responses to babadotan-based fertilizer in hanjeli. These findings suggest that crop responses need not increase proportionally with application volume. In the present experiment, the lack of a significant difference between P4 and P5 provides no evidence that doubling the extract volume improved the measured shoot traits.

No statistically significant root responses were detected within four weeks. Studies of organic nutrient inputs in maize [29,30] provide useful context but do not establish the causes of these nonsignificant

results. Failure to detect a difference should not be interpreted as evidence that the treatments have identical effects on root development.

Root responses to babadotan-based inputs may depend on crop species and application conditions [17], while different organic amendments can affect individual growth traits differently [31]. The four-week duration, four replicates per treatment, and rhizobox geometry (21 × 2 × 30 cm, with 1 kg of soil) limit interpretation of the root results. In particular, the 2-cm width restricts lateral rooting space relative to field soil. The contributions of rooting restriction, observation duration, and experimental variability were not independently tested. Root-hair counts also require a clearly specified counting scale before they can be compared with other studies.

The six treatment combinations constitute a complete 3 × 2 factorial structure, although the reported tests compare combinations as a single factor. Consequently, the presented results do not quantify separate extract and manure main effects or their interaction. Factorial experiments such as that of Sinaga et al. [31] illustrate the value of distinguishing these effects. Neither the superior shoot means of P5 relative to the single-input treatments nor its numerical advantage over P4 establishes synergism. Longer experiments should assess root development and reproductive performance alongside amendment composition, soil nutrient availability, and tissue nutrient concentrations. Nutrient-uptake measurements are particularly relevant because responses have differed among organic-amendment studies [29,32]. The absence of an inorganic-fertilizer comparator also prevents conclusions about replacement of conventional fertilization. An optimal or economically preferable application volume cannot be identified from the present results.

In practical terms, the absence of a significant difference between the two combined treatments means that the higher extract volume cannot be preferred on growth evidence alone. The lower volume warrants further evaluation, but an efficiency or cost advantage would require information on preparation costs, application effort, nutrient delivery, and performance over a longer period. Likewise, the observed shoot response cannot establish the suitability of the amendment for unrestricted rooting environments. Field evaluation should retain appropriate untreated and nutrient-management comparators and assess reproducibility across soils and seasons. Such comparisons would help distinguish a context-specific early response from a broadly transferable management option without assuming that the current rhizobox results predict reproductive performance.

CONCLUSION

At four weeks after planting, P5 (30 mL babadotan leaf extract + 4 g chicken manure) produced the highest observed leaf number, shoot fresh weight, and shoot dry weight. These means were significantly higher than those of the control and single-input treatments but did not differ significantly from P4 (15 mL extract + 4 g manure). No statistically significant differences were detected for plant height, root traits, or the shoot–root ratio. The findings are limited to early vegetative growth in rhizoboxes containing 1 kg of soil. They do not establish an optimal application volume, synergism, field effectiveness, or yield benefits.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Plant Science Laboratory, Faculty of Agriculture, Universitas Borneo Tarakan, for providing laboratory equipment and research facilities to support this study. This research was independently conducted and received no specific external funding.

REFERENCES

[1] Osman MMA, Kuunya R, Alrasheed R, Hassan MM, Wasikoyo E, Gumisiriya C, Mudawi HI, Elsalahi R. (2025). Maize nutrient dynamics: growth, yield and sustainable practices: a narrative review. Acta Agraria Debreceniensis (2):83–91.

[2] Batool M. (2023). Nutrient Management of Maize. In: Kaushik P (Ed.), New Prospects of Maize. IntechOpen, London. https://doi.org/10.5772/intechopen.112484.

[3] Appiah E. (2023). Integrated Nutrient Management on Growth and Yield of Maize (Zea mays L.). Master of Philosophy Thesis. Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ghana.

[4] Afrida E, Saragih M, Rahman A. (2024). Impact of macro and micro-nutrient omission on maize growth and yield: assessing critical limiting factors in nutrient management. International Journal of Design & Nature and Ecodynamics 19(5):1511–1518. https://doi.org/10.18280/ijdne.190505.

[5] Gezahegn AM. (2021). Effect of Organic Fertilizers on Maize (Zea mays L.) Production and Soil Physical and Chemical Properties. World Applied Sciences Journal 39(1):11–19. https://doi.org/10.5829/idosi.wasj.2021.11.19.

[6] Shah MN, Wright DL, Hussain S, Koutroubas SD, Seepaul R, George S, et al. (2023). Organic fertilizer sources improve the yield and quality attributes of maize (Zea mays L.) hybrids by improving soil properties and nutrient uptake under drought stress. Journal of King Saud University – Science 35(4):102570. https://doi.org/10.1016/j.jksus.2023.102570.

[7] Chen X, Li Z, Zhao H, Li Y, Wei J, Ma L, et al. (2024). Enhancing maize yield and nutrient utilization through improved soil quality under reduced fertilizer use: the efficacy of organic–inorganic compound fertilizer. Agriculture 14(9):1482. https://doi.org/10.3390/agriculture14091482.

[8] Ahmad AA, Fares A, Paramasivam S, Elrashidi MA, Savabi RM. (2009). Biomass and nutrient concentration of sweet corn roots and shoots under organic amendments application. Journal of Environmental Science and Health, Part B 44(7):742–754. https://doi.org/10.1080/03601230903163921.

[9] Fadhillah IM, Dasumiati D, Sudjatmiko S. (2023). Growth and yield of sweet corn in response to the liquid organic fertilizer derived from Tithonia diversifolia and Ageratum conyzoides. E3S Web of Conferences 373:03010. https://doi.org/10.1051/e3sconf/202337303010.

[10] Maisyaroh, S., Sari, N. and Rizali, A. (2025) 'Pestisida nabati daun babadotan (Ageratum conyzoides L.) dalam mengendalikan hama pada tanaman pakcoy (Brassica rapa L.)', Jurnal Agroqua: Media Informasi Agronomi dan Budidaya Perairan, 23(2), pp. 149–158. https://doi.org/10.32663/ja.v23i2.5218.

[11] Marschner, P. (ed.) (2012) Marschner's Mineral Nutrition of Higher Plants. 3rd edn. Amsterdam: Academic Press. https://doi.org/10.1016/C2009-0-63043-9.

[12] Gusain, R. and Suthar, S. (2020) 'Vermicomposting of invasive weed Ageratum conyzoides: Assessment of nutrient mineralization, enzymatic activities, and microbial properties', Bioresource Technology, 312, article 123537. https://doi.org/10.1016/j.biortech.2020.123537.

[13] Batish, D.R., Kaur, S., Singh, H.P. and Kohli, R.K. (2009) 'Role of root-mediated interactions in phytotoxic interference of Ageratum conyzoides with rice (Oryza sativa)', Flora, 204(5), pp. 388–395. https://doi.org/10.1016/j.flora.2008.05.003.

[14] Zumbado-Rodríguez, A., Portuguez-García, M.P. and González-Lutz, M.I. (2026) 'Allelopathy of Ageratum conyzoides L. on Bidens pilosa L., Oryza sativa L., and Cucumis sativus L.', Agronomía Mesoamericana, 37, article bc16e790. https://doi.org/10.15517/bc16e790

[15] Wang, L., Li, X., Mang, M., Ludewig, U. and Shen, J. (2021). Heterogeneous nutrient supply promotes maize growth and phosphorus acquisition: Additive and compensatory effects of lateral roots and root hairs. Annals of Botany, 128(4), 431–440. https://doi.org/10.1093/aob/mcab097.

[16] Chen, X., Liu, P., Zhao, B., Zhang, J., Ren, B., Li, Z. and Wang, Z. (2022). Root physiological adaptations that enhance the grain yield and nutrient use efficiency of maize (Zea mays L.) and their dependency on phosphorus placement depth. Field Crops Research, 276, 108378. https://doi.org/10.1016/j.fcr.2021.108378.

[17] Murtilaksono, A., Rika, F. and Hendrawan, F. (2020). Pengaruh pupuk organik cair babadotan (Ageratum conyzoides) terhadap pertumbuhan vegetatif akar hanjeli (Coix lacryma-jobi). Agriprima: Journal of Applied Agricultural Sciences, 4(2), 164–170. https://doi.org/10.25047/agriprima.v4i2.378.

[18] Liu, T., Chen, X., Hu, F., Ran, W., Shen, Q., Li, H. and Whalen, J.K. (2016). Carbon-rich organic fertilizers to increase soil biodiversity: Evidence from a meta-analysis of nematode communities. Agriculture, Ecosystems & Environment, 232, 199–207. https://doi.org/10.1016/j.agee.2016.07.015

[19] Schmidt, J. E., Lowry, C., & Gaudin, A. C. M. (2018). An optimized rhizobox protocol to visualize root growth and responsiveness to localized nutrients. Journal of Visualized Experiments, (140), 58674. https://doi.org/10.3791/58674

[20] Bontpart, T., Concha, C., Giuffrida, M. V., Robertson, I., Admkie, K., Abdi, T. D., et al. (2020). Affordable and robust phenotyping framework to analyse root system architecture of soil-grown plants. The Plant Journal, 103(6), 2330–2343. https://doi.org/10.1111/tpj.14877

[21] Mašková, T., & Klimeš, A. (2020). The effect of rhizoboxes on plant growth and root:shoot biomass partitioning. Frontiers in Plant Science, 10, 1693. https://doi.org/10.3389/fpls.2019.01693

[22] Najerah, N., Ifansyah, H., & Yusran, F. H. (2023). Teknologi penyiapan pupuk organik babadotan (Ageratum conyzoides) terhadap kimia tanah dan tanaman bawang dayak (Eleutherine palmifolia) pada tanah Ultisol. Agroekotek View, 6(3). https://doi.org/10.20527/agtview.v6i3.4785

[23] Soares, D. M., & Gomes, J. D. J. (2024). The effect of chicken manure doses on the growth and production of land kale plants (Ipomoea reptans Poir). Jurnal Teknologi Pangan dan Ilmu Pertanian, 2(1), 51–60. https://doi.org/10.59581/jtpip-widyakarya.v2i1.2863

[24] Fathi, A. (2022). Role of nitrogen (N) in plant growth, photosynthesis pigments, and N use efficiency: A review. https://doi.org/10.5281/zenodo.7143588

[25] Khan, F., Siddique, A. B., Shabala, S., Zhou, M., & Zhao, C. (2023). Phosphorus plays key roles in regulating plants' physiological responses to abiotic stresses. Plants, 12(15), 2861. https://doi.org/10.3390/plants12152861

[26] Shah, I. H., Jinhui, W., Li, X., Hameed, M. K., Manzoor, M. A., Li, P., Zhang, Y., Niu, Q., & Chang, L. (2024). Exploring the role of nitrogen and potassium in photosynthesis: Implications for sugar accumulation and translocation in horticultural crops. Scientia Horticulturae, 327, 112832. https://doi.org/10.1016/j.scienta.2023.112832

[27] Fu, M., Liu, X., Zhang, C., Ding, J., Liu, B., Wu, X., & Wang, Z. (2026). Contrasting physiological, photosynthetic, and growth adaptations of plants to a wide range of nitrogen, phosphorus, and potassium availability. International Journal of Plant Biology, 17(4), 32. https://doi.org/10.3390/ijpb17040032

[28] Mustofa, M. J., Prihatiningrum, A. E., & Nurmalasari, I. R. (2022). Effect of types and concentration of liquid organic fertilizer on the growth and production of pakcoy plants (Brassica rapa L.). IOP Conference Series: Earth and Environmental Science, 1104, 012010. https://doi.org/10.1088/1755-1315/1104/1/012010

[29] Muktamar, Z., Sudjatmiko, S., Chozin, M., Setyowati, N., & Fahrurrozi. (2017). Sweet corn performance and its major nutrient uptake following application of vermicompost supplemented with liquid organic fertilizer. International Journal on Advanced Science, Engineering and Information Technology, 7(2), 602–608. https://doi.org/10.18517/ijaseit.7.2.1112

[30] Maintang, Sudding, F., Asri, M., & Rauf, A. W. (2021). Application of liquid organic and inorganic fertilizer on growth and production of hybrid maize. IOP Conference Series: Earth and Environmental Science, 648, 012140. https://doi.org/10.1088/1755-1315/648/1/012140

[31] Sinaga, N. S., Luta, D. A., & Tarigan, R. R. A. (2023). Increasing the growth and production of sweet corn (Zea mays saccharata) by giving chicken manure and vegetable waste liquid organic fertilizer. Jurnal Agronomi Tanaman Tropika (JUATIKA), 5(2), 322–329. https://doi.org/10.36378/juatika.v5i2.3111

[32] Muktamar, Z., Fahrurrozi, F., Sudjatmiko, S., Setyowati, N., & Chozin, M. (2021). Nitrogen, phosphorous, and potassium uptakes of organically grown sweet corn on coastal Entisols. International Journal of Agricultural Technology, 17(1), 213–226. https://li04.tci-thaijo.org/index.php/IJAT/article/view/5929