Allelopathic Effects of *Leucaena leucocephala* and *Carica papaya* Leaf Extracts on Weed Suppression and Yield of Japanese Cucumber (*Cucumis sativus* L.)

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ABSTRACT

Background: This study aims to evaluate the efficacy of *Leucaena leucocephala* and *Carica papaya* leaf extracts as bioherbicides for controlling weeds and enhancing the growth and yield of Japanese cucumber (*Cucumis sativus* L. var. Japanese) across different extract types and concentrations.

Methods: A randomized complete block design (RCBD) experiment consisting of six treatment groups and one control group was used for a single factor. The experiment was replicated three times and resulted in a total of 21 experimental plots. The treatment groups included the control group as well as extract concentrations of 30%, 45% and 60% obtained from young leaf material of *Leucaena leucocephala* and mature green leaf material of *Carica papaya*. The dominant weed species found throughout the cucumber plots and the subject of the weeding treatment groups was *Cyperus rotundus*. Treatment for weeds in the plots was provided *via* sprays that were applied to weeds prior to their early vegetative stage. Sprays continued until the total amount of spray volume was 216 mL per plot or until the surface of the soil was uniformly moistened. Care was taken while spraying to prevent direct contact between the extracts and the cucumber plant by directing the sprays toward the weed canopy and the soil surface. Data collection and statistical analysis of data were completed using DMRT at a 95% confidence interval. This study was conducted from March through May of 2025 in Sleman, Indonesia.

Result: The application of 45% leaf extract demonstrated the most effective weed control and promoted optimal growth of Japanese cucumbers, resulting in a yield of approximately 28.36 tons per hectare during the study. Weeds began to emerge at 7 days after planting (DAP). Spraying was conducted at 14 DAP, when weeds were already present and no synthetic herbicides were applied during the experiment. These findings highlight the potential of *Leucaena leucocephala* and *Carica papaya* leaf extracts as effective, eco-friendly bioherbicides that suppress weed interference without compromising crop performance. Their ease of preparation and availability as agricultural by-products offer a sustainable weed-management alternative for farmers and further research across diverse conditions and cropping systems is recommended to expand their practical application.

Key words: Allelopathy, Bioherbicide, Carica papaya, Japanese cucumber, *Leucaena leucocephala*.

INTRODUCTION

Japanese cucumbers (*Cucumis sativus* L. var. Japanese) are among the most highly sought-after cucumber varieties (Akter and Islam, 2019). The level of production of hybrid Japanese cucumbers in Indonesia still remains low as the crop is mainly grown as an alternative or secondary crop and not as the main one (Sofyadi *et al*., 2021; Badri *et al*., 2024). It was also reported that production declined sharply from 471,941 tons in 2021 to 444,057 tons in 2022 (Mahmudan, 2022). Alptekin and Gürbüz (2022) reported that cucumbers grown without weed control yielded 2,110-2,221 kg/da. In contrast, when weeds were managed using a biopesticide, cucumber yields reached 4,285 kg/da. These results indicate that weed can reduce cucumber yield by nearly 50%. Competition among weeds (Daramola, 2021) is one of the factors contributing to this decline, underscoring the importance of weed control. Weeds can be controlled with chemical and bioherbicides (Hasan *et al*., 2021; Kraehmer *et al*., 2014; Radhakrishnan *et al*., 2018; Zhang, 2003).

Although synthetic herbicides are commonly used for weed control, their repeated application may negatively affect cucumber growth by causing phytotoxicity, reducing soil microbial activity and increasing the risk of herbicide residues in agricultural products (Frimpong *et al*., 2018; Gao *et al*., 2020; Ghazi *et al*., 2023). These limitations highlight the need for safer, environmentally friendly alternatives to weed management in cucumber cultivation.

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Bioherbicides are the most environmentally friendly method of controlling weeds, since they can be developed using a wide variety of natural sources (Roberts *et al*., 2022; Trang *et al*., 2024) and because they are derived from natural products that have been shown to inhibit the growth of weeds through allelopathy (Kostina-Bednarz *et al*., 2023).

Allelopathy will only occur when there are bioactive chemicals called allelochemicals present in a plant's environment that can either stimulate or inhibit the growth of another plant (Hussien and Abbas, 2023; Motalebnejad *et al*., 2023). Allelochemicals are usually secondary metabolites found in all types of plants, some of which include artemisinin, glucosinolates, isothiocyanates and momilactones (Al-Taie *et al*., 2020; Motmainna *et al*., 2021). Using allelopathy is an attractive strategy for managing weeds (Khamare *et al*., 2022; Huseynova, 2024). Lamtoro (*Leucaena leucocephala*) and papaya (*Carica papaya* L.) are examples of plants that contain allelochemicals within their leaves, which are the richest source of these substances. It has been reported that lamtoro leaves contain the following concentrations of bioactive compounds: flavonoids (4.57%), tannins (3.79%), saponins (5.88%) and mimosine (5.78%) (Aye and Adegun, 2013). Previous studies demonstrated that lamtoro leaf extracts effectively suppressed dominant weeds, including *P. nitens* and *P. dubium*, without causing severe phytotoxic effects on cultivated plants (Alvim *et al*., 2023). Additionally, green papaya leaves are equally recorded to possess 0.25% alkaloids, 0.14% flavonoids, 0.30% saponins and 11.34% tannins and other phytochemicals deleterious to other plants (A'Yun and Laily, 2015). Papaya leaf extracts have been reported to reduce weed biomass and populations across several cropping systems, suggesting their potential as plant-based herbicides (Setiawan *et al*., 2024). Specifically, papaya leaf extract is able to inhibit the growth of weed grass (*C. rotundus*). The papaya leaf extract concentration that most effectively inhibits weed growth is 50%, with a mortality rate of 64% (Setiawan *et al*., 2024).

Kato-Noguchi and Kurniadie (2022) investigated the use of lamtoro leaves in weed management and Anwar *et al.* (2019) and Setiawan *et al.* (2024) did the same with papaya leaves. However, the use of lamtoro leaves and papaya leaves in relation to the growth of Japanese cucumber has not been explored. Hence, this research aims to address this by investigating the efficacy of lamtoro and papaya leaf extracts for weed management and their impact on the growth of Japanese cucumber.

MATERIALS AND METHODS

Research design

The study was conducted in the experimental field of the Faculty of Agriculture, Universitas Pembangunan Nasional Veteran Yogyakarta, Sleman Regency, Indonesia, from March to May 2025. The experiment used a single-factor randomized complete block design (RCBD) with six treatments and one control, each replicated three times, yielding 21 experimental plots. The treatments included: no treatment (control), lamtoro leaf extract at concentrations of 30% (L30), 45% (L45) and 60% (L60) and papaya leaf extract at concentrations of 30% (P30), 45% (P45) and 60% (P60). The observational data were analyzed using Duncan's multiple range test (DMRT) at the 5% level.

Japanese cucumber planting

Before land preparation, three blocks of the field were established for conducting vegetation analysis. Each block had three separate vegetation samples taken randomly with the use of a square quadrat (0.5 m × 0.5 m), as well as each sample being oven dried; the weeds within each sample were separated by species, counted by species and the summed dominance ratio (SDR) for each sample was also determined.

Land preparation involved clearing weeds and loosening the soil with a hoe. The experimental field measured 13 m × 16.4 m, with a total area of 213.2 m^2. The field was divided into three blocks, each containing seven plots. Each plot measured 3 m × 1.2 m, with 1 m spacing between plots. A basal application of cattle manure at 20 tons/ha (equivalent to 7.2 kg per 3.6 m^2) was evenly distributed.

Planting was carried out at 60 cm × 50 cm by dibbling holes to a depth of 2-5 cm, placing two seeds per hole and then covering the holes with soil. Gap filling and thinning were performed 14 days after planting (DAP). Irrigation was carried out daily. Supplemental fertilization with NPK 16:16:16 was applied at 100 kg/ha (3 g/plant) when plants were 14 DAP and 150 kg/ha (4.5 g/plant) at 28 DAP, by broadcasting fertilizer around the plants.

Extract preparation

Young lamtoro (*Leucaena leucocephala*) and mature green papaya (*Carica papaya* L.) leaves were prepared from healthy plants by thoroughly washing and oven-drying at 60°C for 48 hours until completely dry. Papaya leaves were cut into small pieces and ground in a blender without water, whereas lamtoro leaves were blended directly without being cut. The ground material was then sieved.

The extracts were prepared by mixing the leaf powder with water at a leaf weight-to-solvent volume ratio of 1:10. A total of 250 g of leaf powder was soaked in 2.5 liters of water for 24 hours in a closed container, kept in darkness at room temperature. The mixture was filtered and the resulting solution was used as the stock concentration (100%), serving as the reference for subsequent dilutions.

Extract application

Treatments were applied to the plots using a sprayer with a total of 600 liters per hectare. Spraying was done by hand until either 216 mL had been sprayed onto each plot or the soil was visibly wet and covered uniformly. The bioherbicidal treatments were applied as post-emergent applications to the Japanese cucumber plots for weed control. Treatments were sprayed directly onto the soil and into the weed canopy, while the Japanese cucumber plants were observed to evaluate their response, assessing the potential indirect impacts to the plants' safety, as well as to their growth and yields. Treatments were made at 14 and 28 DAP, while the fruit was harvested from the plant stalks, through four harvest events that occurred at 42, 46, 50 and 54 DAP (every fourth day).

Observation parameters

A vegetation analysis was conducted using a 0.5 m × 0.5 m quadrat placed once in each plot at 35 DAP. Within each quadrat, weeds were removed from the soil surface, separated and counted for each species. Then, the dried weights of the weeds were measured and the SDR of the weeds was determined. Observation parameters used to assess the effect of herbicide treatment included the number of weed plants per species, the total dry weight of weeds, the degree of phytotoxicity, the percentage of control achieved, the plant height, the fruit weight per plot and the fruit weight per hectare. Weeds began to emerge at 7 DAP. Spraying was conducted at 14 DAP, when weeds were already present and no synthetic herbicides were applied during the experiment.

RESULTS AND DISCUSSION

The most abundant species, *C. rotundus*, was found to have the highest SDR in Blocks I, II and III (at 29.5%, 39.7% and 45.2%), as shown by Table 1. Additionally, as shown by Table 2, the community coefficient values were all greater than 75% between Block I and Block II, Block I and Block III and Block II and Block III. These high coefficients indicated homogeneity of the weeds present in each block. The homogenous distribution of weed species among the three blocks demonstrates that weed management can be applied in this area.

C. rotundus demonstrated dominance over all treatments based on the population relative to the other weed species, as shown in Table 3 and 4. In terms of SDR, the highest SDR value was obtained from P30 (papaya leaf extract at 30%), while, in terms of population size, the control treatment showed the highest number of individuals with 345. Overall, it is evident that *C. rotundus* continued to be the dominant weed species in each of the treatments measured by SDR and population size. While there were noted differences between the treatments, none of these treatments was capable of decreasing their relative dominance.

Data in Table 5 revealed that the dry mass of weeds in the control treatment was the largest (110 g) and therefore, there was no weed suppression present in this treatment. Conversely, the least dry mass of weeds was noted in the L60 (66.33 g), P60 (68.33 g) and L45 (69.10 g) treatments; these treatments did not differ from one another statistically. Treatments with less concentrated levels, *i.e.*, L30, P30 and P45, had intermediate results that differed statistically from the control, but were larger than the most effective treatments. The above findings indicate a general trend to reduce weed biomass as the concentrations of both lamtoro and papaya leaf extracts increase, with the 45% and 60% concentrations showing the greatest weed suppressive effects. Furthermore, there was no sign of phytotoxicity in the Japanese cucumber plants at 28 DAP (including the control) when observing the plants on days 1, 2, 3 and 7 after treatment with lamtoro and papaya leaf extracts, indicating the safety of all tested concentrations of these extracts for use with this crop as they caused no visible injury or growth inhibition when comparing them to untreated plants.

The most effective weed control for the treatments was observed in the L60 (lamtoro leaf extract at 60%) treatment, which had an efficacy of 39.7% (Table 5). The lamtoro leaf extract treatment efficacy value is below 50%; thus, according to the efficacy testing criteria outlined by Miranda *et al.* (2022), it is considered "slightly effective."

Based on Table 6, at 21 DAP, the tallest Japanese cucumber plants were observed in the L45 treatment (71.33 cm), which was significantly taller than all other treatments. The control (C) and L60 treatments had intermediate heights (65.33 cm and 64.89 cm, respectively), while P45 had the shortest plants (61.33 cm). Treatments L30, P30 and P60 showed intermediate values that were not significantly different from the control.

At 28 DAP, the tallest plants were again recorded in the L45 treatment, measuring 114.11 cm, which was significantly greater than in all other treatments. Treatments L60 and L30 were intermediate, measuring 98.55 cm and

Table 1: Summed dominance ratio (SDR) of each block before land preparation.

Weed species and type	SDR block I (%)	SDR block II (%)	SDR block III (%)
Broadleaf weeds			
P. oleracea	8.77	8.19	9.28
M. procumbens	5.35	5.24	5.48
D. integrifolia	7.09	6.53	5.10
Grasses			
D. aristatum	10.70	7.14	15.80
D. sanguinalis	28.90	26.00	12.60
C. dactylon	9.69	7.19	6.57
Sedges			
C. rotundus	29.50	39.70	45.20

94.55 cm, respectively. The control treatment (82.22 cm) and the papaya extract treatments (P30: 93.34 cm, P45: 91.67 cm, P60: 92.45 cm) were lower. These findings suggest that 45% lamtoro leaf extract (L45) was the only treatment to induce the greatest amount of plant growth

Table 2: Community coefficient values before land preparation.

Community 1	Community 2	Community coefficient (%)
Block I	Block II	89.79
Block I	Block III	78.56
Block II	Block III	84.55

compared to the control and other extract treatments by 28 DAP.

At 35 DAP, the Japanese cucumber plants treated with the 45% lamtoro leaf (L45) treatment were the tallest, at a height of 128.33 cm and significantly taller than all other treatments. The other lamtoro leaf extract treatments had intermediate heights (L60: 113.44 cm, L30: 121.00 cm) and also did the papaya leaf extracts (P30: 119.11 cm, P45: 118.11 cm, P60: 119.56 cm). Overall, these data show that 45% lamtoro leaf extract (L45) continued to be the most effective for promoting the highest amount of plant growth by 35 DAP, as compared to all of the papaya leaf

Table 3: Summed dominance ratio (SDR) of weeds under different treatments at 35 DAP (%).

Weed species and type	Treatment						
	C	L30	L45	L60	P30	P45	P60
Broadleaf weeds							
P. oleracea	7.7	8.3	8.4	7.7	9.5	9.4	12.0
M. procumbens	4.4	4.3	5.3	4.4	4.5	4.1	N/A
D. integrifolia	5.5	6.6	8.2	9.1	7.0	7.3	9.6
C. viscosa	4.9	4.3	N/A	4.5	5.1	6.1	11.0
A. conyzoides	3.8	3.9	N/A	N/A	4.2	N/A	N/A
A. spinosus	4.4	N/A	N/A	4.5	5.4	4.7	N/A
Grasses							
D. aristatum	12.0	10.0	11.0	9.3	11.0	11.0	12.0
D. sanguinalis	18.0	22.0	25.0	22.0	15.0	14.0	14.0
C. dactylon	7.9	7.7	6.1	4.0	N/A	5.2	6.9
Sedges							
C. rotundus	32.0	32.0	36.0	35.0	39.0	38.0	35.0

Note: C = Control, L30 = *Leucaena leucocephala* leaf extract at 30% concentration, L45 = *Leucaena* leaf extract at 45% concentration, L60 = *Leucaena* leaf extract at 60% concentration, P30 = Papaya leaf extract at 30% concentration, P45 = Papaya leaf extract at 45% concentration, P60 = Papaya leaf extract at 60% concentration.

Table 4: Total weed population at 35 DAP.

Weed species and type	Treatment						
	C	L30	L45	L60	P30	P45	P60
Broadleaf weeds							
P. oleracea	43	31	17	21	41	37	41
M. procumbens	15	5	4	5	8	3	-
D. integrifolia	25	20	20	27	21	21	25
C. viscosa	12	4	-	4	9	13	27
A. conyzoides	6	1	-	-	3	-	-
A. spinosus	3	-	-	1	3	2	-
Grasses							
D. aristatum	115	54	41	37	61	55	56
D. sanguinalis	100	79	70	61	45	37	31
C. dactylon	37	24	9	2	-	12	15
Sedges							
C. rotundus	345	165	142	121	222	197	182
Total	701	383	303	279	413	377	377

Note: C = Control, L30 = *Leucaena leucocephala* leaf extract at 30% concentration, L45 = *Leucaena* leaf extract at 45% concentration, L60 = *Leucaena* leaf extract at 60% concentration, P30 = Papaya leaf extract at 30% concentration, P45 = Papaya leaf extract at 45% concentration, P60 = Papaya leaf extract at 60% concentration.

extracts and the lower lamtoro leaf concentration treatments.

Japanese cucumber plants treated with 45% lamtoro leaf extract (L45) consistently exhibited the tallest records of growth during the observation periods, which topped at 71.33 cm at 21 DAP, 114.11 cm at 28 DAP, 128.33 cm at 35 DAP and 139.33 cm at 42 DAP and which were significantly greater than all other treatments, during all observation periods. Treatment with *Leucaena leucocephala* at a 60% concentration (L60) also significantly enhanced cucumber plant growth (64.89-127.67 cm), whereas the control plants (C), which were not treated with any *L. leucocephala* leaf extract, consistently exhibited the smallest growth across all observation periods. Cucumber plant growth was increased by treatment with papaya leaf extract concentrations of 30%, 45% and 60% (P30, P45, P60) and with the lower lamtoro leaf extract concentration (L30). In comparison to the control, which had the least amount of growth, each of these treatments had a greater amount of growth than the control, but L45 was the concentration of lamtoro leaf extract that produced the greatest amount of cucumber plant growth during the 42-day experiment.

Table 7 indicates that the total fruit yield for Japanese cucumbers was greatest in the L45 treatment (45% lamtoro leaf extract), which had a 10.21 kg/plot (3.6 m^2) and 28.36 ton/ha total fruit yield, greater than all other treatments. Total fruit yield for the L60 treatment was better than the control; however, not as great (7.13 kg/plot and 19.81 ton/ha). Papaya leaf extract treatments (P30, P45, P60) and the lower lamtoro concentration (L30) produced intermediate yields, generally higher than the control (C: 4.97 kg per plot, 13.82 ton/ha) but lower than L45. These results indicate that 45% lamtoro leaf extract (L45) was the most effective treatment for enhancing fruit production, likely due to its combined effect on weed suppression and plant growth.

Following application, weeds did not die immediately but showed inhibited growth, indicating a suppressive rather than lethal allelopathic effect. The increased weed emergence observed at 28 DAP may be due to new germination from the soil seed bank or regrowth following suppression. At 35 DAP of Japanese cucumbers and in the area immediately surrounding those plants, prior to tilling of the soils, *C. rotundus* had been found to be the most numerous weed species based on the highest SDR values. *C. rotundus* is a perennial type of weed, which has the potential to continuously generate new shoots throughout its life cycle (Peerzada, 2017; Bangash *et al.*, 2025). This aerial portion of *C. rotundus* is often desiccated in order to die as a result of drought conditions in the environment, but the root system and rhizome are able to maintain life underground and will be activated by suitable environmental growth conditions, after which the aerial portion will grow from underground and the plant will go into seed production to guarantee continued survival and reproduction of the species (Rahayu, 2019; Leguizamón, 2024).

Shifts in weed species and in weed populations were noted at 35 DAP, with the emergence of some previously unobserved weed species, including *C. viscosa*, *A. conyzoides* and *A. spinosus*. *M. procumbens* was absent in the P60 plots, while *C. dactylon* was not found in the P30 plots. Decreases in the population of *P. oleracea*, *D. sanguinalis* and *C. rotundus* were noted on all plots. Decreases in the population of *M. procumbens*, *D. aristatum* and *C. dactylon* occurred on all treatments with the exception of the control. Populations of *D. integrifolia* decreased in both L30 and L45 plots. The appearance of new weeds can be attributed

Table 5: Mean total weed dry weight and weed control efficiency under different treatments at 35 DAP.

Treatment	Weed dry weight (g)*	Weed control efficiency (%)**
C	110^{a}	0
L30	80.33^{bc}	27.0
L45	69.10^{cde}	37.2
L60	66.33^{e}	39.7
P30	84.97^{b}	22.8
P45	78.63^{bcd}	28.5
P60	68.33^{de}	37.9

Note: *Numbers followed by the same letter in the column indicate no significant difference according to DMRT at the 5% level. **Highly efficient >95.1%, efficient 85.1-95%, moderately efficient 50.1-85%, slightly efficient <50%, not efficient 0% (Miranda *et al.*, 2022).

Table 6: Mean plant height of Japanese cucumber.

Treatment	Plant height (cm)			
	21 DAP	28 DAP	35 DAP	42 DAP
C	65.33^{b}	82.22^{d}	100.44^{c}	111.89^{d}
L30	64.00^{bc}	94.55^{bc}	121.00^{b}	133.89^{b}
L45	71.33^{a}	114.11^{a}	128.33^{a}	139.33^{a}
L60	64.89^{b}	98.55^{b}	113.44^{b}	127.67^{c}
P30	63.55^{bc}	93.34^{c}	119.11^{b}	132.67^{bc}
P45	61.33^{c}	91.67^{c}	118.11^{b}	131.11^{bc}
P60	64.33^{bc}	92.45^{c}	119.56^{b}	134.78^{ab}

Note: Numbers followed by the same letter in the column indicate no significant difference according to DMRT at the 5% level.

Table 7: Mean fruit weight per plot and per hectare of Japanese cucumber.

Treatment	Fruit weight per plot (kg/3.6 m^2)	Fruit weight per hectare (ton/ha)
C	4.97[c]	13.82[c]
L30	6.80[bc]	18.89[bc]
L45	10.21[a]	28.36[a]
L60	7.13[b]	19.81[b]
P30	6.15[bc]	17.07[bc]
P45	6.18[bc]	17.17[bc]
P60	5.50[bc]	15.29[bc]

Note: Numbers followed by the same letter in the column indicate no significant difference according to DMRT at the 5% level.

to the presence of a seed bank in the soil (Schwartz-Lazaro and Copes, 2019; Gao *et al*., 2020), as well as by the residues of weeds remaining in the soil contributing to the establishment of that seed bank which will become a future source of weeds when environmental conditions allow for germination (Siahaan *et al*., 2014).

Based on the findings, applications of lamtoro and papaya leaf extracts at 30%-60% concentrations did not cause phytotoxic symptoms in cucumber plants, indicating that they are safe for use. Bioherbicides are toxic to weeds but not to cultivated plants due to physiological and biochemical differences in sensitivity to the active compounds (Ammar *et al*., 2023; Ling *et al*., 2023). Phytoxicity is caused by all of the above through inhibition of the weed's major metabolic processes, such as photosynthesis, respiration, protein synthesis and cell division, due to the presence of the plant's secondary metabolites or allelopathic compounds in the bioherbicide. The main reason why the cultivated crop does not experience this same toxicity is because of its superior ability to tolerate or detoxify the compounds (Zhang *et al*., 2021) present in the bioherbicide. This results in a lack of toxic effects on the crop (Ridwan *et al*., 2023).

The differing levels of lamtoro and papaya leaf extracts produced various levels of impact on suppressing weeds. The L60 treatment had the least amount of weeds and weed biomass as measured by the total number of weeds and dry weight at 35 DAP. This indicated that there is a direct relationship between the level of lamtoro leaf extract and the strength of weed suppression. A similar reduction of weed growth occurred when using P60, but it was less effective compared to lamtoro treatments. These results support the assertion that an increase in the level of the extract will increase the degree of weed suppression through an increase in the quantity of allelochemicals in the extract, consistent with other research studies showing that higher extract concentrations have been shown to result in greater inhibitory effects (Septiani *et al*., 2019; Anwar *et al*., 2021), which stated that higher extract concentrations are capable of resulting in greater inhibition of weed growth through an increase in the quantity of allelochemicals present in the extract.

While a better suppressive effect of weeds was noted for L60, it is clear that L45 had the best plant height, fruit weight per plot and yield per hectare, which is indicative that L45 provides the most optimal concentration of allelochemicals for both effective weed control and safe crop production. Treatments with higher levels of allelochemicals than L45 (such as L60) can have some level of mild physiological stress effects upon cucumber plants, potentially limit plant growth and therefore reduce yields, without producing any observable signs of phytotoxicity. The papaya leaf extracts used in this experiment provided some moderate degree of weed suppression and were found to be safe from a detrimental impact on cucumber growth and development; however, these extracts also resulted in significantly reduced cucumber yields when compared to lamtoro leaf extracts, indicating the potential lower potency of the allelopathy of papaya leaf extracts under the same experimental conditions.

Significant differences in plant growth parameters for plant growth-specifically plant height and fruit weight per plot and fruit weight per hectare-were also determined. Among the treatments tested, the highest yields were found to be those using a 45% lamtoro leaf extract treatment (L45). The L45 treatment was considered optimal because any treatment using a greater concentration of lamtoro leaf extract than 45% would likely result in an overexposure of allelochemicals to the plants, which would inhibit plant metabolism. The lamtoro leaf extract from *Leucaena leucocephala* has many secondary metabolites that have allelopathic effects, including flavonoids, tannins, phenols, alkaloids, saponins and mimosine (Bageel *et al*., 2022; Islamiyati *et al*., 2023). When at 45%, the cucumber plants used the nutrient supply optimally, so they did not become overloaded by their nutrient needs and thus disrupted their own metabolic balances. This agrees with Marschner (2012) principle that plants will only take up the nutrients needed. While these compounds suppress weed growth, when applied at appropriate doses, they do not cause phytotoxicity to the main crop, such as Japanese cucumber and may even support its growth. From a practical perspective, the L45 treatment is recommended as it provides effective weed suppression while maximizing cucumber growth and yield.

CONCLUSION

The results show that there is an opportunity to use leaf extracts from both *Leucaena leucocephala* and *Carica papaya* as a bioherbicide to help control weeds in Japanese cucumber production. The highest percentage of reduction in weed biomass by treatment was achieved using the 45% *Leucaena leucocephala* leaf extract, with no signs of phytotoxicity occurring and a significant increase in plant size and yields compared to other treatments. In contrast, papaya (*Carica papaya*) leaf extract treatments also reduced weed biomass and showed no phytotoxic effects on Japanese cucumber plants; however, their effects on plant growth and yield were generally lower than those of lamtoro leaf extract. Although higher extract concentrations provided slightly greater weed suppression, they did not increase cucumber productivity. These findings indicate that selecting an optimal extract concentration is more important than increasing dosage for achieving effective weed control and maximizing crop yield.

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Not applicable.

Disclaimers

The opinions and the conclusions drawn in the paper reflect the opinions and views of the authors alone and may not be representative of the views of their associated institutions. The authors are accountable for providing complete and accurate information in the content presented here; however, the authors will not be liable to any party for loss, whether direct or indirect, arising from use of this content.

Informed consent

Not applicable.

Conflict of interest

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