Research Article

Application of Weed Extracts from Billygoat (*Ageratum Conyzoides*) and Siam (*Chromolaena Odorata*) to Control Late Blight (*Phytophthora infestans*) on Potatoes

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Abstract | Late blight is an important disease in potato plants caused by the fungus *Phytophthora infestans*. The disease can develop quickly, be very severe and cause up to 100% loss in potato yields in high rainfall, humidity and temperature at 18°-20°C. The research aims to determine the effect of applying goat weed leaf extracts and siam weed leaf extracts as a botanical fungicide to control potato late blight. The research was carried out in Pandansari Village, Paguyangan District, Brebes Regency, Central Java, Indonesia, at 2050 m altitude a region endemic to late blight. The research was conducted using Completely Randomized Design with 1 treatment factor and 5 treatment levels : no fungicide (B0), goat weed leaf extract 100g/l aquadest (B1), siam weed leaf extract 100g/l aquadest (B2), goat weed leaf 50g+siam weed leaf extract 50g/l aquadest (B3) and fungicide propamocarb hydrochloride 3 ml/l aquadest (B4). Each treatment consisted of 10 replications. Granola variety potato tubers were planted in soil media which are placed in polybags measuring 45 cm x 45 cm. The distance between polybags is 120 cm. The variables observed included : late blight intensity, tuber rot intensity, plant height, canopy diameter, total number of tubers, number of healthy tubers, number of sick tubers, weight of healthy tubers, and weight of sick tubers. The important results show that the application of siam weed leaf extract resulted in an intensity of potato late blight of 17.58%, which was not significantly different from the application of the fungicide Propamocarb Hydrochloride, while the control treatment without fungicide resulted in a late blight intensity of 43.28%. Therefore, siam weed leaf extract can have practical implications as a botanical fungicide to control potato late blight. Siam weed leaf extract improves vegetative growth of potato plants and produces the heaviest healthy tuber weight : 207.80 g/plant.

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Introduction

Potatoes are a versatile food commodity and are the fourth largest food crop in the world after wheat, rice and maize (Hou *et al*., 2022). This commodity is a staple food for most of the world's population and is consumed by many people in various forms of processed food. Due to high demand, potatoes play an important role in the economic aspect and are one of the sources of income for a country (Sinha and Singh, 2019; Suo-meng and Shao-qun, 2022). One country that is trying to increase potato production is Russia. Russia is targeting potato yields of 25-30 t/ha from the previous 17-18 t/ha. One reason for low potato production in Russia is the susceptibility of crops to disease due to non-certified seeds (Anisimov, 2022).

In Indonesia, potato production is low compared to international production standards due to the high intensity of potato diseases, one of which is due to the dominant use of the Granola cultivar and the use of uncertified seeds (Taylor and Dawson, 2021). These several examples show that there are many obstacles in the form of disease in potato plants which can reduce potato yields.

Late Blight disease is one of the most destructive diseases in potato plants caused by the fungus *Phytophthora infestans*. This disease can reduce potato yields by up to 100% (Tsedaley, 2014; Suo-meng and Shao-qun, 2022). Apart from attacking potato plants, the fungus *P. infestans* is also reported to attack tomato plants (Ivanov *et al*., 2021). According to Hou *et al*. (2022), Late Blight disease can destroy potato crops within a few days in conditions of high rainfall, very humid and temperatures 18°-20°C. Therefore, the problem of late blight is an important limiting factor in efforts to achieve food security for the potato commodity (Yuen, 2021). In North America, the pathogen that causes potato late blight has been reported to survive on infected tubers, in piles of tubers to be destroyed, and on volunteer plants (Tsedaley, 2014; Robinson *et al*., 2022).

The high number of diseases that attack many plants and concerns about the risk of crop failure, farmers use a lot of inorganic chemicals (Budi, 2021). The use of inorganic fungicides is widely applied in potato cultivation to protect plants so they can produce optimally (Gościnna *et al*., 2024). This chemical fungicide, when applied over a long period of time at high doses and concentrations and short time intervals in potato cultivation, will give rise to resistance genes in *P. infestans* and cause some fungicides to become ineffective (Yuen, 2021). Inorganic pesticides can also cause negative impacts on soil and water systems, destroying the natural balance, plant metabolic processes, as well as human health problems through the skin and breathing (Damalas and Koutroubas, 2016; Pathak *et al*., 2022; Hajoeningtijas *et al*, 2025) and reduce human immunity (Bagchi *et al*., 2024).

Because there are many negative effects from using inorganic fungicides, there is a need for alternative methods of controlling Late Blight disease that are more eco-friendly, one of which is by using plants or weeds. Weeds are usually thrown away by farmers because weeds interfere with cultivated crops. Botanical materials in the form of weeds can be used as ecofriendly fungicides because they are easily degraded, relatively safe for human health and more economical (Chahal *et al*., 2021; Budi *et al*., 2023). Botanical materials contain secondary metabolites which function for body defense and various ecological functions of the plant, these compounds have the potential to be used as pesticides (Nabavi *et al*., 2020). One example of botanical ingredients in the form of extracts of soursop leaves, kaffir lime leaves, betel leaves and a mixture of the three can reduce the intensity of downy mildew disease in maize plants by around 18.50% -22.91% compared to controls without fungicide application : 48.16% (Budi *et al*., 2024).

Goat weed (*Ageratum conyzoides*) contains secondary metabolites including chromenes, terpenoids, flavonoids and coumarins which are reported to be effective in suppressing the growth of various species of pathogenic fungi such as *Aspergillus, Alternaria, Candida, Fusarium, Phytophthora* and *Pythium* (Chahal *et al*., 2021). Antifungal compounds such as precocene II and polymethoxyflavones contained in goat weed show strong antifungal activity against *Pyricularia oryzae* which causes blast disease in rice and *Rhizoctonia solani* which causes sheath blight in rice in vitro (Nguyen *et al*., 2021). Siam weed (*Chromolaena odorata*) extract is reported to suppress the growth of several soil-borne fungal pathogens including *Fusarium spp*. and inhibits the growth of pathogenic colonies *Lasiodiplodia theobromae* and *Lasiodiplodia pseudothobromae* (Noguchid *et al*., 2023).

Materials and Methods

Experimental details and treatments

Experimental material: The research was carried out in Pandansari Village, Paguyangan District, Brebes Regency, Central Java, Indonesia, at an altitude of 2050 m, from May to August 2024. The research location is an endemic area of late blight where late blight consistently appears during every potato season in this area. Therefore, in this study, no inoculaton of pathogenic fungi was carried out. The potato tubers used are the Granola variety, the tubers were selected for health and uniformity, each weighing approximately 8 g. The tubers are planted in soil media placed in polybags measuring 45 x 45 cm. Polybags are placed with a distance between polybags: 120cm x 120 cm.

Treatments: The study used a Completely Randomized Design with one factor and five treatment levels : no fungicide (B0), goat weed leaf extract 100g.L^{-1} aquadest (B1), siam weed leaf extract 100g.L^{-1} aquadest (B2), goat weed leaf extract 50g+siam weed leaf extract 50g.L^{-1} aquadest (B3) and fungicide propamocarb hydrochloride 3 mL.L^{-1} aquadest (B4). Potato tubers of the Granola variety were planted in soil media placed in polybags measuring 45 cm x 45 cm, each treatment had 10 replicates. The variables observed included : late blight intensity, tuber rot intensity, plant height, canopy diameter, total number of tubers, number of healthy tubers, number of infected tubers, weight of healthy tubers, and weight of infected tubers.

Statistical analysis

The data obtained from the observation results were analyzed with the help of CoStat and SPSS 26 software. Data was analyzed statistically using analysis of variance 5% . If the ANOVA test shows a significant effect or the calculated F value is greater than the F table, the analysis is continued with the Duncan Multi Range Test (DMRT) 5%.

Results and Discussion

Based on the results of the analysis of variance, it shows that the weed extract treatment had a significant effect on late blight intensity, plant height, canopy diameter, weight of healthy tuber and weight of infected tuber but no significant effect was observed on tuber rot intensity, total number of tubers, number of healthy tubers, number of infected tubers. Treatments that show a significant effect are then subjected to DMRT tests at a level of 5%. Based on the data in Table 1, it can be seen that the weed extract treatment has a significant effect on the intensity of late blight. The siam weed extract treatment (B2) and inorganic fungicide (B4) effectively reduced the intensity of late blight compared to the control without fungicide (B0). The inorganic fungicide treatment showed a late blight intensity of 21.00% and in the siam weed extract treatment: 17.58%. Both treatments were lower than the control (B0): 43.28%. In the observations of tuber rot intensity, all treatments showed no significant effect.

Table 1: *The effect of goat weed extract and siam weed extracts application on late blight intensity and tuber rot intensity of potato plants*

Treatment	Late blight intensity (%)	Tuber rot intensity (%)
B0 (No fungicide)	43.28 b	16.28
B1 (Goat qeed)	29.70 ab	14.08
B2 (Siam qeed)	17.58 a	2.95
B3 (Goat weed+Siam weed)	35.30 ab	5.63
B4 (Propamokarb hidroklorida)	21.00 a	7.35

Note : Numbers followed by different notations in 1 column are significantly different (DMRT 5%).

Based on the data in Table 2, it can be seen that the weed extract treatment had a significant effect on plant height and canopy diameter. The goat weed extract treatment (B1) resulted in plant height: 44.50 cm and siam weed extract (B2): 43.20 cm higher than the control without fungicide (B0): 37.50 cm. The application of goat weed extract (B1) resulted in a canopy diameter of 41.63 cm and 43.17 cm, respectively, which were wider than the control without fungicide (B0): 35.50 cm.

Table 2: *The effect of goat weed extract and siam weed extracts application on plant height and canopy diameter of potato plants*

Treatment	Plant height (cm)	Canopy diameter (cm)
B0 (No fungicide)	37.50 a	35.50 b
B1 (Goat weed)	44.50 b	41.63 c
B2 (Siam weed)	43.20 b	43.17 c
B3 (Goat weed+Siam weed)	40.80 ab	39.23 bc
B4 (Propamokarb hidroklorida)	38.10 a	28.06 a

Note : Numbers followed by different notations in 1 column are significantly different (DMRT 5%).

Based on the data in Table 3, it can be seen that the weed extract treatment had a significant effect on the weight of healthy tubers and the weight of infected tubers. The application of siam weed extract (B2) resulted in the heaviest healthy tuber weight: 207.8 g/plant compared to other treatments. Inorganic fungicide treatment (B4) resulted in the lightest weight of diseased tubers: 15.3 g/plant. When observing the total number of tubers, the number of healthy tubers and the number of infected tubers, all treatments showed no significant effect.

Table 3: *The effect of goat weed extract and siam weed extracts application on crop harvest results of potato plants*

Treat-ment	Observation				
	TNT (tubers)	NHT (tubers)	NIT (tubers)	WHT (g)	WIT (g)
B0	6.70 a	5.30 a	1.40 a	141.40 a	39.90 ab
B1	6.50 a	4.70 a	1.80 a	133.30 a	69.50 b
B2	6.90 a	5.70 a	1.20 a	207.80 b	41.10 ab
B3	6.20 a	4.40 a	1.80 a	129.70 a	62.60 b
B4	5.50 a	4.80 a	0.70 a	125.20 a	15.30 a
	tn	tn	tn	*	*

Note : Numbers followed by different notations in 1 column are significantly different (DMRT 5%).

The application of siam weed extract fungicide (B2) showed an intensity of 17.58% and inorganic fungicide (B4) showed an intensity of 21.00%. Both treatments were effective in reducing the intensity of late blight compared to the control without fungicide (B0), showing a disease intensity of 43.28%. It is possible that the compound content in the siam weed extract is able to control fungal infections that cause late blight, comparable to the chemical fungicide Propamocarb Hydrochloride, which was also effective in controlling the late blight fungus. This is consistent with findings by Shilpa *et al.* (2020) who reported that the essential oils, flavonoids, tannins, monoterpenes, querticin and alkaloids contained in siam weed show high effectiveness as anti-fungal compounds. Apart from essential oils, siam weed also contains tau-Cadinol, α Bisabolol, cis-muurola-4 (14) 5-diene, Isobornyl acetate, and Isocaryophyllene which effectively inhibit bacterial pathogens including the *Pseudomonas* (Choudhary *et al.*, 2023).

The results of tests conducted by (Bishoyi *et al.*, 2024) stated that siam weed synthesized biogenic silver nanoparticles (AgNPs) produced excellent antifungal activity against the pathogens *Candida tropicalis* and *Trichophyton rubrum*. *C. odorata* leaf powder at a concentration of 0.5g has an antifungal effect of 74% against *Aspergillus ustus*, the papaya fruit rot fungus (Olufunmilola *et al.*, 2022). This shows the potential for siam weed leaf extract to be effective in controlling fungal infections. Siam weed extract is reported to be able to inhibit the growth of several soil-borne fungal pathogens and significantly inhibit the growth of colonies of pathogenic fungi in the *Botryosphaeriaceae* family that cause leaf necrosis, cancer and death in many plant species. Apart from that, it was reported that in the soil where the surface was covered with siam weed (*C. odorata*), there was an increase in the population of the *Mycorrhiza arbuscular Paraglomus* spp. Therefore, application of siam weed extract to potato plants is very likely to support the proliferation of *Mycorrhiza* populations in the soil and ultimately improve the ability of potato plants to absorb water and nutrients, their defense function against various stress conditions and their resistance to pathogens. (Noguchid and Kato, 2023).

Figure 1: *Potato plant research (60 days after planting)*

Tannin compounds in siam weed tissue act as antioxidant compounds that protect the biological structure of plants from harmful effects, including oxidative stress and increase resistance to biotic stress, especially against pathogen infections (Das *et al.*, 2020; Mora *et al.*, 2022). According to Brunetti *et al.* (2018), flavonoid compounds can function as antioxidants that regulate plant growth to respond to excess metal ions and photosynthetic redox imbalances. It is strongly suspected that flavonoids influence the signals of the phytohormones auxin and abscisic acid and influence the process of opening and closing stomata in plants, enhancing resistance to foliar pathogens and better plant growth.

The application of the fungicide Propamocarb Hydrochloride showed a low intensity of late blight, this shows that the active ingredient Propamocarb Hydrochloride is still effective in inhibiting the *Phytophthora* fungus. In line with (Simanjuntak *et al*., 2017), Propamocarb Hydrochloride can inhibit the colony diameter of pathogenic fungi : *Aspergillus sp*. from 8.40 cm to 5.14 cm, *Penicillium sp*. from 8.32 cm to 4.65 cm, *Mucor sp*. from 8.50 cm to 5.84 cm on the seventh day of observation after application of the active ingredient.

Figure 2: *Late blight symptoms on potato leaves*

Botanical material extracts had a significant effect on the growth of plant height and plant canopy diameter. The goat weed extract (B1) and siam weed extract (B2) treatments showed higher plant growth and wider canopy diameters than the control treatment (B0). It is possible that the application of goat weed and siam weed extracts which produce low intensity of late blight causes more efficient photosynthesis so that the results of photosynthesis can support plant height growth and maximum canopy development.

The treatment of botanical extracts and inorganic fungicides have no significant effect on the total number of tubers, the number of healthy tubers and the number of infected tubers. This is because the botanical fungicide treatment and inorganic fungicides is a treatment aimed at suppressing the growth of the fungus that causes late blight, so it is possible that it will not have a direct effect on the formation of the number of tubers or the development of tuber enlargement. Fungal attacks appear to show symptoms of tuber rot with a percentage (2.95%-16.28%) so that it has no effect on the formation of tuber development and tuber numbers.

Figure 3: *Teqnique of spraying extract*

When observing the weight of healthy tubers, it was seen that the treatment with siam weed extract (B2) resulted in a heavier weight of healthy tubers : 207.8 g/plant which was significantly different from the other treatments. This is related to the effectiveness of the siam weed extract which shows the lowest intensity of leaf rot, higher plant height and canopy diameter and on average produces the highest number of healthy tubers. These factors influence each other synergistically, resulting in a heavy weight of healthy tubers. Some secondary metabolite compounds contained in siam weed extract may show a better influence on the resistance of potato plants to *Phytophthora* and have a better effect on the growth and development of potato plants.

Flavonoid compounds have a functional role in heat acclimatization in plants and tolerance of extreme cold temperatures (Mierziak *et al*., 2014). Flavonoids can neutralize high doses of ultraviolet-B light, excess metal ions and imbalances in the photosynthetic oxidation-reduction process and influence signals for the formation of the phytohormones auxin and abscisic acid (Brunetti *et al*., 2018). According to Bhambhani *et al*. (2021), alkaloid compounds also act as nitrogen storage reservoirs where these compounds will be released from specific gland organelles and exported to target tissues that experience stress signals from the biotic and abiotic environment.

Terpenoid compounds can act as antioxidants that are beneficial for extensive plant growth (Babychan *et al*., 2017; Mohandas and Kumaraswamy, 2018).

Terpenoids also function to protect plants against environmental stress through direct reactions of terpenoids with oxidants intracellularly or between the leaf surface and the atmosphere (Boncan *et al*., 2020). Tannins have a function as antioxidants to protect biological structures from the effects of oxidative stress, increasing the body's resistance to biotic factors, especially against pathogens and abiotic stresses such as light stress and injury (Tshabalala *et al*., 2019; Mora *et al*., 2022). According to Das *et al*. (2020) tannin compounds also act as plant defense molecules. This compound provides a barrier against the invasion of phytopathogens in plants so that it can prevent disease in plants.

The application of siam weed extract showed a good effect on the weight of healthy potato tubers. It is possible that the compounds in siam weed support the proliferation of *Arbuscular mycorrhizal* fungal populations, especially *Paraglomus spp*. in the soil but this still needs to be studied further. If this really happens, the increase in *Mycorrhiza* population due to the siam weed extract application will cause the absorption of water and nutrients, especially phosphorus and nitrogen in plants, to increase (Noguchid and Kato, 2023). Observing the weight of infected tubers showed that the fungicide Propamocarb Hydrochloride (B4) treatment produced the lightest weight of infected tubers (15.30 g/plant) and showed significantly different from the other treatments. This shows that the application of inorganic fungicides is more effective in minimizing the number of infected tubers, this condition will produce low weight of infected tubers.

Conclusions and Recommendations

Application of siam weed leaf extract showed a late blight intensity of 17.58%, which was not significantly different from the Propamocarb Hydrochloride treatment. Without fungicide treatment the intensity of potato late blight : 43.28%. These findings support the potential use of Siam weed extract as an effective botanical alternative to synthetic fungicides for managing late blight in potato.

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Novelty Statement

Siam weed extract has the potential to be an effective and more eco-friendly alternative botanical fungicide in managing potato late blight

Author's Contribution

Gayuh Prasetyo Budi: Drafted the research concept, interpreted the data and wrote the first draft of the manuscript.
Toti Ariya Pangestu: Observed the data in the laboratory and in the field
Aman Suyadi: Reviewed the manuscript critically
Oetami dwi Hajoeningtijas: Reviewed the manuscript critically.
Hafid Firmansyah: Compiled the completeness of the manuscript for submission purposes

Generative AI or AI-assisted technology statement
In writing this article, the author did not use the assistance of AI technology.

Conflict of interest
The authors have no conflict of interest.

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