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Research Article

Evaluation of Wedelia water extract on soybean, purple nutsedge, and billygoat seeds germination

Dyah Weny Respatie [1,*], Aziz Purwantoro [1], Didik Indradewa [1], Qurrotul Uyun [1], and Haviah Hafidhotul Ilmiah [1]

[1] Department of Agronomy, Faculty of Agriculture, Universitas Gadjah Mada, Jl. Flora No. 1, Bulaksumur, Sleman 55281, Yogyakarta, INDONESIA
* Corresponding author (✉ wenyrespatie@ugm.ac.id)

ABSTRACT

Weeds cause significant yield loss in many agriculture crops; thus, management practices are urgently needed to alleviate losses while conserving environmental and human health. This study aimed to evaluate the allelopathic potential of Wedelia leaf and flower extracts on the germination and early growth stage of three plant species. The research was conducted using a completely randomized design experiment with two factors and four replicates. The first factor was extract sources: leaves (S1) and flowers (S2). The second factor was the concentration: control (C0) and extract concentrations of 1% (C1), 5% (C5), and 10% (C10). The extract was tested on three different plant species: soybean (Glycine max), nutsedge (Cyperus rotundus), and billygoat weed (Ageratum conyzoides). Fifty seeds of three different plants were germinated separately in Petri dishes and treated using Wedelia extracts. The allelochemicals in Wedelia leaf and flower extracts inhibited germination and induced abnormal sprouting. Wedelia leaf extract showed the most pronounced inhibitory effects and highest inhibition levels across all measured parameters. Moreover, a clear concentration-response relationship was observed, where increased extract concentration increased the degree of inhibition. These findings contribute to the development of bioherbicides and can help reduce the use of synthetic herbicides for more sustainable agriculture.

Keywords: *Ageratum conyzoides*; bioherbicide; *Cyperus rotundus*; *Glycine max*; weed control

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INTRODUCTION

Weeds are the most damaging biotic constraint to agricultural production and compete with crops resulting in considerable productivity loss (Jabran et al., 2015; Gharde et al., 2018). Weeds impede crops by competing with the standing crop for nutrition and other resources, which stifle crop growth and development. As a result, crop yield eventually shows qualitative and quantitative decreases that later have significant economic effects on farmers (Mlombo et al., 2024).

Soybean (*Glycine max* L.) is a major leguminous crop that is grown worldwide (Khojely et al., 2018). In soybean production, weed competition threatens more than 34-37% of global productivity with purple nutsedge (*Cyperus rotundus* L.) and billgoat weed (*Ageratum conyzoides* L.) being the main weed species (Imaniasita et al., 2020; MacLaren et al., 2020; Li et al., 2021; Airi et al., 2023). Purple nutsedge have been reported to cause substantial yield losses between 23%-89% in summer crops in South Asia (Peerzada, 2017). In tomato, the investation of purple nutsedge reduces the dry weight of shoots by 18% (Morales-Payan et al., 2003). The weeds also arable soil to be infertile by altering soil microbiome composition (Liu et al., 2022).

Cultural, physical, chemical, and biological controls and combination among all options are some strategies for purple nutsedge management. The increase in herbicide control results in high risks to human health and the environment. In addition, excessive herbicide application causes the development of herbicide-resistant weed populations (Hulme, 2022). Therefore, a cost-effective alternative strategy for the control of purple nutsedge that is also environmentally friendly is important (Peerzada, 2017).

Bioherbicides refer to natural products derived from living organisms or their natural metabolites; they are used to control weed populations without harming the environment (El-Amier & Abdullah, 2014). Allelopathy can be used in weed management and comply with environmental issues and is cost-effective (El-Amier & Abdullah, 2014; Jabran et al., 2015). This method provides an alternative for the development of environmentally friendly agricultural practices that increase crop productivity and support ecosystem stability (Scavo et al., 2018). Therefore, allelopathy has the potential as a natural herbicide (Anh et al., 2021).

Wedelia (*Wedelia trilobata* L.) is a weed that contains different bioactive compounds with varying biological activities. The metabolomics of Wedelia leaf water extract revealed the presence of alkaloids, diterpenoids, and monosaccharides, which have allelopathic effects (Azizan et al., 2016). As this weed contains secondary metabolites that have been found to have herbicidal activities, plant organs that effectively inhibit germination must be determined. To support sustainable agriculture, we investigated the allelopathic potential of Wedelia extracts from different plant organs on the germination and early growth stage of soybean, purple nutsedge, and billygoat weed.

MATERIALS AND METHODS

Collection site

Wedelia leaves and flowers were collected from the experimental field of the Agricultural Faculty of Universitas Gadjah Mada, Banguntapan, Bantul District, Special Region of Yogyakarta Province, Indonesia (07° 48′17″ S and 110°24′45″E) in November 2023.

Determination of phenolic content equivalent to gallic acid

Total phenolic content (TPC) was determined via the Folin–Ciocalteu method (Singleton et al., 1999). The total phenol equivalent of gallic acid was determined by adding 0.5 mL Folin–Ciocalteu phenol reagent and 7.5 mL distilled water to 50 mg of samples. The solution was then shaken and left for 10 min. Afterward, 1.5 mL 20% sodium carbonate solution was added, and the mixture was shaken and left again for 10 min. Next, up to 10 mL of distilled water was added to the solution, and the absorption was read at a wavelength of 760 nm.

Extract and solution preparations

Wedelia leaves and flowers were dried to constant weight at 40 °C for 48 h. Dried leaves and flowers were macerated into powder and then sifted using a 16-mesh sieve. The powder was weighed separately at 1, 5, and 10 g. A total of 100 mL distilled water was added to the bottle containing the powder materials and left at room temperature. After 24 h, the materials were filtered to obtain 1%, 5%, and 10% extracts respectively. The solutions were then extracted again through a muslin cloth (<0.1 mm diameter), followed by Whatman filter paper No. 1. The final filtered solution was stored in a refrigerator (Uyun et al., 2024).

Bioassays

The experiment was conducted using a factorial completely randomized design consisting of two factors. The first factor was Wedelia tissue source of leaves (S1) and flowers (S2). The second factor was extract concentrations that consisted of control (C0), 1% (C1), 5% (C5), and 10% (C10). This experiment was tested in three different plant species: soybean, purple nutsedge, and billygoat seed. Each species was separately germinated in a petri dish containing Wedelia extract. Fifty seeds with four replications were used for each treatment combination.

The Wedelia extracts obtained from the leaves and flowers at a predetermined concentration were pipetted to a filter paper as a germination medium at 10 mL for each petri dish. The extract was repeatedly used to wet the filter paper to maintain the humidity up to a dose of 25 mL for each petri dish. Germination was observed for 7 days.

Research using soybean seeds, nutsedge, and billygoat weed seeds was conducted to determine the effect of Wedelia extracts on the different plant species' germination. Results from the germination stage can be used as initial indicators to determine the inhibitory levels of Wedelia leaf and flower extracts. Treatment using various sources of Wedelia plant extract in the germination phase was thought to influence the metabolic activity of soybean seeds, especially the embryos for germination, which resulted in a different germination response compared with the seeds that were germinated without the extract. Preliminary findings suggest that the Wedelia extracts significantly influence the germination process of soybean seeds, nutsedge, and billygoat weed seeds.

Observations of growth parameters

In this study, we systematically evaluated several parameters to assess seedling development and extract effects. Observations included the germination rate, germination index, average germination time, and incidence of abnormal sprouts, which were recorded daily for seven days. Abnormal sprouts, which were characterized by atypical growth patterns such as stunted or deformed shoots and roots, were specifically noted for soybean, purple nutsedge, and billygoat weed, indicating potential interference with normal seedling development. On the seventh day, we measured shoot length, root length, number of leaves, and fresh weight of sprouts. Additionally, the electrical conductivity and osmotic potential of Wedelia extracts were assessed once before application.

Statistical analysis

Observation data were analyzed via analysis of variance at the level of α = 5%. For any significant differences observed, the test was followed by Tukey's Honestly Significant Difference (HSD) test at a 95% confidence level to determine the most effective plant organ source and concentration of Wedelia extract. All statistical tests were conducted in SAS OnDemand for Academics (https://welcome.oda.sas.com/).

RESULTS AND DISCUSSION

The test results show higher total phenolic equivalent gallic acid content (TPC) in the flowers (11.5% w/w) than in the leaves (9.10% w/w) (Table 1). The biochemical properties of the extract solution with distilled water indicate that the extract tended to be acidic and had a relatively low electrical conductivity (Table 2). The pH of the extract solution, which tended to be acidic, implies that the flower extract contained water-soluble organic acid compounds. The pH may inhibit plant growth by shifting pH levels from optimal conditions required by plants or by interacting with soil nutrition and affecting nutrient uptake (Barrow et al., 2020) though its effects may vary within plant species (Wang et al., 2020).

Table 1. Total Phenolic Content (TPC) of Wedelia leaf and flower extracts.

Sample	TPC equivalent gallic acid (% *w/w*)
Leaf	9.10
Flower	11.5

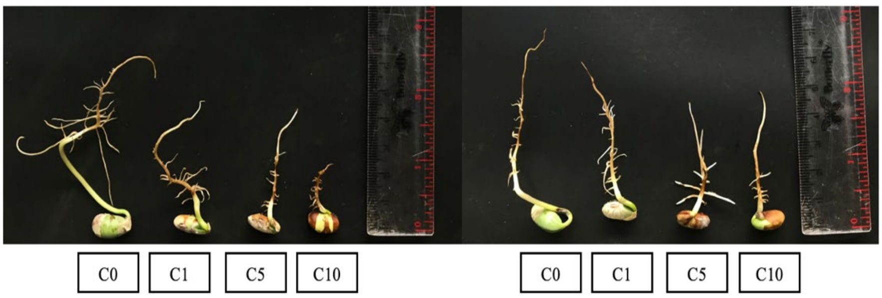
TPC refers to the concentration of phenolic compounds in a plant or extract. Phenolics are secondary metabolites with antioxidant properties and are involved in plant defense. These compounds can influence allelopathic interactions, which involve the release of chemicals by one plant species that affect the growth and development of other plants. Understanding TPC can therefore help in studying these interactions and their potential applications in bioherbicide development (Singleton et al., 1999).

Table 2. pH and electrical conductivity of Wedelia leaf and flower extracts.

Parameters	Organ sources	Concentrations		
		1%	5%	10%
pH	Leaves	6.8	6.5	6.3
	Flowers	5.2	5.0	4.9
EC	Leaves	0.9	3.2	5.4
	Flowers	0.7	2.5	3.6

Soybean germination

The seed germination rate is an indicator of the level of success of seed germination with a greater percentage indicating higher successful germinated seeds (Respatie et al., 2019). Seed exposure to allelochemicals can cause deterioration that results in decreased germination rate (Respatie et al., 2018). Wedelia flower and leaf extracts significantly influenced the germination of seeds from the three studied plants, with significantly higher inhibition observed at high concentrations (Tables 3, 4, and 5). Between extract sources, the germination of soybean seeds treated with 10% Wedelia leaf extract showed the highest inhibition. Meanwhile, 10% and 5% Wedelia leaf extracts caused the highest inhibition in nutsedge germination. Wedelia leaf extract with concentrations of 10% and 5% and Wedelia flower extract caused the highest inhibition of the germination of billygoat weed seeds. Germination percentage decreased accordingly to concentrations of Wedelia leaf and flower extract which indicates concentration-dependent inhibitory properties (Shahena et al., 2021). The Wedelia leaf extract also showed a potential inhibitory effect on the germination of rice (Nie et al., 2005) and purple nutsedge (Uyun et al., 2024). This inhibitory effect increased with the increase in extract concentration (concentration-dependent) (Zhang et al., 2013). Allelochemicals inhibit seed germination by suppressing the mitotic activity of young cells (Simpson & Ku, 2021). In this study, Wedelia leaf extract exerted a strong allelopathic effect on soybean, nutsedge, and billygoat, which may be one aspect of its strong competition with some crops. The application of Wedelia leaf and flower extract exerted inhibitory effects on soybean seed germination (Figure 1).



(a) (b)

Figure 1. Germination of soybean seeds treated with Wedelia leaf (a) and flower (b) extracts at various concentrations. C0 = control, C1 = 1% extract concentration, C5 = 5% extract concentration, and C10 = 10% extract concentration.

The potential of using plant extracts as bioherbicides is gaining attention in sustainable agriculture. Wedelia is one such plant whose extracts have shown promising herbicidal properties (Uyun et al., 2024). However, the application of these extracts in soybean fields requires careful consideration to minimize any negative impact on the soybean crops. The possibility of using Wedelia extract in soybean fields hinges on finding the right concentration that offers weed control benefits without harming the soybean plants. This requires thorough experimental research, including dose-response studies and field trials. If successful, this approach could contribute significantly to sustainable agricultural practices by reducing the dependence on synthetic chemicals.

Table 3. Growth of soybean seeds treated with Wedelia extract from different organ sources and at various concentrations.

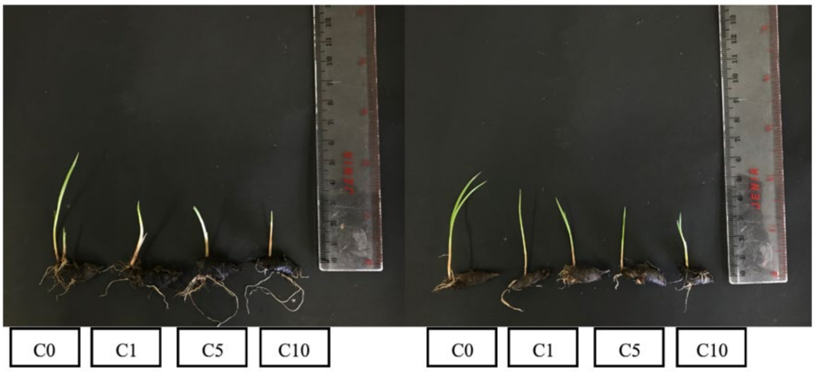
Parameter	Organ source	Concentration			
		Control	1%	5%	10%
Germination rate (%)	Leaves	100.000 ± 0.000a	95.500 ± 3.786ab	92.000 ± 5.164ab	49.500 ± 11.358c
	Flowers	98.000 ± 1.633ab	96.000 ± 1.000ab	95.000 ± 3.456ab	86.500 ± 8.226b
Germination index	Leaves	25.450 ± 0.629a	20.540 ± 3.943b	17.621 ± 1.532bc	8.270 ± 2.635d
	Flowers	25.619 ± 0.463a	20.229 ± 0.750b	17.633 ± 0.898bc	13.858 ± 1.658c
Average germination time (day)	Leaves	0.070 ± 0.012b	0.094 ± 0.010b	0.103 ± 0.008b	0.193 ± 0.011a
	Flowers	0.076 ± 0.020b	0.072 ± 0.012b	0.079 ± 0.022b	0.088 ± 0.017b
Abnormal sprouts (%)	Leaves	13.500 ± 1.915b	25.741 ± 4.286b	33.024 ± 5.315b	84.632 ± 29.574a
	Flowers	8.665 ± 1.916b	15.030 ± 4.309b	18.454 ± 2.280b	32.164 ± 8.836b
Shoot length (cm)	Leaves	2.630 ± 0.205cde	2.970 ± 0.471cd	2.040 ± 0.222de	1.525 ± 0.156e
	Flowers	8.030 ± 0.560a	6.105 ± 0.871b	3.830 ± 0.455c	3.635 ± 0.859c
Fresh weight of sprouts (g)	Leaves	16.325 ± 0.593bc	14.647 ± 0.811cd	14.005 ± 1.028d	13.245 ± 0.803d
	Flowers	18.900 ± 1.019a	17.905 ± 0.701ab	16.852 ± 0.604b	16.055 ± 1.091bc
Dry weight of sprouts (g)	Leaves	13.895 ± 0.603ab	11.852 ± 0.586bc	11.750 ± 0.319 bc	9.397 ± 4.993c
	Flowers	17.658 ± 1.1667a	16.220 ± 0.528ab	15.778 ± 0.627 ab	14.735 ± 0.764ab

Note: Numbers followed by the same letter indicate non-significant differences based on the HSD test (α = 5%).

The Wedelia leaf extract exerted an inhibitory effect on various parameters associated with soybean seed germination, including the germination rate (%), germination index, average germination time, abnormal sprouts, shoot length (cm), fresh weight of sprouts (g), dry weight of sprouts (g), and increased abnormal sprouting (Table 3). Wedelia leaf extract exhibited the most pronounced inhibitory effects, with the highest levels of inhibition observed across all measured parameters. Higher extract concentration correlated with a corresponding escalation in the degree of inhibition. These results emphasize the potent inhibitory potential of Wedelia leaf extract in various aspects of soybean seed germination and highlight the need for further exploration of specific biochemical mechanisms underlying these effects and their implications for agricultural practices.

Purple nutsedge germination

The Wedelia leaf and flower extract considerably impeded the germination process of nutsedge, a common weed species, and was concentration-dependent (Figure 2). In the study, the application of Wedelia leaf extract exerted an inhibitory effect on various germination-related parameters of nutsedge, which encompassed the germination rate (%), germination index, average germination time, shoot length (cm), root length (cm), number of leaves, fresh weight of sprouts (g), dry weight of sprouts (g), and increased abnormal sprouting. The findings indicate that the Wedelia leaf extract exhibited the highest level of inhibition across all measured parameters (Table 4). Moreover, a clear concentration-dependent relationship was established, with increased concentrations of the extract correlating with a proportional increase in the degree of inhibition.



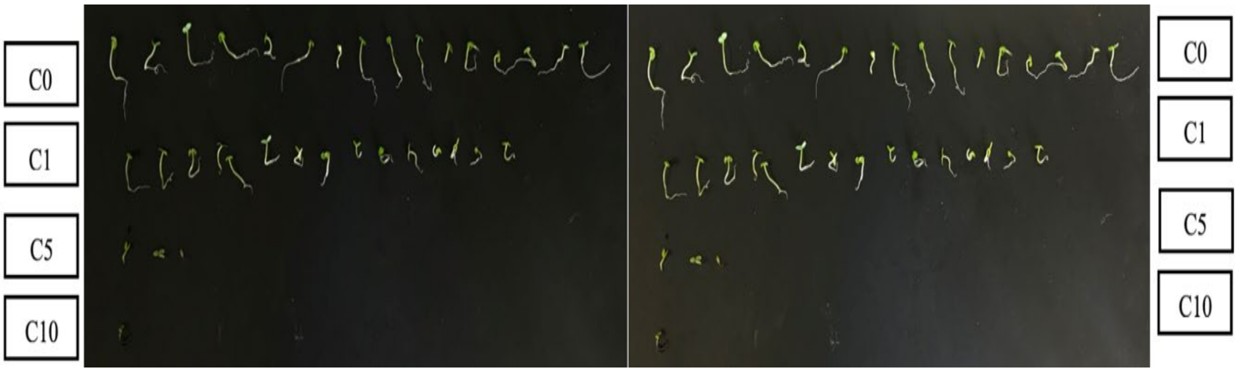
(a) (b)

Figure 2. Germination of nutsedge seeds treated with Wedelia leaf (a) and flower (b) extracts at various concentrations. C0 = control, C1 = 1% extract concentration, C5 = 5% extract concentration, and C10 = 10% extract concentration.

Table 4. Growth of purple nutsedge seeds treated with Wedelia extract from different organ sources and at various concentrations.

Parameter	Organ source	Concentration			
		Control	1%	5%	10%
Germination rate (%)	Leaves	46.000 ± 1.632b	30.000 ± 1.632f	16.000 ± 0.000g	18.000 ± 1.632 g
	Flowers	56.000 ± 1.632a	42.000 ± 1.632c	38.000 ± 1.632d	34.000 ± 1.632 e
Germination index	Leaves	8.342 ± 1.726a	4.218 ± 0.555bc	2.253 ± 0.273de	2.063 ± 0.168 e
	Flowers	5.619 ± 0.587a	5.758 ± 0.268b	4.818 ± 0.464bc	3.917 ± 0.151 cd
Average germination time (day)	Leaves	0.305 ± 0.011b	0.369 ± 0.054b	0.656 ± 0.062a	0.361 ± 0.242 b
	Flowers	0.250 ± 0.007b	0.273 ± 0.017b	0.275 ± 0.042b	0.194 ± 0.132 b
Abnormal sprouts (%)	Leaves	2.500 ± 1.000bc	5.000 ± 1.915abc	8.000 ± 4.320ab	10.500 ± 3.416 a
	Flowers	2.000 ± 0.000c	4.500 ± 1.000bc	5.000 ± 2.000abc	7.000 ± 2.581 abc
Shoot length (cm)	Leaves	4.205 ± 0.134b	3.835 ± 0.411b	3.245 ± 0.439cd	3.050 ± 0.237 cd
	Flowers	5.210 ± 0.062a	4.075 ± 0.411b	3.910 ± 0.066b	3.640 ± 0.203 bc
Root length (cm)	Leaves	4.800 ± 0.395a	2.875 ± 0.150de	2.475 ± 0.189e	1.960 ± 0.108 f
	Flowers	4.475 ± 0.163ab	4.075 ± 0.095b	3.450 ± 0.100c	2.950 ± 0.191 d
Number of leaves	Leaves	3.1 ± 0.1a	2.2 ± 0.2d	1.9 ± 0.2de	1.6 ± 0.1 e
	Flowers	3.6 ± 0.2b	2.8 ± 0.2bc	2.6 ± 0.2c	1.9 ± 0.1 de
Fresh weight of sprouts (g)	Leaves	28.852 ± 0.273a	26.247 ± 0.417cd	24.975 ± 0.068de	23.320 ± 1.353 e
	Flowers	29.742 ± 0.479ab	27.525 ± 0.578bc	25.842 ± 0.335d	24.012 ± 1.140 e
Dry weight of sprouts (g)	Leaves	24.915 ± 0.184ab	23.282 ± 0.562cd	23.105 ± 0.533cd	20.720 ± 0.883 f
	Flowers	25.255 ± 0.497a	23.895 ± 0.635abc	23.432 ± 0.825bcd	22.260 ± 0.968 de

Note: Numbers followed by the same letter indicate non-significant differences based on the HSD test (α = 5%).



(a) (b)

Figure 3. Germination of billgoat weed seeds treated with *Wedelia* leaf (a) and flower (b) extracts at various concentrations. C0 = control, C1 = 1% extract concentration, C5 = 5% extract concentration, and C10 = 10% extract concentration.

Billygoat weed germination

Wedelia leaf and flower extracts revealed significant inhibitory effects on the germination of billygoat weed and demonstrated a concentration-dependent for both leaf and flower extracts (Figure 3). Wedelia leaf extract demonstrated inhibitory effects across various germination parameters of billygoat weed. Wedelia leaf extract consistently exhibited the highest level of inhibition on germination rate (%), germination index, average germination time, shoot length (cm), root length (cm), the number of leaves, fresh weight of sprouts (g), dry weight of sprouts (g), and increased abnormal sprouting (Table 5). Moreover, an evident concentration-dependent pattern was also observed with increased extract concentrations demonstrating proportional intensification of the inhibitory effects. These findings highlight the potency of Wedelia leaf extract in impeding multiple aspects of nutsedge germination, which later indicates its potential as a bioherbicide.

After treatment by Wedelia leaf and flower extracts for 7 days, the seeds from three different plant types showed decreases in fresh and dry weights (Tables 3, 4, and 5). The 10% leaf extract and 1% flower extract showed the highest and lowest inhibitory powers, respectively. A decrease in the metabolic activity of aerial and underground plant parts may cause a considerable reduction in the fresh and dry weights of the treated seeds. Germination and growth are outcomes of plant cell division and we assumed that the phenolic compounds in Wedelia extract inhibited the growth of legume seedlings through the suppression of mitosis in treated species (Shahena et al., 2021). Plant dry weight was also reduced in the germinated rice plants treated with Wedelia leaf extract. Compared with that from other organ sources, the *Wedelia* leaf extract provided the highest pressure (Nie et al., 2005). The dry weight of plants was also affected by concentration; the higher the concentration of Wedelia leaf extract, the lower the plant's dry weight (Uyun et al., 2024).

Table 5. Growth of billygoat weed seeds treated with Wedelia extract from different organ sources and at various concentrations.

Parameter	Organ source	Concentration			
		Control	1%	5%	10%
Germination rate (%)	Leaves	36.000 ± 1.632a	16.000 ± 1.632c	4.000 ± 0.000de	2.000 ± 1.632e
	Flowers	32.000 ± 2.828b	30.000 ± 1.632b	6.000 ± 0.000d	2.000 ± 0.000e
Germination index	Leaves	5.209 ± 0.137a	1.999 ± 0.140d	0.394 ± 0.048ef	0.192 ± 0.150f
	Flowers	4.913 ± 0.099b	3.427 ± 0.209c	0.644 ± 0.039e	0.200 ± 0.000f
Average germination time (day)	Leaves	0.305 ± 0.024b	0.666 ± 0.131ab	1.000 ± 0.000a	0.750 ± 0.500ab
	Flowers	0.377 ± 0.031b	0.385 ± 0.050b	1.000 ± 0.000a	0.750 ± 0.500ab
Abnormal sprouts (%)	Leaves	2.500 ± 1.000bc	5.000 ± 1.154abc	6.500 ± 1.914ab	5.500 ± 4.123abc
	Flowers	1.500 ± 1.000c	3.500 ± 1.000abc	5.000 ± 1.154abc	7.000 ± 1.154a
Shoot length (cm)	Leaves	0.905 ± 0.137a	0.425 ± 0.34bc	0.275 ± 0.028cd	0.225 ± 0.050d
	Flowers	0.810 ± 0.044a	0.505 ± 0.070b	0.133 ± 0.038d	0.175 ± 0.050d
Root length (cm)	Leaves	0.940 ± 0.058a	0.280 ± 0.000c	0.241 ± 0.145c	0.225 ± 0.055c
	Flowers	1.060 ± 0.000a	0.710 ± 0.080b	0.425 ± 0.125c	0.325 ± 0.095c
Number of leaves	Leaves	2.0 ± 0.0a	2.0 ± 0.0a	2.0 ± 0.0a	2.0 ± 0.0a
	Flowers	2.0 ± 0.0a	2.0 ± 0.0a	2.0 ± 0.0a	2.0 ± 0.0a
Fresh weight of sprouts (g)	Leaves	0.977 ± 0.051a	0.817 ± 0.009a	0.605 ± 0.079ab	0.235 ± 0.017b
	Flowers	0.597± 0.574ab	0.870 ± 0.483a	0.655 ± 0.052ab	0.275 ± 0.028b
Dry weight of sprouts (g)	Leaves	0.435 ± 0.058ab	0.387 ± 0.032bc	0.290 ± 0.018d	0.105 ± 0.010e
	Flowers	0.472 ± 0.045a	0.437 ± 0.022ab	0.337 ± 0.038cd	0.147 ± 0.026e

Note: Numbers followed by the same letter indicate non-significant differences based on the HSD test (α = 5%).

Germination time uniformity is described by the germination index. The addition of extracts to germination media may negatively affect seed germination (Respatie et al., 2019). A significant difference in the germination index was observed between the seeds treated with Wedelia flower and leaf extract solutions at 10% concentration. Leaf extract at a concentration of 10% provided the highest inhibitory effect on the germination index compared with other treatments. However, at the average germination time of billygoat and purple nutsedge seeds, the leaf extract with 5% concentration inhibited germination, whereas, for soybean seeds, the inhibition occurred after leaf extract treatment at a concentration of 10% (Table 3, 4, and 5).

Compared with the control, the application of wedelia leaf extract at a concentration of 5% provided 8% inhibition on soybeans, 65% on purple nutsedge, and 89% on billygoat. Meanwhile, the application of wedelia flower extract at a concentration of 5% provided 3% inhibition on soybeans, 32% on purple nutsedge, and 83% on billygoat. The organ source also influenced the emergence of abnormal seeds in soybeans, nutsedge, and billygoat weed. The 10% concentration Wedelia leaf extract had significant effects on the appearance of abnormal soybean seeds, which existed in the form of moldy seeds. However, for nutsedge and billygoat weed, the 5% leaf extract produced the highest number of abnormal seeds.

Germination rate is a common indicator for the detection of allelopathic potential. The presence of allelopathic compounds inhibits germination (Yan et al., 2022). *Wedelia* leaf extract has been reported to inhibit the germination and growth of *Cicer arietinum*, *Vigna unguiculata*, and *Vigna radiata* seedlings (Shahena et al., 2021). The osmotic stress exerted by leaf extract may cause differences in water uptake by plants (Xie & Wang, 2024). A high germination rate was observed in the controls and plants treated with low extract concentrations (Tables 3, 4, and 5). Various metabolic and physiological changes that occur during seed germination may be related to water uptake (Khaeim et al., 2022; Soltani et al., 2021).

The 10% *Wedelia* leaf extract caused the highest inhibition in the shoot and root length of soybean and purple nutsedge seeds (Tables 3 and 4). Meanwhile, 5% *Wedelia* flower extract caused the highest inhibition in the shoot and root lengths of billygoat weed seeds (Table 5). Leaf etiolation and dwarfism have been reported in plants treated with *Wedelia* extract (Shahena et al., 2021). The allelopathic potential of Wedelia leaf extract in the suppression of shoot and root length also suppressed the growth of nut tubers, the higher the concentration, the higher the effect on growth (Uyun et al., 2024). The effect of Wedelia leaf extracts on rape (*Brassica sp*.) shoot length was concentration-dependent with significant reductions in shoot length by concentrations from 25% to 100% but no reduction by 5% of concentration (Zhang et al., 2013).

After treatment by Wedelia leaf and flower extracts for 7 days, the seeds from three different plant types showed decreases in fresh and dry weights (Tables 3, 4, and 5). The 10% leaf extract and 1% flower extract showed the highest and lowest inhibitory effects, respectively. Germination and growth are thought to be outcomes of cell division. Phenolic compounds in Wedelia extract inhibited the growth of legume seedlings through the suppression of mitosis (Shahena et al., 2021). Plant dry weight was also reduced in the germinated rice plants treated with Wedelia leaf extract, the Wedelia leaf extract provided the highest pressure (Nie et al., 2005). The dry weight of plants was also affected by concentration; the higher the concentration of Wedelia leaf extract, the lower the plant's dry weight (Uyun et al., 2024).

Sensitivity to bioherbicides can vary among different weed species, due to variations in the affected target site or biochemical pathways. The sensitivity of weeds to bioherbicides is influenced by their growth stage such as germination, seedling, or flowering stages. The sensitivity of weeds to bioherbicides may also depend on the diversity of weed species in a particular area. This research revealed the unique response of each plant during treatment with Wedelia extracts. Notably, soybeans, purple nutsedge, and billygoat were susceptible to the application of Wedelia leaf extract, which resulted in a significant reduction in seed germination.

CONCLUSIONS

Application of Wedelia extracts significantly influenced the germination process of soybean seeds, purple nutsedge, and billygoat seeds. The inhibitory effects were concentration-dependent, with high concentrations exhibiting more pronounced inhibition. Germination index, average germination time, and the emergence of abnormal seeds were also influenced by the organ source and concentration of Wedelia extracts. The concentration-dependent inhibitory properties observed in this study underscore the need for further research to comprehend the underlying mechanisms and potential applications of Wedelia extracts as bioherbicides.

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