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ORIGINAL RESEARCH PAPER in HERBOLOGY

Galinsoga parviflora Response to Different Application Rates of the Herbicide Chwastox Turbo 340 SL in Spring Barley

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Abstract

The aim of this study was to evaluate the response of *Galinsoga parviflora* to different doses of the herbicide Chwastox Turbo 340 SL [2-methyl-4-chlorophenoxyacetic acid (MCPA) + dicamba] used alone and with an adjuvant. The study was conducted on the spring barley cultivar 'Suweren.' During the tillering stage of spring barley, a weed control treatment was applied using Chwastox Turbo 340 SL at a rate of 100% and at rates reduced by 33% and 50%, and was applied either alone or with an oil adjuvant. Plots without herbicide and adjuvant application were the control treatment. The present study showed that in spring barley the largest plants of *G. parviflora*, which produced the highest number of branches, flower heads, and achenes, occurred in the control treatment where no herbicide and adjuvant were applied. Morphology, productivity, and biomass were not found to vary greatly between *G. parviflora* plants occurring in the plots where the reduced rates of Chwastox Turbo 340 SL and in those where the manufacturer's recommended rate were applied. The number of achenes produced by *G. parviflora* was positively correlated with plant height and negatively with plant biomass. The germination capacity of *G. parviflora* diaspores was not significantly different between the herbicide protection treatments.

Keywords

Galinsoga parviflora; herbicide; 2-methyl-4-chlorophenoxyacetic acid; dicamba; adjuvant

1. Introduction

Galinsoga parviflora (gallant soldier) is a spring annual weed commonly found worldwide (Ali et al., 2017; Shen et al., 2019). It is a thermophilous species native to Central and South America. Gallant soldier grows in moderate and subtropical regions of the world (Damalas, 2008; Shen et al., 2019). As a result of climate change, it quickly spreads even under Poland's climatic conditions despite its high frost sensitivity (Staniak et al., 2017; Wnuk & Ziaja, 2010). Flowering of gallant soldier occurs in the period from April to October, and its fruits reach full maturity in just 2 weeks. Achenes of gallant soldier are pappus-bearing and because of this they can be dispersed by wind, apart from autochory. This species occurs in ruderal and segetal habitats (Ali et al., 2017; Biczak & Pawłowska, 2016; Damalas, 2008; Kolczyk et al., 2014). In Poland, it infests mainly vegetable, root, maize, and other spring cereal crops (Głowacka, 2011; Wnuk & Ziaja, 2010), whereas in other parts of the world it is a great threat to cotton, citrus fruit, and banana crops (Damalas, 2008). Gallant soldier competes with the crop for water, light, and nutrients. It hinders mechanical harvesting and contaminates the seed of crop plants (Biczak & Pawłowska, 2016). *Galinsoga parviflora* prefers permeable soils with high humus content (Tokarska-Guzik et al., 2012, pp. 62–63). Gallant soldier is considered to be an invasive species that can cause large economic losses in agriculture. The species *Galinsoga ciliata*, which is closely related to *G. parvi lora*, also has the same status (Kolczyk et al., 2014; Tokarska-Guzik et al., 2012, pp. 62–63; Z. Zhang et al., 2019). The quick spread of *G. parviflora* is associated with its high productivity and a low weight of 1,000 achenes, owing to which they can spread by anemochory, as well as with achene maturation and dispersal before harvest of the crop. It is difficult to reduce the seed bank thus produced (Damalas, 2008; Tokarska-Guzik et al., 2012, pp. 62–63).

Many factors (atmospheric and environmental) affect the effectiveness of herbicides. The influence of some may be limited by the use of herbicides with adjuvants. Adjuvants support the retention and absorption of the active ingredient, as also the effectiveness of the herbicide (Kieloch & Kucharski, 2018). Thus, herbicides can be used in reduced doses while maintaining high effectiveness (Abbas et al., 2018).

The aim of this study was to evaluate the reaction of *G. parviflora* to different doses of the herbicide Chwastox Turbo 340 SL [2-methyl-4-chlorophenoxyacetic acid (MCPA) + dicamba] used alone and with an adjuvant. The hypothesis was verified: The use of herbicide at a reduced dose with adjuvants results in a decrease in the biomass and productivity of *G. parviflora*.

2. Material and Methods

The study was conducted on the spring barley cultivar 'Suweren.' Over the period 2011–2014, a controlled field experiment was conducted at the Czesławice Experimental Farm (51°18′23″ N, 22°16′02″ E), belonging to the University of Life Sciences in Lublin. The experiment was set up on a loess-derived Luvisol classified as good wheat soil complex and soil class II. The soil was characterized by slightly acidic pH (from 6.1 to 6.4), a high content of phosphorus (33.0–45.0 mg per 100 g of soil) and magnesium (8.3–8.5 mg per 100 g of soil), as well as a medium or high potassium content (16.0–21.3 mg per 100 g of soil).

The experiment was set up as a randomized block design with three replicates. The plot area was 50 m^2. During the tillering stage of spring barley (BBCH 22–25), a weed control treatment was applied using the herbicide Chwastox Turbo 340 SL (MCPA + dicamba). This herbicide is designed to kill dicotyledonous weeds in spring and winter cereals. The active substances contained in it are primarily taken up by the leaves. The first of these substances is a compound from the group of phenoxy carboxylic acids, whereas the other is a derivative of benzoic acid. Both disrupt cell growth and functioning. It causes growth disorders and inhibition, and then leads to plant death. (Praczyk & Skrzypczak, 2004).

The herbicide was used at the manufacturer's recommended rate and at rates reduced by 33% and 50%. It was applied either alone or with the addition of an activating oil adjuvant – Atpolan 80 EC (paraffin oil) – at a rate of 1.5 L ha^{-1}. The herbicide treatment was performed using a field sprayer at a pressure of 0.25 MPa and a spray liquid discharge rate of 250 L ha^{-1}. Plots without herbicide and adjuvant application were the control treatment.

Before harvest of the crop, fruiting specimens of *G. parviflora* were collected. Every year, a minimum of five specimens were collected from each plot. The following weed morphology components were evaluated: plant height, number of lateral branches, number of inflorescences per plant, as well as number of seeds per plant and plant dry weight. Productivity was estimated by multiplying the number of inflorescences per plant by the average number of achenes, calculated based on 50 inflorescences, or a smaller number (in the case of there being fewer), collected from the individual study plots each year.

Statistical analysis of the results of plant characteristics such as plant height, number of branches, and number of generative organs involved the calculation of coefficients of variation as a percentage of the mean and confidence intervals with an error rate of 0.05. These intervals were used to find significant differences (or their absence) between the means, i.e., the so-called interval estimation. Differences in productivity and weed dry weight between the treatments were estimated using one-way analysis of variance (ANOVA), whereas homogeneous groups were determined by the Tukey's test at a significance level of 0.05. The calculations were performed using Statistica 13.1 (TIBCO Software).

Moreover, the percentage proportion of generative parts (inflorescences, flowers, fruits, and seeds) in the dry weight of the entire aboveground shoot was calculated. The above-mentioned indicator is called the potential reproductive effort (Harper & Ogden, 1970). The calculation of reproductive effort enables the determination of the extent to which weeds change their reproductive strategy. A similar value of this indicator is evidence of low variation, whereas the greater the reproductive effort, the higher is the reproductive capacity of plants.

Galinsoga parviflora fruits were collected from each plot to evaluate their germination capacity. Seed germination was performed under controlled conditions (in a climate chamber) following the International Rules for Seed Testing (Lutman, 2002). The experiments were conducted in six replicates. Containers with a surface area of 268.75 cm^2 were lined with five layers of filter paper and subsequently 50 achenes were placed in each container. The germination was conducted at a temperature of 20–22 °C under dark conditions and at 25 °C in light. Each day, the containers were watered with distilled water to maintain constant moisture content of the growing medium. Before establishment of the experiment, the seeds were cooled at 5 °C over a period of 7 days to break the dormancy period. Germination capacity was evaluated after 14 days.

The study results were analyzed statistically using analysis of variance (ANOVA), and the differences found were verified by the Tukey's test at a significance level of 0.05. Before the statistical calculations were performed, the percentage values were transformed according to the following formula:

$$y = arc \sin \sqrt{x}.$$

3. Results

Plant height of *G. parviflora* in the spring barley crop was significantly (<0.05) modified by the herbicide protection applied (Figure 1). The highest plants were found under control conditions (on average 49.0 cm, max 111 cm), whereas plants in the plots treated with the 100% herbicide rate were significantly (<0.05) lower (on average 34.2 cm, max 67 cm). The same relationships were demonstrated in the case of number of branches (Figure 2). The number of inflorescences per plant was also the highest in the control treatment – 64.5 pieces (pcs), max 252. Significantly (<0.05) fewer inflorescences were found under the application rate of 50% herbicide without adjuvant (on average 30.1 pcs, max 125) and the 100% herbicide application rate with adjuvant (on average 24.5 pcs, max 82) and without adjuvant (on average 20.4 pcs, max 88) (Figure 3). The differences in herbicide rates and addition of adjuvant did not have a significant (<0.05) effect on plant height or the number of branches and flower heads produced (Figure 1–Figure 3). Plant height in the spring barley crop after application of the tested rates of the herbicide Chwastox Turbo exhibited low variation, as the coefficients of variation ranged from 35.4 to 56.4. Greater differences were found in the case of number of branches as the coefficients of variation for this characteristic ranged from 59.8 to 85.3. The largest interindividual variation in *G. parviflora* plants in the spring barley crop was observed for the number of inflorescences per plant. In the case of this trait, the average coefficient of variation was 119.8, whereas its range was from 95.2 after application of the herbicide at a rate of 67% to 142.6 after application at the rate of 50% with adjuvant (Table 1). The number of achenes produced per plant was directly related to the number of inflorescences per plant. The most achenes were found in the control treatment (1,677 pcs), whereas their number was significantly (<0.05) low after application of all the herbicide rates tested. Under application of the manufacturer's recommended rate, the productivity of *G. parviflora* was the lowest – 510 achenes (Table 2). The highest productivity of individuals under control conditions was not coincident with their biomass. These plants were characterized by the lowest weight of aboveground parts, whereas, as a result of decreased weed competition, plants in the plots with application at the 50% rate with adjuvant significantly (<0.05) produced the highest biomass (Table 2). The reproductive effort of gallant soldier in the spring barley crop was from 10.3% after application at the rate of 50% herbicide to 17.8% under the application rate of 50% and 67% with adjuvant (Figure 4). The linear regression model shows that the productivity of *G. parviflora* plants in spring barley rose on average by 70 achenes if the plant height increased by 1 cm and the plant weight remained at an unchanged level. If the plant weight increased by 1 g with an unchanged height, the plants produced on average 262 fewer achenes (Figure 5).

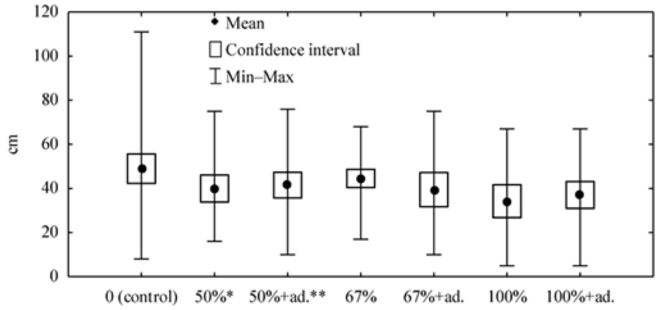

Figure 1 Height of *Galinsoga parviflora* plants in spring barley (cm). * % of the full dose; ** ad. – adjuvant.

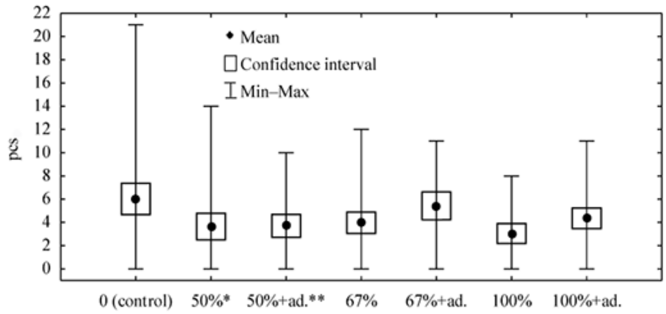

Figure 2 Number of *Galinsoga parviflora* branches in spring barley (pcs – pieces per plant). * % of the full dose; ** ad. – adjuvant.

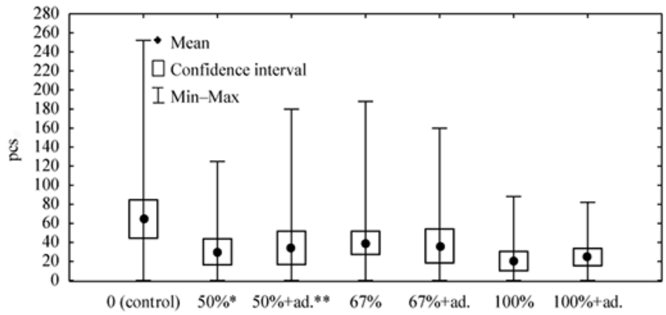

Figure 3 Number of inflorescences per *Galinsoga parviflora* plant in spring barley (pcs – pieces per plant). * % of the full dose; ** ad. – adjuvant.

The germination capacity of *G. parviflora* diaspores was not significantly (<0.05) different between the individual herbicide protection treatments. Nonetheless, herbicide application decreased the germination capacity of this species' achenes by 6.3% to 27.6%. Achenes collected from the plots where the herbicide at rate of 50% with adjuvant was applied germinated the poorest (53.7%) (Figure 6).

Table 1 Coefficients of variation as a percentage of the mean for selected biometric characteristics of *Galinsoga parviflora* in spring barley.

Herbicidal protection variants	Height of plants (cm)	Number of branches (pcs**)	Number of inflorescence (pcs)
0 (control)	45	74	102
50%*	42	85	123
50% with adjuvant	40	76	143
67%	35	71	95
67% with adjuvant	53	60	132
100%	56	75	131
100% with adjuvant	49	62	113
Mean	46	72	120

* % of the full dose; ** pcs – pieces.

Table 2 Seed production and air-dry weight of *Galinsoga parviflora* aboveground parts in spring barley (per plant).

Herbicidal protection variants	Seed production (pcs**)	The weight of the aboveground parts of plants (g)
0 (control)	1 677 a	0.67 c
50%*	783 bc	0.95 bc
50% with adjuvant	887 bc	1.51 a
67%	985 b	1.05 b
67% with adjuvant	905 bc	1.10 b
100%	510 c	0.93 bc
100% with adjuvant	613 bc	0.99 bc

* % of the full dose; ** pcs – pieces.

4. Discussion

In agricultural ecosystems, weed morphology is dependent on many factors, such as soil conditions, crop plant species, and agronomic field practices (Clark & Bullock, 2007; Haliniarz, 2006; Hübner et al., 2003; Jastrzębski et al., 2015; Kristensen et al., 2008; Kwiecińska, 2004; Kwiecińska-Poppe, 2006; Lutman, 2002). In dense crops, where there is considerable competition from crop plants, weeds have a limited possibility of branching or tillering and owing to this, the number of diaspores produced is relatively small. In wide row crops, weeds have more free space, in particular until interrow closure, and therefore their seed production capacity is greater (Haliniarz, 2006; Kwiecińska, 2004; Kwiecińska-Poppe, 2006). In the present study, the plant height of gallant soldier ranged from 5 to 111 cm, whereas the number of branches ranged from 0 to 21. A study by Shen et al. (2019) revealed that where there is no competition from other species, the height of *G.*

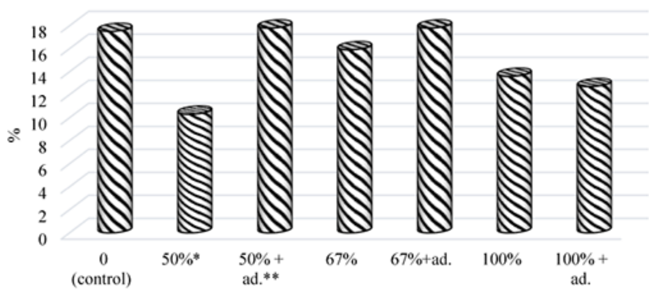

Figure 4 Reproductive effort of *Galinsoga parviflora* in spring barley (%). * % of the full dose; ** ad. – adjuvant.

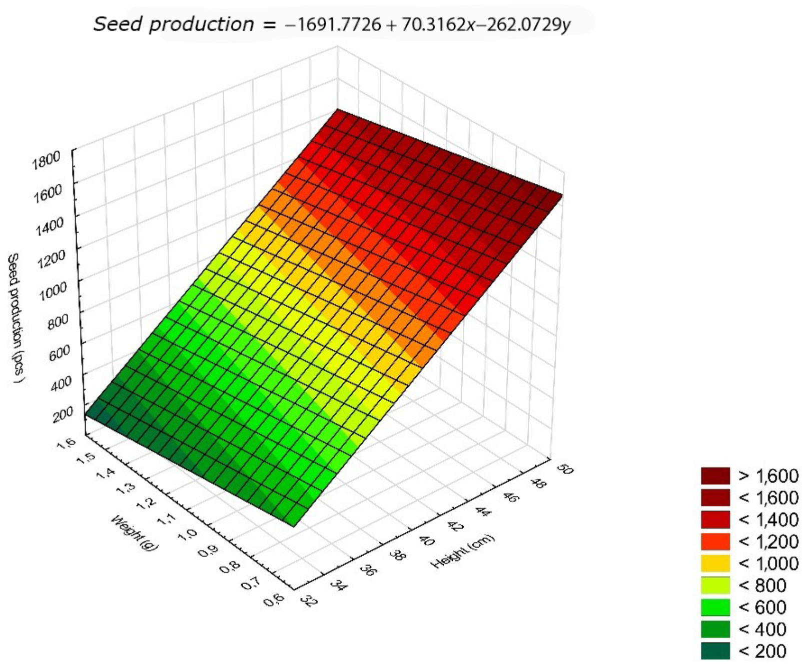

Figure 5 Relationship between *Galinsoga parviflora* seed production and plant height and weight in spring barley (pcs – pieces).

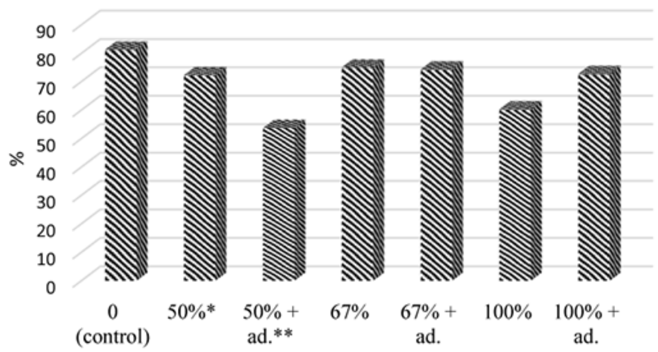

Figure 6 Germination capacity of *Galinsoga parviflora* seeds collected from spring barley (%). * % of the full dose; ** ad. – adjuvant.

parviflora plants was lower and did not exceed 70 cm, the number of branches reached as many as 103, and the number of inflorescences ranged from 351.4 to 552.1.

Seed productivity is the most important characteristic of weeds that ensures species survival (Lutman, 2002). *Galinsoga parviflora* exhibits high variations in productivity associated with its interindividual diversity resulting from habitat conditions (Kwiecińska, 2004; Kwiecińska-Poppe, 2006; Pawłowski et al., 1970). In the spring barley crop, the highest productivity of gallant soldier, 1,677 diaspores, was found under the control conditions. Kott (1961) and Markov (1978), however, showed that this species' productivity can reach even 300,000 achenes. According to Pawłowski et al. (1970), gallant soldier growing on loess fallow produced a maximum of 81,041 achenes, whereas Kwiecińska (2004) and Kwiecińska-Poppe (2006) report that this species' productivity in potato was on average 1,266 pcs. In spring cereal crops, Kwiecińska (2004) and Kwiecińska-Poppe (2006) found a much lower productivity than that observed in the present study. According to them, *G. parviflora* produced on average 267 achenes on light soils, whereas 193 on rendzina soil.

The number of diaspores produced per plant is frequently correlated with plant biomass and height (Haliniarz, 2019). In this study, *G. parviflora* productivity was positively correlated with plant height and negatively with plant biomass. In other crop plants, such as faba bean, potato, and maize, Haliniarz (2019) found a positive correlation between productivity and biomass of *G. parviflora* plants. Majda et al. (2007) demonstrated that among 13 segetal weed species studied, only *Cirsium arvense* was found not to show a significant relationship between biomass and productivity.

Application of reduced herbicide rates, even if it does not destroy an unwanted plant, will disrupt the plant's life processes thereby affecting weed morphology and biomass (Haliniarz, 2019; Idziak & Woźnica, 2013). A varying response of other weed species to active substances from the group of growth regulators was also confirmed by Domaradzki and Kieloch (2007), applying the herbicides Chwastox Mix 292 EW (MCPA + fluroxypyr) and Lancet 530 EW (fluroxypyr + 2.4-D). Chwastox Mix 292 EW applied at the 2–3 whorl stage of *Galium aparine* significantly reduced the fresh weed biomass after application at a rate reduced by half, whereas with the herbicide Lancet 530 EW, satisfactory effects were obtained when the rate was reduced by 25%. The biomass of *Stellaria media* was substantially reduced by both herbicides tested. In a study on *Anthemis arvensis*, *Chenopodium album*, and *Stellaria media*, Kieloch and Domaradzki (2011) showed the highest reduction in the biomass of these weeds after application of the manufacturer's recommended rate of the herbicides tested (tribenuron-methyl, iodosulfuron-methyl-sodium + amidosulfuron, metribuzin + amidosulfuron). In contrast, Idziak and Woźnica (2013) found a large decrease in biomass after application of reduced rates of nicosulfuron applied alone and with adjuvant with respect to *Viola arvensis, Echinochloa crus-galli, Polygonum convolvulus*, *P. aviculare*, and *Geranium pusillum.* A study by Kaczmarek and Matysiak (2015) did not demonstrate significant differences in the weed control efficacy of chlorosulfuron between treatments where the herbicide was applied alone and treatments with adjuvant application.

Application of biologically active substances can change the physiological properties of seeds, affecting their viability, survivorship, and germination capacity (Andersson, 1996; Carrithers et al., 2004; Qi et al., 2017). The present study did not reveal significant differences in the germination capacity of gallant soldier achenes collected from the treatments where the different herbicide rates and adjuvant were applied. Gange et al. (1992), however, proved under laboratory conditions that some insecticides and fungicides significantly reduced the germination capacity of weed seeds, but these authors found a substantially greater phytotoxic effect in the case of a combination of several biologically active substances than for single pesticides. Nevertheless, in the literature on the subject there is very little information regarding to what extent application of plant protection products influence the germination capacity of diaspores occurring in a weed community. Experiments conducted by J. Zhang and Cavers (1994) as well as by Shuma et al. (1995) indicate a greater germination capacity of seeds collected from plants treated with reduced rates of herbicides than in weed diaspores subjected to the action of full rates of these products. Tanveer et al. (2009), however, did not confirm such relationships.

5. Conclusions

In the spring barley crop, herbicide protection treatments modified the habit, productivity, and biomass of *G. parviflora* plants. Application of the full herbicide rate of Chwastox Turbo 340 SL and those reduced by 33% and 50% with adjuvant addition did not have a significant effect on plant height or on the number of branches and flower heads. *Galinsoga parviflora* produced the greatest biomass after the application of 50% herbicide with adjuvant. The number of achenes produced by gallant soldier was positively correlated with plant height and negatively with plant biomass. The germination capacity of *G. parviflora* diaspores was not significantly different between the herbicide protection treatments.

The present study showed that in spring barley there were no large differences in the morphology, productivity, and biomass between *G. parviflora* plants occurring in the plots where the reduced rates of the herbicide Chwastox Turbo 340 SL

(MCPA + dicamba) were applied and those in the plots where the manufacturer's recommended rate was used. Therefore, it is possible to use reduced rates of this herbicide without contributing to a larger soil seed bank and without increasing potential weed infestation with this species in succeeding crops in a crop rotation.

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