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Harmful effects of creeping thistle (*Cirsium arvense* (L.) Scop.) in winter wheat cultivation

Abstract

The research was conducted in 2021–2023 in a production field with winter wheat cultivation in Czyrna near Krynica (Southern Poland). The subject of the study was a single-factor field experiment designed using the random method, concerning the effect of weed infestation with creeping thistle (*Cirsium arvense*) on the yield of winter wheat and accumulation of the most important minerals in tissues. The study included two objects – winter wheat plots weedy with *C. arvense* and adjacent plots, but not overgrown, with thistle. The study found that the creeping thistle in the winter wheat field hurt the number of winter wheat ears and the total biomass of winter wheat. Compared to the biomass of winter wheat, the biomass of thistle was characterised by a significantly higher content of mineral components. The accumulation of minerals by thistle occurs mainly by taking them from deeper layers of the soil.

Keywords: crop/yield, field experiment, *Triticum*, weed infestation

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Introduction

The harmfulness of crop weeds in agriculture is widely known. They negatively affect the yield of crops, worsen the quality of the crop, increase the costs of agrotechnical treatments, and participate in the transmission of diseases and pests (e.g. Marshall et al., 2003; Dobrzański, 2007; Dobrzański, Adamczewski, 2009; Sekutowski, 2024). There is also no shortage of descriptions reporting the positive impact of weeds on agriculture and the environment (Hochół, 2001, 2003). This positive role of weeds, especially dicotyledonous ones, results from, among other things, their deep root system, which results in the movement of mineral components from deeper to shallower layers of the soil.

The level of weed infestation in field crops is influenced by many factors resulting from the cultivation system used, the type and level of fertilisation, and the succession of plants (Alaru et al., 2003; Sekutowski, 2024). In the bibliography, opinions on the effect of fertilisation on weed infestation are divided. In the studies by Adamiak (2007), Małecka-Jankowiak et al. (2015), fertilisation promoted the growth of weeds, especially those that prefer nitrogen. In turn, in the studies by Harasim and Wesołowski (2013) and Suwara et al. (2019), fertilisation, especially by nitrogen, was a factor limiting weed infestation in cereals. These phenomena certainly require further research.

One of the troublesome and common weeds in cereal and root crops is the creeping thistle (*Cirsium arvense* (L.) Scop.), also known as Canada thistle or field thistle (Krawczyk, Stachecki, 2000; Kieloch, 2024). It is a perennial, root geophyte, native to European flora. It grows in all types of soil but prefers well-aerated, nutrient-rich soils; and tolerates highly saline soils (Sudnik-Wójcikowska, 2011). The commonness of this weed is due to the production of a large number of seeds by one plant – up to 1,000–5,000 achenes. However, they have little capacity to germinate. The seeds are dispersed by the wind (anemochory) and remain viable for 20 years (Kieloch, 2024). The second "advantage" of this plant is the possibility of vegetative reproduction. It reproduces very dynamically from rhizomes cut during cultivation. Seedlings and new shoots appear in spring. Individuals that emerged from seeds grow slower and are less competitive than those that emerged from rhizomes, while the development of rhizomes cut during cultivation is very dynamic (Strobach et al., 2008).

The harmfulness of *C. arvense* is the result of creating a large assimilation surface due to having a branched stem and a significant number of leaves, growing above-cultivated plants, and having a strongly developed root system that penetrates the soil with a dense network of roots in several layers (Eber, Brandl, 2003; Niederstrasser, Gerowitt, 2008; Kieloch, 2024; Skorupinski et al., 2024). Observations conducted during this study show that thistle is also a host for aphids (Aphidomorpha) during flowering. Moreover, *C. arvense* has documented allelopathic potential (Wilson, 1979; Kazinczi et al., 2001; Woźnica, 2008). In particular, the roots and leaves of *C. arvense*, emit chemical substances into the soil that negatively affect the germination and development of many crop plants.

The aim of the study was to assess the effect of creeping thistle *Cirsium arvense* presence on the biomass size and yield of winter wheat *Triticum* sp. (*i*) and the effect of thistle on the content of major mineral components in the biomass of winter wheat (*ii*).

Materials and methods

Study site and experimental design

The research was carried out in 2021–2023 in a production field with winter wheat cultivation, located at the Mountain Experimental Station of the Krakow University of Agriculture in Czyrna (49°28'05.9"N 21°01'52.4"E) near Krynica (545 m a.s.l.) (Southern Poland) (Fig. 1A).

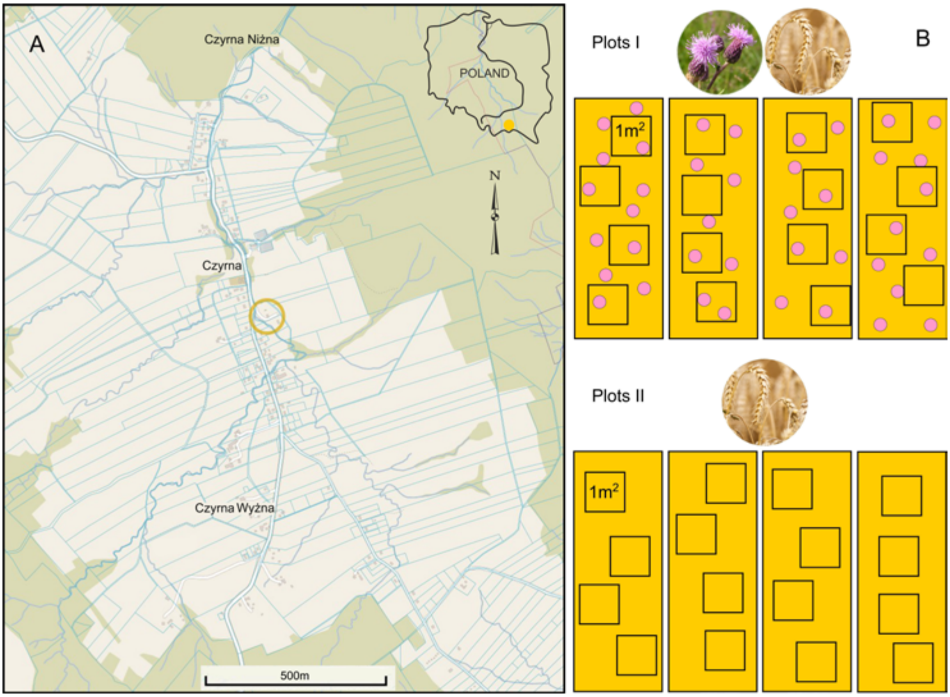

Fig. 1. Location of the field experiment site (A); simplified scheme of the field experiment (B); Plots I – winter wheat (*Triticum* sp.) areas infested with creeping thistle (*Cirsium arvense* (L.) Scop.), Plots II – areas with winter wheat without thistle

The research subject was a single-factor field experiment established using the random method. The study included two objects, each with 4 replicates (Fig. 1B). The first object was the winter wheat areas infested with creeping thistle (*Cirsium arvense*). The second object was the areas located nearby but not infested with thistle. Every year, two weeks before wheat harvest, 4 plots of 1 m^2 in size were randomly cut out in the winter wheat field for each object. On the surface, the number of thistle individuals and wheat ears was carefully determined. Only the number of wheat ears was determined on the without-thistle objects. Next, the fresh mass of thistle and winter wheat plants was determined. The collected biomass was dried for three hours at 105°C to obtain the dry mass yield of thistle plants and winter wheat. The dried plants were ground and the ground material was subjected to chemical analysis – material from thistle and winter wheat separately. The content of total nitrogen was determined using the Kiejdahl method (Jones Jr, 2001), and the content of K, P, Ca, Mg by a spectrometric method using an ICP-OES plasma spectrometer (*Spectro*, Poland).

Environmental conditions

The soil of the experimental field was defined as brown, developed from weathered flysch rocks, with a granulometric composition of medium skeletal clay. It was included in the 12th oat-potato-mountain complex, class V of soil utility quality. The average content of available phosphorus in the arable layer was low and that of potassium was average; the pH in KCl was 5.7.

Wheat was grown after potatoes on manure. Mineral fertilisation was applied in the amount of 45.3 kg $P \cdot ha^{-1}$ and 76.3 kg $K \cdot ha^{-1}$. The nitrogen dose of 72 kg $N \cdot ha^{-1}$ was divided into spring (50%) and during stalk emergence (50%). No herbicides were used.

In the research area, the average annual air temperature for the multi-year period is 6.1°C, and the length of the vegetation period is 173 days (Hess, 1965). According to the assumptions by Z. Kaczorowska (1962) and monthly rainfall totals, the growing season in 2022 can be classified as dry, and in the remaining years as average (Tab. 1).

Tab. 1. Monthly precipitation totals (measured at Czyrna Station, Southern Poland)

Years	**Month/ Precipitation** [mm]												IV–VIII	I–XII
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
1961–1990 average	58	47	48	62	85	105	115	98	79	56	44	51	465	848
2021	32.7	27.5	31.4	52.1	117.0	110.3	143.4	145.1	49.2	22.3	48.3	40.2	567.9	819.5
2022	43.5	37.6	31.0	71.1	30.4	68.4	128.9	87.9	51.6	27.8	41.7	58.2	386.7	678.1
2023	64.6	53.2	51.2	76.9	95.4	119.4	118.1	85.0	52.7	54.8	43.2	57.8	494.8	875.3

Data analysis

The results were statistically tested for variance analysis, using the *Statistica* 13.3 program. The significance of mean differences between objects was analysed using the Tukey test at a significance level of $p \leq 0.05$. The distribution of the resulting data meets the requirements of the normal distribution.

Results

In the object without creeping thistle (*Cirsium arvense*), the number of stalks with ear of winter wheat ranged on average from 401.3 pcs in 2022 to 454 pcs in 2021 (Tab. 2).

Tab. 2. Number of stalks with ears of winter wheat and creeping thistle (*Cirsium arvense* (L.) Scop.) plants [pcs · m^{-2}]; n = 4, average ± SD; SSD – the smallest statistically significant difference, i.d. – means statistically insignificant difference

Years	Winter wheat			Thistle
	Without thistle	With thistle	Average*	
2021	454.0 ± 5.9	420.2 ± 5.7	437.1 ± 18.8	2.00
2022	401.3 ± 8.6	379.0 ± 5.3	390.1 ± 13.6	1.25
2023	437.1 ± 4.6	408.3 ± 12.6	422.7 ± 17.7	1.50
3 year average	430.8 ± 25.7	402.5 ± 19.7	416.6 ± 25.7	1.58
SSD = 0.05	6.53		9.72	i.d.

(*) – the data in this column refer to the averages for the results obtained in the individual years of the study

This number in the plots with *C. arvense* ranged from 379 to 420.2 pcs in the above-mentioned years, with the average number of thistles ranging from 1.15 to 2.0 individuals. On average, during the study period, 1 thistle plant on 1 m^2 plots reduced the number of spike stalks by 28.3 pcs.

In the plots without *C. arvense*, the wheat dry mass per 1 m^2 was on average 734.8 g and was 114.2 g higher than the dry mass of wheat alone in the plots with the presence of thistle (Tab. 3). The data in tables 2 and 3 show that the dry mass of one spike stalk in the plots without thistle was 0.16 g higher than the mass of the spike stalk in the plots with *C. arvense*.

Tab. 3. Dry mass yield of winter wheat and field creeping thistle (*Cirsium arvense* (L.) Scop.) [g · m^{-2}] n = 4, average ± SD; SSD – the smallest statistically significant difference

Years	Winter wheat			Thistle
	Without thistle	With thistle	Average*	
2021	767.4 ± 6.4	615.8 ± 6.3	691.6 ± 20.6	78.2 ± 8.4
2022	706.0 ± 9.5	617.5 ± 5.8	661.7 ± 14.9	31.8 ± 8.1
2023	731.0 ± 5.1	628.5 ± 13.8	679.7 ± 19.4	36.8 ± 10.3
3 year average	734.8 ± 28.3	620.6 ± 21.6	677.7 ± 28.2	48.9 ± 18.1
SSD = 0.05	16.59		24.68	17.18

(*) – the data in this column refer to the averages for the results obtained in the individual years of the study

Also, the total average dry mass of wheat in the plots with thistle (620.6 g · m^2) was 114.2 g lower than the mass of wheat (734.8 g · m^2) in the plots without thistle. In turn, the dry mass of *C. arvense* was on average 48.9 g, which constituted 7.5% of the total mass of wheat and thistle, which amounted to an average of 620.6 g (Tab. 3).

The biomass of wheat in the plots without thistle was generally characterised by a similar content of assessed mineral components as its biomass in the plots weedy by thistle (Tab. 4).

Tab. 4. Chemical composition of winter wheat and creeping thistle (*Cirsium arvense* (L.) Scop.) biomass; 3-year mean ± SD

Nutrients	Winter wheat		Thistle
	Without thistle	With thistle	
	[g · kg^{-1}]		
Nitrogen (N)	14.3 ± 4.7	14.0 ± 4.5	19.5 ± 5.6
Phosphorus (P)	1.20 ± 6.8	1.08 ± 6.3	1.11 ± 8.1
Potassium (K)	6.01 ± 4.1	5.92 ± 4.7	13.7 ± 4.9
Calcium (Ca)	1.10 ± 4.0	1.07 ± 4.2	17.2 ± 5.1
Magnesium (Mg)	0.60 ± 3.9	0.52 ± 4.3	2.40 ± 4.6

However, the biomass of *C. arvense* was significantly richer in the analysed minerals than the biomass of wheat, with the exception of phosphorus. The phosphorus content in both types of biomass was similar. In turn, the content of nitrogen, potassium, calcium and magnesium in the biomass of *C. arvense* compared to the biomass of wheat was higher, respectively: nearly 1.5-fold, 2.3-fold, 17-fold and 4.5-fold.

The content of macroelements taken up by winter wheat in the plots with thistle was lower by 18% on average compared to the plots without this weed; in the case of nitrogen and potassium by 17%, Ca and Mg by 18%, and P by 24% (Tab. 5). In total, similar contents of potassium and magnesium, slightly lower contents of nitrogen and phosphorus, and twice as high calcium contents were found in the biomass of wheat and thistle (compared to the biomass of wheat from the plots not infested with thistle). The content of components taken up by *C. arvense* in the total uptake by wheat and thistle had the following shares: N – 9.84%, P – 7.46%, K – 15.4%, Ca – 55.7% and Mg – 26.6%.

Tab. 5. Macroelement uptake with biomass of winter wheat and creeping thistle (*Cirsium arvense* (L.) Scop.); 3-year mean ± SD

Nutrients	Winter wheat			Thistle	Share of thistle in total uptake by wheat and thistle
	Without thistle	With thistle	Difference		
	[g · m^2]		[%]	[g · m^2]	[%]
Nitrogen (N)	10.5 ± 4.4	8.73 ± 4.6	17 ± 4.5	0.95 ± 4.7	9.84 ± 4.8
Phosphorus (P)	0.88 ± 6.5	0.67 ± 6.3	24 ± 6.4	0.05 ± 5.9	7.46 ± 6.1
Potassium (K)	4.42 ± 4.6	3.69 ± 4.5	17 ± 4.5	0.67 ± 4.4	15.40 ± 4.4
Calcium (Ca)	0.81 ± 4.2	0.67 ± 4.3	18 ± 4.3	0.84 ± 4.5	55.70 ± 4.6
Magnesium (Mg)	0.44 ± 4.1	0.32 ± 4.2	18 ± 4.2	0.12 ± 4.3	26.60 ± 4.5

It is worth noting that the biomass of creeping thistle, which amounted to an average of 48.9 g · m^2, constituted only 7.30% of the total biomass of wheat and *C. arvense* (Tab. 3).

Short discussion

The negative impact of creeping thistle (*Cirsium arvense*) on the development of winter wheat was multifaceted. It was most visible in the reduction of the number of spike stalks and the mass of a single stalk (Tab. 2–3), and to a lesser extent in the chemical composition of biomass (Tab. 4–5). The smaller number of ears in the weedy plots is confirmed by other studies (Brzozowska et al., 2018; Kwiatkowski, 2009; Kuś et al., 2007; Puła, 2013). This is the result of crop plants losing the competition with weeds for nutrients necessary for growth and the required living space of a single crop plant being limited beyond the minimum. On the other hand, the lower biomass of a single spike in the present study, apart from the competition factor, could additionally result from the alleopathic effect of *C. arvense*, as mentioned earlier (Wilson, 1979; Kazinczi et al., 2001; Woźnica, 2008). In studies by Wilson (1979), the presence of roots and leaves of creeping thistle in the soil reduced the height of several crop plants, including winter wheat, by about 25%.

The threshold of economic harmfulness of *C. arvense* in winter wheat cultivation is the presence of 1 weed per 1 m^2 of area, causing a 5% reduction in grain yield. Kieloch (2024) generally states that its harmfulness threshold is 1–2 pcs · m^2 for cereal, maize, and rapeseed crops. In the present study, the presence of *C. arvense* reduced the dry mass of wheat by about 18%, compared to the wheat dry mass in the object uninfected by thistle (Tab. 3).

The relatively small difference found in the content of the analysed mineral components in the biomass wheat of weed-free and thistle-infested plots allows us to assume that probably creeping thistle did not compete with wheat in their uptake. The lack of such a relationship should be attributed to the deep root system of *C. arvense* and its uptake of nutrients from deeper soil layers. This is supported by the fact that the difference in mineral content between wheat biomass and thistle biomass concerns mainly nitrogen, potassium, calcium, and magnesium – components susceptible to migration into deeper soil layers (Kacorzyk et al., 2016), as opposed to phosphorus, the content of which in wheat and thistle biomass was similar. The overall lower uptake of nitrogen and phosphorus with the biomass of wheat and thistle from the weedy plots (in comparison to the biomass from the object without thistle) should be mainly attributed to the smaller number of wheat stalks with ears, as the content of these components in the wheat biomass on both types of plots was similar. On the other hand, high contents of potassium, magnesium, and calcium in the biomass of thistle resulted in similar uptake of the first two components in the biomass in both weeded and non-weeded plots and twice as high calcium uptake in the plots infested with *C. arvense*. The high content of the analysed mineral components in creeping thistle should be attributed to its abundant deep root system and high nutritional requirements. The latter relationship is confirmed by Fijałkowski et al. (1992), who believe that *C. arvense* does not occur on sandy soils because its roots do not find fertile and moist soil layers within their range.

Conclusions

[i] Creeping thistle (*Cirsium arvense*) in the winter wheat field hurt the number of ears and the total average dry mass. The presence of one thistle plant per 1 m^2 reduced the number of winter wheat by an average of 28.3 spikes. Thistle also causes a significant reduction in the dry mass of winter wheat.

[ii] The biomass of *C. arvense*, in comparison with the biomass of winter wheat, was characterised by a significantly higher content of mineral components. In the case of N, P, and K the content was 1–2.5 times higher, and Mg and Ca were 4.5–17 times higher. The accumulation of minerals by thistle probably came largely from taking them up from deeper soil layers. Moving minerals to shallower soil layers can be considered beneficial from the point of view of their possible use by cultivated plants.

Conflict of interest

The authors declare no conflict of interest related to this article.

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Szkodliwość ostrożenia polnego (*Cirsium arvense* (L.) Scop.) w uprawie pszenicy ozimej

Streszczenie

Szkodliwość chwastów w uprawie roślin rolniczych dotyczy zmniejszenia jakości i wielkości plonów. Celem podjętych badań była ocena wpływu ostrożenia polnego (*Cirsium arvense*) na wielkość biomasy i plon pszenicy ozimej (*Triticum* sp.) oraz akumulację najważniejszych składników mineralnych w tkankach. Badania przeprowadzono w latach 2021–2023 na polu produkcyjnym z uprawą pszenicy ozimej, zlokalizowanym w Czyrnej k. Krynicy (Południowa Polska). W badaniach uwzględniono dwa obiekty. Pierwszym obiektem były poletka pszenicy ozimej zachwaszczone *C. arvense*, a drugim poletka położone obok, lecz nie zachwaszczone. Corocznie, 2 tygodnie przed zbiorem pszenicy, wycinano w łanie losowo po 4 powierzchnie o wielkości 1 m^2 dla każdego obiektu. Na poletkach z ostrożeniem określono liczbę sztuk tego gatunku i liczbę kłosów pszenicy. Na poletkach bez ostrożenia określono jedynie liczbę kłosów pszenicy ozimej. W następnej kolejności zbadano plon suchej masy ostrożenia oraz pszenicy ozimej. W biomasie określono zawartość azotu i K, P, Ca, Mg. Stwierdzono, że obecność *C. arvense* w łanie pszenicy ozimej ujemnie wpłynęła na liczbę kłosów pszenicy ozimej i jej sumaryczną suchą masę. Obecność 1 rośliny *C. arvense* zmniejszała liczbę kłosów pszenicy ozimej średnio o ok. 28. Biomasa ostrożenia, w porównaniu z biomasą pszenicy ozimej, cechowała się znacznie większą zawartością składników mineralnych. W przypadku zawartości N, P, K różnica była 1–2,5-krotnie, a w przypadku Mg i Ca 4,5–17-krotnie większa. Akumulowanie składników mineralnych przez *C. arvense* prawdopodobnie w znacznym stopniu pochodziło z pobierania ich z głębszych warstw gleby.

Słowa kluczowe: uprawa/plon, eksperyment polowy, *Triticum*, zachwaszczenie

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