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EVALUATION OF WEED INFESTATION OF MAIZE CULTIVATED IN MIXED SOWING WITH SELECTED PLANT SPECIES

Summary

The aim of the study was to evaluate the weed infestation of maize grown in mixed sowing with other plant species (sunflower, common bean, vetch). The field experiment was carried out in the years 2014-2016 at the ecological farm in Chwałowice, belonging to the Advisory Agricultural Center in Radom, using the randomized block method, in 4 replications, on the soil of the good wheat complex, class IIIa. An assessment of species composition, species abundance, fresh and air dry weed weight and biomass index were determined. The analysis showed that the mix sowing of maize with different plant species significantly reduced weed infestation. The highest weight of weed was found in maize cultivation in pure sowing. The most competitive with weeds was maize grown in mix sowing with sunflower, where weed weight was reduced by 36% compared to pure maize sowing. The number of weed species in the maize cultivated in mixed sowing of the studied crop species varied considerably over the years of the study. Most weed species were identified in the first year of the study (average of 23 species), characterized by high moisture content, and the lowest in the third year of the study (average of 8 species). The lowest values of the biomass index for the three years of the study were found for control and maize grown with common bean. While the largest for maize grown in mixed sowing with sunflower.
Key words: maize, mixed sowing, weed infestation, ecologic farm, weed biomass

ZACHWASZCZENIE KUKURYDZY UPRAWIANEJ WSPÓŁRZĘDNIE Z WYBRANYMI GATUNKAMI ROŚLIN

Streszczenie

Celem badań była ocena zachwaszczenia kukurydzy uprawianej współrzędnie z innymi gatunkami roślin (słonecznik, fasola zwyczajna, wyka). Doświadczenie polowe przeprowadzono w latach 2014-2016 w gospodarstwie ekologicznym w Chwałowicach, należącym do CDR w Radomiu, metodą bloków losowanych, w 4 powtórzeniach, na glebie kompleksu pszennego dobrego, kl. IIIa. Przeprowadzono ocenę składu gatunkowego, liczebności poszczególnych gatunków, oznaczono świeżą i powietrznie suchą masę chwastów oraz określono współczynnik biomasy. Analiza wykazała, że uprawa współrzędna kukurydzy z różnymi gatunkami roślin istotnie ograniczała zachwaszczenie. Największą masę chwastów stwierdzono w uprawie kukurydzy w zasiewie czystym. Natomiast najbardziej konkurencyjny w stosunku do chwastów był łan kukurydzy uprawianej współrzędnie ze słonecznikiem, gdzie masa chwastów została zredukowana o 36%, w porównaniu do czystego zasiewu kukurydzy. Liczba gatunków chwastów we współrzędnych zasiewach kukurydzy z badanymi gatunkami roślin uprawnych zmieniała się istotnie w poszczególnych latach badań. Najwięcej gatunków flory segetalnej rozpoznano w pierwszym roku badań (średnio 23 gatunki), charakteryzującym się dużą ilością opadów, natomiast najmniej w trzecim roku badań (średnio 8 gatunków). Najniższą wartość współczynnika biomasy dla trzech lat badań stwierdzono dla obiektu kontrolnego oraz w uprawie kukurydzy z fasolą. Natomiast największe dla kukurydzy uprawianej współrzędnie ze słonecznikiem.
Słowa kluczowe: kukurydza, siew współrzędny, zachwaszczenie, gospodarstwo ekologiczne, biomasa chwastów

1. Introduction

The mixed sowing of maize with legumes allows for increased protein content in the fodder although the increase in total yield may be insignificant as a result of competition for light and water [2]. Mixed sowing also allow for higher yield of fresh and dry matter from the surface unit [1, 4, 10, 16], and more efficient use of nutrients to reduce crop expenditure [5, 19]. There is also less risk of weed [6]. The mixed sowing of maize with legumes is associated with the interaction of plants. In maize occurs C4 photosynthesis, which results in a high competition for water, sun light, nutrients and space for the development of roots and above ground parts, thus reducing the yield of legumes and maize [11]. Mixed sowing of the two species is similar to that of legumes alone grown with increased sowing rate. Weakening of growth and morphological changes may be a result of shading by maize, especially in the early growth periods [9]. Interspecific competition is weaker than intra-species competition, which is influenced by agrotechnical factors such as mineral fertilization or sowing proportion [12].

The aim of the study was evaluation of weed infestation of maize cultivated mix sowing with other species as sunflower, common bean, vetch.

2. Material and methods

The field experiment was carried out in the years 2014-2016 at the ecological farm in Chwałowice [51°10′56″N 21°18′17″E], belonging to the Advisory Agricultural Center in Radom, using the randomized block method, in 4 replications, on the soil of the good wheat complex, class IIIa. The following items were compared: control – maize (Smolicop cultivar, 240 FAO) (A), plant species: sunflower (B), vetch (C), common bean (D). The area of a plot was 30,0 m². The

contents of available nutrients amounted (g· kg⁻¹ soil): phosphorus – to 35,6; potassium – to 21,4 and magnesium – to 4,4. Soil pH, as determined in 1 N KCl, was 6,5. Mineral fertilization was not used. Maize was sown on 24 of April, while vetch and common bean – 30 of April, and sunflower – depending on year of the study between 30 of April to 18 of May. Plants were harvested at the milk-dough stage of mixture components at the first decade of September.

Weed infestation was analyzed a couple days before harvesting plants, on the surface of 0,5 m², with four replications. The study included an evaluation of weed species composition, number of individual species and the designation of fresh and dry matter of weeds. For comparison of weed infestation of maize depending on plant species in mixed sowing, the biomass index was determined and calculated for two years (2015 and 2016) according to the formula by Patriquin [13]:

$$Biomass \cdot index = \frac{crop \cdot biomass \times 100}{weed \cdot biomass + crop \cdot biomass}$$

The dry matter of the above ground of plants and weeds from the surface of 1m² were taken into account.

Assessing the significance of the impact of the considered factors on the features under investigation was based on the variance analysis, indicating Tukey's confidence half-intervals at a significance level of 0,05.

3. Results and discussion

Comparative analysis of the results showed that the weed infestation of maize depended on the species with which it was cultivated, the year of the study and the weather conditions during the vegetation period (Table 1).

Table 1. Weather conditions during the vegetation periods
Tab. 1. Przebieg warunków pogodowych w okresie wegetacji roślin

Specification	Year	Month							Sum / Mean (III-IX)
		III	IV	V	VI	VII	VIII	IX	
Rainfalls (mm)	2014	61,7	56,9	184,4	46,7	157,7	198,1	0,3	702,8
	2015	62,0	49,2	142,0	46,0	31,7	13,5	0,5	344,9
	2016	65,5	17,8	41,7	37,8	26,9	75,7	44,7	310,1
Rainfalls mean from multi-years (mm)		42,5	32,1	102,7	74,9	123,4	67,7	42,3	485,6
Temperature (°C)	2014	6,5	10,2	14,0	14,7	20,7	13,2	14,1	13,3
	2015	5,2	8,6	13,0	17,3	20,1	22,4	20,4	15,3
	2016	4,1	10,3	15,0	19,3	19,0	18,6	16,1	12,9
Temperature mean from multi-years (°C)		2,5	8,4	13,8	16,4	18,6	18,0	13,2	13,0

Source: / Źródło: Database of Meteorological Service of IUNG-PIB / Baza danych Stacji Meteorologicznej IUNG-PIB

Course of weather conditions were different in the years of study. In the first year of the study (2014), excess of moisture (due to heavy rainfall) in April, May, July and August, exceeding the 77, 76, 28 and 298% respectively of the multi-year norm for these months. The sum of precipitation during the vegetation period that year exceeded the multi-year norm and amounted to 703 mm. Excess moisture and the accompanying high temperatures in July in excess of 11% of the multi-year norm contributed to the development of segetal flora in the maize. In 2015, uneven distribution of precipitation in the vegetation period was also found. In

May, excess of moisture was noted, exceeding the 38% multi-year norm for that month, while in June, July and August, the deficit was 39, 74, 80% of the multi-year norm, respectively. The third year of research (2016) was the least favorable in terms of precipitation. Between April and July, moisture deficiency was observed. The largest deficit was found in May and July respectively: 59 and 74% of the multi-year norm. In addition, the amount of precipitation during the vegetation period that year was 36% lower than the average for many years. According to Zaliwski and Górski [18], the sum of effective temperatures above the 6°C threshold for maize with hybrids less than 2400 for silage is less than 1200°C.

Cultivation of maize with selected crop species (sunflower, vetch and common bean) significantly reduced the condition of weed infestations. The greatest weed infestation was found in pure sowing of maize, indicated by fresh and dry matter of weeds (Table 2, 3). The most competitive for weeds was maize grown with sunflower, where fresh and dry weed matter was reduced by 36% compared to pure sowing of maize.

Table 2. Dry matter of weeds depending on the plant species in mixed sowing in the years 2014-2016 (g·m⁻²)
Tab. 2. Sucha masa chwastów w zależności od gatunku rośliny współrzędnej w latach 2014-2016 (g·m⁻²)

Plant species in mixed sowing	Year			Mean
	2014	2015	2016	
A*	301,8b**	282,4c	67,2c	217,1c
B	221,5a	144,3a	56,3b	140,7a
C	285,6b	209,5b	32,5a	175,9b
D	215,7a	317,3c	38,8a	190,6b
Mean	256,2	238,4	48,7	181,1

* A - maize, B – maize+sunflower, C – maize+vetch, D – maize+common bean
** - Values followed by a different letter are significantly different (p<0.05)   *Source: own study/Źródło: opracowanie własne*

Table 3 Number of weeds (plants·m⁻²) in mixtures depending on the plant species in mixed sowing (mean) in the years 2014-2016
Tab. 3. Skład gatunkowy oraz liczba gatunków chwastów w zależności od gatunku rośliny współrzędnej (szt.·m⁻²) średnio w latach 2014-2016

Specification	Plant species in mixed sowing				Mean
	A*	B	C	D	
Monocotyledonous weeds	92,4	123,7	114,6	83,6	103,6
Dicotyledonous weeds	66,7	27,9	84,2	54,2	58,3
Number of total weeds	159,1	151,8	198,8	137,8	161,9
Number of weed species	15,1	13,7	16,3	12,0	14,3

Source: own study / Źródło: opracowanie własne
*See Table 2

On average for the three years of study, the least undesirable species was shown in maize cultivated with common beans (138 plants·m⁻²), while maize grown in pure sowing and with sunflower was characterized by a similar number of weeds (152-159 plants ·m⁻²) (Table 4). On the other hand, the greatest number of weeds area was characterized by maize

cultivated with vetch (199 units·m^{-2}). In this way of maize cultivation we also recognized the highest number of weed species - 16. While the lowest number of weed species was found in the maize grown in mixed sowing with common bean - 12 numbers of weed. The number of weed species in the mix sowing of maize with the tested crop species varied over the years of the study. (Table 4).

Table 4. Weed species composition and number of weeds (plants·m^{-2}) in the first year of the study (2014)
Tab. 4. Skład gatunkowy chwastów w zależności od gatunku rośliny współrzędnej (szt.·m^{-2}) w pierwszym roku badań (2014)

Weed species	Plant species in mixed sowing				Mean
	A*	B	C	D	
Monocotyledonous					
Echinochloa crus-galli	140,7	266,0	231,0	125,5	**194,6**
Elymus repens	20,0	2,5	8,5	7,5	**9,6**
Sum of monocotyledonous	**160,7**	**268,5**	**239,5**	**133,0**	**204,3**
Dicotyledonous					
Anchusa arvensis	8,0	-	2,5	9,5	**6,7**
Anthemis arvensis	1,5	-	-	0,5	**1,0**
Capsella bursa-pastoris	3,5	2,5	4,0	7,5	**4,4**
Chenopodium album	14,5	5,0	7,5	8,5	**8,9**
Cirsium arvense	2,5	9,5	9,5	5,0	**6,6**
Convolvulus arvensis	-	-	0,5	-	**0,5**
Euphorbia helioscopia	2,0	-	-	-	**2,0**
Fallopia convolvulus	8,0	6,5	13,5	7,0	**8,8**
Fumaria officinalis	1,0	-	2,5	-	**1,8**
Galeopsis ladanum	5,5	0,5	4,5	6,5	**4,3**
Galinsoga parviflora	19,5	5,0	16,0	26,0	**16,6**
Galium aparine	0,5	1,0	1,0	-	**0,8**
Geranium molle	8,0	1,0	1,5	2,0	**3,1**
Geranium pusillum	26,0	8,5	11,0	14,0	**14,9**
Lamium amplexicaule	-	0,5	-	-	**0,5**
Lamium purpureum	-	-	0,5	-	**0,5**
Lapsena communis	9,0	1,0	3,0	5,0	**4,5**
Matricaria maritima	-	-	0,5	1,0	**0,8**
Melandrium album	-	0,5	-	-	**0,5**
Plantago major	0,5	-	-	-	**0,5**
Polygonum persicaria	-	1,5	2,5	1,0	**1,7**
Sinapis arvensis	0,5	-	-	-	**0,5**
Solanum nigrum	30,5	13,5	24,0	16,0	**21,0**
Sonchus arvensis	2,5	-	0,5	-	**1,5**
Stellaria media	4,5	4,0	2,0	7,0	**4,4**
Thlaspi arvense	0,5	-	1,5	2,0	**1,3**
Trifolium arvense	1,5	-	-	1,5	**1,5**
Veronica persica	15,0	4,0	9,0	11,0	**9,8**
Vicia hirsuta	1,0	-	-	2,0	**1,5**
Viola arvensis	10,0	3,0	4,0	4,0	**5,3**
Sum of dicotyledonous	**176,0**	**67,0**	**121,5**	**137,0**	**125,4**
Total	**336,7**	**335,5**	**361,0**	**270,0**	**329,6**
Number of weed species	**26**	**19**	**24**	**22**	**23**

Source: own study / Źródło: opracowanie własne
*See Table 2

The highest number of weed species was noted in the first year 2014 of the study (average 23 species), characterized by excess of moisture, and least in the third year (2016) of the study (8 on average), which was also the result of weather conditions.

Głowacka [6] showed that the mixed sowing of maize significantly reduced the number of weeds per unit area, but did not significantly reduce the production of their dry mat-ter. This author has found that weeds in mixed sowing of maize has been reduced by 43% compared to maize cultivated in pure sowing.

In our own study the species diversity of segetal flora was similar in all crops. A total of 21 species of weeds, including 4 monocotyledons and 17 dicotyledonous species, were identified. Irrespective of the type of crop, more numerous were monocotyled species, which accounted for an average of 64% of all weeds. The most common were: *Echinochloa crus-galli*, *Digitaria sanguinalis*, and *Setaria pumila*. Among Dicotyledonous species dominated the *Chenopodium album*. According to Stupnicka-Rodzynkiewicz et al. [15] the composition of weed infestation has an impact on the weed damage, as individual species differ in their ability to compete with the crop. These authors believe that the greater diversity of species composition, the less harmful it is. Research of Głowacka [7] has shown that the mixed sowing increases the biodiversity of weed infestation compared to pure sowing. Under the conditions of its application we have found 20 weed taxons, while in pure sowing - 13. In addition, this crop reduces both the number of weeds and their weight. Also Liebman and Dyck [8] confirm the effect of mixed sowing cultivation on weed infestation of crop plants. In their research, the mixed sowing reduced the weeds number per unit area compared to pure sowing, but increased species diversity of weeds. Similar correlations were demonstrated by Carruthers et al., [3] and Weil and McFadden [17].

In the first year of the study, the largest weed infestation characterized pure maize sowing, where the largest fresh and dry matter of weeds was recorded. Large weed infestation was also demonstrated in maize sowing with common bean. In contrast, significantly lower fresh and dry weed matter was found in the mixed sowing of maize with sunflower (Table 2, 3). Sunflower has strong allelopathy impact. The fresh matter of weed in maize grown in mixed sowing with these crop species was reduced by 25 and 23%, respectively, and dry matter by 27 and 29%, respectively, relative to pure sowing of maize.

The weed number in the mixed sowing of maize with the tested plant species was not much differentiated. Least undesirable species have been demonstrated in maize with common bean (270 number per 1 m^2), while the other seeds were characterized by a similar weed number (average 344,4 numbers per 1 m^2) (Table 5).

The species diversity of segetal flora was similar in all crops. A total of 32 weed species, including 2 monocotyledonous and 24 dicotyledonous species, were identified. The greatest variety of weed species characterized pure sowing of maize (26 species). The most abundant species of weed, irrespective of the cultivar were: *Solanum nigrum, Galinsoga parviflora* and *Geranium pusillum. Echinochloa crus-galli* dominated as a monocotyledonous species. According to Praczyk [14] due to the high frequency of occurrence harmfulness, *Echinochloa crus-galli*, *Chenopodium album* and *Amaranthus retroflexus.*are the most dangerous weed species in maize.

In the second year of the study, the largest fresh and dry weed matter was found in maize with common beans and only slightly less in pure sowing of maize. Mixed sowing of maize with sunflower and vetch were more competitive for weeds, where fresh weed matter was reduced by 52 and 32%, respectively, and dry matter was reduced by 49 and 26%, respectively, compared to pure sowing of maize.

Table 5. Weed species composition and number of weeds (plants·m^{-2}) in the second year of the study (2015)
Tab. 5. Skład gatunkowy chwastów w zależności od gatunku rośliny współrzędnej (szt.·m^{-2}) w drugim roku badań (2015)

Weed species	Plant species in mixed sowing				Mean
	A*	B	C	D	
Monocotyledonous					
Echinochloa crus-galli	70,5	94,5	69,0	92,5	81,6
Digitaria sanguinalis	-	31,5	30,5	18,5	20,1
Elymus repens	9,0	3,5	0,5	5,0	4,5
Setaria pumila	42,5	4,5	1,5	2,5	12,8
Sum of monocotyledonous	**113,0**	**94,5**	**99,5**	**111,0**	**104,5**
Dicotyledonous					
Amaranthus retroflexus	0,5	1,0	-	-	0,4
Anagallis arvensis	-	1,0	0,5	0,5	0,5
Anthemis arvensis	-	-	0,5	-	0,1
Capsella bursa-pastoris	2,0	2,0	2,5	0,5	1,8
Centaurea cyanus	-	-	-	0,5	0,1
Chenopodium album	10,5	4,0	12,5	19,5	11,6
Erodium cicutarium	-	1,0	1,0	-	0,5
Fallopia convolvulus	0,5	0,5	0,5	-	0,4
Galinsoga parviflora	-	1,3	0,5	-	0,4
Matricaria maritima	-	0,5	1,0	-	0,4
Papaver rhoeas	0,5	0,5	-	-	0,2
Polygonum aviculare	0,5	-	1,5	-	0,5
Spergula arvensis	1,5	-	-	-	0,4
Stellaria media	-	1,0	-	-	0,2
Viola arvensis	-	-	0,5	-	0,1
Sum of dicotyledonous	**16,0**	**11,5**	**21,0**	**21,0**	**17,4**
Equisetum arvense	-	1,5	-	-	0,4
Total	**129,0**	**106,0**	**120,5**	**132,0**	**121,9**
Number of weed species	**10**	**15**	**14**	**8**	**12**

Source: own study / Źródło: opracowanie własne
*See Table 2

Table 6. Weed species composition and number of weeds (plants·m^{-2}) in the third year of the study (2016)
Tab. 6. Skład gatunkowy chwastów w zależności od gatunku rośliny współrzędnej (szt.·m^{-2}) w trzecim roku badań (2016)

Weed species	Plant species in mixed sowing				Mean
	A*	B	C	D	
Monocotyledonous					
Echinochloa crus-galli	0,7	0,7	-	-	**0,4**
Setaria viridis	2,7	8,0	4,7	6,7	**5,5**
Sum of monocotyledonous	**3,4**	**8,7**	**4,7**	**6,7**	**5,9**
Dicotyledonous					
Achillea millefolium L	1,3	-	-	-	**0,3**
Capsella bursa-pastoris	-	-	0,7	0,7	**0,4**
Centaurea cyanus	-	-	-	0,7	**0,2**
Chenopodium album	1,3	2,0	1,3	1,3	**1,5**
Cirsium arvense	-	-	0,7	-	**0,2**
Convolvulus arvensis	0,7	-	-	-	**0,2**
Euphorbia cyparissias	2,0	-	0,7	-	**0,7**
Galinsoga parviflora	-	-	0,7	-	**0,2**
Geranium molle	1,3	0,7	2,7	0,7	**1,4**
Matricaria maritima	0,7	0,7	0,7	-	**0,5**
Plantago major	-	-	0,7	-	**0,2**
Polygonum lapathifolium	0,7	1,3	-	-	**0,5**
Sonchus arvensis	-	0,7	-	-	**0,2**
Veronica persica	-	-	0,7	1,3	**0,5**
Viola arvensis	-	-	2,0	-	**0,5**
Sum of dicotyledonous	**8,0**	**5,3**	**10,7**	**4,7**	**7,2**
Total	**11,4**	**14,0**	**15,4**	**11,4**	**13,0**
Number of weed species	**9**	**7**	**11**	**6**	**8**

Source: own study / Źródło: opracowanie własne
*See Table 2

The number of weeds in the mixed sowing of maize with the tested crop species was not much different (Table 6). The smallest undesirable species was found in maize grown with sunflower (106 units·m^{-2}), while the others in mixed sowing were characterized by similar weed numbers (120-132 units·m^{-2}).

The species diversity of segetal flora was similar in all crops. A total of 21 species of weeds, including 4 monocotyledons and 17 dicotyledonous species, were identified. Irrespective of the type of crop, more numerous monocotyledonous species, which accounted for an average of 85,7% of all weeds. The most common were: *Echinochloa crus-galli*, *Digitaria sanguinalis* and *Setaria pumila*. The *Chenopodium album* dominated among the dicotyledonous species.

In the third year of the study, the largest weed were characterized by pure maize sowing, where the largest fresh and dry matter of weeds was recorded. Large weeds have also been reported in maize and sunflower cultivation. On the other hand, a significantly lower dry matter of weeds was found in maize cultivated with vetch. Mixed sowing with plants reduced weeds by 32, 60 and 54%, respectively. The least undesirable species was shown in pure sowing of maize and in mixed sowing of maize with common bean (11,4 units per 1 m^2), while cultivation of maize with vetch was characterized by a higher weed abundance (average 15 plants per 1 m^2) (Table 7). A total of 16 species of weeds, including two monocots and 14 dicotyledonous species, were identified. The greatest diversity of weed species was found in maize cultivated with vetch (11 species) and in pure sowing of maize (9 species). *Setaria viridis*, as a representative of monocots and *Geranium molle* were the most abundant species of weeds.

The biomass index is an additional indicator of the degree of weed infestation of the crop. The lowest values for this index were found for maize cultivated in pure sowing and in maize with common bean, indicating a high share of weed matter in the total biomass of maize per unit area. On the other hand, maize grown in mixed sowing sunflower had the highest biomass factor.

Table 7. Biomass index depending on the plant species in mixed sowing (mean) in the years 2014-2015

Tab. 7. Współczynnik biomasy w zależności od gatunku rośliny współrzędnej (%) w latach 2014-2015

Plant species in mixed sowing	Year		mean
	2014	2015	
A*	81,7	65,5	73,6
B	85,2	80,8	83,0
C	81,4	73,8	77,6
D	85,4	61,9	73,6
Mean	83,4	70,5	77,0

Source: own work / Źródło: opracowanie własne

4. Conclusions

1. The weed infestation of maize depends on the species with which it was cultivated and on the weather during the growing season.
2. The mixed cultivation of maize with various plant species significantly limited weed infestation. The highest fresh and dry matter of weeds was found in maize cultivation in pure sowing. The most competitive with weeds was maize growing with sunflower, where weed mass was reduced by 36%, compared to pure maize sowing.
3. On average for three years of study, the least weed species was recorded in maize grown with common bean. The greatest abundance of undesirable species on the area unit characterized maize grown in the mixed sowing with vetch.
4. The number of weed species in the maize cultivated in mixed sowing with other crops was varied over the years. The highest number of weed species was noted in the first year (2014) of the study (an average of 23 species).
5. The lowest values of the biomass index were found for maize in pure sowing and in maize with common bean.

5. References

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