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INFLUENCE OF UNDERSOWN SPECIES ON MAIZE YIELDING

Summary

The field experiment was conducted in the years 2014-2016 at AES Grabów (Mazowieckie Voivodeship), belonging to Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy, (Poland) and in ecological farm in Chwałowice (Poland) in the years of 2014-2015. The trial was conducted in the randomized block method, in four replications. The following treatments were compared: control and intercrop sowings with: buckwheat, phacelia, white mustard and white clover. The inter-row cultivation of buckwheat, phacelia, white mustard and white clover had a positive effect on maize yield. On average, for the four species of the intercrops, the yield increase was 17-22%, and in Grabów, in the year with unfavorable distribution of total precipitation, this increase was significantly higher and amounted to about 60%. In the summers with favorable weather conditions (2014 and 2016), intersowing buckwheat proved the least useful in Grabów, while in the dry year, as well as in Chwałowice, this species was less competitive than maize. Intersowing different species into maize crops had a relatively small effect on the dry matter content of whole plants and cobs, while in Grabów in 2015, with unfavorable weather conditions, it had a positive effect on its content.

In Grabów, the structure of maize plants was little diversified by the applied intercrop species. The lowest share of the cob was recorded in 2014. In Chwałowice, maize grown with intercrops formed cobs only in 2014. In this location, intercrops stimulated the number of grains produced per cob, while in Grabów, an intercrop species had a small impact on the number of grains per cob.
***Key words**: maize (Zea mays* L.*), species undersown, structure of maize plant*

WPŁYW GATUNKU WSIEWKI NA PLONOWANIE KUKURYDZY

Streszczenie

Doświadczenie polowe przeprowadzono w latach 2014-2016 w RZD Grabów (woj. mazowieckie), należącym do IUNG-PIB w Puławach, oraz w latach 2014-2015 w Pokazowym Gospodarstwie Ekologicznym w Chwałowicach, należącym do CDR Radom. Doświadczenie przeprowadzono metodą podbloków losowanych w 4 powtórzeniach. Porównywano następujące obiekty: kontrola, gatunki wsiewki: gryka, facelia, gorczyca biała, koniczyna biała. Uprawa w międzyrzędziach gryki, facelii, gorczycy białej i koniczyny białej wpływała korzystnie na plonowanie kukurydzy. Średnio dla czterech gatunków wsiewki, zwiększenie plonów wynosiło 17-22%, a w Grabowie w roku o niekorzystnym rozkładzie i sumie opadów było znacząco większe i wynosiło około 60%. W Grabowie w latach o sprzyjającym przebiegu warunków atmosferycznych (2014 i 2016) najmniej celowe było wsiewanie gryki, a w roku suchym, jak również w Chwałowicach, gatunek ten był mniej konkurencyjny dla kukurydzy. Wsiewanie różnych gatunków wsiewek w łan kukurydzy miało stosunkowo niewielki wpływ na zawartość suchej masy w całych roślinach i kolbach. Natomiast w Grabowie w roku o niesprzyjającym przebiegu pogody (2015) korzystnie wpływało na jej zawartość. W Grabowie struktura roślin kukurydzy była stosunkowo mało różnicowana zastosowanym gatunkiem wsiewki, a udział kolby był najmniejszy w 2014 roku. Natomiast w Chwałowicach, kukurydza uprawiana z wsiewkami zawiązała kolby tylko w 2014 roku. W Chwałowicach wsiewki wpływały stymulująco na liczbę wytworzonych ziaren na kolbie, a w Grabowie gatunek wsiewki miał stosunkowo mały wpływ na zaziarnienie kolby.
***Słowa kluczowe**: kukurydza (Zea mays* L.*), gatunki wsiewek, struktura roślin kukurydzy*

1. Introduction

Maize, along with wheat, rice and soya, is one of the main cultivated species in the world [9, 14]. Also in Poland, from a plant of marginal economic importance, maize has become an important crop species over the recent 50 years. This is reflected in a dynamic growth of its cultivation area (in 2000 - 314 thousand ha, in 2016 - 1.2 million ha). Such an increase in the cultivated area and in the yield level have not been achieved in any other country. This development results from biological, technological and organizational progress of Polish agriculture. Moreover, it also depends on the possibilities of its varied use. Grains, individual plant fractions (cob cores, embryos), and straw have been used in biofuel production in recent years, while the whole above-ground parts are used as silage raw material. Whole-plant maize silage is the most valuable bulk feed for ruminants, mainly due to its high content of easily digestible carbohydrates and structural scales necessary for the digestive processes in the digestive tract of these animals. One of the most important elements (apart from fertilization) limiting maize growth is weed infestation, which influences yields, as well as chemical composition and nutritional value of plants. Since maize grows slowly in the initial period, the root system is underdeveloped and competes poorly with weeds for nutrients in soil solutions [8, 12, 13, 23]. Convenient conditions for weed development are created due to the late sowing of maize, a wide inter-row tillage, and a low plant density per unit area. That is why it is so important to maintain weed-free plantations in the early stages of maize growth. Yield losses caused by weed infestation of maize, as reported by Rola and Rola [19], may amount to 70%, while according to Skrzypczak [21], at large weed occurrence, even reach 90%. According to Skrzypczak et al. [22], the yield of fresh matter of maize weeded out with herbicides was twice as high as of the control plants, while the effectiveness was 94.5 -99.7%. In the study of Rychcik [20], herbicides destroyed from 49.4 to 82.1% of weeds.

There are few reports of only mechanical treatments for maize [11]. According to Waligóra et al. [24], in sweetcorn cultivation, the herbicidal effectiveness of the mechanical method was much lower than that of the chemical method, and it turned out to be beneficial only in the controlling of barnyard grass. In turn, Wilson [25] informs that mechanical treatments can destroy about 87% of weeds in maize. According to Adamczewski [1], mechanical treatments allow limiting weed abundance by only 50%, and only in between rows. In turn, Bojarszczuk et al. [4] and Księżak et al. [15, 16] noted a strong reduction in weed infestation after mechanical treatments in maize grown under organic conditions. In the conventional system, weed infestation in maize cultivation is most effectively limited by herbicides, while in the organic system, weed control can be achieved by mechanical or biological methods**.** In organic farms keeping ruminant animals, maize is a very important source of energy feed. Weed control in such farms can be performed only by means of officially permitted methods for the cultivation of this species. The aim of the study was to evaluate the suitability of different intercrops for reducing weed infestation in organic `maize cultivation.

2. Materials and methods

The field experiment was conducted in the years 2014-2016 at the AES Grabów [51°21′18″N 21°40′09″E] (mazowieckie voivodeshiop), belonging to Institute of Soil Science Cultivation – State Research Institute (Poland) and at the ecological farm in Chwałowice [51°10′56″N 21°18′17″E], belonging to the Center Advisory Agriculture in Radom, in the years 2014-2015. The trials were conducted in the randomized block method, in four replications. The following treatments were compared: buckwheat, phacelia, white mustard and white clover. Before harvesting, the height of the cob setting and the height of the plants were determined for 10 randomly selected plants from each plot. The dry matter content of the whole plant and cob, as well as the structure of maize plants (stem, seed, corncob and cover leaves), were also determined. After the harvest, the yields of green and dry matter were determined. In Chwałowice, the size of the plot was 30,0 m^2, and the experiments were carried out on the soil of the good wheat complex, class IIIa (2014), and good rye complex, class IVa (2015). The content of available phosphorus (in mg per 1000 g of soil) was 121 - 136, potassium 131 - 214, and magnesium 44 - 69. The soil pH determined in 1n KCl was 5.1 - 6.5. Maize together with intercrops were sown from 24 to 25 April. The plants were harvested in the milk-dough maturity stage from 8^{th} to 10^{th} September. In Grabów, the plot size at the set-up was 30 m^2, while at harvest, 28,0 m^2. The experiment was carried out on the soil of a very good rye complex, class IIIa. The content of available phosphorus (in mg per 1000 g of soil) was 114-149, of potassium 151-172 and of magnesium 60-68. The soil pH determined in 1n KCl was 5.4-5.9. In 2014, maize together with intercrops were sown on 7^{th} May. In 2015 and 2016, maize, phacelia, mustard and buckwheat were sown 4-5^{th} May, while white clover 7-10 days later. Maize was harvested during the milk-dough maturity stage on 17-29^{th} September. Mineral fertilization was not applied. The significance of the effect of the studied factors on features was evaluated by means of variance analysis. The confidence semi-intervals were determined with Tukey test at the significance level of $\alpha = 0.05$.

3. Results and discussion

Course of weather conditions were different in the years of study (Table 1). In Grabów, in May of 2014 it have been noted a lower temperature than the long-term average in May, which had a significant impact on the emergence, growth, and development of maize. The total precipitation from March to September was much higher than the long-term average. A large amount of rainfall was recorded in May, which at low temperatures strongly favored the growth of weeds. In 2015, rainfall was high in May and in June, the third decade of July, and especially in August, there was low rainfall compared to the multi-years average, which had a negative impact on the growth and development of plants. Moreover, in July and August air temperatures were mostly high, which further worsened the conditions for yielding. The lowest rainfall between March and the end of September compared to the previous two years was observed in 2016. A higher air temperature during the growing season and evenly distributed precipitation, especially in July and August, ensured the highest level of maize yields. The sum of precipitation during the vegetation period this year exceeded the multi-year norm and amounted to 703 mm. Excess of 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.

The level of fresh and dry matter yields in maize were significantly influenced by the location of cultivation, the course of weather conditions during the growing season and the sown plant species undersown. In 2014, the yields in Grabów were similar to those in Chwałowice, while in 2015, yields were higher in Grabów (Tables 2, 3). In Grabów, the highest fresh yield was recorded in 2016, which was on average by 84% higher than in 2014 and by 110% higher than in 2015. In both regions, intersowing of phacelia, white mustard and white clover had a positive effect on maize yield. In Grabów, on average, the fresh yield increase for the four seeding species in 2014 and 2016 was 17-20%, while in 2015, which had unfavorable distribution and total precipitation, it was higher and amounted to about 60%. In Chwałowice, on the other hand, the difference in comparison to the control ranged from 22 to 29%. In Grabów, in the years with favorable weather conditions (2014 and 2016), planting buckwheat was the least useful, while in the dry year, this species was conducive to maize yields (significant differences control ranged). In Chwałowice, on light soils, this species turned out to be the least competitive with maize. Buchner and Köller [6] achieved the highest yields of maize dry matter by sowing a mixture of perennial ryegrass with white clover and subterranean clover. Moreover, according to the authors, such sowing effectively limited water erosion. Beredonk [3] informs that all the intercrops (subterranean clover, mixtures of Italian ryegrass with white clover and of perennial ryegrass with white clover) decreased the yields of maize dry matter. The mixture of Italian ryegrass and white clover had the most limiting effect. Moreover, this author observed a stronger response of maize to the presence of intercrops in dry and cold years. Lütke Entrup and Stemann [17] recorded only slightly lower yields of maize dry matter grown together with intercrops compared to pure sowing. These authors, as well as Borowiecki and Lipski [5], found that perennial ryegrass is less aggressive and has a lower impact on maize than the faster and more intensively growing Italian ryegrass. In addition, according to Lütke Entrup and Stemann [17], due to a smaller reduction in maize yield, a lower sowing rate of perennial ryegrass and a later sowing date, when maize is already larger and better able to withstand competition, are more advantageous. The information presented in the study by Essais de semis [7] shows that there was a certain tendency to increase the dry matter yield of maize with intersown perennial ryegrass compared to pure sowing. Borowiecki and Lipski [5] reported that sowing grasses into maize rows did not significantly differentiate its yield, while the term of grass sowing did not have a significant impact on its yields. They also underlined that grasses act as mulch to protect the soil from excessive evaporation. Albrecht and Andrzejewska [2] reported that *Trifolium ambiguum* is a good species to be intersown with maize. These authors suggested that such use of this plant can primarily protect the soil against erosion. In Africa, Hassen et al. [2009] did not observe any decrease in grain yield of maize cultivated with the following species: *Chloris gayana, Stylosanthes hamata, Desmodium intortum and Macrotyloma axillare.*

The level of fresh and dry matter yields in maize were significantly influenced by the area of cultivation, the course of weather conditions during the growing season and the plant species sown. In 2014, the yields in Grabów were similar to those in Chwałowice, while in 2015, yields were significantly higher in Grabów (Tables 2, 3). In Grabów, the highest yield was recorded in 2016, which was on average by 25% higher than in 2014 and by 110% higher than in 2015. In both regions, intersowing of buckwheat, phacelia, white mustard and white clover had a positive effect on maize yield. In Grabów, on average, the yield increase for the four seeding species in 2014 and 2016 was 17-20%, while in 2015, which had unfavorable distribution and total precipitation, it was significantly higher and amounted to about 60%. In Chwałowice, on the other hand, the difference in comparison to the control ranged from 20% to 22%. In Grabów, in the years with favorable weather conditions (2014 and 2016), planting buckwheat was the least useful, while in the dry year, this species was conducive to maize yields (significant differences). In Chwałowice, on light soils, this species turned out to be the least competitive with maize. Buchner and Köller [6] achieved the highest yields of maize dry matter by sowing a mixture of perennial ryegrass with white clover and subterranean clover. Moreover, according to the authors, such sowing effectively limited water erosion. Beredonk [3] informs that all the intercrops (subterranean clover, mixtures of Italian ryegrass with white clover and of perennial ryegrass with white clover) decreased the yields of maize dry matter. The mixture of Italian ryegrass and white clover had the most limiting effect. Moreover, this author observed a stronger response of maize to the presence of intercrops in dry and cold years. Lütke Entrup and Stemann [17] recorded only slightly lower yields of maize dry matter grown together with intercrops compared to pure sowing. These authors, as well as Borowiecki and Lipski [5], found that perennial ryegrass is less aggressive and has a lower impact on maize than the faster and more intensively growing Italian ryegrass. In addition, according to Lütke Entrup and Stemann [17], due to a smaller reduction in maize yield, a lower sowing rate of perennial ryegrass and a later sowing date, when maize is already larger and better able to withstand competition, are more advantageous. The information presented in the study by Essais de semis [7] shows that there was a certain tendency to increase the dry matter yield of maize with intersown perennial ryegrass compared to pure sowing. Borowiecki and Lipski [5] reported that sowing grasses into maize rows did not significantly differentiate its yield, while the term of grass sowing did not have a significant impact on its yields. They also underlined that grasses act as mulch to protect the soil from excessive evaporation. Albrecht and Andrzejewska [2] reported that *Trifolium ambiguum* is a good species to be intersown with maize. These authors suggested that such use of this plant can primarily protect the soil against erosion. In Africa, Hassen et al. [2009] did not observe any decrease in grain yield of maize cultivated with the following species: *Chloris gayana, Stylosanthes hamata, Desmodium intortum and Macrotyloma axillare.*

In Grabów, in 2014 the dry matter content of whole plants and cobs was lower than in the following years (Table 4,). That year, maize did not produce grains on the cobs, and the cover leaves constituted more than half of the maize cob. Sowing of different crop species into maize in 2016 had little effect on the content of the dry mass of maize cobs and of the whole plants, whereas in 2015, in which occurred adverse weather conditions, it had a positive effect on the above content. On the other hand, a species of the intercrop had only little impact on the concentration of dry matter in whole plants and cobs. Moreover, in 2014 the dry matter content of the cobs was lower than in the whole plants, which was not observed in the next two years. In Chwałowice, the dry matter content of the whole plants in 2015 was slightly higher than in 2014, while sowing various species into maize crops had a relatively small effect on the dry matter content. The study by Essais de Semis [7] presented information on a slight increase in the dry matter content of maize grown with intersown perennial ryegrass.

The structure of maize plants in Grabów was relatively little differentiated by the intersowing of the plant species, and the cob established the smallest percentage in the plant structure in 2014, while the largest in 2015 (Table 6-9). In Chwałowice, in 2014, all the plants formed cobs. On the areas, where maize was cultivated with intercrops, cobs constituted about 56,9%, and while maize was cultivated without any intercrops, slightly below 50%. In this location, in 2015, cobs were produced only on the control treatments. The number of cobs per plant in both regions of cultivation and in all the years of the research was very similar. In 2014 in Grabów, maize plants did not develop grains, and cover leaves accounted for about 57,4% of the cob structure. Share of grain per cob in 2016 was higher than in 2015, and the intercrop species had a relatively small effect on the number of grains per cob. In Chwałowice, the smallest amount of grain was produced by cobs in the control, while more grains were recorded in cobs in the treatments with intersown white mustard and white clover. The applied species of intercrops slightly differentiated the length and diameter of the cobs, but they stimulated the number of grains produced per cob, with buckwheat (in Chwałowice) intercrops having the lowest impact (phacelia in Grabów) (Table 10, 11). In the second and third year of experiments in Grabów, the intersowing of all the tested species had a positive effect on the height of the cob settling and the height of plants, especially in the case of intersowing white clover. In Chwałowice, on the other hand, no such tendencies were observed (Tables 12, 13).

Table 1. Course of weather conditions during the vegetation of maize
Tab. 1. Przebieg warunków meteorologicznych w okresach wegetacji kukurydzy

Specification	Month							Sum/ Mean III-IX
	III	IV	V	VI	VII	VIII	IX	
Grabów 2014								
Rainfall (mm)	36,5	51,1	161,7	93,1	101,4	91,9	15,2	550,9
Temperature (°C)	-	9,9	13,5	15,2	20,4	17,9	14,4	15,2
Grabów 2015								
Rainfall (mm)	63,2	34,8	107,0	30,3	51,7	6,2	93,9	387,1
Temperature (°C)	-	7,8	13,4	16,3	18,2	17,9	13,3	14,5
Grabów 2016								
Rainfall (mm)	52,3	45,1	39,4	60,1	81,9	53,6	20,3	352,7
Temperature (°C)	3,9	9,2	14,9	18,7	19,2	18,1	15,7	16,6
*Average rainfall from multi-years	30,0	39,0	57,0	71,0	84,0	75,0	50,0	406,0
Average temperature from multi-years	1,6	7,7	13,4	16,7	18,3	17,3	13,2	12,6
Chwałowice 2014								
Rainfall (mm)	61,7	56,9	181,4	46,7	157,7	198,1	0,3	702,8
Temperature (°C)	6,5	10,2	14,0	14,7	20,7	13,2	14,1	13,3
Chwałowice 2015								
Rainfall (mm)	60,2	49,2	142,0	46,0	31,7	13,5	0,5	343,1
Temperature (°C)	5,2	8,6	13,0	17,3	20,1	22,4	20,4	15,3

*Average of multi years 1871-2000 (AES Grabów)

Source: / Źródło: Database of Meteorological Service of Grabów and Chwałowice / Baza danych Stacji Meteorologicznej w Grabowie i Chwałowicach

Table 2. Fresh and dry matter yields of maize depending on species undersown (Grabów) (t/ha)
Tab. 2. Plon świeżej i suchej masy kukurydzy w zależności od gatunku wsiewki (Grabów) (t/ha)

Undersown species	Fresh matter yield				Dry matter yield			
	2014	2015	2016	Mean	2014	2015	2016	Mean
Control	17,0	11,5	31,9	20,1	3,5	3,6	9,6	5,6
Buckwheat	17,1	20,2	34,4	23,9	3,4	7,4	11,4	7,4
Phacelia	22,5	17,5	38,4	26,1	4,5	6,4	12,2	7,7
White mustard	21,3	16,6	37,3	25,1	4,7	6,2	11,5	7,5
White clover	20,8	19,2	38,9	26,3	4,4	7,4	11,8	7,8
Mean	19,7	17,0	36,2	-	4,1	6,2	11,3	-
$NIR_{0,05}$ $HSD_{0,05}$	5,12	4,13	4,35	-	1,22	1,10	n.s.	-

n.s. - not significant difference *Source: own work / Źródło: opracowanie własne*

Table 3. Fresh and dry matter yields of maize depending on undersown species (Chwałowice)
Tab. 3. Plon świeżej i suchej masy kukurydzy w zależności od gatunku wsiewki (Chwałowice)

Undersown species	Fresh matter yield (t/ha)			Dry matter yield (t/ha)		
	2014	2015	Mean	2014	2015	Mean
Control	17,4	8,5	13,0	5,5	2,6	4,1
Buckwheat	22,6	10,7	16,7	6,8	3,5	5,2
Phacelia	21,8	10,4	16,1	7,0	3,3	5,2
White mustard	21,5	9,6	15,6	6,8	3,2	5,0
White clover	19,0	13,3	16,2	4,0	3,2	3,6
Mean	20,5	10,5	15,5	6,0	3,2	4,6
$NIR_{0,05}$ $HSD_{0,05}$	3,09	2,97	-	1,26	0,88	-

Source: own work / Źródło: opracowanie własne

Table 4. Dry matter content in plants and cob of maize (%) (Grabów)
Tab. 4. Zawartość suchej masy w roślinach i kolbach kukurydzy (%) (Grabów)

Undersown species	2014		2015		2016	
	Plants	Cob	Plants	Cob	Plants	Cob
Control	20,6	13,7	31,7	35,4	30,1	47,4
Buckwheat	19,8	15,1	36,5	48,3	33,1	44,6
Phacelia	20,0	14,4	36,4	47,6	31,8	44,1
White mustard	22,3	15,4	37,1	46,4	30,8	44,5
White clover	21,0	14,6	38,3	48,6	30,3	45,4
Mean	20,7	14,6	36,0	45,3	31,2	45,2
$NIR_{0,05}$ $HSD_{0,05}$	2,39	n.s.	3,21	3,30	n.s.	n.s.

n.s. - not significant difference *Source: own work / Źródło: opracowanie własne*

Table 5. Dry matter content in plants and cob of maize (%) (Chwałowice)
Tab. 5. Zawartość suchej masy w roślinach i kolbach kukurydzy (%) (Chwałowice)

Undersown species	2014		2015	
	Plants	Cob	Plants	Cob
Control	31,5	41,0	34,4	37,0
Buckwheat	30,0	35,5	32,7	-
Phacelia	32,3	40,6	31,1	-
White mustard	31,8	40,2	33,1	-
White clover	31,7	38,1	34,1	-
Mean	31,5	39,1	33,1	
$NIR_{0,05}$ $HSD_{0,05}$	n.s.	3,98	n.s.	

n.s. - not significant difference *Source: own work / Źródło: opracowanie własne*

Table 6. Structure of maize plant (%) (Grabów)
Tab. 6. Struktura roślin kukurydzy (%) (Grabów)

Undersown species	2014		2015		2016	
	Stem	Cob	Stem	Cob	Stem	Cob
Control	83,4	16,6	48,6	51,4	64,6	35,4
Buckwheat	81,0	19,0	49,2	50,8	62,5	37,5
Phacelia	85,0	15,0	47,6	52,4	63,0	37,0
White mustard	82,8	17,2	49,3	50,7	62,5	37,5
White clover	80,2	19,8	47,8	52,2	63,3	36,7
Mean	82,5	17,,5	48,5	51,5	63,2	36,8

Source: own work / Źródło: opracowanie własne

Table 7. Structure of maize plant (%) (Chwałowice)
Tab. 7. Struktura roślin kukurydzy (%) (Chwałowice)

Undersown species	2014		2015	
	Stem	Cob	Stem	Cob
Control	51,1	48,9	75,3	24,7
Buckwheat	43,7	56,3	100	-
Phacelia	41,4	58,6	100	-
White mustard	43,2	56,8	100	-
White clover	44,0	56,0	100	-
Mean	44,7	55,3	95,1	

Source: own work / Źródło: opracowanie własne

Table 8. Cob structure of maize (%) (Grabów)
Tab. 8. Struktura kolby kukurydzy (%) (Grabów)

Undersown species	2014			2015			2016		
	Seeds	Corncob	Covering leaf	Seeds	Corncob	Covering leaf	Seeds	Corncob	Covering leaf
Control	-	45,6	54,4	71,1	15,8	13,1	74,9	15,6	9,4
Buckwheat	-	46,3	53,7	73,2	14,6	12,2	73,8	16,5	9,6
Phacelia	-	39,5	60,5	70,5	16,4	13,1	73,3	17,1	9,6
White mustard	-	39,5	60,5	70,3	15,6	14,1	73,4	16,8	9,7
White clover	-	41,9	58,1	70,4	14,9	12,7	74,8	16,0	9,4
Mean		42,6	57,4	71,1	15,5	13,0	74,0	16,4	9,5

Source: own work / Źródło: opracowanie własne

Table 9. Cob structure of maize (%) (Chwałowice)
Tab. 9. Struktura kolby kukurydzy (%) (Chwałowice)

Undersown species	2014			2015		
	Seeds	Corncob	Covering leaf	Seeds	Corncob	Covering leaf
Control	54,3	21,3	22,3	73,7	11,6	14,7
Buckwheat	61,1	19,6	19,3	-	-	-
Phacelia	63,8	21,2	15,0	-	-	-
White mustard	64,9	20,0	15,1	-	-	-
White clover	64,9	20,0	15,1	-	-	-
Mean	61,8	20,4	17,4			

Source: own work / Źródło: opracowanie własne

Table 10. Length, diameter and number of grains in corncob (Grabów)
Tab. 10. Długość, średnica i liczba ziaren w kolbie kukurydzy (Grabów)

Undersown species	2014		2015			2016		
	Length (cm)	Diameter (mm)	Length (cm)	Diameter (mm)	Number of grains in cob	Length (cm)	Diameter (mm)	Number of grains in cob
Control	5,6	11,8	4,2	14,9	114	17,4	38,7	364
Buckwheat	7,0	17,2	7,5	20,6	142	17,3	39,2	370
Phacelia	7,8	18,4	6,9	20,9	133	15,4	37,6	351
White mustard	8,1	18,1	7,2	20,6	132	15,6	38,3	384
White clover	7,6	19,4	6,7	21,4	148	15,2	37,2	388
Mean	7,2	17,0	6,5	19,7	133,	16,2	38,2	371

Source: own work / Źródło: opracowanie własne

Table 11. Length, diameter and number of grains of grains in corncob (Chwałowice)
Tab. 11. Długość, średnica i liczba ziaren w kolbie kukurydzy (Chwałowice)

Undersown species	2014			2015		
	Length (cm)	Diameter (mm)	Number of grains in cob	Length (cm)	Diameter (mm)	Number of grains in cob
Control	12,3	30,9	218	7,5	20,0	97,0
Buckwheat	10,5	32,9	225	-	-	-
Phacelia	11,5	32,2	239	-	-	-
White mustard	10,5	31,8	248	-	-	-
White clover	11,4	31,5	249	-	-	-
Mean	11,2	31,9	235	-	-	-

Source: own work / Źródło: opracowanie własne

Table 12. The height of maize plants, settling of cob and number of cobs per plant (Grabów)
Tab. 12. Wysokość roślin kukurydzy, osadzenie kolby i liczba kolb na roślinę (Grabów)

Undersown species	2014			2015			2016		
	Height of cob settling (cm)	Height of plants (cm)	Number of cobs per plant	Height of cob settling (cm)	Height of plants (cm)	Number of cobs per plant	Height of cob settling (cm)	Height of plants (cm)	Number of cobs per plant
Control	48	100	0,8	56	121	1	111	240	0,9
Buckwheat	46	109	0,8	81	191	1	119	254	0,8
Phacelia	44	106	0,7	81	182	1	121	260	0,9
White mustard	49	118	0,8	78	183	1	123	263	0,9
White clover	48	125	0,7	83	195	1	125	265	0,9
Mean	47	111	0,8	75	174	1	119	256	0,9

Source: own work / Źródło: opracowanie własne

Table 13. The height of maize plants, settling of cob and number of cobs per plant (Chwałowice)
Tab. 13. Wysokość roślin kukurydzy, osadzenie kolby i liczba kolb na roślinę (Chwałowice)

Undersown species	2014			2015		
	Height of cob settling (cm)	Height of plants (cm)	Number of cobs per plant	Height of cob settling (cm)	Height of plants (cm)	Number of cobs per plant
Control	47	130	0,9	47	87	1
Buckwheat	46	136	0,8	-	86	-
Phacelia	43	130	0,8	-	90	-
White mustard	47	136	0,8	-	88	-
White clover	45	132	0,8	-	85	-
Mean	45	132	0,8		87	

Source: own work / Źródło: opracowanie własne

4. Conclusions

The inter-row cultivation of buckwheat, phacelia, white mustard and white clover had a positive effect on maize yield. On average, for the four species of the intercrops, the yield increase was 17-22%, and in Grabów, in the year with unfavorable distribution and total precipitation, this increase was significantly higher and amounted to about 60%. In the summers with favorable weather conditions (2014 and 2016), intersowing buckwheat proved the least useful in Grabów, while in the dry year, as well as in Chwałowice, this species was less competitive than maize.

Intersowing different species into maize crop had a relatively small effect on the dry matter content of whole plants and cobs, while in Grabów in 2015, with unfavorable weather conditions, it had a positive effect on its content.

In Grabów, the structure of maize plants was slightly diversified by the applied intercrop species. The lowest share of the cob was recorded in 2014. In Chwałowice, maize grown with intercrops formed cobs only in 2014. In this location, intercrops stimulated the number of grains produced per cob, while in Grabów, an intercrop species had a small impact on the number of grains per cob.

The inter-row cultivation of buckwheat, phacelia, white mustard and white clover had a positive effect on maize yield. On average, for the four species of the intercrops, the yield increase was 17-20%, and in Grabów, in the year with unfavorable distribution and total precipitation, this increase was significantly higher and amounted to about 60%. In the summers with favorable weather conditions (2014 and 2016), undersowing buckwheat proved the least useful in Grabów, while in the dry year, as well as in Chwałowice, this species was less competitive than maize.

Undersowing different species into maize crop had a relatively small effect on the dry matter content of whole plants and cobs, while in Grabów in 2015, with unfavorable weather conditions, it had a positive effect on its content.

In Grabów, the structure of maize plants was slightly diversified by the applied intercrop species. The lowest share of the cob was recorded in 2014. In Chwałowice, maize grown with intercrops formed cobs only in 2014. In this location, intercrops stimulated the number of grains produced per cob, while in Grabów, an intercrop species had a small impact on the number of grains per cob.

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