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EFFECTIVENESS OF SELECTED METHODS OF WEED MANAGEMENT AND THEIR EFFECT ON NUTRITION VALUE AND STORAGE ABILITY OF RED HEAD CABBAGE

Summary

The studies were conducted in the years 2011-2013 at the Research Institute of Horticulture in Skierniewice, to compare the effectiveness of selected methods of weed control, useful in organic production of red head cabbage and to determine their impact on the yield and nutritional value and storage ability. In experiments the effectiveness of such methods as: mechanical treatments, soil mulching with polypropylene (PP) and biodegradable black foil, the use of cover crops and hand weeding were evaluated. The results showed diverse effectiveness of weed control methods. Polypropylene and biodegradable foil mulches as well as hand weeding completely reduced the weeds infestation. Mechanical weeding was very effective in controlling weeds, but its effect was short-lived and shortly after the treatment re-emergence of weeds was observed. Cover crops cut into small pieces and left on the soil surface strongly limited the number and weight of weeds, in comparison to check, while effect of cover crops incorporated with soil was similar to the check. The highest yields were obtained for red cabbage grown in mulches from polypropylene and in biodegradable foil and the lowest from cover crops. After the storage the highest biomass weight losses were observed in red cabbage weeded mechanically, while the lowest in cabbage grown in mulch of cover crops. The highest content of total sugars characterized by a head of cabbage weeded mechanically and manually, both fresh and after storage and the lowest from polypropylene and biodegradable foil mulching as well as from cover crops cut and mixed with the soil. The highest nitrate content in fresh heads and after storage was observed in cabbage mulched with polypropylene and the lowest in fresh cabbage weeded mechanically. The low nitrate content after storage was also observed in the heads of cabbage grown in mulch of cover crops.
***Key words**: red cabbage, weeds, weeding, mechanical treatments, mulching, biological value*

EFEKTYWNOŚĆ WYBRANYCH METOD REGULOWANIA ZACHWASZCZENIA I ICH WPŁYW NA WARTOŚĆ BIOLOGICZNĄ I TRWAŁOŚĆ PRZECHOWALNICZĄ KAPUSTY GŁOWIASTEJ CZERWONEJ

Streszczenie

W latach 2011-2013 w Instytucie Ogrodnictwa w Skierniewicach przeprowadzono badania, których celem było porównanie efektywności wybranych metod ochrony przed chwastami, przydatnych w ekologicznej uprawie kapusty głowiastej czerwonej, określenie ich wpływu na plonowanie oraz wartość odżywczą i trwałość przechowalniczą główek. Doświadczenia polowe przeprowadzono w latach 2011 i 2012, natomiast doświadczenia nad przechowywaniem w sezonach 2011/2012 i 2012/2013. Porównywano efektywność następujących metod: odchwaszczanie mechaniczne, ściółkowanie gleby włókniną ściółkującą (PP) i folią biodegradowalną (PE), mulczowanie gleby roślinami okrywowymi, pozostawionymi na powierzchni gleby, roślinami okrywowymi mieszanymi z glebą oraz pielenie ręczne. Wyniki badań wykazały zróżnicowaną skuteczność zastosowanych metod ochrony przed chwastami. Włóknina ściółkująca, folia biodegradowalna i pielenie ręczne całkowicie ograniczały wzrost chwastów. Pielenie mechaniczne skutecznie niszczyło chwasty, jednak efekty jego działania było krótkotrwałe i w krótkim czasie po jego wykonaniu obserwowano ponowne wschody chwastów. Rośliny okrywowe rozdrobnione i pozostawione na powierzchni gleby silniej ograniczały liczbę i masę chwastów, w porównaniu do kontroli. Natomiast w obiektach, w których rośliny okrywowe mieszano z glebą, stopień zachwaszczenia był podobny jak w kontroli. Najwyższe plony uzyskano w obiektach ściółkowanych włókniną i folią biodegradowalną, zaś najniższe obiektów mulczowanych roślinami okrywowymi. Po okresie przechowywania największe ubytki masy obserwowano w kapuście czerwonej odchwaszczanej mechanicznie, natomiast najmniejsze w kapuście uprawianej w mulczu z roślin okrywowych. Najwyższą zawartością cukrów ogółem charakteryzowały się główki kapusty odchwaszczanej mechanicznie i ręcznie (zarówno świeże, jak i po przechowywaniu), najniższą - ściółkowane folią i włókniną oraz uprawiane w mulczu z roślin okrywowych rozdrobnionych i mieszanych z glebą. Najwyższą zawartość azotanów w kapuście świeżej i po przechowywaniu odnotowano w kapuście ściółkowanej włókniną, a najniższą w świeżej kapuście pielonej mechanicznie. Niską zawartość azotanów, po okresie przechowywania, zanotowano też w główkach kapusty uprawianej w mulczu z roślin okrywowych.
***Słowa kluczowe**: kapusta czerwona, chwasty, odchwaszczanie, zabiegi mechaniczne, ściółkowanie, wartość odżywcza*

1. Introduction

In vegetables organic production various non-chemical methods, mainly mechanical, are used for weed control. Mechanical treatments and hand weeding are usually the basic way of weed control and they can be a good supplement to other methods, also. Mulching the soil before planting and use the cover crops is of great importance in the weed infestation reduction in some vegetable crops, grown in rows. The materials used for mulching are

impermeable for the light or limit the access of light to the soil. In vegetable production there are used black polypropylene covers, having the weight of 50-60 g/m^2 or black biodegradable foil. The mulches form the physical barriers that prevent germination and growth of weeds and limit access of the light to soil surface [23]. However, they are expensive, and polypropylene covers need to be removed from the field after harvest. Biodegradable foil, produced from plant starch is completely decomposed into the water and carbon dioxide under the influence of soil microorganisms, so its use is especially recommended in organic farming [1]. However, this foil is delicate and it is easy to damage it. The cover crops can be cut and left on the soil surface or cut and incorporated with soil, so they can limit the weed emergence and plants growth. They also prevent leaching of nutrients, particularly nitrogen from the soil profile [10], and also prevent soil erosion and increase the biological activity of the soil in providing the organic matter [20]. Locher et al. [17] found in their studies that black mulches will significantly increase the yield of pepper. Adamczewska-Sowińska and Kołota [2] proved that the yield of eggplant grown in black foil was higher by 7.8% than the yield from uncovered plots, while the mulching with polypropylene did not affect the growth of the crop. The mulching with black polypropylene and black foil had a positive effect on the yield of zucchini [16].

Red cabbage is an important source of biologically active substances and their nutritional value has a high importance to consumers. The aim of the study was to determine the effectiveness of selected methods of weed management on weeds control, yield of red cabbage, storage stability of heads and its nutritional value before and after the storage.

2. Methods

The studies were carried out at the Research Institute of Horticulture in Skierniewice in red head cabbage field, during the growing seasons of the years 2011-2013. Field experiments were conducted in the years of 2011 and 2012 and experiments with storage in the seasons 2011/2012 and 2012/2013. The field trials were set up with 4 replications in a completely randomized block design, on a pseudopodsolic soil (organic matter – 1.3-1.5%, pH – 6.7-6.9). The ability of nutriens in the soil in the year of 2011amounted: N – 147 kg/ha; P_2O_5 – 356 kg/ha; K_2O – 395 kg/ha; MgO – 280 kg/ha; CaO – 1247 kg/ha and in the year 2012: N – 135 kg/ha; P_2O_5 – 337 kg/ha; K_2O – 339 kg/ha; MgO – 222 kg/ha; CaO – 1114 kg/ha. The plots size with mechanical treatments were 12.2 m^2, with soil mulching 6.8 m^2 and with cover crops and hand weeded 9 m^2. Red cabbage plants cv. Lectro F_1 were planted 30 May 2011 and 4 June 2012 and effectiveness of various weed management methods was compared in the studies. The following methods of weed control were compared: mechanical treatments, soil mulching with polypropylene (PP), soil mulching with biodegradable black foil, the use of cover crops (rye and hairy vetch mixture), cutting the cover crops and incorporating with the soil and hand weeding.

Biodegradable foil (made from the starch) and black polypropylene (basic weight 50 g/m^2) were spread out on the soil by hand, immediately prior to planting, and the seedlings were planted in drilled holes, cut in the appropriate row spacing corresponding to the spacing of the plots not mulched. Mechanical treatments were carried out using a tractor with suspended weeder hoe "EcoPielnik EP-4", equipped with traditional weeding elements (ploughshare and angled blades) with finger and torsion elements. In cabbage, 1-2 mechanical treatments were carried out on seedlings (after 21 and 31 days of planting), depending on the term of weeds emergence and crop conditions.

Cover crops were sown in the autumn, in previous year of red cabbage cultivation and in the spring the number and fresh weight of plants of individual species were determined. Then the crops were cut and left on the soil surface or cut and incorporated with the soil and cabbage transplants were planted in. Red cabbage was harvested at the end of October and the heads were placed into the storage.

In the field experiments the coverage of soil surface by individual weed species were determined at 28-38 days from cabbage planting, the number and fresh biomass of weeds after 37-39 days and secondary weed infestation at 136-142 days after cabbage planting. Before harvest the cover of soil surface by red cabbage plants was determined and cabbage was harvested at the stage of maturity, after 136-142 days from cabbage planting. Cabbage yields and analytical data were calculated statistically by analysis of variance using Newman-Keuls to evaluate the differences between the mean, at a significance level α=0.05%. The impact of weather conditions on weeds growth and effectiveness of weed management methods was analyzed in the experiments. During the experiments, the mean daily air temperature at a height of 2 m above the ground and rainfall in mm were specified (Fig. 1).

In storage experiments the heads were packed in plastic boxes lined with polypropylene material. The trials were set up in 4 replications, each consisting of 6 heads of cabbage. In each replication cabbage heads were wrapped in polyethylene foil and put into the plastic boxes. The heads of cabbage were stored through 177 days in 2011/2012 and 182 days in 2012/2013, at the temperature of 0^{o}C. The marketable yield, rotted heads, diseased heads, yellowing leaves and rotted and partly rotted leaves were determined after storage.

The content of some nutrition components was determined in fresh cabbage heads and after a storage period. Dry matter content was determined by drying-weighing method at temperature up to 104^{o}C, total sugars were assayed by Luff-Schoorl method [19] and nitrates content by using the Ionanalyser® Orion Model 407A and ion selective nitrate electrode Thermo Orion Model 9307™ [18].

3. Results and discussions

In the experiments in red cabbage several weed species were observed. The average number of all weeds, at 37-39 days after cabbage planting was 125.6 per m^2. The highest number of individual weed species such as: *Thlaspi arvense* (THLAR) - 44.1 per m^2, *Capsella bursa-pastoris* (CAPBP) - 36.1 per m^2, *Galinsoga parviflora* (GASP) - 16.6 per m^2 and *Lamium amplexicaule* (LAMAM) - 12.5 per m^2 was evaluated (Fig. 2). The number of remaining weed species ranged between 0.3 and 6.3 per m^2. The higher weed infestation was observed in 2012, what was associated with weather conditions favorable for growth and development of weeds. However, in 2011 the higher number of *Urtica urens* (URTUR) and *Echinochloa crus-galli* (ECHCG), in comparison to 2012 was noted. The average fresh biomass

of weeds at this time was 9.6 t/ha. In many years studies Dobrzański [7] found that the fresh biomass of weeds in head cabbage evaluated at similar time - 35 days after planting, was 5.4 t/ha and ranged from 1.1 to 16.5 t / ha.

The weather condition in 2011 were more favourable for weeds and red cabbage growth than in 2012. At the beginning of June the temperatures in 2011 were higher than in 2012 but in the other months were lower or at the same level. More uniform precipitations in June 2012 and higher temperatures in first decade of July effected faster growth of plants in comparison to 2012. Better weather conditions for the plants caused faster re-growing of weeds after hand and mechanical weeding.

The weed infestation was completely reduced in red cabbage grown in biodegradable black foil and black polypropylene mulches and hand weeded plots (Fig. 3 and 4). The mulches make the physical barriers preventing access of the light to the plants, which may partially or completely prevent weeds emergence [23]. Dobrzański and Anyszka [9] reported that weeds may appear in the holes in foil and polypropylene covers or pierce it, especially species which form raised and stiff stems, for example *Equisetum arvense* L. The number of weeds in the holes around cabbage plants depends mainly on the shape of the crop, weather conditions and seed bank accumulated in the soil. In the trials, at several weeks after planting the leaves of red cabbage completely covered the holes in the mulches and prevented emergence of weeds in these places, so that red cabbage grew free of weeds until harvest. Similar results were obtained using the biodegradable foil and black polypropylene mulching in Chinese cabbage [12], where due to rapid growth of cabbage and its short growing season, weeds growth has been completely reduced.

The high efficiency of mulching with various materials in other vegetable crops were reported by some authors: in pepper [4, 5], celeriac [15], lettuce [22], snap bean and red cabbage [15] and leek [12]. Manual weeding can remove the weeds from the rows of cabbage and from intra-rows, however, due to large time-consuming and high costs hand weeding is not recommended to use in large plantations [8].

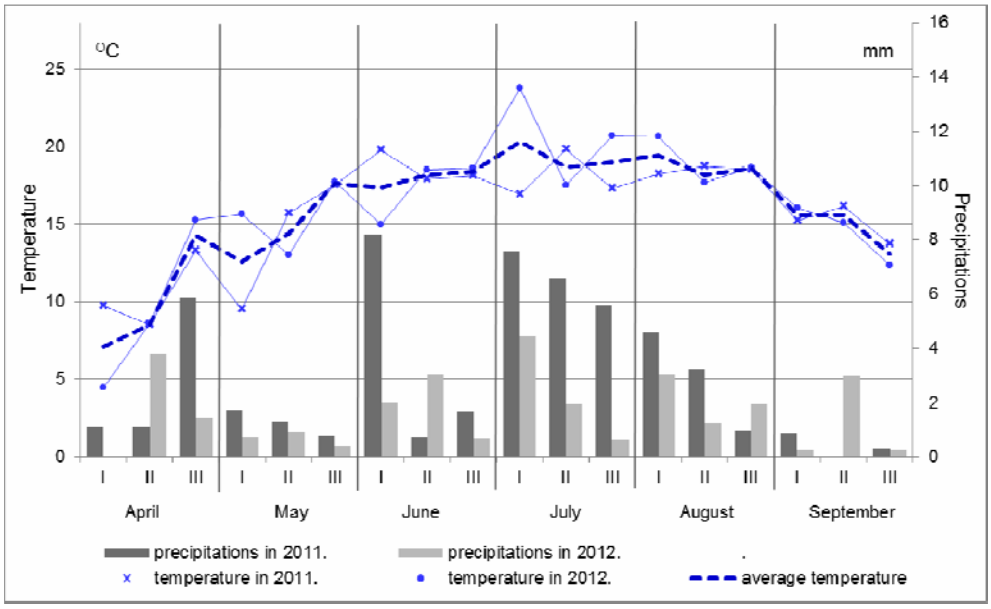

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Fig. 1. Weather conditions during the years of 2011-2012
Rys. 1. Warunki pogodowe w latach 2011-2012

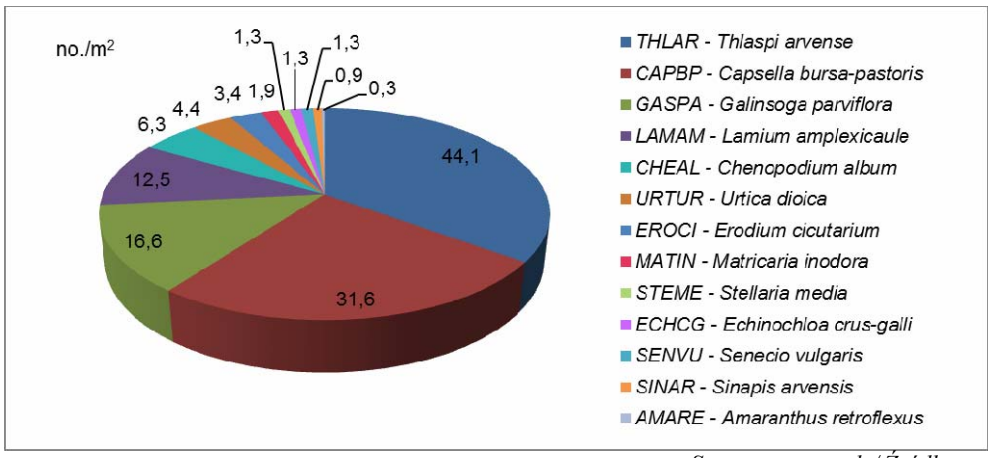

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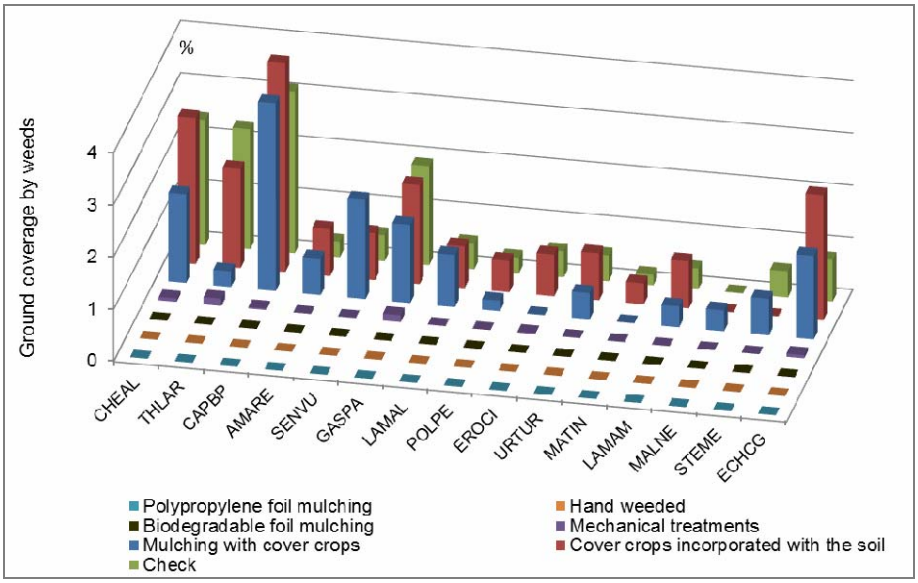
Fig. 2. The number of weeds of individual species in red cabbage, 37-39 days after planting (means for the years 2011-2012)
Rys. 2. Liczba chwastów poszczególnych gatunków w kapuście czerwonej, po 37-39 dniach od sadzenia (średnie z lat 2011-2012)

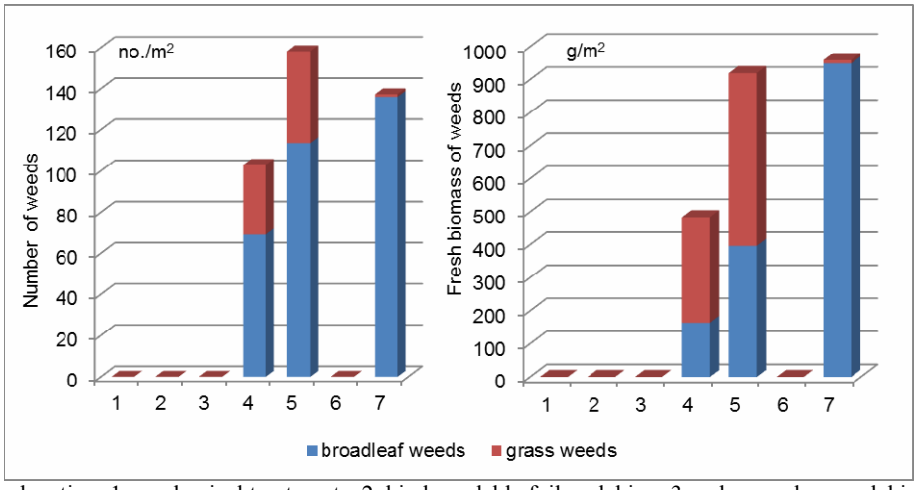


Explanation: 1. mechanical treatments; 2. biodegradable foil mulching; 3. polypropylene mulching; 4. mulching with cover crops; 5. cover crops incorporated with the soil; 6. hand weeding; 7. check

Source: own work / Źródło: opracowanie własne

Fig. 3. The soil coverage by weed species at 28-38 days after red cabbage planting, depending on method of weed control (means for the years 2011-2012)

Rys. 3. Pokrycie gleby przez chwasty, po 28-38 dniach od sadzenia kapusty czerwonej, w zależności od metody ochrony przed chwastami (średnie z lat 2011-2012)



Explanation: 1. mechanical treatments; 2. biodegradable foil mulching; 3. polypropylene mulching; 4. mulching with cover crops; 5. cover crops incorporated with the soil; 6. hand weeding; 7. check

Source: own work / Źródło: opracowanie własne

Fig. 4. The number and fresh biomass of weeds, at 37-39 days after red cabbage planting, depending on method of weed control (means the years 2011-2012)

Rys. 4. Liczba i świeża masa chwastów po 37-39 dniach od sadzenia kapusty czerwonej, w zależności od metody ochrony przed chwastami (średnie z lat 2011-2012).

It was estimated that effort of manual labor on hand weeding in red cabbage requires 150-250 hours per hectare. For effective weed control 1-3 treatments are necessary, similarly as in cauliflower cultivation [6]. Hand weeding must be careful not to damage the root system of the plants. The effect of hand weeding is short-lived and the weeds emerge in some days. In the trials ground coverage by red cabbage weeded manually was the highest in experiment and the lowest when was grown in mulch from covers crops. The weed infestation before harvest was the highest in cabbage grown in cover crops cut and incorporated with soil.

The mulch from cover crops was less effective in reducing the weed infestation. The cover crops cut and left on the soil surface reduced the overall weeds number by 25.1% and their fresh biomass by 49.6% (Fig. 4). The cover crops cut and incorporated with the soil did not reduce the weeds infestation, even resulted in increasing weeds number by 15.3%. The fresh biomass of weeds was similar to biomass obtained in uncovered check. Despite the reduction in dicotyledonous weeds, the low herbicidal effect was caused by very high infestation of *Echinochloa crus-galli*. In the mulch left on the soil surface the fresh biomass of this species was more than 30 times higher than in check, and in mulch incorporated with soil over 50-times higher. The high weed infestation in cover crops

significantly reduced the yield of red cabbage (Tab. 1, Fig. 5). In the studies in celeriac Anyszka and Kohut [3] proved that mulch from cover crops had a positive impact on the yield, but after cutting the plants and incorporating with the soil, there was no such effect observed.

Table 1. Weed infestation and ground coverage by red cabbage before harvest

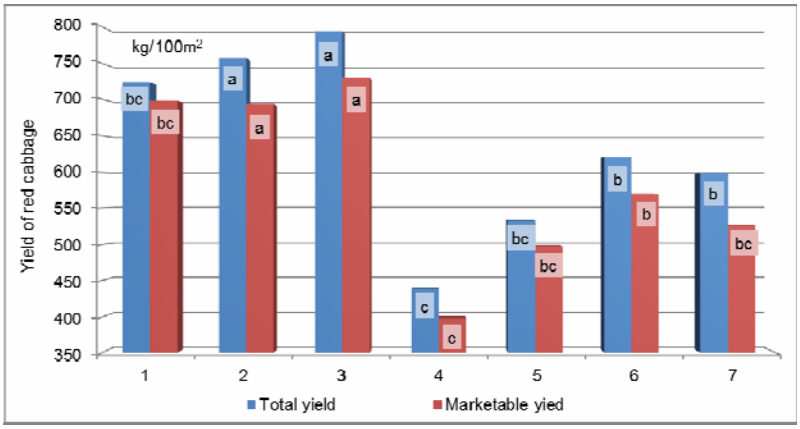
Tab. 1. Zachwaszczenie wtórne i stopień pokrycia gleby przez kapustę czerwoną przed zbiorem

Weed management method	Ground coverage by red cabbage before harvest [%]	Weeds infestation before harvest [%]
Mechanical treatments	89.3	3.1
Biodegradable foil mulching	85.6	0.0
Polypropylene mulching	94.1	0.0
Mulch from cover crops	82.7	9.0
Cover crops incorporated with soil	87.8	1.8
Hand weeding	94.0	0.0
Check	93.9	2.4

Source: own work / Źródło: opracowanie własne

In experiments the highest total and marketable yield were obtained when red cabbage was grown in polypropylene mulch, slightly lower in mulch with biodegradable foil and after mechanical treatments (Fig. 5). The high yield of red cabbage mulching with tested materials was obtained either due to the lack of weed competition throughout the growing season and by positive impact of these mulches on microclimate around the root system. It is confirmed by Woźnica [23] and Grundy et al. [13]. The beneficial effects of black mulches on the yield of white head cabbage obtained Dobrzański and Anyszka [9], Chinese cabbage and leek from transplants [12], celeriac [9, 11] celery [21], pepper [4, 5]. The yield of hand weeded cabbage was slightly higher than from check.

The studies has shown that the method of weed control used during cabbage cultivation affected the storage ability of red cabbage. The highest marketable yield was obtained when the cabbage was grown in cover crops cut and left on soil surface, slightly lower in cover crops incorporated with soil and hand weeded (Fig. 6). The highest share of heads with yellowing leaves in mechanically weeded cabbage was noted.

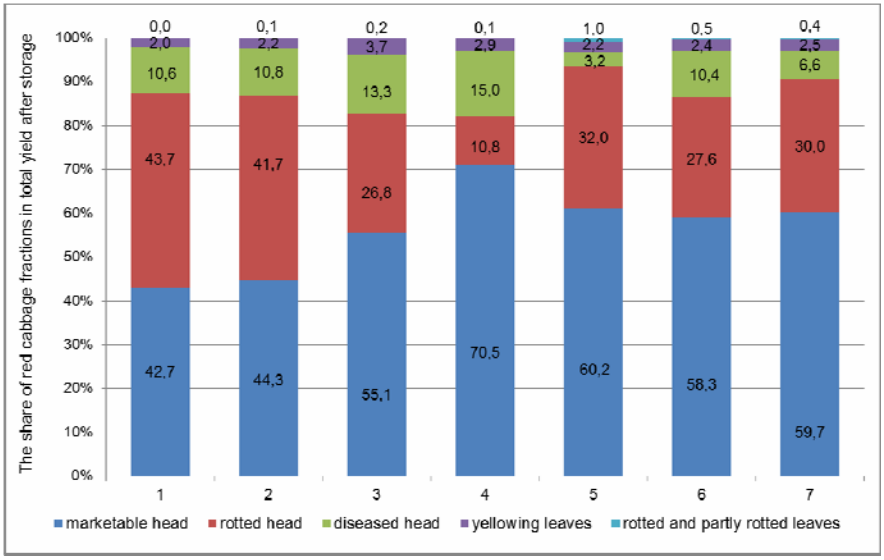


Explanation: 1. mechanical treatments; 2. biodegradable foil mulching; 3. polypropylene mulching; 4. mulching with cover crops; 5. cover crops incorporated with the soil; 6. hand weeding; 7. check

Source: own work / Źródło: opracowanie własne

Fig. 5. The influence of weed management methods on the yield of red cabbage

Rys. 5. Wpływ metody ochrony przed chwastami na plony kapusty czerwonej



Explanation: 1. mechanical treatments; 2. biodegradable foil mulching; 3. polypropylene mulching; 4. mulching with cover crops; 5. cover crops incorporated with the soil; 6. hand weeding; 7. check

Source: own work / Źródło: opracowanie własne

Fig. 6. The share of red cabbage fraction in total yield, after storage

Rys. 6. Udział frakcji kapusty czerwonej w plonie ogólnym, po okresie przechowywania

Table 2. Content of some nutrients components in red cabbage after harvest and after storage (average for the years 2011-2012)
Tab. 2. Zawartość składników odżywczych w kapuście czerwonej, po zbiorze i po przechowywaniu (średnie z lat 2011-2012)

Weed management method	Dry matter [%]		Total sugars [%]		Nitrates [mg/kg]	
	analyzed cabbage					
	fresh	stored	fresh	stored	fresh	stored
Mechanical treatments	11.4	10.9	5.40	5.14	130.2	122.9
Biodegradable foil mulching	10.7	9.9	5.34	4.82	211.5	157.5
Polypropylene mulching	10.7	9.9	5.19	4.74	180.5	182.5
Mulch from cover crops	10.7	10.2	5.10	4.98	98.5	78.4
Cover crops incorporated with soil	11.1	10.5	5.30	4.84	59.5	62.4
Hand weeding	11.1	10.2	5.32	5.55	122.5	139.5
Check	11.1	10.6	5.20	5.60	94.0	149.5
LSD □=0,05	2.01	1.71	1.03	2.22	54.5	11.5

Source: own work / Źródło: opracowanie własne

The highest dry matter content was observed in fresh cabbage weeded mechanically, and the lowest in cabbage grown in soil mulching with biodegradable foil and black polypropylene and in cover crops (Tab. 2). After storage the similar trends of dry matter content in cabbage were found. The highest content of total sugars in fresh cabbage heads weeded mechanically, manually and in soil covered with biodegradable foil was shown. After storage the highest concentration of sugars was found in heads weeded mechanically, manually and in untreated check. Differences in content of dry matter and sugars in cabbage between treatments were insignificant. The highest nitrate content in fresh cabbage and after storage was observed in cabbage mulched with biodegradable foil and black polypropylene but the lowest level of nitrates was stated in cabbage grown in cover crops cut and incorporated with soil. After storage the lowest nitrate content was found in the heads of cabbage grown in cover crops incorporated with soil. Differences in nitrates content in cabbage between treatments were significant in most cases.

4. Conclusions

1. Hand weeding and mulches with biodegradable black foil and black polypropylene completely reduced weed infestation in red cabbage.
2. Mechanical and hand weeding were very effective in controlling weeds, but their effects were short-lived, and weeds re-emerged in short time.
3. The highest yields of cabbage grown in mulch with black polypropylene and the lowest in cover crops left on soil surface were obtained.
4. The highest marketable yield after storage was obtained when the cabbage was grown in cover crops cut and left on soil surface, slightly lower in cover crops incorporated with soil and hand weeded.
5. The highest dry matter content was obtained in fresh cabbage weeded mechanically and the lowest grown in mulches with biodegradable foil, black polypropylene and cover crops.
6. The highest content of total sugars in fresh cabbage heads weeded mechanically and nitrate content in fresh cabbage and after storage when was mulched with biodegradable foil and black polypropylene.

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