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The impact of different weed control approaches on strawberry yield

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Abstract

Plant protection today is based on the principles of integrated plant protection. For many years, scientific research in the field of plant protection has been oriented towards the study of scientific foundations that are absolutely necessary for the successful implementation of integrated protection of plants against various harmful organisms. Using the examples of good practice and the results of scientific research, it has been shown in this paper how certain principles of integrated plant protection can be successfully incorporated into the integrated protection of strawberries against weeds. In the area of the Brčko District of Bosnia and Herzegovina, the village of Popovo Polje, a research was conducted for three years (2021, 2022, 2023) on several variations of strawberry production: plots with the soil covered with synthetic material, i.e. with black plastic film, plots where the soil was covered with organic material, in this case with straw, plots on which weed control was to be carried out with herbicides, and plots on which no soil covering or weed control was to be carried out. The research was conducted in greenhouses. The aim of the experiment was to determine whether there was a significant difference in the final strawberry yield, effect of weed control methods, or effect of weed control treatments, as well as to determine the interaction observed over the years. To calculate these, the yields achieved per strawberry plant shown in grams were used. The collection of fruits from different test plots and the formation of representative samples using the methods of inferential statistical processing led to results that represent

a key indicator of the success of weed control and, ultimately, the success of the agricultural process.

Key words: strawberry, yield, weeds, integral protection, herbicides

Introduction

Strawberry plants have shallow roots and a weak habit, so in competition with weeds they regularly lose the battle if effective measures for their protection are not implemented. According to some studies, weeds can reduce the strawberry yield by more than 40% (Ellis et al., 2006). In addition to the yield, weeds significantly affect the quality of fruits, they host fungal and viral diseases, harbour many pests, make harvesting difficult, make it difficult to apply plant protection products, make it difficult to apply foliar fertilizers, change the microclimate in the plantation, so strawberry plants are more exposed to the attack of diseases and pests (Ellis et al., 2006). Because of all of the above, strawberry producers consider the fight against weeds to be the most important, demanding, and expensive agrotechnical measure (Anonymous, 2011). Until the middle of the last century, the fight against weeds in general, including strawberries, was based on cultural and mechanical measures (crop rotation, cultivation, hoeing, weeding, etc.). After the invention of selective herbicides, chemical weed control measures have taken a leading role in all crops, including strawberries. Three decades later, meeting agricultural demand by intensive use of synthetic fertilizers and pesticides has led to land degradation and environmental pollution in several agroecosystems which has had an adverse effect on humans, animals, and aquatic ecosystems (Devarinti, 2016). Hence, new strategies of integrated plant production, which include activities that prevent devastation, improve the use of energy, reduce environmental pollution, and respect the knowledge and skills of agricultural producers and their ancestors have been developed (Ostojić, 2006). The aim of the experiment was to determine whether there was a significant difference in the final strawberry yield, effect of weed control methods, or effect of weed control treatments, as well as to determine the interaction observed over the years.

The strategy of integrated production of agricultural products "implies the balanced application of agrotechnical measures in such a way that it takes into account economic, ecological and toxicological factors, whereby for equal performance, preference is given to those ecologically and economically more acceptable" (Anonymous, 2011). It enables continuous plant production in harmony with nature, and ensures the consumer high-quality and healthy products (Ostojić, 2006). Integrated weed control in strawberries involves constant monitoring (monitoring) of weed infestation in the plantation and

mapping of the weed condition (Ostojić et al., 2015). In strawberry plantations, weeds are usually suppressed by mulching. From the point of view of origin, mulch is divided into natural (straw, leaves, compost, paper, tree bark, etc.) and synthetic (plastic). Natural mulch will only prevent weeds from sprouting if it covers the soil with a layer of at least a few centimetres (5-8). It must not contain weed seeds or harmful organisms. For larger areas, larger amounts of plant mass are needed, so mulch is mainly applied on limited areas. Its disadvantage is that it is relatively expensive, it can be a shelter for snails, rodents, insects, and other organisms harmful to strawberries. It is often blown away by the wind (Ostojić & Barić, 2002). Regular inspection of plantings ensures timely identification of weed species, taking into account their developmental stage and intensity of presence, on the basis of which timely control will be initiated. Regular inspections should begin immediately after planting and continue throughout the summer, with a frequency of every two weeks. During autumn and winter, it is sufficient to inspect the plot once a month.

Proper planning and implementation of integrated weed control in strawberries requires a good understanding of the weed flora. Once weed species have been identified at the selected location, the development of a control plan can begin. Weeds in strawberries, depending on their life cycle, can be divided into three main groups: annuals (spring and winter), two-years (biennials), and perennials (perennials). The usual division of annual weeds into broadleaf and narrowleaf is not always applicable to strawberries, because as perennials, different types of weeds occur during different seasons.

Annual summer weeds are a major competitor to strawberries in the first years of cultivation, especially in the first season. This group includes broadleaf weeds such as *Chenopodium album, Amaranthus retroflexus, Polygonum spp., and Ambrosia artemisiifolia*, and narrowleaf weeds such as *Echinochloa crus galli, Setaria viridis, Setaria glauca,* and *Digitaria sanguinalis*. These weeds may also appear in autumn, but they perish after the first frosts. Annual winter weeds flower and fruit in spring before they perish. The most important weeds in this group are *Stellaria media, Lamium purpureum, Capsella bursa-pastoris, Anthemis arvensis,* and *Sinapis arvensis* among broadleaf weeds, and *Poa annua* and *Lolium spp.* among narrowleaf weeds. Herbicides are most effective for controlling these weed species if they are applied before the weeds develop a rosette. Later, during winter and spring, when they develop a rosette, existing herbicides are not effective. Biennial weeds do not represent a significant problem in strawberry production. Perennial weeds, in addition to reproducing by seed, can also reproduce vegetatively from tubers, rhizomes, root shoots, and other parts. This is precisely why they are one of the biggest problems, because they spread easily and are very difficult to eradicate. The best-known representatives are *Taraxacum officinalis, Cirsium arvense, Convolvulus*

arvensis, and *Sonchus arvensis* among broadleaf weeds, as well as *Agropyron repens, Cynodon dactylon,* and *Sorghum halepense* among grasses. These weeds require special treatment before planting in order to be eradicated.

In strawberry plantations, weed control is most often done by covering, that is, by mulching the soil. There are different types of materials that are used for this purpose and, based on the origin of the material, they are divided into natural (straw, leaves, compost, paper, tree bark, etc.) and synthetic (plastic). Mulching with black or dark plastic successfully suppresses weeds for several years after planting. It has an advantage over natural mulch. It suppresses seed weeds well under the plastic, and lets them pass through the holes drilled for planting, right next to the strawberry plants. As soon as they sprout, before they develop roots, they should be removed by manual weeding. Later, when they develop, we can pull out the strawberry plants with the weeds. Mulching with black plastic also has certain disadvantages. The foil slowly disintegrates and is blown across the field by the wind. Biodegradable plastic in this sense has a great advantage, but it is also significantly more expensive. A big advantage of natural mulch over plastic is that it enriches the soil with organic matter. Natural mulch will only prevent weeds from sprouting if it covers the soil with a layer of at least a few centimetres (5-8). It must not contain weed seeds or harmful organisms. For larger areas, larger amounts of plant mass are needed, so this mulch is mainly applied on limited areas. Its disadvantage is that it is relatively expensive, and it can also be a shelter for snails, rodents, insects, and other organisms harmful to strawberries. It is often blown away by the wind (Ostojić & Barić, 2002). Weeds grow freely in the spaces between beds that are not covered by mulch, so they need to be repeatedly controlled by mechanical or chemical measures.

Cultivation and manual hoeing can only be carried out in plantations that are not covered with mulch. On the other hand, in the space between the beds that is not covered by mulch, weeds develop unhindered, so it is necessary to suppress them repeatedly during the season mechanically (with a tiller), by hoeing, using a rotary tiller, or by applying non-selective (allowed) herbicides. Weeds that have emerged from the hole drilled for planting should be weeded out several times throughout the year by pulling them out. Perennial (*Sorghum halepense, Cirsium arvense, Convolvulus arvensis*) or annual weeds with a strong habit (*Chenopodium album, Amaranthus retroflexus, Ambrosia artemisiifolia*) must not be allowed to develop in that place, because uprooting them will also uproot the strawberry seedling.

Three soil-based herbicides containing different active ingredients are available for weed control in strawberries: Dual Gold 960 (s-metolachlor), Devrinol 45 FL (napropamide), and Pendigan 330 EC (pendimethalin). While all three herbicides are effective against annual weeds, their effectiveness against perennial weeds is negligible. Devrinol 45 FL and Pendigan 330 EC should be

applied shallowly into the soil with a tool, the former being photolabile and the latter being volatile (Ostojić et al., 2015). It is also possible to combine these agents to broaden the spectrum of activity. Cultivation under plastic film limits the application of herbicides, but in some parts of the world this is still practiced in the early spring or late autumn. It should be noted that, while herbicides are effective, they will not eliminate all weeds. Some of them will always remain, and these weeds can pose a major problem in the future. This is why weeding is an essential measure in protecting strawberries from weeds.

After the invention of selective herbicides, chemical weed control measures have taken a leading role in all crops, including strawberries. Three decades later, seeing the negative consequences of the intensive use of pesticides, mineral fertilizers, narrow crop rotation, and intensive soil cultivation, man pays more and more attention to the so-called sustainable management. Sustainable agriculture has been defined as an alternative integrated approach that could be used to solve fundamental and applied issues related to food production in an ecological way (Lal, 2008). It integrates biological, physical, chemical, and ecological principles to develop new practices that are not harmful to the environment (Lichtfouse et al., 2009). Moreover, sustainability can potentially help to meet food agricultural needs worldwide (Singht et al., 2011).

Material and Methods

A strawberry plantation (the Roxana variety) was established at the location of Popovo Polje, a village in the eastern part of the Brčko District of Bosnia and Herzegovina (Figure 1).

Fig. 1 Brčko District of Bosnia and Herzegovina
https://www.google.com/search

The study lasted three years (2021–2023), the area of the greenhouse in which the experimental plots were placed was 160m², while the surface of each experimental plot was 2.5m x 4m (10m²). The study was conducted using the technology of integrated strawberry production in a protected area. The experimental plots were marked differently, so the experimental plots on which weed control was not carried out were marked OG1K1, the plots on which the soil was covered with synthetic material, i.e. black plastic film, were marked OG2foil, the plots with the mark OG3straw had the soil covered with organic material, in this case straw, while on the plots marked OG4herbicide, weed control was carried out with herbicides.

OG1K1_b	**OG3straw_a/uz**
OG2 foil_v	**OG4herbicide_v**
OG3straw_b	**OG1K1_a/uz**
OG4herbicide_b	**OG2 foil_b**
OG1K1_v	**OG3straw_v**
OG2foil_a/uz	**OG4herbicide_a/us**
OG3straw_g	**OG1K1_g**
OG4herbicide_g	**OG2 foil_g**

Fig. 2 Schematic representation of a divided greenhouse and mirror arrangement

Each sample plot was set up in four replicates in a random order and labelled a, b, c, g to differentiate when labelling the samples taken, so as to avoid repetition in some of the sample plots.

ACTIVITY			DESCRIPTION OF WORKS	NUTRITION	PROTECTION
MARCH	1	February 15 - 29	Strawberry pruning begins with the removal of all old leaves. It is mandatory to remove them from the planting. Weeding is done at the same time as mowing, with one hand gently pressing the plant at the roots while the other removes the weeds. After pruning the plant, we must protect it from blight and root neck rot through the irrigation system.	In this period, we do not feed the plants because the plants are well winterized. In this way, we delay the vegetation in order to avoid late spring frosts.	Ridomil gold MZ 68 WG (1 kg per 400 l of water for 1 dunum (let through the irrigation system)
	2	March 1 - 7	We start feeding through the irrigation system to get the plants back in shape.	Novalon 12-48-06 (4 kg per 1000 l of water for approx. 1000m^2)	
	3	March 6 -12	This is followed by feeding the plants through the irrigation system in order to strengthen the root system of the plants. Treatment with a copper-based preparation to suppress overwintering pathogens.	Novalon 12-48-06 (4 kg per 1000 l of water for approx. 1000m^2)	Use of preparations based on copper.
	4	Around March 20th	Feeding plants through the irrigation system to intensify plant growth.	Novalon 20-20-20 (4 kg per 1000 l of water for approx. 1000m^2)	
	5	Around March 25th	Feeding plants through the irrigation system to intensify growth. Treatment of plants for protection against anthracnose. Foliar feeding of plants.	Novalon 20-20-20 (4 kg per 1000 l of water for approx. 1000m^2); Bioplex (150ml in 100l of water for 1000m^2)	Quadris 100ml Scanner 25 WG (0.2 kg/ha)
APRIL	6	Around April 1st	Weeding plants as needed. Feeding the plants through the irrigation system.	Calcinite (3 kg per 1000 liters of water approx. for 1000m^2)	
	7	Around April 8th	Feeding plants through a calcium irrigation system. Feeding plants through the leaves (foliar) Slavol. Treatment with means of protection in the evening.	Calcinite (3 kg per 1000 liters of water approx. for 1 dunum; Slavol (1 liter per 100 l of water for 1000m^2)	Vertimec 018 (a.m. A bamectin) 60ml per 100l of water
	8	Around April 13th	Feeding the plants through the irrigation system for more intensive flowering. Feeding plants through the leaves (foliar) Bioplex. In case of attack by flower eaters, do the treatment only in the evening hours.	Novalon 15-05-35 (4 kg per 1000 l of water for approx. 1 dunum; Bioplex (150ml in 100l of water for 1000m^2)	Karate Zeon (a.m. Lambda cyhalothrin) 30 ml per 100l of water
	9	Around April 18th	Feeding the plants through the irrigation system for more intensive flowering. Feeding plants through the leaves (foliar) Slavol. Treatment of plants in the flowering phase against anthracnose and fruit rot.	Novalon 15-05-35 (4 kg per 1000 l of water for approx. 1 dunum; Slavol (1 liter per 100 l of water for 1000m^2)	Quadris (am. Azoksistrobin) 100ml per 100l of water; Teldor SC 500 (a.m. fenhexamid) 100ml per 100l of water
	10	Around April 24th	Feeding the plants through the irrigation system in the fruit setting phase with calcium due to the firmness of the fruits. Treatment of plants against anthracnose and fruit rot.	Calcinite (3 kg per 1000 liters of water approx. for 1000m^2)	Signum (a.m. Boskalid + pyraclostrobin) 150 g per 100 l of water
	11	Around April 29th	Feeding the plants through the pre-harvest irrigation system with high-potassium fertilizer to improve fruit quality. Feeding plants through the leaves (foliar) Bioplex.	Novalon 10-10-40 (4 kg per 1000 l of water for approx. 1 dunum; Bioplex (150ml in 100l of water for 1000m^2)	
MAY	12	Around May 2nd	Feeding the plants through the irrigation system at the beginning of the harvest with a fertilizer with a high potassium content to improve the quality of the fruits. Feeding plants through the leaves (foliar) Slavol.	Novalon 10-10-40 (4 kg per 1000 l of water for approx. 1 dunum); Slavol (1 liter per 100 l of water for 1000m^2)	
	13	Around May 5th	Feed the plants through the irrigation system in full harvest with a high potassium fertilizer to improve fruit quality.	Key mag 10-0-40 (3 kg per 100 l of water for approx. 1000m^2)	
	14	Around May 8th	Feed the plants through the irrigation system in full harvest with a high potassium fertilizer to improve fruit quality.	Key mag 10-0-40 (2 kg per 100 l of water for approx. 1000m^2)	
	15	Around May 11th	Feed the plants through the irrigation system in full harvest with a high-calcium fertilizer for better fruit firmness.	Calcinite (2 kg per 1000 liters of water approx. for 1000m^2)	
	16	Around May 14th	Feed the plants through the irrigation system in full harvest with a high potassium fertilizer to improve fruit quality.	Key mag 10-0-40 (2 kg per 100 l of water for approx. 1000m^2)	

Results and Discussion

The results of the study show significant differences in strawberry yields depending on the weed control method used. The average yield on plots without mulch, where no weed control was applied, was 436.23 g per sod. In contrast, plots on which mulch film (black plastic film) was used achieved an average yield of 765.16 g per sod, which is 43% higher than the control plot. Plots with organic mulch (straw) achieved yields of 699.17 g per sod, which is 37.6% higher than the control, while plots on which herbicides were applied had yields 23% higher than plots without mulch.

Tab. 1 Display of measured yields per sod

	Mode of weeds control											
	No cover			Foil mulch			Straw mulch			Herbicides		
Year/Plot	2021	2022	2023	2021	2022	2023	2021	2022	2023	2021	2022	2023
1.	461.5	398.1	439.6	769.2	802.2	689.9	592.3	754.3	698.3	615.4	548.1	615.4
2.	418.2	400.1	469.3	697	758.4	748.6	655.2	678.5	765.2	543.7	599.7	533.7
3.	480.9	412.3	400.1	801.5	784.1	796.6	745.4	740.8	745.4	633.2	589.5	633.1
4.	411.1	443.8	450.7	734	701.1	806.1	666.7	706	735.7	586.1	518.6	584.1
5.	432.2	426.6	453.7	732.6	769.7	786.8	659.3	723.5	659.6	564.1	639.8	544.1
6.	456.1	439.6	461.5	812.2	800.1	779.9	755.3	598.3	620.9	632.1	625.4	622.1
7.	451.3	429	418.2	738.4	749.9	748.6	688.5	765.2	671.6	577.1	533.7	587.1
8.	462	400.1	480.9	802.1	801.2	796.6	740.1	745.4	732.9	400.2	633	412.2
9.	397.3	463.8	431.1	751.1	724.9	757.1	706	665.7	622.1	556.8	586.1	556.1
10.	401.8	443.7	452.2	781.7	758.4	774.8	733.9	659.6	746.1	492.8	554.1	482.8
Av. Con.	436.23			765.16			699.17			566.67		

Also, analysis of variance (ANOVA) has shown that there was a statistically significant difference between weed control methods (p-value for samples was 2.76E-52), while the interaction between year and weed control method was not statistically significant (p-value for interaction was 0.835202). These results indicate that different weed control methods have a significant impact on strawberry yield, regardless of year.

T-test analyses have also confirmed statistically significant differences between all weed control methods, with the lowest t-test between control plots and those with mulch film, indicating an extremely high impact of this method on yield. These values suggest that the null hypothesis (that there is no significant difference in yields among weed control methods) is rejected, while the alternative, which confirms a significant difference in strawberry yields between the different weed control methods, is accepted.

Based on the results obtained, it can be concluded that all applied weed control methods have significantly affected strawberry yield. The highest yields were achieved in plots where plastic mulch was used, which is in line with previous research suggesting that it effectively suppresses weeds and improves yield within a few years after planting. The mulch creates a physical barrier that prevents weed growth, thereby reducing competition for water, light, and nutrients, while at the same time retaining moisture in the soil, which contributes to better fruit production (Ellis et al., 2006). Interestingly, the plots with organic mulch (straw) achieved lower yields compared to those with plastic mulch, but they still showed a significant increase compared to the control plot. Organic mulch enriches the soil with nutrients, but does not provide the same protection against weeds as plastic film. In addition, since the organic mulch does not create a complete barrier to light, a certain number of weeds still managed to germinate, which could have affected the yield reduction. This is in line with research that emphasizes the importance of the density and thickness of a mulch layer in the effective weed control (Ostojić & Barić, 2002). The application of herbicides also increased the yield, but only by 23% compared to the control plot, which indicates that herbicides were not sufficiently effective in long-term weed control. Although herbicides can be useful for reducing the number of weeds, they cannot completely eliminate all types of weeds, and some of them can develop resistance to the applied chemicals. Therefore, additional manual weeding is sometimes required, which increases costs and labour in strawberry production. This indicates the need to combine different methods for a longer-term and more sustainable solution. In conclusion, the most effective method of weed control in strawberry plantations was the application of foil mulch, while organic mulch and herbicides showed lower efficiency. In plots where the soil was covered with foil mulch, the average yield achieved was 43% higher compared to the control plot, confirming previous research that has shown that

weeds can reduce strawberry yield by more than 40% (Ellis et al., 2006). It is important to note that the application of foil mulch, although extremely effective in weed control, has certain environmental disadvantages, such as the slow decomposition of the material and the risk of spreading plastic throughout the field. In this context, biodegradable plastic could be a better option, but it is also significantly more expensive (Ostojić, 2006).

Conclusion

Based on the experiment conducted and the results obtained, it can be concluded that the most effective way to control weeds in the strawberry plantation is the application of plastic mulch film (foil). It is important to state that mulching with black or dark plastic successfully suppresses weeds for several years after planting. The disadvantages of using these foils are that they slowly disintegrate and are blown across the field by the wind. Biodegradable plastic would be preferable in that sense, but it is also significantly more expensive. After the mulch film, the highest yields were achieved on the plot where organic matter, i.e., straw, was used as a cover. A big advantage of natural mulch over plastic is that it enriches the soil with organic matter. It is very important that the organic matter used does not contain weed seeds or harmful organisms. For larger areas, larger amounts of plant mass are needed, so this kind of mulch is mainly applied to limited areas. Its disadvantage is that it is relatively expensive, it can be a shelter for snails, rodents, insects, and other organisms harmful to strawberries. Weed control with herbicides gave only 26% higher yields than plots where weed control was not performed. The reason for this is that all available herbicides are soil herbicides. It should be noted that herbicides, no matter how effective they are, will never control all weeds. Therefore, they should be spotted in time and removed by weeding.

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Утицај различитих приступа сузбијању корова на принос јагоде

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Сажетак

Савремена заштита биљака данас се заснива на начелима интегралне заштите биљака. Научна истраживања из подручја заштите биљака дуги су низ година оријентисана на изучавање научних основа пријеко потребних за успјешно провођење интегралне заштите биљака од различитих штетних организама. У овом је раду на примјерима добре праксе и резултатима научних истраживања приказано како се поједина начела интегралне заштите биљака могу успјешно уклопити у интегралну заштиту јагоде од корова. На подручју Брчко дистрикта БиХ, село Попово Поље кроз три године (2021, 2022, 2023) проведена су истраживања у више варијанти производње јагоде: парцеле на којима се земљиште прекрива синтетичким материјалом то јест црном пластичном фолијом, парцеле на којима се земљиште прекрива органским материјалом, у овом случају сламом, парцеле на којима ће се сузбијање корова вршити хербицидима, те парцеле на којима се неће вршити прекривање земљишта нити сузбијање корова. Истраживање је спроведено у пластеницима. Циљ огледа јесте да се утврди да ли постоји значајна разлика у коначном приносу јагоде, а у зависности од ефекта покривача земљишта у односу на присуство корова, као и да се утврди интеракција посматрано кроз године. Подаци који су као метод узети за израчунавање интересних података јесу приноси који су остварени по бусену јагоде приказани у грамима. Сакупљањем плодова са различитих огледних парцела и формирањем репрезентативних узорака методама инференцијалне статистичке обраде дошло се до резултата који представљају кључни показатељ успјешности сузбијања корова и у коначници успјешности пољопривредног процеса.

Кључне ријечи: јагода, корови, интегрална заштита, хербициди

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