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Review

Possibilities and limitations of weed management in fruit crops of the temperate climate zone

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Abstract: This manuscript contains information on the species composition of weed communities in orchards in Poland and other countries of the temperate climate zone. The manuscript deals with the influence of weeds on crops and the interaction between the weeds and other living organisms. The main methods of weed regulation are described. Characteristics of the particular crops – fruit trees and small fruits – and solutions that are either objects of study or have already been introduced into practice, are presented. Advantages and disadvantages of different methods of weed control are discussed, such as soil cultivation and tillage, cover crops, mulches, herbicide use, and flame burning.

Key words: cover crops, herbicides, mulches, orchard, small fruit plantations, soil cultivation, weeds

Introduction

In Poland, fruit crops cover an area of around 450,000 ha. Poland is one of the main world suppliers of temperate climate zone fruit: apples, high blueberries, raspberries, blackcurrants, and chokeberries. Because of the diversification of fruit crop biology and cultivation technologies, weed control in orchards, strawberry fields, and for fruit bushes has a specific character. Persistent (fruit trees and high blueberry bushes are exploited for 15–50 years, raspberry, currant, and gooseberry for 8–15 years, and strawberry up to four years) problems with the mechanisation of soil cultivation in densely planted rows and insufficient rotation of the control methods, all favour weed compensation. The first aim of the work is to present major threats to fruit production which are the result of weed infestation. The second aim is to present the current state of integrated protection of orchards and fruit agricultural fields against weeds in Poland and other countries which have a temperate climate zone.

Weed species and their harmful effects on fruit crops

Species composition of weeds depends on environmental conditions (chiefly the climate and soil properties), cultivation techniques, and fertilisation. In Polish orchards and farm fields, where the main method of weed control is the use of herbicides, there are around 30 species of frequently occurring segetal and ruderal weeds. Annual weeds are common: *Stellaria media* (L.) Vill., *Chenopodium album* L., *Senecio vulgaris* L., *Capsella bursa-pastoris* (L.) Med., *Geranium pusillum* Burm. F. ex L., *Lamium purpureum* L., *Viola arvensis* Murr., *Conyza canadensis* (L.) Cronq., *Polygonum aviculare* L., *Polygonum persicaria* L., *Fallopia convolvulus* (L.) A. Löve, *Galium aparine* L., *Amaranthus retroflexus* L., *Galinsoga parviflora* Cav., *Urtica urens* L., *Veronica persica* Poir., *Matricaria maritima* L. ssp. *inodora* (L.), *Chamomilla suaveolens* (Pursh) Rydb., *Echinochloa crus-galli* (L.) P. Beauv., *Setaria pumila* (Poir.) Roem et Schult., *Poa annua* L. Perennial weeds include: *Taraxacum officinale* F. H. Wigg., *Epilobium adenocaulon* Hausskn., *Cirsium arvense* (L.) Scop., *Equisetum arvense* L., *Convolvulus arvensis* L., *Rorippa sylvestris* (L.) Besser, *Artemisia vulgaris* L., *Rumex acetosella* L., and *Agropyron repens* L. [*Elytrigia repens* (L.) Desv. ex Nevski] (Wróbel 1999; Lipecki 2004; Lisek 2012b, c). Weeds such as *S. media*, *C. bursa-pastoris* or *G. pusillum*, which are typical of the regional orchards where herbicides are applied, did not occur in the flora of young organic orchards in Skierniewice (Central Poland). These weeds consist of 25 species (Mika 2004). These annuals did not have a chance to establish due to compost mulching or soil cultivation and competition from other species such as *Polygonum hydropiper* L., *A. retroflexus*, and *S. pumila*.

Some species like *C. arvensis* are cosmopolitan plants and occur as weeds in the orchards of various countries: Argentina (Conticello and Gandullo 1991), Bulgaria (Tasseva 2005) and Turkey (Ustuner and Ustuner 2011). *Ch. album* is an example of a cosmopolitan one-year weed, frequently occurring in the orchards of South Korea (Jung *et al*. 1997), Argentina (Novo *et al*. 2000), New Zealand (Harrington *et al*. 2002), Canada (Rifai *et al*. 2002), Bulgaria (Tasseva 2005), and Turkey (Ustuner and Ustuner

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2011). According to the previously cited authors, *S. media*, *C. bursa-pastoris*, *E. crus-galli*, and *P. aviculare* belong to the group of species commonly occurring in the orchards of different countries and continents. This means that the anthropogenic factor – the orchard floor management – has a significant influence on the species composition of orchard synanthropic flora, including weeds. Although rarely occurring in orchards, the following are frequently found in the fields of high blueberry: *Spergula arvensis* L., *Spergularia rubra* (L.) J. Pres et C. Presl., *Viola tricolor* L., *Polygonum lapathifolium* L., *Polygonum amphibium* L. var. *terrestre*, *Vicia cracca* L., *Chamaenerion angustifolium* (L.) Scop., *Agrostis gigantea* Roth and *Calamagrostis epigejos* (L.) Roth (Lisek 2012c).

The negative influence of weeds on fruit crops is a complex issue. Competition exists for water, nutrients, and light. There is allelopathy to be taken into consideration (Zimdahl 1980; Lipecki 2006) as well as conditions that favour the proliferation of rodents (Byers 1984), pests (Łęski 1983), fungi, and virus diseases (Jones and Sutton 1996). Weeds can also stimulate the freezing of flowers during spring frosts (Futch 2000). Weeds make it difficult or impossible to use a fruit harvester to harvest fruit from bushes (Cianciara 1987). The presence of honey weeds blooming during the period of intensive chemical used in orchards and farm fields, may poison bees and other pollinators due to the chemical residues of plant protection products on the weeds (Anderson and Glova 1984).

A precise determination of critical periods, and weed injury levels, is difficult due to the biology of the trees and the great number and changeability of factors. Weed harmfulness – and consequently the date of treatment and the number of weeds that need to be treated – are modified by: the cultivar (including the rootstock), the age and condition of trees, type and richness of soil, and species composition of weeds. The development phase of both weeds and trees and the course of weather conditions, mainly the amount of precipitation, also play a part. In the case of trees which are perennial crops, the harmful effects of weeds have been observed to be shifted to the next vegetative period (Al-Hinai and Roper 2001). Weeds might be one of the factors that cause alternate bearing (Gut *et al*. 1996). Pome trees are particularly susceptible to weed competition during spring and the first half of summer, from April to the end of July in the northern hemisphere (Gut *et al*. 1996; Merwin 2003). The situation is similar in the case of currants. The critical period lasts from the beginning of vegetation until the shoots stop growing (Rhodes 1984). Stone trees require effective weed control from April to September (Al-Hinai and Roper 2001). Raspberry is susceptible to weed competition in spring, between May and July, and should be free from weeds in June when primo-canes are developing (Lawson and Wiseman 1976a). Blueberry, due to the lack of root hair, is susceptible to weed competition throughout the whole vegetative period, until October, with greatest attention being paid to weed control from April to August (Caroll *et al*. 2012). Weed competition is oppressive to strawberry from April to June (Lawson and Wiseman 1976b; Pritts and Kelly 2001). In strawberry fields planted in spring (March–April), the first weed control treatment should take place no later than between the fourth and the eighth week after the crops have been planted (Lisek 2010). July and August are also considered to be critical periods for strawberry. This period is when weed competition has a cumulative character. Losses increase when weeds grow in consecutive critical periods, but too frequent soil cultivation or the use of herbicides have a negative impact on the growth and yielding of strawberry. In well-maintained, fruitful fields, it is sufficient to conduct a thorough weed control treatment 2–3 times per season (Pritts and Kelly 2004).

Synanthropic flora can also be beneficial. It constitutes a significant part of the landscape. Synanthropic flora has an influence on many living organisms: soil bacteria, arbuscular mycorrhizal fungi, annelida worms, arthropod fauna and vertebrate, co-determining the biological diversity (Kennedy and Smith 1995; Wyss 1996; Burrows and Pfleger 2002; Storkey and Westbury 2007). This type of flora improves the chemical and physical properties of the soil. These properties include organic matter content, porosity and water holding capacity, protection of the soil against erosion (deterioration caused by water and wind) during winter dormancy of the fruit trees, accumulation of nutrients in the green biomass preventing leaching. Snow is kept within the orchard which increases the reserve of moisture in the soil and limits the frost damage to tree roots (Lipecki 2006).

Main methods of orchard floor management and integrated weed control

Contemporary orchard floor management combines soil cultivation and tillage, cover crops, mowing of weeds and cover plants, mulches and herbicide use, and a relatively new method – flame burning of weeds. The solution for the typical Polish orchards is to maintain grassed alleyways and herbicide fallow under the tree canopies. The width of the herbicide strip is 0.6–2.0 m. This model is effective and creates conditions that favour tree growth and machine work in the orchard. Herbicides are effective, easily executed, relatively cheap, and ensure high yielding of trees (Harrington *et al*. 2005). Fruit tree roots grow better in herbicide fallow than mechanical fallow or under cover plants (Parker *et al*. 1993). Recently, the small number of herbicides registered for use in orchards and berry fields has been a growing problem. Polish producers can use nine herbicides: soil acting – pronamide and post-emergence – glyphosate, propachizafop, quizalofop-p-ethyl (bushes and orchards); MCPA, 2,4-D, fluroxypyr (orchards); clopyralid and glufosinate-ammonium (fruit bushes) (Lisek 2014). The overuse of glyphosate leads to: phytotoxicity, the presence of its residue in the environment (Heinonen-Tanski *et al*. 1985; Giesey *et al*. 2000; Humphries *et al*. 2005) and crops (Roy *et al*. 1989), proliferation of uncontrolled weeds such as *E. adenocaulon*, *R. sylvestris* (Lipecki 2004; Lisek 2012c), and selection of weed biotypes resistant to herbicides (Peachey *et al*. 2013). In the years 1996–2013, 29 weed species were observed to create biotypes resistant to glyphosate (WeedScience 2014). Resistant forms of *C. canadensis* were observed in

Poland (Adamczewski *et al*. 2011). Glyphosate, its metabolites and adjuvants which are included in the herbicide, mainly polyethoxylated tallowamin, have endocrine and toxic effects on mammals (Richard *et al*. 2005). Glyphosate phytotoxicity is a result of a typical herbicide effect after incorrect use – inhibition of shikimic acid pathway and cytochrome P450 modulation (Lamb *et al*. 1998; Schonbrunn *et al*. 2001). Glyphosate phytotoxicity has a negative impact on the rhizosphere of the crops and reduces the availability or uptake of essential macro- and micro-elements (Neumann *et al*. 2006; Zobiole *et al*. 2010). Doses of the glyphosate used in the orchards might be limited by combining the use of glyphosate with adjuvants (Lisek 2012a). The reduction in the number of glyphosate treatments to 1–2 per year and the restoration of the rotation of other herbicides requires registration of those herbicides, and a number of active substances may be taken into account. In the USA, 14 pre-emergence herbicides (dichlobenil, diuron, halosulfuron-methyl, flumioxazin, indaziflam, napropamide, norflurazon, oryzalin, oxyfluorfen, pendimethalin, pronamide, saflufenacil, and simazine, terbacil), and 8 post-emergence herbicides (carfentrazone, clethodim, clopyralid, glufosinate-ammonium, glyphosate, paraquat, pyraflufen-ethyl, rimsulfuron) have been allowed to be used in the orchards (Buckelew 2009; Lehnert 2012). After regular, multi-year use of pre-emergent herbicides, the amount of soil organic matter, and the density of fungi and bacteria populations were all less than in the orchard sites which were under cover crops (Tworkosky and Welker 1996; Tworkoski and Miller 2001). For this reason, pre-emergent herbicides should be used with special care. These herbicides should be used in narrower herbicide strips, and in conjunction with herbicides such as glyphosate.

To improve the effectiveness and safety of chemical weed control methods, there has been ongoing research into natural (organic) herbicides. Pelargonic acid, acetic acid (vinegar), citric acid, citrus acid (d-limonene), octanoic acid, clove oil (eugenol), cinnamon oil, lemongrass oil, and iron chelate are all regarded as natural (organic) herbicides (Dayan *et al*. 2009; Quarles 2010; Patton and Weisenberger 2012). The enumerated herbicides have limited effects and are used on weed seedlings.

Repeated treatments are required which entails high costs (Rowley *et al*. 2011). Pelargonic acid may be used together with glyphosate, which lessens the drawbacks of both products (Wehtje *et al*. 2009). Corn gluten meal (Christians 1995), corn gluten hydrolysate, and white mustard seed meal (Yu and Morishita 2014) are considered biologically active allelochemicals with a pre-emergent herbicidal effect. The bacteria *Streptomyces acidiscabies* Lambert *et* Loria might be used as a microbial herbicide against grass and broadleaf weeds (Quarles 2010). *Pseudomonas fluorescens* (Flügge) Migula might be used against *Setaria viridis* (L.) P. Beauv. (Caldwell *et al*. 2012). Pathogenic fungi, *Phoma macrostoma* Montagne (among others) might be used against *T. officinale*, *S. media*, *Matricaria perforata* Mérat (Graupner *et al*. 2006; Bailey *et al*. 2010). *Sclerotinia minor* Jagger. might be used against *C. arvense*, *T. officinale*, and others (Abu-Dieyeh and Watson 2007). The disadvantage of microbials is that there are problems with their commercialisation, expense, instability in the environment, generally narrow host range, and their unreliable effect connected with favourable environmental conditions (Hallett 2005).

Cover plants are most often maintained in orchard alleyways. Such plants: provide shelter to beneficial organisms, proper traction properties of the orchard floor, limit the kneading of the soil, and provide nutrients (Doran *et al*. 1998; Sanchez *et al*. 2003). Cover plants prevent the soil from losing nitrogen. Plants from the family Fabaceae possess the ability to fix nitrogen loss (den Hollander *et al*. 2007). Sodgrass in the alleyways is usually set up between the first year (fertile soil, hilly land) and the third year after the trees have been planted. Cover crops are called "living mulches" (Shribbs and Skroch 1986a, b; Hartley *et al*. 2000). The presence of cover crops (from the moment the cover crops are planted) in the rows of a young orchard or on the whole surface of the orchard (Neilsen and Hogue 2000) might impair the growth and yielding of trees. Cover crops, like some of the mulches, increase *Phytophthora cactorum* (Lebert *et* Cohn) Schröt. infestation and root damage caused by rodents, more than the test plots treated with herbicides (Merwin *et al*. 1992; Merwin *et al*. 1999; Wiman *et al*. 2009). Popular cover crops in Poland are: creeping red fescue – *Festuca rubra* L., Kentucky blue grass (smooth meadow-grass) – *Poa pratensis* L., and the perennial ryegrass – *Lolium perenne* L. Different kinds of grass are also sown as combinations of 2–3 species, sometimes with the addition of white clover – *Trifolium repens* L. Many other species of perennial and one-year cover crops (sown in spring and autumn) are used in both tests and practice. Most of them come from the families Fabaceae and Poaceae: Persian clover – *Trifolium resupinatum* L., subterranean clover – *T. subterraneum* L., berseem clover – *T. alexandrinum* L., medick – *Medicago* sp. (Sanchez *et al*. 2003; TerAvest *et al*. 2010), bird's foot trefoil – *Lotus corniculatus* L. (TerAvest *et al*. 2010), common vetch – *Vicia sativa* L., pea – *Pisum sativum* L. (Bugg *et al*. 1996), white lupine − *Lupinus albus* L. (Walsh *et al*. 1996), crown vetch – *Coronilla varia* L. (Merwin *et al*. 1992, 1994, 1999, Merwin and Stiles 1994; Sanchez *et al*. 2003), common serradella – *Ornithopus sativus* Brot. (Sosna *et al*. 2009), blue (sheep's) fescue – *Festuca ovina* L. (Sosna *et al*. 2009), hard fescue – *F. longifolia* Thuill. (Sanchez *et al*. 2003), tall fescue – *F. arundinacea* Schreb. (Tworkoski *et al*. 1997), annual ryegrass – *Lolium multiflorum* Lam. (Sanchez *et al*. 2003), colonial bent grass – *Agrostis vulgaris* With. (Hoagland *et al*. 2008; Sosna *et al*. 2009; Wiman *et al*. 2009; TerAvest *et al*. 2010), timothy grass – *Phleum pretense* L. (Tworkoski and Glenn 2001), orchard grass – *Dactylis glomerata* L. (Neilsen and Hogue 1985; Shribbs and Skroch 1986a, b; Tworkoski *et al*. 1997; Tworkoski and Glenn 2001), wheat – *Triticum aestivum* L. (Shribbs and Skroch 1986a, b), rye – *Secale cereale* L. (Sanchez *et al*. 2003; Granatstein and Mullinix 2008), barley – *Hordeum vulgare* L., and oat – *Avena sativa* L. (Bugg *et al*. 1996). Beside legumes and grasses, cover crops can include Harlequin marigold – *Tagetes patula nana* L. (Rozpara *et al*. 2008), white mustard − *Sinapis alba* L. (Rieux 1999), tansy phacelia – *Phacelia tanacetifolia* Benth. (Sosna *et al*. 2009), and buckwheat – *Fagopyrum esculentum* Moench (Brown and Glenn 1999). The effectiveness of cover crops depends on several factors. One factor is the place of sowing, for example; alleyways, strips under trees, and the strips on both sides of tree rows. Ecological conditions, for example the species and cultivars of trees and rootstocks, also must be taken into account. The age of the orchard, and in the context of fruit trees and soil management practices, and the pruning of trees are all factors which must be considered as well (Tworkoski 2000). Crop regulations, irrigation, and nutrition also play a role (Weibel 2002; Merwin 2003; Granatstein and Sanchez 2009; Stefanelli *et al*. 2009). In older orchards, the trees are strong. Weakly growing weeds with limited water and nutrient needs, such as *P. annua*, can be treated as cover plants (Mika *et al*. 1998).

Mechanical soil cultivation is used mainly in newly established and young orchards, on the whole area or with the exclusion of strips under the tree canopies. At present, there exists the option of fully mechanising the cultivation of soil under tree canopies with the use of retracting tree rotary weeders (Rabcewicz and Białkowski 2011). Cultivation with these weeders, though, destroys the soil structure, reduces the organic matter, and causes soil erosion (Merwin *et al*. 1994a, b) and damage to tree roots located near the surface (Cockroft and Wallbrink 1996). The weeders are hardly effective when it comes to controlling perennial, deeply rooted weeds. Unless their work is combined with the use of herbicides, some weeds such as *A. repens* proliferate (Lisek 2012c).

Synthetic mulches can successfully control weeds in orchards. Synthetic mulches include: polyethylene plastic (Mage 1982; Camposeo and Vivaldi 2011), woven polypropylene fabric (Szewczuk and Gudarowska 2006; Markuszewski and Kopytowski 2008; Rozpara *et al*. 2008), nonwoven polyacrylic fabric (Camposeo and Vivaldi 2011) as well as natural mulches like grain and rape straw (Niggli *et al*. 1990; Varga *et al*. 2004; Rowley *et al*. 2011; Sas-Paszt *et al*. 2014), sawdust (Szewczuk and Gudarowska 2004; Czynczyk *et al*. 2011; Sas-Paszt *et al*. 2014), wood chips (Treder *et al*. 2004; Rowley *et al*. 2011), wood bark (Niggli *et al*. 1990; Szewczuk and Gudarowska 2004; Varga *et al*. 2004; Markuszewski and Kopytowski 2008; Rozpara *et al*. 2008; Sas-Paszt *et al*. 2014), manure (Varga *et al*. 2004; Sas-Paszt *et al*. 2014), shredded paper (Rowley *et al*. 2011), compost (Sas-Paszt *et al*. 2014), hay (Stefanelli *et al*. 2009), aggregated lignite (Kwiatkowska 2007), composted poultry litter (Braun and Tworkosky 2004), fruit pomace (Camposeo and Vivaldi 2011), textile (linen, jute, wool) fabric and waste (Rozpara *et al*. 2008; Czynczyk *et al*. 2011), and peat moss (Sas-Paszt *et al*. 2014). Straw mulch in horticultural crops may originate not only from the grain and rape mentioned above, but also from buckwheat (Kosterna 2014). Plastic and fabric are most often laid out in newly established orchards (Mage 1982; Camposeo and Vivaldi 2011). Mulches reduce weed infestation, preserve soil moisture, level soil temperature, increase the amount of soil organic matter and aeration, improve the absorption of nutrients by the trees, help uniform root distribution, and increase the microbial activity of the soil, which might improve tree growth and yield (Sanchez *et al*. 2003; Varga *et al*. 2004; Yao *et al*. 2005). Organic mulches do not provide sufficient protection against perennial weeds such as *A. repens* (Stefanelli *et al*. 2009). Mulches that are rich in cellulose (bark, wood dust, straw, wood chips) with a high C : N ratio, reduce nitrogen availability (Treder *et al*. 2004).

The practical use of a particular weed control method is related to the implementation costs. Mulching the soil or the use of organic herbicides is several times more costly than the use of synthetic herbicides (Merwin *et al*. 1995; Markuszewski and Kopytowski 2008). Mulches obtained as cheap waste materials may be used locally (Rowley *et al*. 2011).

Since particular methods of orchard floor management used on their own, have disadvantages, the methods are often combined together. The Swiss Sandwich System (SSS) is used in organic orchards. This modified tillage system consists of a 30–50 cm wide strip of native spontaneous undisturbed vegetation in the centre of the tree row, two shallow tilled strips at each side of the tree row 60–90 cm wide, and grass sod in the alleyways (Weibel 2002; Stefanelli *et al*. 2009). Cultivation is done at depths of 5–10 cm with a rotary hoe cultivator, a notched disc cultivator or a spring tooth harrow when weeds are about 10 cm high. Cultivation is done 5–6 times in the period from April/May to August. An untillaged area encourages predatory insects to complete their life cycle. Thus, pests are limited, biodiversity is increased, soil conditions improve, and nutrient cycling is enhanced (Horton *et al*. 2003). The Swiss Sandwich System is easy to manage. This system reduces competition for water and nutrients, reduces threats caused by rodents, and reduces damage to trunks and roots of trees caused by machines working under the tree canopies (Stefanelli *et al*. 2009). Another example of integrated weed control is the use of organic herbicides in orchards mulched with organic material when the layer of mulch is violated or when weeds which have been dispersed by wind, start to germinate (Brown and Tworkosky 2006; Rowley *et al*. 2011).

Propane flame burning is not popular in Poland due to: the need for specialised equipment, fire risk, uselessness of this method in periods of drought, damage caused to trees, little efficiency in controlling perennial weeds and grass, and insufficiently studied effects on beneficial insects. It does, however, have its advantages. It is relatively cheap, as the costs are comparable with tillage, and it does not disturb the soil (Stefanelli *et al*. 2009).

Weed management in small fruit crops

Weed control in farm fields with fruit bushes is much more difficult than in orchards. It is difficult for the bushes to compete with weeds. There is no possibility of mechanised soil cultivation or the use of non-selective foliar herbicides in densely planted rows of fruit bushes. Interrows in such farm fields, like in the orchards, might be cultivated, or the interrows might be used by cover plants such as *V. sativa*, *T. repens*, *L. perenne*, *F. ovina* or *H. vulgare* (Zebarth *et al*. 1993; Bowen and Freyman 1995; Lindhard Pedersen 2002). Currants with grass growing in the interrows yield poorly as compared with bare fallow (Dale 2000). Yielding of raspberry on farm fields where *T. repens* was used as a cover plant was better than the yielding obtained with the use of *L. perenne* (Zebarth *et al*. 1993; Bowen and Freyman 1995). Sowing of *Medicago sativa* L./*D. glomerata* and *Trifolium pratense* L./*P. pratense* as cover crops along bush rows, reduced yielding of blackcurrant in comparison with results achieved in rows covered with bare soil (Larsson 1997). A November treatment with glyphosate can control overwintering, and hardy weeds. This treatment is safe for blackcurrant bushes which are at least three years old (Lisek 2005). Promising results for controlling the *C. arvensis* binding on blackcurrants were obtained after a post-emergence oxadiazon treatment. This treatment is selective for the already harvested currant (Cianciara 1987) or after the post-emergence bentazon treatment in May, conducted with the use of a sprayer with protective shields (Lisek 2003). Currants yield better in mulch of black plastic than in herbicide fallow (Dale 2000). The use of wood chips and black plastic does not increase the yielding of blackcurrant as much as bare soil (Larsson 1997). Raspberry growing in straw mulch yields better than on hand-weeded plots, in herbicide fallow (simazine or napropamide) or when using synthetic mulches such as black polyethylene, or white-on-black polyethylene (Trinka and Pritts 1992).

No herbicides which control weeds in highbush blueberry farm fields were registered in Poland. In the USA and Canada, where cultivation of highbush blueberry covers a substantial area, a great number of soil and foliar herbicides have been registered, such as flumioxazin, isoxaben, oryzalin, mesotrione, napropamide, norflurazon, pronamide, clethodim, fluazifop, glufosinate, and pelargonic acid. The use these herbacides are characterised by the safety of the cultivated crops and by the high efficiency in weed control (Dittmar and Williamson 2013). Regardless of the use of herbicides in highbush blueberry farm fields, mulching the soil with pine bark, sawdust and needles improves the chemicophysical properties and is a routine treatment (Spiers 1986; Mercik and Smolarz 1995; Burkhard *et al*. 2009). Highbush blueberry grows and yields better in organic mulches like peat, sawdust, and woodchips. Highbush blueberry does not grow as well with black plastic and plastic woven weedmat (Albert *et al*. 2010; Cox *et al*. 2014).

In strawberry farm fields, soil cultivation is being successfully combined with the use of herbicides and mulches. In farm fields of strawberry for processing, the costs of weed control are highly significant. In these fields, the need for hand-weeding in matted-rows is reduced by the use of new cultivation tools, like the flex-tine harrow, finger weeder, and brush hoe (Kelly *et al*. 2007). The following herbicides have been registered for use in Polish strawberry fields: pre-emergence – lenacil, napropamide, pendimethalin; pre- and post-emergence – metamitron, ethofumesate; and post-emergence – phenmedipham, desmedipham, clethodim, fluazifop-p-butyl, propaquizafop, quizalofop-p-ethyl, clopyralid and glufosinate-ammonium (Lisek 2014). A mixture containing phenmedipham, desmedipham and ethofumesate (PDE) is used in a form of split application. Tolerance of strawberry cultivars to PDE is varied. The varied tolerance is probably connected to the thickness and durability of the cuticle covering the leaves (Lisek *et al*. 2002). Corn gluten meal and corn gluten hydrolysate with allelopatic activity are an alternative to synthetic herbicides (Nonnecke and Christians 1997; Dilley *et al*. 1999). Some mulches for the soil are: cereal straw, colored polyethylene plastics, polypropylene and polyacrylic spun, woolen landscaping fabric, wood bark, and sawdust. They are effective and widely used in the production of table strawberry (Forcella *et al*. 2003; Kęsik and Maskalaniec 2004; Johnson and Fennimore 2005). The use of biodegradable mulches from polymers and paper is inefficient due to inadequate sustainability and effectiveness (Weber 2003). Cover plants are occasionally sown in strawberry farm fields as so-called interseeded crops. The best for this purpose are spring barley and rye, sown at the end of July or in August (Cloutier and Lamarre 1997). The crops limit the growth of weeds and in the winter they reduce frost damage to strawberry. Barley dies in late autumn but remains stiff until spring. Rye requires mowing or removal in the following season. Spring rape as inter-row cover crop competes too strongly with strawberry. Spring rape, like weeds, causes a decrease in yielding (Forcella *et al*. 2003).

Conclusions

Weed management in fruit crops should favour primary values such as the safety of people and the environment, including the quality of soil, and should take into account the effectiveness, costs, and influence on yielding of the cultivated crops. Integrated weed control based on rational use of herbicides and alternative methods, fulfils the above requirements. Synthetic herbicides are the most effective way of controlling weeds within fruit crops. But synthetic herbicides need to be used carefully so that problems with their use can be minimised. To preserve the effectiveness and rotation, it is necessary to register a proper number of herbicides with diversified modes of action. Some of the main alternative herbicides, for example pelargonic acid, can be used positively to help with weed management. If the number of registered herbicides is small or non-existent, alternative (non-chemical) methods of weed control are indispensable.

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