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LIVING MULCHES IN VEGETABLE CROPS PRODUCTION: PERSPECTIVES AND LIMITATIONS (A REVIEV)

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Abstract. Different aspects of living mulches application in vegetable crops production is discussed in the paper. They compete with vegetables for light, moisture and nutrients and for this reason in most cases cause the yield reduction of cash crops. However, at the end of vegetation period, after ploughing down as green manure they enhance the organic matter content in the soil, improve its physical and chemical properties, which are beneficial for the subsequent species in crop rotation. Undersowing is best suited in perennial crops like rhubarb or the species with relatively long vegetation period, grown from transplants (leek, cabbage, sweet corn, stake tomato, pepper). The most important attributes required for species used as living mulches are quick emergence and soil covering, short height, low water and nutrients demands. In most cases the legume crops (white clover *Trifolium repens* L., red clover *Trifolium pratense* L., hairy vetch *Vicia villosa* Roth., seradella *Ornithopus sativus* Brot.), grasses (perennial ryegrass *Lolium perenne* L.) or cereals, especially rye *Secale cereale* L. are used for this purpose. Their competitiveness to the cash crops may be diminished by the delayed term of undersowing the only in strips between plant rows, mowing the biomass or the use of sublethal doses of herbicides. The beneficial effects of living mulches include the suppression of weed infestation, reduced insect pests and diseases pressure, and prevention from soil degradation. They suppress soil compaction, wind and water erosion, improve soil structure, reduce the surface water runoff and nutrients leaching. Living mulch cover is favourable for biological activity of the soil and the amounts of available nutrients after decomposition. Further intensive studies will be needed to introduce such intercropping, friendly to the environment system to the wide practice, especially in the terms of possible decrease of competitiveness to the cash crops.

Key words: vegetable species, weed control, pests, diseases, soil properties

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IMPORTANCE OF LIVING MULCHES TO ENVIRONMENTAL FRIENDLY SYSTEMS OF PLANT CULTIVATION

Widespread application of chemicals in conventional system of agriculture and horticulture brings about, apart from industry and transportation, gradually increasing pollution of environment. On the other hand, there is observed a growing concern for its protection and keeping in good conditions for the sake of future generations. In connection with undertaking involving the mentioned issue, there have been introduced into the practice the cultivation systems in which the great attention is being paid to limiting use of chemicals for plant protection as well as mineral fertilizers, or even their complete elimination from the use. In these integrated and organic systems of vegetable growing, the basic problems involve appropriate tillage, protecting the soil from degradation, wind and water erosion, nitrates leaching from the root zone and allowing to keep its good structure. A great attention has been paid on application of natural and organic fertilizers in order to maintain high fertility of the soil, as well as on introduction of other, not chemical methods of plant protection.

One of the culture methods which have a highly beneficial effect on soil environment as well as plant canopy of vegetable crops is the use of living mulches. According to Weston [1990] and Hartwig and Ammon [2002] living mulches are species which can be planted in either before in autumn or spring or after the vegetable is planted and allow to grow together with cash crop. They maintain as a mulch layer all season long [Leary and DeFrank 2000] and thereafter ploughed down as green manure or left during the winter. In this case the plants cover of the soil protects the nutrients from runoff and soil surface from wind erosion that can be a serious problem in some land area. Presence of living mulches comprehensively affect on the environment of plant growth and, therefore, their application should be considered from the point of view of different fields of knowledge and practice, while weed control, which was especially underlined by Putnam [1990], Müller-Schärrer and Potter [1991] and Hartwig and Ammon [2002], is there a crucial importance.

The main task of living mulches in vegetable crops production system is to protect soil surface from the influence of unfavorable factors as well as to improve the growing conditions for the cash crops [Baumann et al. 2000, Brainard et al. 2004]. They protect soil surface from wind and water erosion [Starck et al. 1996, Leary and DeFrank 2000] and also preserve soil structure due to mitigation of soil compaction. This effect can be accounted for minimized contact of tractor implements to the soil and reduced unfavorable effects of atmospheric factors eg. heavy rains or sprinkler irrigation use on soil aggregates [Nicholson and Wien 1983, Paine et al. 1995, Stirzaker and White 1995, Jędrszczyk and Poniedziałek 2009]. Another positive aspect of their presences in the field is contribution to the enhancement of organic matter, better water infiltration, water and nutrient retention [Wiles et.al. 1989], prevention of water evaporation and smaller fluctuation of diurnal soil moisture and temperature. They diminish the risk of nutrients, especially nitrates, and pesticides runoff and as results of this prevent grounwater from the contamination by these chemicals [Sainju and Singh 1997, Hartwig and Ammon 2002]. There is also observed some improvement of nutrient cycling due to their uptake from deep soil layers and after decompostion of plant biomass, enriching the root zone of succeeded crops in available forms of nutrients. For this reason the beneficial effects of living mulches on physical and chemical soil properties should be calculated not only in the season of their presence in the field but in crop rotation throughout the subsequent years [Dabney et al. 2001, Hartwing and Ammon 2002, Kołota and Adamczewska-Sowińska 2003a].

Beneficial effects of living mulches on vegetables can be also attributed to mutual exchange of root exudates which stimulate absorption and accumulation of ions and as a result of this promote plant growth. According to Wójcik-Wojtkowiak et al. [1998] the exchange level in such culture system may be even 1.5–7.0 times higher than in monoculture system.

The living mulch not only provides for the effective management of weeds but also for the decrease of insect pest pressure resulting in lower requirement for pesticide use. The diminished pest population may be explained by the fact that species grown in interrows of vegetable crops may play the role of repellants or attractants (catch crops) or lead to higher population of antagonistic insects [Müller-Schärrer and Potter 1991].

Similarly to conventional system of production, the farmer applying living mulches is equally interested in high yield of excellent quality vegetables. A successful living mulch system provides balance between competition against weeds and acceptability for the cash crop with respect to light, water and nutrients. Many data from the literature demonstrated the decrease of vegetable crop yield in such culture [Shennan 1992, Paine et al. 1995, Galloway and Weston 1996, Bottenberg et al. 1997, Brandsæter et al. 1998, Henning 1998, Adamczewska-Sowińska and Kołota 2007, 2010, Jędrszczyk and Poniedziałek 2007a, 2007b, Borowy 2012]. However, there are also the research indicating the results of yield comparable or even higher than in conventional cultivation in soybean [Ateh and Doll 1996], pepper [Guldan et al. 1996], tomato [Abdul-Baki and Teasdale 1993], broccoli [Infante and Morse 1996] and sweet corn [Starck et al. 1996]. Bottenberg et al. [1997] assume that the main factor affecting decrease of vegetable yield in just competing for water. Jędrszczyk and Poniedziałek [2007b] proved that differences between the amount of available water in the soil under monoculture crop and the one with living mulches are especially evident in shortage of precipitation. As it was reported by Brainard et al. [2012] living mulch rye in asparagus cultivation caused, after completing the harvest, reduced soil available water by 26% to 52%, while had no detectable effect on asparagus yield. Irrigation during water deficiency periods and adjustment of fertility management to minimize potential interference with living mulches are seem to be the most important factors for receiving high yield of vegetable crops in such production system. In cultivation of warm season crops such as tomato the lower temperature of soil covered by living mulch may be the reason for delayed maturation and smaller fruit yield [Borowy 2012].

Generally, the results of such culture practice are highly dependent on vegetable crop species as well as cover plant species chosen for intercropping. Undersowing is best suited in perennial crop eg. rhubarb or grown from transplants annual or biennial crops with relatively long vegetation period like leek, onion, cabbage, stake tomato, pepper, or sweet corn [Müller-Schärrer and Potter 1991, Kołota and Adamczewska-Sowińska 2003a, Adamczewska-Sowińska et al. 2009, Borowy 2012].

PLANT SPECIES USED AS LIVING MULCHES

Cover plants used as living mulches in vegetable crops should have the following attributes: the ability to suppress weeds without stressing the crop as a result of quick emergence, fast soil coverage and short height, to lower insect pest pressure on the crop by favoring their antagonists organisms, and to favor nitrogen availability in the soil for the crop by using the species with low N demand or leguminous plants with N-fixing bacteria [Müller-Schärrer and Potter 1991]. The other desired properties involve tolerance to drought and low soil fertility as well as low maintenance budget associated with mowing intervals, fertilizer need and chemical mowing [Paine and Harrison 1993]. Seeds of species destined for living mulches should germinate at lower temperature than those of common weeds [Phatak 1992]. Nonrhizomatous spread is also desired to minimize competitions by keeping the mulch from growing into the crop row [Newenhouse and Dana 1989]. The important feature indicated by many authors is their resistance to water deficit [Paine and Harrison 1993, Leary and DeFrank 2000, Adamczewska-Sowińska 2004, Winiarska 2005].

A basic problem connected with planning vegetable cultivation with living mulches is matching appropriate species, which should take into account the cash crop being produced and local climate. In the conditions of moderate climate, the species most often recommended belong to *Fabaceae* family: white clover *Trifolium repens* L., red clover *Trifolium pratense* L., *Trifolium subterraneum*, hairy vetch *Vicia villosa* Roth., saradella *Ornithopus sativus* Brot., birdsfood trefoil, as well as to *Poaceae* family: perennial ryegrass *Lolium perenne* L., Kentucky bluegrass *Poa pratensis* L., red fescue *Festuca rubra* L., wheat *Triticum aestivum* L., rye *Secale cereale* L. and barley *Hordeum vulgare* L. Among other species there can be mentioned winter rape *Brassica napus* L., mustard *Sinapis alba*, phacelia *Phacelia tanacetifolia* Benth. and buckwheat *Fagopyrum esculentum* Moench.

Desirable attributes of grass species as living mulches include early high density and low growth habit. As the best suitable for this purpose there are recognized a tillering or bunch-type grasses, which in general provide better weed control than legumes [Nicholson and Wien 1983], and are less competitive for moisture. Among the grasses the most promising species as living mulch seem to be perennial ryegrass, commonly used in turf and pasture. It is low growing, generally not overtopping vegetable plant and in the studies conducted by Masiunas et al. [1996] and Bottenberg et al. [1997] had less adverse effected on cabbage than did the red clover. In field trial conducted in Switzerland [Müller-Schärrer et al. 1992] the yield of leek was comparable to that obtained in the control in the case if grass was sown 5 weeks after its planting. In long term research conducted in Department of Horticulture at Wrocław University of Environmental and Life Sciences [Adamczewska-Sowińska 2004, 2008] the response of pepper to intercropping with perennial ryegrass was similar to white clover. Both these species caused the decrease of fruit yield by 12.4% up to 53.3%, depending on weather conditions in particular years.

Spring planted small grains, such as rye and wheat can be used as living mulches although crop yield reduction may be a problem. In soybean production, interseeded winter rye effectively suppressed weeds without suppressing the crop where rainfall was adequate but reduced it in low rainfall years [Ateh and Doll 1996]. Conversely, in irrigated broccoli and not irrigated asparagus this mulch had negative effect on crop yield [Brainard et al. 2004, 2012].

Many clovers are low growing and fix nitrogen [Nicholson and Wien 1983, Hargrove 1986] and can be used by the accompanying cash crops. Positive effects of growing such vegetable crops as leek, tomato, pepper and *Solanum aetiopicum* with living mulches belonging to *Fabaceae* family were observed in studies conducted by Winiarska and Kołota [2004] Ofori and Gamedoagbao [2005], Adamczewska-Sowińska [2008], Adamczewska-Sowińska and Kołota [2008].

One of the most promising legume species for this purpose appeared to be white clover because of the low growth and excellent soil surface coverage [Poniedziałek and Stokowska 1999, Kołota and Adamczewska-Sowińska 2003a]. Less suitable for this purpose seem to be red clover, which was able to overtop the cabbage, restricting light from reaching the crop canopy and cause yield reduction [Masiunas 1998]. The other valuable species belonging to this family is hairy vetch producing high biomas and efficiently suppress weeds population [Decker et al. 1994, Teasdale and Daughtry 1993, Brandsæter and Netland 1999, Kotliński 2001, Borowy 2012]. According to Bradow and Connick [1990] this positive effect may be due to the contens of several allelochemicals inhibiting germination of weed seeds.

In Department of Horticulture at Wroclaw University of Environmental and Life Sciences there were also made some attemps to use French marigold *Tagetes patula* L. and dwarf cultivars of pot marigold *Calendula officinalis* L. as undersown species in vegetable cultivation. Pot marigold is recommended for intercropping with vegetables as a plant masking the crop and repelling insect pests, while in blooming stage attracts beneficial insects, which are natural predators for pests. It produces high amounts of biomass, but in our studies [Adamczewska-Sowińska and Kołota 2007] appeared to be highly competitive to tomato plants. French marigold is phytosanitary species, which roots exudate sulphur compounds into soil decomposing to ozone having nematocide properties [Reynolds et al. 2000]. It may be used as living mulch, thoroughly covering soil surface only in the case of favourable moisture conditions and dwarf and highly tillering cultivar will be chosen.

REDUCTION OF COMPETITIVENES THE LIVING MULCHES

Managing competition between living mulch and the cash crop is a major concern for the farmes. It is quite evident that by competing for nutrients, water and light they may affect adversly the growth and yield of vegetables. There have been undertaken numerous attempts to minimize this competition. The trials on this subject involve providing vegetables with optimal growing conditions by proper supply of nutrients and water, the choice of sowing time for living mulches as well as direct operations for reduction of their growth rate. Leary and DeFrank [2000] report that the use of drip irrigation will minimize competition from the living mulch by providing moisture and nutrients directly to the cash crop. The term of living mulches sowing should be chosen carefully so they can ensure optimal soil covering as well as production of hight amounts of their biomass, but at the same time they should not be high competitive to vegetables, especially in the periods of their highest sensitivity [Kołota and Adamczewska-Sowińska 2003a, Müller-Schärrer and Potter 1991]. The need to delay the sowing date beyond the critical period of weed infestation indicate also Wiles et al. [1989] and Vrabel et al. [1980]. It was found that the cover plants sown 5 weeks before or at the time of planting caused a substantial reduction of sweet corn yield while no detrimental effect was observed when it was done 5 weeks after planting.

In our studies good effects expressed by the marketable fruit yield on the level comparable to conventional culture provided the white clover and seradella sown in the term of tomato planting [Adamczewska-Sowińska and Kołota 2007]. The same term of white clover sowing was also favourable for eggplant growth and yielding, while not in the case of perennial ryegrass which should be sown 3 weeks after planting [Adamczewska-Sowińska and Kołota 2010]. In leek, which characterizes slow growth rate early after transplanting, the delay of undersowing the living mulch up to 7 weeks assured satisfactory crop yield [Winiarska and Kołota 2004]. In cabbage, the undersowing of hairy vetch and oats ten days after planting caused the significant yield reduction, while delayed to 20–30 days provided similar effects as conventional growing [Brainard et al. 2004]. Gibson et al. [2011] report that buckwheat used as living mulch in tomato did not negatively affect the fruit yield, if sown after critical period of weed competition.

The other important factor in management of living sods is the reduction of their growth. Two methods that have been reported in the literature are mechanical mowing and chemical suppression with selective herbicides [Vrabel 1983, Zandstra and Warncke 1993, Leary and DeFrank 2000]. Despite the chemical suppression is not an acceptable solution for organic production, it can be recognized as the most promising strategy. Positive effect of early destruction of oat mulch expressed by higher total and large grade onion was found by Greenland [2000]. However, it is worth stressing that the destruction of undersown plants should take place after satisfactory covering the soil surface by the remaining biomass. In the trials conducted with eggplant [Leary and DeFrank 2000], cabbage [Brainard et al. 2004] and sweet corn [Jędrszczyk and Poniedziałek 2007a] the use of chemical living mulch suppression did not affect the crop yield, while had some disadvantageous effect in leek [Jędrszczyk and Poniedziałek 2007b], pepper [Adamczewska-Sowińska 2008] and zucchini [Walters and Young 2008].

Plants used as living mulches in vegetable crops may be sown as early as in the autumn in the preceding year. They protect the soil from degradation and nutrients runoff during the winter and in the spring are destroyed in the strips destined for vegetable rows. The growth of remaining mulch can be restricted by the use of sublethal doses of herbicides or by mowing. In the study conducted by Poniedziałek et al. [2005] there was observed 25% decrease of cabbage yield grown between single mowed strips of winter rye, due to the competitiveness of re-grown plants for water and nutrients. The other reason of this adverse effect might be the shortage of nitrogen due to its biological sorption during the mineralization process of rye biomass. According to Brandsæter et al. [1998] better results than even twofold mowing in white cabbage-living mulch system can be obtained by destroying the cover crop biomass by the application of herbicide in 6 weeks after plating.

Another possible way to reduce competition is sowing the living mulches in strips between the rows of vegetables or mowing their biomass during the vegetation period [Greenland 2000, Swenson et al. 2004]. Data of our studies [Adamczewska-Sowińska 2008, Adamczewska-Sowińska and Kolota 2008] proved that the best results can be obtained by multiple mowing of living mulches, which caused the increment of pepper and tomato yield by 20% and 10%, respectively, in comparison to the treatments where their growth was not restricted. This effect may be particularly pronounced in the case of using for undersowing the species producing high amounts of biomass such as marigold, perennial ryegrass or white clover, and much lower in the case of seradella [Adamczewska-Sowińska and Kołota 2007, Adamczewska-Sowińska 2008]. Some mulching species eg. grasses rapidly regrow after cutting and again may become highly competitive to vegetable crops, and in this case multiple mowing may by effective.

WEED CONTROL BY LIVING MULCHES

Positive effect of living mulches on reduction of weed population can result from their high competitiveness, regarding water, nutrients and light, as well as living space. An important property, which ensures them the advantageous development, is their rapid growth and good covering of soil surface, as early as since the beginning of growing period. Teasdale et al. [1991] showed that when a cover crop produced more than 300 $g \cdot m^{-2}$ biomass and had greater than 90% ground cover, weed infestation was reduced 78% compared to treatments without cover crops. Due to living mulches the decrease in weeds number can range 50–90%. [Jędrszczyk et al. 2005] reported that in cultivation of cabbage with white clover there took place reduction in weeds fresh weight, as well as their number, by 96% and 89%, respectively. Research conducted by Araki and Tamura [2008] proved that barley sown in inter row spacing of asparagus in the half of April, after three months reduced weeds infestation by 18% as compared to cultivation without living mulches. Beneficial effect of living mulches, consisting in weeds suppression, was also observed by Walters and Young [2008] in zucchini intercropping with winter species, while Gibson et al. [2011] reported that in tomato intercropped with buckwheat, there was not only reduced the number of weeds, but also their bank of seeds in the soil. The same study indicated that living mulch cutting not always provided for significant reduction in weeds infestation. Brainard et al. [2012] recommend, monitoring weed infestation and supplementary use the other methods of weed control in order to prevent accumulation of weed seeds in the soil living mulches. According to these authors, after three years of asparagus intercropping with rye, density of annual weeds was over ten times higher than in standard herbicide treatments.

The amount of produced biomass has an important meaning in suppression of weeds infestation by living mulches. Barberi et al. [2008] found the proportional decrease in total biomass of weeds in spinach cultivation in relation to the amount of biomass of living mulch from *Trifolium subterraneum*. Brandsæter and Netland [1999], after

Almeida [1985] reported that living mulches leaving more than 450 g of dry matter after cutting or destroyed by herbicides were satisfactory efficient in reducing weed infestation.

Chase and Mbuya [2008] consider rye as a good living mulch, which to the highest degree, contributed to the suppression in weed infestation in broccoli cultivation, taking into account their number and biomass. In sweet corn cultivation, rye also proved to be the most efficient in reducing the weed infestation and this effect could be observed in early stages of growth, in reverse to legume species [Jędrszczyk and Poniedziałek 2009]. Wójcik-Wojtkowiak et al. [1998] stressed the role of rye in weeds reduction due to allelopathic compounds, inhibiting germination of weed seeds. These compounds are excreted by the alive plants or released by plant residues after mowing the biomass which is left on soil surface. Rice [1979] indicated similar allelopathic properties of barley and Sudan grass, while Bradow and Connick [1990] the hairy vetch. Containing several allelochemicals hairy vetch appeared to be very effective in reducing weed infestation in the studies conducted by Teasdale and Daughtry [1993], Brandsæter and Netland [1999] and Borowy [2012].

Brainard et al. [2004] reported that at the earliest sowing term of living mulch from this species or oat, when the mulch produced the highest amount of biomass, there was observed even twelve fold reduction in weeds biomass in cabbage cultivation.

Generally, it can be assumed that living mulches often suppress weeds when compared with untreated control, especially if sown in early terms [Araki and Tamura 2008]. However, when compared with common grower practices in which chemical and mechanical weed control is applied, living mulches often result in higher weed infestation of the grown crops [Teasdale 1998, Brainard et al. 2012].

PESTS AND DISEAES CONTROL

There is widely emphasized that plants grown in high densities and low diversity are more susceptible to insect infestation when compared to plants grown in complex natural communities [Müller-Schärrer and Potter 1991]. Living mulches that increase the biodiversity in agro-ecosystem cause the increased number of beneficial insects-natural predators of pests affecting vegetables eg. beetle insects or spiders [Hooks and Johnson 2003].The impact of undersowing vegetables with cover crops on insect pest densities have been examined mainly in Brassica crops [Costello and Altieri 1994, Vidal 1997, Hooks and Johnson 2002], and in most of these studies there were observed the positive effects. In a such field trial conducted by Hooks and Johnson [2004] undersown living mulch with different species of covers appeared to be promising in reducing lepidopteran pest densities and increasing activity of predators in broccoli planting.

In the other field trial with zucchini grown as intercrop with buckwheat Nyoike and Liburd [2010] recorded higher population of natural predators of whiteflies and aphides than in treatment where synthetic mulch was used. As a result of this there was observed the insect pests reduction and smaller infection of zucchini plants by viruses [Nyoike et al. 2008]. The beneficial effects of perennial legume living mulch on reduction of cabbage aphid number compared to a broccoli monoculture were observed by Costello and

Althieri [1994]. The phenomenon of lower pests number in the living mulch plots may be explained by the lower light intensities reflected off the plants. The other reason may be the fact, that increased number of plants on cultivated area constitutes natural barrier to pests and making localization of host species more difficult. Covering the whole soil surface by plants causes that an image seen by the insect becomes poorly contrasted and, therefore, not so attractive.

According to Jankowska et al. [2009] the example of species that can successfully suppress the occurrence of cabbage aphid, flea beetles as well as number of small cabbage white eggs and caterpillars are Franch marigold and pot marigold. In reverse to this finding, Theriault et al. [2009] proved a significant increase in the occurence of small cabbage white caterpillars on broccoli cultivated with living mulch from lucerne and red clover. With regard to two major pests insects in leeks the grass living mulch caused the decrement of the population of onion thrips, while no effects was observed in the presence of leek moth [Müller-Schärrer et al. 1992]. The considerable reduction of onion trips number on leeks was also observed in the study where white clover was used as living mulch [Thieunissen and Schelling 1998]. This species undersown in white head cabbage suppressed the population of cabbage aphids and cabbage moth [Wiech and Wnuk 1991], while not root fly on carrot plants [Finch 1993].

Living mulches used as cover crops can also affect on lower degree of infection of vegetables by pathogens. This can be exemplified by higher tomato resistance to rust fungi reported by Xu et al. [2008]. One of the causes of that phenomenon is probably lower content of nitrates in plants resulting from the presences of Kentucky bluegrass living mulch. There was also observed the advantageous effect of hairy vetch [Abdul-Baki et al. 1996] and mixture of hairy vetch and rye [Kotliński and Abdul-Baki 2000] used as living mulch on potato blight infestation of leaves of determinate tomato cultivars. This effect was not so distinct in the experiment conducted by Borowy [2012], who found, however, the lower yield of fruits affected by this disease, if compared to conventional cultivation.

PHYSICAL AND CHEMICAL SOIL PROPERTIES AND ITS BIOLOGICAL ACTIVITY

Living mulches positively affect the soil physical and chemical properties. Their presence in the field during vegetation period reduces the need for some soil tillage operations, which can contribute to soil compaction and dispersion. Providing a protective layer on soil surface they prevent from disadvantageous impact of atmospheric factors such as heavy rains or wind [Nicholson and Wien 1983, Paine et al. 1995, Stirzaker and White 1995] and, therefore, maintaining the soil in good structure and improved aeration and water infiltration. According to Russell [1971] the roots of undersown plants are habitat for bacteria producing polysaccharide gums, taking part in creating soil aggregates.

Beneficial impact of living mulches on soil structure is associated with increment of water resistance of soil aggregates. Studies of Poniedziałek and Stokowska [1999] and

Jędrszczyk et al. [2005] revealed that white clover, meadow fescue and common vetch grown as cover crops in white head cabbage caused the increase of largest soil aggregates of 2.5–1.0 mm in diameter, while the drop of smallest ones. Similar effects were also noted in sweet corn intercropping cultivation, especially with rye [Jędrszczyk and Poniedziałek 2009]. This effect may be partly due to the protection against raindrops impact and reduction runoff velocity on the soil surface [Jasa and Dickey 1991].

By covering the surface of the soil, living mulches protect it from water and wind erosion, reduce evaporation rate and increase soil moisture [Boyd et al. 2000]. This protective effect is especially important in cultivation of vegetables on hilly or mountainous areas, and the country which strongly develops this system is Switzerland [Hartwig and Ammon 2002]. In the study conduction by Hall et al. [1984] the birdsfoot trefoil or crowvetch used as living mulches in corn grown on 12% slope greatly reduced the surface water runoff and almost eliminated the loss of nutrients and leaching the residual herbicides.

Higher soil moisture under living mulch cover due to lower evaporation rate in comparison to conventional cultivation was observed by Swenson et al. [2004] and Borowy [2012]. The adverse impact was reported by Brainard et al. [2012] who indicated a strong competition of rye living mulch for water and contributed to significant reduction of soil available water in the second half of vegetation period of asparagus cultivation.

By shading the soil surface, the cover crops decrease its temperature and this may be the reason for slower growth of plants and delayed maturation of the warm season crops such as tomato [Borowy 2012]. On the other hand, they help to maintain the soil temperature more uniform by preventing it from excessive heating at intensive insolation and by reducing the rate of cooling during cooler periods [Teasdale and Mohler 1993].

After harvest of vegetable crops they are ploughed down as a green manure, and like the other catch crops may be recognized as the valuable source of organic matter [Koch 1990, Shennan 1992, Hartwig and Ammon 2002], which improves the soil productivity. After decomposition they serve as the source of available forms of nutrients for the subsequent crops. The species from *Fabacea* family used for this purpose enrich the soil in nitrogen, and allow to reduce the doses of this nutrient by one third or even by half of recommended rate.

In the regions with heavy rains and winds during the winter season the living mulches can be left in the field till spring in order to protect from wind and water erosion as well as nutrients leaching from the root zone. They may also play a protective role for vegetable crops wintering in the field. In our studies with leek [Kołota and Adamczewska-Sowińska 2003b] it was revealed that the presence of white clover, especially from early term of undersowing created better conditions for plant survival that perennial ryegrass and hairy vetch.

Living mulches favor development of different soil organisms and positively influence the biodiversity of soil environment. Hartwig and Ammon [2002] reported that in this cultivation system the earthworm biomass may be even seven times higher that is in conventional growing. Also Pelosi et al. [2009] paid attention to higher their number inhabiting the soil under living mulches from white clover and birdsfoot trefoil. Moreover, they underline the fact the composition of species settled the soil was different from traditional cultivation system. This phenomenon can be explained by the higher amounts of organic matter, limited use of chemicals and reduced soil tillage. Considerable amounts of root biomass produced by soil covering plants cause the increase of soil microbiological activity, including arbuscular fungi which colonize roots of majority crops, leading to intensified mycorrhizal process and uptake of nutrients. According to Deguchi et al. [2007] the host for those mycorrhizal fungi was white clover intercropped with sweet corn, and in the studies Xu et al. [2008] Kentucky bluegrass undersown in tomato.

CONCLUSIONS

The use of living mulches may be recognize as an important part of crop management in the most friendly to the environment integrated and organic systems of vegetable production, which allow to reduce or even eliminate the application of chemicals for weed and pests control as well as decrease of mineral fertilizer need. Thought the competition between living mulch plants and cash crops cause often a substantial yield reduction, the other benefits including improvement of soil physical and chemical properties, increment the soil organic matter, the suppression of weeds and insect pests pressure may favor such cultivation. The efficiency of this system need to be calculated in 2 or even 3 years of crop rotation, when the ploughed down biomass of living mulches used as green manure will decompose and provide the benefits for the subsequent vegetable species.

Managing competition between living mulch and the cash crop is a major concern for farmers. Thus the common application of this cultivation system needs further intensive studies upon the selection of desirable mulch species well adopted to the local climate and soil conditions. The other area of research should be devoted for elaboration the efficient methods of reduction the competitiveness of these species by choosing the proper time of undersowing and the suppression of their growth rate by using the sublethal doses of herbicides or mowing the biomass, in the interrows of vegetables.

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ŻYWE ŚCIÓŁKI W UPAWIE WARZYW: KORZYŚCI I OGRANICZENIA W ICH STOSOWANIU

Streszczenie. W pracy przedstawiono różne aspekty zastosowania żywych ściółek w warzywnictwie polowym na podstawie dotychczasowych wyników badań. Żywe ściółki, konkurując o światło, wodę i składniki pokarmowe, są w większości przypadków przyczyną obniżki plonu warzyw. Jednak po przyoraniu na zakończenie wegetacji, jako zielony nawóz, przyczyniają do zwiększenia zawartości substancji organicznej w glebie oraz poprawy jej właściwości fizycznych i chemicznych, co wpływa korzystnie na wzrost roślin następczych w ogniwie zmianowania. Najbardziej odpowiednie do uprawy współrzędnej z żywymi ściółkami są warzywa wieloletnie (np. rabarbar), bądź rośliny o długim okresie wegetacji uprawiane z rozsady (por, kapusta, kukurydza cukrowa, pomidor przy palikach, papryka). Najważniejsze cechy, którymi powinny się odznaczać gatunki wykorzystywane jako żywe ściółki to krótki okres wschodów, dobre okrycie powierzchni gleby, niski wzrost oraz małe zapotrzebowanie na wodę i składniki pokarmowe. Są to z reguły rośliny bobowate (koniczyna biała, koniczyna czerwona, wyka ozima, seradela), trawy (życica trwała) bądź zboża, szczególnie żyto. Konkurencyjność tych roślin w stosunku do warzyw można ograniczyć poprzez opóźnienie terminu ich siewu przeprowadzanego tylko w międzyrzędziach roślin, koszenie wytworzonej biomasy oraz stosowanie dawek subletalnych herbicydów. Korzyści ze stosowania żywych ściółek to ograniczenie zachwaszczenia, szkodników i chorób, a także degradacji gleby. Żywe ściółki wpływają ponadto na zmniejszenie zwięzłości gleby i poprawę jej struktury, zapobiegają erozji wietrznej i wodnej, ograniczają spływ wody powierzchniowej oraz wypłukiwanie składników mineralnych. Podkreśla się również korzystny wpływ żywych ściółek na aktywność biologiczną gleby i zawartość dostępnych form składników po ich mineralizacji w glebie. Aby wprowadzić ten przyjazny dla środowiska naturalnego system uprawy warzyw do szerokiej praktyki warzywniczej, niezbędne są intensywne prace badawcze, które powinny być prowadzone szczególnie w zakresie ograniczenia konkurencyjności żywych ściółek w stosunku do roślin uprawnych.

Słowa kluczowe: gatunki warzyw, redukcja zachwaszczenia, szkodniki, choroby, właściwości gleby

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