LIVING MULCHES IN FIELD CULTIVATION OF VEGETABLES

Katarzyna ADAMCZEWSKA-SOWIŃSKA, Eugeniusz KOŁOTA, Sylwia WINIARSKA

Department of Horticulture
Wrocław University of Environmental and Life Sciences
Pl. Grunwaldzki 24a, 50-363 Wrocław, Poland

Received: March 17, 2009; Accepted: April 23, 2009

Summary
Living mulches as an element of vegetable cultivation in the integrated and ecological production systems perform a protective function towards the soil and the cultivated crops. They improve the physical, chemical and biological properties of the soil, and reduce weed and pest infestation. At the same time, however, they compete with vegetable plants for nutrients, water and space, and that is why research work has been carried out with the aim of minimizing this competition. The success of vegetable production with the assistance of living mulches depends on the right selection of the species, sowing or planting dates, as well as the means of controlling the growth of the companion plants. The experiments carried out at the Department of Horticulture of Wrocław University of Environmental and Life Sciences demonstrated the usefulness of white clover and pink serradella as living mulches for tomato and leek, and of perennial ryegrass for pepper. Controlling the biomass of companion plants by regular mowing brought about a 2-17.2% increase in the yield of tomato fruits. The most favourable sowing date for these plants in the cultivation of pepper was week 9 and 12 of pepper plant growth, and week 4 and 6 in the cultivation of leek.

key words: living mulches, tomato, pepper, leek

INTRODUCTION
Owing to the rapidly advancing degradation of the natural environment in the 20th century and at present, caused by, among other things, the intensification of agriculture involving heavy use of chemical plant protection products, herbicides, mineral fertilizers, and mechanization, interest in environmentally-friendly methods of plant cultivation has greatly increased. Satisfying the needs of people and the environment, while at the same time protecting the soil, is the underlying principle of so-called ‘sustainable agriculture’, which makes use of simplified and conserving methods of soil cultivation (Starck 1998, Abdul-Baki...
et al. 2002). The principles of conservation cultivation are based on the assumption that at least 30% of plant residue from the previously grown crop is left behind on the soil surface in the critical period for the plants of the after-crop. One element of such a system is represented by cover crops, including living mulches, that is, species of plants that grow in the field between successive vegetable crops, or together with them over the whole vegetative cycle, performing a protective function towards the soil and the cultivated crops (Baumann et al. 2000). They protect the soil surface from water and wind erosion, from the destructive action of repeated mechanical treatments, and also improve the physical properties of the soil. Living mulches also contribute to a reduction in the losses of minerals from the soil layer that is occupied by the majority of roots of cultivated crops - for example, they prevent ammonium nitrogen from leaching deeper into the soil and entering the groundwater, or from escaping to the atmosphere. They also help in controlling pests and weeds. After the harvest of the vegetables that have been growing alongside them, living mulches are ploughed in and serve as green manure.

Some of the most desirable characteristics that plants used as living mulches should have include: very fast initial growth rate, low, recumbent growth habit, ability to produce a quantity of biomass to thoroughly cover the soil surface, but at the same time low or medium productivity, good resistance to drought and low nutritional demands, as well as low costs of fertilization and breaking up the above-ground parts, e.g. by mowing (Paine and Harrison, 1993). The species most often recommended for use as living mulches are those from the legume family – clover (Trifolium repens, T. pratense, T. fragiferum, T. subterraneum L.), winter vetch (Vicia villosa Roth.), bird’s-foot trefoil (Lotus corniculatus L.), pink serradella (Ornithopus sativus Brot); from the grasses family – perennial ryegrass (Lolium perenne L.), smooth-stalked meadowgrass (Poa pratensis L.), red fescue (Festuca rubra L.), and also wheat, rye, and barley. Others include winter rape (Brassica napus L.), charlock (Sinapis arvensis L.), tansy phacelia (Phacelia tanacetifolia Benth.) pot marigold (Calendula officinalis L.) – low-growing varieties, and spreading tagetes (Tagetes patula L).

For co-cultivation (intercropping) with living mulches the most suitable are vegetables with a long vegetative period, high growth rate, and late harvest. The most often cited are annual species grown from seedlings – tomato, pepper, head cabbage, and leek, or those grown from seed – sweetcorn, onion, common bean, and perennial vegetables – asparagus and rhubarb.

PROTECTION AGAINST PESTS

One of the effects of diversifying an agroecosystem by introducing living mulches is that pests have a problem finding and recognizing food (Hooks et al. 1998, Wnuk 1998). In a thick stand of mulching plants, and at a lower contrast between the cultivated crop and soil surface, finding host plants is difficult; besides, insects move around more, spending less time on searching through vegetable crops. Costello (1994), and Costello & Altieri (1995) found fewer aphids in the cultivation of broccoli intercropped with white clover (Trifolium
repens L.) or strawberry clover (T. fragiferum L.). Also, Hooks et al. (1998) showed that zucchini plants were less affected and damaged by aphids and the silverleaf whitefly (Bemisia argentifolii Bellows and Perring) in intercropping with buckwheat (Fagopyrum esculentum Moench) or white mustard (Sinapis alba L.) than in a homogeneously-grown crop. Living mulches of strawberry clover (T. fragiferum L.) and subterranean clover (T. subterraneum L.), or white clover (T. repens L.), also contributed to a reduction in the infestation of leek by thrips (Weber et al. 1999, Legutowska & Kucharczyk 2000). A shortened feeding period of the flea beetle (Phyllotreta cruciferae) on broccoli grown in tandem with white clover, spring vetch, and field bean was observed by Hooks & Johnson (2003), and also Garcia & Altieri (1992).

A significant advantage of living mulches from an ecological point of view is the fact that they create a suitable environment for the natural enemies of crop plant pests, e.g. ground beetles (Carabidae) or spiders. Living mulches thus contribute to an increase in the size of their populations (Riechert & Bishop 1990).

**PROTECTION AGAINST WEED INFESTATION**

In the ecological and integrated production of vegetables, the use of living mulches can be regarded as an alternative to the mechanical and chemical methods of controlling weeds (Infante & Morse 1996). Living mulches compete with weeds for light, water and nutrients, not to mention space. Some species exude compounds with allelopathic properties that inhibit root growth or development of weed seedlings (Putnam 1986, Wójcik-Wojtkowiak et al. 1998). A particularly important characteristic of the species used for this purpose is their rapid growth and good coverage of the soil surface right from the beginning of their vegetative development. Owing to their presence, the reduction in the number of weeds can be as high as 50-90%. Good results in terms of a substantial reduction in weed infestation were obtained by Infante & Morse (1996) in the cultivation of broccoli with red clover, white clover and winter vetch, and by Brandsaeter et al. (1998) in the cultivation of cabbage with subterranean clover (T. subterraneum L.), as well as by Poniedziałek & Stokowska (1999) for white head cabbage grown together with white clover, common vetch and meadow fescue (Festuca pratensis Huds.).

Brandsaeter & Netland (1999) reported that it was more beneficial to sow living mulches in advance of the vegetable crop, mow them once or twice after they have covered the soil surface, and only then plant vegetables in strips prepared beforehand by mechanical or chemical means.

**EFFECT ON SOIL ENVIRONMENT**

Numerous studies have revealed a positive effect of living mulches on the physical properties of the soil. The elimination of weed control and soil cultivation treatments allows the soil structure to be preserved, or even improved by the action of the roots of the companion crop. The firmness of the soil decreases, soil aeration and soaking-up of water increase thanks to the passages
that are left behind by dead roots. And the bacteria living on those roots produce polysaccharides and gums, which help to create soil aggregates (Russell 1971).

By covering the surface of the soil, living mulches protect it from water and wind erosion, and raise its humidity (Boyd et al. 2000). They help to keep the soil temperature uniform – by preventing the soil from becoming excessively hot when exposed to strong sunlight, and by reducing the rate of cooling during colder periods.

The beneficial effect of living mulches on vegetable plants may be attributed to the exchange of root exudates between them, which stimulates absorption and accumulation of ions in cultivated crop plants. This exchange is 1.5–7 times greater than among plants in a monoculture. In mixed-crop cultivation, such a positive mutual effect on the growth and yield of the species grown together has been observed frequently (Wójcik-Wojtkowiak 1987).

Living mulches fulfil their role not only during the vegetable growing season, but they also serve as a means of fixing nitrogen in the autumn and winter, and at any time when it is not needed by the crop plants (Paschold et al. 1995). For the most part of the year, nitrogen is in danger of being washed out. This applies particularly to soils of lower sorptive capacity, where relatively little rainfall can lead to noticeable relocation of this element. Companion plants immobilize nitrogen until the process is disrupted by the first severe frost. After that, depending on the weather, nitrogen mineralization begins.

After the vegetable growing season, living mulches can be ploughed in to serve as green manure. The biomass of living mulches enriches then the soil in organic matter, which while decomposing undergoes mineralization and releases the accumulated minerals (Wiles & Crabtree 1989). The increased amount of humus causes favourable changes in the physical, biological and chemical properties of the soil substrate, and makes microbiological activity in it more intense. This very rapid increase should happen towards and past the end of vegetative growth of the crop plant being cultivated, and for that reason living mulches intended for late sowing must be selected out of those species that do not respond to shorter daylight with weight loss. It is advantageous then to use plants of the species from the Brassica family, Phacelia, grasses, and also some from the bean family (Leguminosae). A long delay in sowing time, however, may be unfavourable because despite the high capacity of the plants to grow back, their growing period becomes too short for them to develop fully (Siebeneicher 1997).

The weight and depth of the root system of the plants intended for use as green manure is also of great importance because of its capacity to take up nutrients from the deeper layers of the soil. With a large biomass of such plants, considerable amounts of nutrients can be taken up, stored and processed.

Living mulches can also play a protective role towards the vegetable plants left for the winter in the field. Experiments conducted by Kołota & Adamczewska-Sowińska (2003) demonstrated that the presence of white clover and winter vetch in the field contributed to an improvement in the degree of overwintering in leek, which manifested itself in an 84% share of the spring yield in the
autumn yield, with that share being only 75% in homogeneous crop cultivation (Table 1). What was important in all this was the large size of the biomass produced by the living mulches, which were thus able to provide protective cover for the overwintering plants of leek. The best able to survive the winter were the leek plants with winter vetch and white clover as companion plants, which had been sown at the earliest time, i.e. 3 and 5 weeks after planting the leek plants. The yield of leek obtained in this way, however, was significantly lower than in the control combination.

Table 1. Effect of using living mulches on overwintering of leek (1997-1999)

<table>
<thead>
<tr>
<th>Sowing date of living mulches (weeks from date of planting leek)</th>
<th>spring/autumn yield ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>perennial ryegrass</td>
</tr>
<tr>
<td>3</td>
<td>69</td>
</tr>
<tr>
<td>5</td>
<td>70</td>
</tr>
<tr>
<td>7</td>
<td>69</td>
</tr>
<tr>
<td>9</td>
<td>72</td>
</tr>
<tr>
<td>11</td>
<td>72</td>
</tr>
<tr>
<td>mean</td>
<td>70</td>
</tr>
<tr>
<td>without living mulches</td>
<td></td>
</tr>
</tbody>
</table>

LIMITING COMPETITIVENESS OF LIVING MULCHES

A factor that makes it difficult to carry out cultivation in the presence of living mulches is the fact that they compete with vegetable plants for water, nutrients, and light, and often are the reason for reducing their yield. A reduction in the yield of maize grown in the company of a mixture of white clover and grasses was recorded by Nicholson & Wien (1983). Lower yields of pepper grown together with white clover (by 27.6%) and perennial ryegrass (by 12.4%) in comparison with cultivation without these intercrop plants was reported by Adamczewska-Sowińska & Kółta (2001) (Table 2). The reduction in yield and lack of economic advantages were also pointed out by Guldan et al. (1998), Bauman et al. (2000), and Carruthers et al. (2000). Consequently, this method of cultivation needs to be thoroughly examined in terms of the effects of many external factors and interdependence among the species.

The competitive effect of living mulches can be eliminated or reduced (Brandsaeter & Netland 1999, Hooks & Johnson 2003). This is achieved, for example, by watering the cultivated crop, especially during longer periods of water shortage. It is also recommended to use well-matched doses and times of mineral and organic fertilization. Apart from that, plants of the companion crop should not restrict access of light to the cultivated crop plants because not only does it cause a reduction in their yield, but also adversely affects their quality by causing, for example, a drop in dry matter content, as reported by Redfearn et al. (1999). Consequently, it is recommended to mow excessively growing companion plants, leaving their green biomass in the field. This method is particularly useful in the case of species that do not grow back very well after such
One of them is winter vetch, which produces a lot of mulch-forming biomass (Abdul-Baki & Teasdale 1993, Brandsaeter & Netland 1999).

The experiments carried out at the Department of Horticulture of Wroclaw University of Environmental and Life Sciences showed that regular mowing of living mulches of white clover, perennial ryegrass and pot marigold used in the cultivation of tomato resulted in a reduction in the yield of their biomass by 8.6%, 36.8%, 47.2%, respectively, and at the same time in an increase, in relation to plots that had not been mowed, in the yield of tomato fruits by 15.6%, 10.2% and 24.7%, respectively (Adamczewska-Sowińska & Kolota 2008) (Table 3). Application of the herbicide Roundup 360 SL at 4 l·ha⁻¹ resulted in a reduction in the biomass of the living mulches by an average of 70.6%, with a corresponding 12.3% increase in tomato fruit yield.

Other treatments that can be done to inhibit growth of cover plants include breaking up their biomass and leaving it between the rows of vegetables, or mixing it with the soil by shallow ploughing. Brandsaeter et al. (1998) reported that by breaking up the living mulch of white clover and subterranean clover with a rototiller 6 weeks after planting white head cabbage contributed to an increase in cabbage yield. Under evaluation is also the possibility of coating the leaves of living mulches with organic paints that are able to block the process of photosynthesis, or applying to these plants selectively-acting pathogens. It turns out that frequent breaking-up of the above-ground parts of the companion plants causes a decrease in the number of their roots. Such an outcome is beneficial, because, as stated by Lucero et al. (1999), the growth of different species planted side by side is mainly affected by the competition between their root systems.

Another method that reduces the negative effect of living mulches on vegetable plants consists in increasing the distance between them, or cultivating companion plants in narrow strips. Paschold et al. (1995) state that the distance between the rows of asparagus co-cultivated with living mulches should exceed 2 m. When growing vegetables at large inter-row spacings, living mulches should be sown only on 60% of their surface area. Masiaunas (1998), White & Worsham (1990), and also Czapar et al. (2002) also pointed out the advantages of intercrop cultivation in which companion plants and vegetables are grown in strips.

When good conditions of cultivation are assured and the right selection of the living mulch plant species has been made, the resulting yields of vegetables can be comparable with those of homogeneous crops (Kołota & Adamczewska-Sowińska 2000, Adamczewska-Sowińska 2004). In our own experiments, carried out in the years 1998-2000, the marketable yield of tomato fruits obtained in co-cultivation with white clover was 44.45 t·ha⁻¹, and was at the level of the yields collected from the plots without living mulches (Table 2). The use of perennial ryegrass resulted in a yield reduction of 11%. A companion crop that was not found to be very competitive towards tomato was pink serradella (Ornithopus sativus Brot.) (Table 3). As a consequence of the very early sowing time of living mulches – 6 weeks before planting tomato – in the co-cultivation with serradella the drop in fruit yield of tomato with respect to control was found to be the lowest.
Table 2. Marketable yield of tomato and pepper (t·ha⁻¹) depending on the species and sowing date of living mulches

<table>
<thead>
<tr>
<th>Sowing date of living mulch (weeks from date of planting vegetables)</th>
<th>tomato</th>
<th>pepper</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>white clover</td>
<td>perennial ryegrass</td>
</tr>
<tr>
<td>2</td>
<td>39.87</td>
<td>35.00</td>
</tr>
<tr>
<td>5</td>
<td>44.76</td>
<td>37.61</td>
</tr>
<tr>
<td>8</td>
<td>45.24</td>
<td>41.56</td>
</tr>
<tr>
<td>11</td>
<td>47.94</td>
<td>44.11</td>
</tr>
<tr>
<td>Mean</td>
<td>44.45</td>
<td>39.57</td>
</tr>
<tr>
<td>Control (without living mulch)</td>
<td>44.49</td>
<td>12.30</td>
</tr>
</tbody>
</table>

LSDₐ₀.₀₅ for:
- species of living mulch 2.56  n.s.
- sowing date of living mulch 3.27  1.85
- interaction I x II n.s.  n.s.

Table 3. Effect of the species of living mulch and growth control method on its biomass and marketable yield of tomato (2004-2006)

<table>
<thead>
<tr>
<th>Sowing date of living mulch and method of controlling its growth</th>
<th>Biomass of living mulches (t·ha⁻¹)</th>
<th>Marketable yield (t·ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pot marigold</td>
<td>perennial ryegrass</td>
</tr>
<tr>
<td>05.04. + k</td>
<td>47.47</td>
<td>17.73</td>
</tr>
<tr>
<td>05.04. + h</td>
<td>25.07</td>
<td>11.20</td>
</tr>
<tr>
<td>Mean</td>
<td>26.28</td>
<td>11.81</td>
</tr>
<tr>
<td>Control</td>
<td>58.79</td>
<td></td>
</tr>
</tbody>
</table>

LSDₐ₀.₀₅ for:
- species of living mulch 3.87  3.10
- sowing date of living mulch and method of controlling its growth 4.52  3.56
- interaction I x II 9.23  7.30

In the cultivation of pepper with living mulches, however, it was noticed that perennial ryegrass was less competitive towards the pepper crop than white clover, but nevertheless both species of the companion crop caused a reduction in fruit yield of 12-17.5% in comparison with the homogeneous crop. On the basis of the experiments carried out in 1999-2001 at the Department of Horticulture of Wrocław University of Environmental and Life Sciences, it was proven that white clover was the most useful plant for intercrop growing with leek (Kołota & Adamczewska-Sowińska 2000, 2001). The yield of leek was
then higher, by 10% on average, than in co-cultivation with perennial ryegrass and winter vetch. At the same time, it was found that all these species reduced that yield by 13-22% compared with conventional cultivation. Subsequent experiments, conducted in 2001-2004, also confirmed the effect of cover plant species on the yield of leek (Winiarska 2005) (Table 4). The size of that yield in co-cultivation with winter rape was by 18-22% smaller than in co-cultivation with pink serradella, spreading tagetes, or white clover. It was also found that employing the three species of intercrop plants made it possible to obtain a higher yield of leek than on the control plots.

Table 4. Marketable yield of leek [t·ha⁻¹] depending on the species and sowing date of living mulches (2001-2004)

<table>
<thead>
<tr>
<th>Sowing date of living mulch (weeks from date of planting vegetables)</th>
<th>white clover</th>
<th>pink serradella</th>
<th>winter rape</th>
<th>spreading tagetes</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>21.64</td>
<td>27.37</td>
<td>13.22</td>
<td>26.34</td>
<td>22.14</td>
</tr>
<tr>
<td>5</td>
<td>31.06</td>
<td>32.10</td>
<td>24.75</td>
<td>29.08</td>
<td>29.25</td>
</tr>
<tr>
<td>7</td>
<td>33.86</td>
<td>34.74</td>
<td>29.02</td>
<td>34.37</td>
<td>33.00</td>
</tr>
<tr>
<td>9</td>
<td>37.06</td>
<td>34.23</td>
<td>34.67</td>
<td>35.99</td>
<td>35.49</td>
</tr>
<tr>
<td>Mean</td>
<td>30.90</td>
<td>32.11</td>
<td>25.42</td>
<td>31.45</td>
<td>29.97</td>
</tr>
<tr>
<td>Control (without living mulch)</td>
<td>28.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD₀.₀₅ for:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>species of living mulch</td>
<td>0.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sowing date of living mulch</td>
<td>0.74</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>interaction I x II</td>
<td>1.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The competition between living mulches and cultivated crop plants does not arise only as a result of their species-specific traits, but is also dependent on the length of the period during which they are growing together with vegetable plants. Of special importance here is the necessity to choose the sowing dates for both species in such a way as to ensure maximum development of the crop plants. Generally, a later sowing date is recommended for living mulches; for example, Müller-Schärer & Potter (1991) inform that in the cultivation of leek that date should be past the middle of the vegetative cycle of that vegetable. Vrabel et al. (1980) found that sowing living mulches over the entire cultivated surface area 5 weeks after the sowing date of maize did not cause any yield loss, but with the same sowing dates no yield loss was recorded only in strip cultivation. Riley & Dragland (2002) report that the reduction in the yield of red beat grown in the company of white clover, especially for the first 6 weeks of its vegetative growth, was as much as 45%. In our own experiments, the greatest and significant drop in the yield of tomatoes was recorded for the earliest sowing date of living mulches, which was 2 weeks after the date of planting tomato plants (Table 2). Later sowing dates, especially of white clover, made it possible to obtain yields at the same or even higher level than in homogeneous crop cultivation. A significant increase in yield brought about by delaying the sowing date of living mulches also occurred in the case of pepper. Its yield was the
highest when the companion crops had been sown 8 and 11 weeks after the planting date of that vegetable.

On the basis of the results obtained by Winiarska (2005) in the cultivation of leek, sowing living mulches 3 and 5 weeks after it has been planted should be considered as too early. This cultivation method resulted in the largest losses in marketable yield in relation to the cultivation of a homogeneous crop that had been regularly weeded until the 9th week of its growth.

The experiments carried out over many years at the Department of Horticulture of Wrocław University of Environmental and Life Sciences revealed that co-cultivation with living mulches had little effect on the biological value of vegetables (Adamczewska-Sowińska & Kołota 2001, Adamczewska-Sowińska 2004, Winiarska 2005). The levels of organic and mineral constituents remained unaffected in comparison with their amounts in vegetables grown as homogeneous crops. Provided the right species, sowing and planting dates, and cultivation methods are used, growing vegetables with living mulches can be taken advantage of and bring satisfactory results in the ecological and integrated production systems.

REFERENCES

Adamczewska-Sowińska K. 2004. [Living mulches in tomato and pepper production system using hairy vetch and subterranean clover mulches.] Zeszyty Nauk. AR we Wrocławiu 484, Rozprawy CCXIII. [in Polish with English summary]


ŻYWE ŚCIÓŁKI W POLOWEJ UPRAWIE WARZYW

Streszczenie

Żywe ściółki jako element uprawy warzyw w systemie integrowanym i ekologicznym spełniają funkcję ochronną w stosunku do gleby i roślin uprawnych. Poprawiają właściwości fizyczne, chemiczne i biologiczne gleby, ograniczają występowanie szkodników i chwastów. Jednocześnie jednak kompetują z warzywami o składniki pokarmowe, wodę i miejsce, dlatego też prowadzone są badania mające na celu zminimalizowanie tej konkurencji. Powodzenie uprawy warzyw z żywymi ściółkami zależy od właściwego doboru gatunków, terminu siewu lub sadzenia, a także sposobu ograniczania wzrostu wsiewek. Badania przeprowadzone w Katedrze Ogrodnictwa UP we Wrocławiu wykazały przydatność koniczyny białej i seradeli siewnej jako żywej ściółki dla pomidora i pora, a życicy trwałej dla papryki. Ograniczenie plonu biomasy wsiewek przez systematyczne koszenie spowodowało zwiększenie plonu owoców pomidora o 2 – 17,2%. Najkorzystniejszym terminem ich siewu w uprawie papryki był 9 i 12 tydzień wzrostu warzywa, natomiast dla pora 4 i 6 tydzień.