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Cover crops in organic field vegetable production

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ABSTRACT

Environmental protection and human health have recently become important factors when selecting food production systems. The wide usages of pesticides and synthetic fertilisers in conventional production cause environmental pollution and degradation. Cover crops can reduce the use of external inputs such as pesticides and fertilisers and can at the same time suppress weeds as well as improve and maintain soil fertility. Cover crops can also modify the microclimate which affects pest populations and diseases. The cover crops are usually terminated before the planting of the main crops, but some management practices use cover crops simultaneously with the main crop to, provide living mulch. Determining, cover crop species and management practices is based on the needs and goals of sustainable production.

The summarised studies show that further research is needed for best practices of vegetable production especially using living mulches and roller crimper for termining cover crops before planting vegetables.

1. Importance of cover crops in organic vegetable production

The wide use of pesticides and synthetic fertilisers in conventional food production is causing environmental pollution and degradation. Toxic contamination with pesticides can be caused by leaching through the soil profile into ground water, by surface runoff, by erosion from polluted soil particles or directly by pesticide application (Stolze et al., 2000). The negative aspects of intensive farming include increased wind and water erosion (Zachar, 1982). The loss of soil as a result of erosion can lead to a decline in organic matter and nutrient contents, the breakdown of soil structure and a reduction in water-holding capacity (Bosco et al., 2015). Other environmental problems include the development of pesticide resistance, crop pollination problems and honeybee losses, as well as fish, wildlife and micro-organism losses (Pimentel et al., 1992).

Conventional food often contains toxic pesticide residues. Several studies have shown that pesticides could cause health problems such as birth defects, nerve damage and cancer (Rekha et al., 2006). Many of the herbicide resistant weeds are present on all continents. The highest number of herbicides resistant species (49) occur in the USA and in Europe; most of them belonging to the family of *Poaceae*, *Amaranthaceae*, *Polygonaceae* and *Chenopodiaceae* (Chodová and Mikulka, 2002).

Sustainability has become an important issue in general economic development as well as agriculture and food production (Bavec et al., 2009). Over recent years environmental protection and human health have become important factors when selecting production systems. From both conventional and organic production systems comes the need for sustainable practices to provide long-term soil fertility (Price and Norsworthy, 2013). Compared to conventional production, organic farming minimises the negative environmental effects and is less dependent on external resources. Great attention has been paid to crop rotation and to the applications of organic fertilisers and soil conditioners in order to maintain soil fertility and organic matter content (Montemurro et al., 2013; Thorup-Kristensen et al., 2012), which has consequently reduced the ecological footprints of organic and biodynamic production systems in comparison with conventional and integrated ones (Bavec et al., 2012). In environmentally-friendly vegetable production the basic challenges involve suitable tillage, protection of the soil from degradation, erosion and nitrates leaching from the root zone. One of the possibilities for enhancing these goals relies on the inclu-

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sion of cover crops within the cropping system. Cover crops are not usually grown for harvesting but only to provide agroecological services at field, farm and landscape level (Thorup-Kristensen et al., 2012). Different plants and mixtures can be used for this purpose (Marr et al., 1998) as they contribute to manage soil erosion, soil quality, soil fertility, nutrient losses, weeds, pests, the water, diseases, biodiversity and wildlife within an agro-ecosystem (Lu et al., 2000). Vegetable crops have been promoted as being suitable for contributing to solve the problem of food security because they contain a lot of vitamins, minerals, fibre and a fair amount of protein and carbohydrates (Sridhar et al., 2014). The production system affects the chemical compositions of crops as shown by Jakopič et al. (2013) when compairing the chemical profile of dwarf French beans (*Phaseolus vulgaris* L.) from different production systems: conventional, integrated, organic and biodynamic and control groups. Beans from conventional plots contained the lowest levels of sugars, and many phenolics from various group. Similar results were present in the comparison of red beet (*Beta vulgaris* L.) from the same production systems, where samples from conventional plots had the lowest total phenolic content (Bavec et al., 2010). Some research and review studies have likewise found improved health value of organically versus conventionally produced vegetables, whereas others have concluded that the health value was not significantly affected (Brandt et al., 2011; Dangour et al., 2010; Seljåsen et al., 2013). Stockless organic farming has increased during recent years and increase the demand for alternative methods to ensure sufficient nutrients in organic production. When ruminants are absent, organic growers usually leave the biomass from clover/grass-ley in the field for their residual fertility effect and to control certain weeds (Stinner et al., 2008). Cover crops can be used within intensive vegetable cropping systems for improving weed management, soil fertility and crop yields (Ngouajio et al., 2003) and may represent an important method in organic vegetable production as they increase the biodiversity and the overall sustainability in cropping systems (Feil and Liedgens, 2001).

This review focuses on different aspects and possibilities of cover crop usages in organic vegetable production and provides an overview of the advantages and potential problems, and finally some proposals for the future development of cover crop management.

2. Weed management with cover crops

Weeds reduce yields by competing for nutrients, water, space and sunlight and are potentially responsible for 32 percent of crop losses worldwide (Oerke and Dehne, 2004). Competition depends on weed density and the plant's physical characteristics rather than the aboveground biomass. So, perennial weeds can be less affected by drought than annual weeds (Abouziena et al., 2014-15). Weeds compete for water, reducing water availability, contribute to crop water stress (Zimdahl, 2013) and they usually absorb nutrients faster than many of the cash crop species and accumulate them within their tissue in relatively large amounts.

Organic vegetable growers use different methods for weed control, such as false seed beds, transplanting instead of drilling, inter-row cultivation methods for controlling weeds in rows, flaming (Rasmussen and Ascard, 1993) and organic and inorganic mulches (Sanchez et al., 2008). Weed management can be expensive and labor intensive (Kristiansen, 2003). Some annual weeds can emerge and produce seeds in less than six weeks (Aldrich and Kremer, 1997), producing a few thousand seeds per individual plant (Mohler, 2004) and this is why high labor requirements in row crops and constraints on soil tillage and crop choice are identified as particular problems for organic weed control (Rasmussen and Ascard, 1993). In organic vegetable production of crops having weak competitive abilities, such as onions (*Allium cepa* L.), carrots (*Daucus carota* L.) and leeks (*Allium porrum* L.), more than 400 h ha^{-1} of hand weeding may be needed to reach a level of weed control comparable to that obtained with herbicides in conventional production (Vereijken and Kropff, 1996). Intra-row weeds are unaffected by inter-row cultivation such as hoeing. If they are insufficiently controlled, they cause major problems for organic growers of row crops such as vegetables and maize (*Zea mays* L.). Manual intra-row weeding can be laborious, particularly in slow-growing crops with poor weed competitiveness and can be expensive, time-consuming and difficult to organize (Van der Weide et al., 2008). Fourteen of the world's worst weeds are C4 plants and they produce two to three times more dry matter per used water unit when compared to C3 plants. The harvested crops are mainly C3 plants (76%) (Holm et al., 1977; Zimdahl, 2013). Climate change can affect the competitive outcome between C3 crops and C4 weeds; an increase in atmospheric CO_2 would favor the C3 crop over the C4 weed, whilst an increasing in temperature or reduced water availability would favor the C4 weed (Lundkvist and Verwijst, 2011). In the case of crimson clover (*Trifolium incarnatum* L.) used as a cover crop (up to 20% lower emergence because of lower temperatures of the soil), the maize yield was the same as the one obtained with conventional sowing (Bavec, 1998). Qasem (2009) discussed the effect of weed competition on the growth and yield of cauliflowers (*Brassica oleracea* var. *botrytis*) and argues that longer periods of weed infestations in cauliflowers greatly reduce crop growth and head yield. The average reduction in head yield and shoot dry weight was 89% and 81%. Early weed competition, two weeks after transplanting, reduce the average cauliflower head yield by 41%. Control of weeds, especially *Brassicacea* weeds, is essential for pest management, as they can host a variety of diseases and pests that can be transmitted to the cauliflowers (Dimson, 2001). Cover crops can be used in intensive vegetable production systems for improving weed management, soil fertility and crop yields (Ngouajio et al., 2003).

Cover crops and crop management systems can affect weed populations and yields in the short and long terms. Short-term effects are particularly important to growers who want to convert from conventional to organic production systems (Ngouajio et al., 2003). Most studies that have analysed weed community dynamics following conversion have shown an increase in weed problems. The composition of the weed seed bank hardly changed six years after conversion from conventional to organic systems (Belde et al., 2000). In the arable land of Southern Germany, Albrecht (2005) evaluated the weed seed bank in the soil of farm conversion to organic farming. The first three years after conversion, the total seed number increased from 4050 to 17,320 m^{-2}, and from the fourth to the sixth year it decreased to 10,220 m^{-2}. Over a two year period of different vegetable field management (reduced tillage-usages of cover crops and compost, and conventional tillage), weed densities were monitored and soil samples were taken to measure the effects of the treatments on weed seed bank and microbial biomass. The results showed that seed bank densities were lower in the organically managed fields, microbial biomass was nearly always higher in the organic management and significant negative correlations were found between the microbial biomass and emergence densities of some weed species. These results suggested that microbial biomass addition may lead to a reduction in weed emergence (Fennimore and Jackson, 2003).

Cover crops are usually terminated before the planting of the main crops. This can be done by incorporating the cover crop residue into the soil by tillage or by terminating and leaving the residue on the surface of the soil. By incorporating cover crops through tillage many weed seeds are stimulated to germinate and lower weed emergence can be expected when cover crop residue

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