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The effect of living mulches and conventional methods of weed control on weed infestation and potato yield

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ABSTRACT

Conventional methods of weed control for potato based on the application of herbicides have a number of shortcomings. These include herbicide cost, environmental pollution, reduced tuber quality, crop phytotoxicity, and the reduction of weed biodiversity. Recent findings suggest that the use of living mulch may be an alternative to chemical weed control. Therefore, this study was conducted to evaluate potato yield in response to various methods of weed control, including mechanical, mechanical–chemical and mechanical weeding treatments combined with sowing living mulches of white mustard, common vetch, Persian clover and tansy phacelia. Mechanical–chemical operations reduced the weed biomass by 78%, whereas, with mechanical measures this reduction was only 32%. The application of mechanical treatment combined with the sowing of living mulches contributed to the diminution of weed biomass by, on average, 54%. The total biomass of weeds and living mulches at these sites was still greater than the weed biomass at sites where only mechanical control was used. Each method of regulating the infestation of weeds caused a significant increase in the total and marketable yield of potato tubers in comparison with the control. The highest increase in yields was obtained using mechanical-chemical weeding methods, the lowest with the application of mechanical measures combined with the sowing of mustard and *phacelia*. The effect of weeding measures on the value of yield components was visible in the form of an increase in the mass of tubers and leaves and the number of tubers set. The mechanical–chemical method proved to be the best way to control weeds in potato cultivation, which confirms its suitability in both conventional and integrated production systems. However, the mechanical treatments coupled with sowing living mulches, particularly Fabaceae, could be recommended for use in organic production systems. This is because of their high degree of efficiency in limiting the biomass of weeds and low level of adverse effects on the production of potatoes.

1. Introduction

The presence of weeds on crop plantations is an immediate cause of a decline in yields and the worsening of crop quality. This problem is particularly apparent in widely spaced row planting, such as potato cultivation. Weed control on potato plantations is most frequently conducted based on mechanical tending measures and the application of herbicides. Conventional inter-row cultivation considerably reduces weed number and biomass (Mirabelli et al., 2005), but may also favor soil erosion (Dabney et al., 1993). Despite the application of herbicides, which ensures highly effective and wide-ranging weed control that has been in common use for over seventy years, new problems have appeared. These comprise, among others, new weed species in both plants and areas where they have, so far, been absent or where there have, until now, been herbicide resistant biotypes (Dekker, 1997). Changes in the dynamics of weed populations result from both chemical and other methods limiting weed infestation (agrotechnological, mechanical and biological). When seeking to prevent the negative effects caused by weeds, yield losses and economic issues as well as ecological aspects and the maintenance of habitat biodiversity should be also considered. According to Gerowitt et al. (2003), the total liquidation of weeds may negatively affect the functioning of ecosystems. Activities aimed at sustainable development favor the introduction of other methods to regulate weed infestation. One of these is the cultivation of cover crops including living mulches (Hartwig and Ammon, 2002). The ability to suppress weeds by various plant species sown as living mulches is presented in the literature and ranges widely from 34 to 96% (Ilnicki and Enache, 1992; Hoffman et al., 1993; Moynihan et al., 1996; De Haan et al.,

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1997; Ghosheh et al., 2004; Mohammadi, 2010). The positive role of living mulches is not limited to weed suppression. Their favorable effect has been observed, among others, on limiting soil erosion, the improvement of the biological activity and structure of soil, preventing nutrient leaching into the soil profile, limiting soil evaporation, diminishing daily soil temperature amplitude and limiting some pest populations (Wall et al., 1991; Leary and DeFrank, 2000; Dabney et al., 2001; Hartwig and Ammon, 2002; Nakamoto and Tsukamoto, 2006; Steenwerth and Belina, 2008). The plants that form living mulches grow simultaneously with the crop and compete with it for light, water and nutrients, as do weeds, so therefore, crop yields are lower (De Haan et al., 1997; Carof et al., 2007; Jędrszczyk and Poniedziałek, 2007). Numerous studies indicate a comparable or even greater crop productivity in this system of cultivation than in conventional ones (Ateh and Doll, 1996; Boyd et al., 2001; Adamczewska-Sowińska et al., 2009). In the above mentioned authors' opinion, the success of crop cultivation depends not only on the proper selection of species and the sowing date, but also on the method of limiting the growth of living mulches.

In this work, we studied the effect of the living mulches of white mustard, common vetch, Persian clover and tansy *phacelia*, as well as mechanical and mechanical-chemical weed control treatments on the infestation of weeds and potato yield cultivated on heavy soil. The research hypothesis assumes that living mulches protect potatoes from the adverse effects of segetal vegetation as effectively as traditional weed control methods.

2. Material and methods

2.1. Field experimental design

The investigations were conducted in 2009–2011 at the Experimental Station of the University of Agriculture in Krakow (50°07′ N and 20°05′ E, 271 m a.s.l). The field experiment was set up in a randomized block design in four replications. The experimental factors were the cultivar and weeding method. Two potato cultivars were assessed: early 'Vineta' and medium early 'Tajfun'. These cultivars differ not only in the length of their vegetation period, but also in the habit of plants and their resistance to *Phytophthora infestans*. 'Vineta' potato plants are characterized by their leaf habit and low resistance to potato blight, whereas, 'Tajfun' plants have a stem habit and average resistance to potato blight. The variants of weeding regulation comprised: the control (without weeding)–C, mechanical treatments–M, mechanical–chemical treatments–MCH, and mechanical treatments combined with sowing living mulch of white mustard (*Sinapis alba* L.)–MSA, common vetch (*Vicia sativa* L.)–MVS, Persian clover (*Trifolium resupinatum* L.)–MTR and tansy phacelia (*Phacelia tanacetifolia* Benth.)–MPT. Living mulch seeds were sown manually between rows of potatoes (at BBCH 31–32 phase) in the following amounts: phacelia and clover 15 kg ha^{-1}, mustard 20 kg ha^{-1} and vetch 120 kg ha^{-1}. A detailed description of treatments limiting potato weed infestation is presented in Table 1. The forecrop for potato was winter wheat. Following the wheat harvest, crushed straw was plowed and a catch crop (oilseed radish) was sown. In spring, mineral fertilizers were applied in the following doses: 150 kg N, 60 kg P_2O_5 and 180 kg K_2O ha^{-1}. Potato tubers were planted at 75 × 35 cm spacings in the second week of April. The harvesting plot area was 24 m^2. To prevent potato blight (*Phytophtora infestans*) metalaxyl-M + mancozeb (Ridomil Gold MZ 68 WG, 8 + 128 g a.i. ha^{-1}) was applied and propamocarb-hydrochloride + fluopicolide twice (Infinito 687.5 SC, 1000 + 100 g a.i. ha^{-1}). Thiametoxam (Actara 25 WG, 20 g a.i. ha^{-1}) was used against the Colorado potato beetle (*Leptinotarsa decemlineata* Say).

2.2. Soil and meteorological conditions

The experiment was located on Luvic Chernozem developed from loess. The arable soil layer (0–35 cm) revealed: medium abundance in P (54.1–60.5 mg kg^{-1}) and K (128.5–153.8 mg kg^{-1}); high Mg abundance (116.0–122.0 mg kg^{-1}); slightly acid pH (pH_{KCl} 5.8–6.1); sand content 120–130 g–kg^{-1}; silt 533–540 g kg^{-1}; clay 337–345 g kg^{-1}; organic C concentration 12.3–13.1 g kg^{-1} and total N 1.40–1.68 g kg^{-1}.

The characteristics of the precipitation-thermal conditions during potato vegetation are presented in Table 2. In the years 2009 and 2011, the total precipitation from April to September was approximate to the multi-annual average. However, an irregular distribution over the vegetation period was observed. Rainfall deficiency occurred in April 2009 and June 2011. Excessive rainfall amounts were noted in May and June 2009, and in April and July 2001. However, in 2010 unfavorable weather conditions resulting from an excessive amount of rainfall were noted over almost the whole period of potato cultivation.

2.3. Assessment of weed infestation, tuber yield and its structure

The weed infestation assessment was conducted using the quantity weight method at the potato plant maturation phase (BBCH 91–93). The biomass of weeds and undersown crops was collected from an area of 1 m^2 at two randomly chosen places on a plot. The fresh and dry masses of weeds and living mulches were determined in the samples. Prior to potato harvesting, tuber samples were collected from ten plants to determine the average tuber mass, the number of tubers per plant and the share of marketable tubers in the yield. The marketable fraction consisted of tubers with cross-section diameters exceeding 35 mm. The marketable crop yield was estimated on the basis of the marketable fraction share from which green tubers infected by disease or heavily deformed were separated. A significant deformity was considered to be indicated by a mis-shaping of the genetically established shape resulting from secondary tuber increment, healed cracks more than 2 mm deep and mis-shaping which makes the peeling of the potato by hand difficult, thus necessitating the excision of pieces of flesh measuring over 3 mm in mis-shapen places. Potato harvesting, during which the yield was determined, was conducted in the first week of October.

2.4. Statistical analysis

The results were subjected to statistical evaluation using an analysis of variance. Highly significant differences (*HSD*) for the investigated features were verified using Tukey's test at a significance level of $p < 0.05$. Relationships between weeds and living mulch biomass and crop yield and values of potato tuber yield components were estimated using a regression analysis.

3. Results and discussion

3.1. Biomass of living mulches and weeds

The research demonstrated the significant effect of the weather conditions, experimental factors and their cooperation on shaping living mulch and weed biomass on potato plantations (Table 3). In the group of tested species used as living mulches, Persian clover plants produced the largest biomass, whereas, tansy phacelia generated the smallest (Table 4). Weather conditions favoring mulch development occurred in 2009 when cover plant biomass was twice as big as in the other years of the experiment. Moreover, the lowest weed biomass was observed in 2009, mainly due to the lack of