Chapter 8

Potatoes (*Solanum tuberosum* L.)

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Additional information is available at the end of the chapter

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Abstract

In the area of potato production, targeted research solving concrete and actual problems of potato producers runs on Czech University of Life Sciences in Prague. In the last few years, we were focused on the production of new potatoes designated for early harvest, and we were focused on capitalization of yielding and qualitative characteristics of colored potato variety. These findings were further utilized and transferred to the system of organic farming. Firstly, we watched the influence of organic farming on yield and quality of tubers. Ecological ways of cultivation had strong negative influences on yield (decrease of 36%). From qualitative characteristics, organic farming increased the content of polyphenols by 10.2%, decreased the content of nitrates by 11.0%, and decreased the content of reducing sugars by 22.0%. We also evaluated the possibilities and impacts of mulch on potato cultivation. The mulch on top of ridges affected the temperature of soil (it increased the temperature by 0.2–0.6 °C under black mulching nonwoven fabric, and it decreased by 0.5–0.8 °C under herbal mulch). The mulch also affected soil humidity (herbal mulch decreased the soil humidity) and adjust weed infestation (20 to 92% lower), soil erosion (95% lower), the occurrence of Colorado beetle (the number of larvae was 22.8% lower with herbal mulch and 88.7% higher with mulching textile), and late blight in potato vegetation.

Keywords: Potatoes, organic farming, mulching, plant extracts, quality tubers

1. Introduction

Potatoes in Czech Republic belong to the minority crops cultivated in the system of organic farming. Like the principal tuber crop, it forms ca. 0.5% of the whole certified area of Czech Republic. The area of consumption potatoes actuate over is an area of 200 ha (in 2012, 3,277 tonnes of organic potatoes were harvested on an area of 230 ha).

Cultivating potatoes organically is very demanding on producers. Producers must deal with the absence of chemicals used on crop protection, the absence of synthetic fertilizers, the

obtainment of acceptable yield and good quality of tubers, and the necessity of applying all the procedures to create suitable conditions for growth and development of crops, like any other crop cultivated organically [1].

2. Environmental conditions

The potatoes originate from the mountain area that is why the foothill conditions suit them well. The optimum amount of precipitations for potatoes is 650 to 800 mm annually (60–70% of this amount during the vegetation). The precipitations during the first half of vegetation influence the growth of tops, the precipitations from May to half of July influence the number of tubers under the clump (with consideration of the time of planting and earliness of the variety). The precipitations in the second half of vegetation determine the weight of tubers. The deficiency of precipitations during the period of planting until emergence relatively positively affects the yield of tubers. Plants produce more roots and can manage water better [1].

In case of early potatoes, where the well-timed soil preparation and well-timed planting is important (it occurs until the end of April in the Czech Republic), we choose the fields with soil easily processed early in the spring. From the point of view of the regulation of fungi diseases, we prefer the open fields (air locations which provide quick drying of plants). The good choice of location can regulate the occurrence of late blight [2].

3. Choice of suitable variety

Like any other crops, the choice of variety in the system of organic farming is crucial. The quality and health conditions of chosen planting material are vital, too. Generally recommended are the varieties with shorter vegetation period (with quicker initial growth and quicker tuber formation), lower nitrogen requirements, and higher resistance against diseases [2]. In case of varieties with longer vegetation period (usually intended for autumn consumption and storage), it is important to choose varieties highly resistant against late blight [3].

The choice of variety is submitted to the purpose of production (direct consumption, washing or peeling, on food-processing products such as chips and potato puree). For the consumer varieties, the determining aspects are qualitative indexes expressed by table value. It is commonly expressed by so-called cooking type of tubers (based on evaluation of consistency of cooked tubers, moisture, structure, mealiness, darkening, and taste). For this purpose are potato varieties divided into four groups: (1) cooking type A – consistent, tallowy, of delicate to semi-delicate structure, cannot be overcook, very weakly to weakly farinaceous tubers (suitable for preparation of potato salads or for meals when it is necessary to keep the shape even after cooking, like in case of soups, and for common consumption); (2) cooking type B – semi-consistent, semi-farinaceous, pleasantly moist to dry (suitable generally as a side dish); (3) cooking type C – soft, farinaceous tubers, semi-moist to dry (suitable mainly for preparation

of purees, potato dough, and potato pancakes); (4) cooking type D – rough, strongly farinaceous, and can be overcooked (undesirable for consumption purposes, usable for starch processing or for other products).

Until the present, no compact information is available in Czech Republic concerning the comparison of potato varieties in the system of organic farming.

The colored varieties are an interesting area for organic farming. They are more frequent in organic farms abroad. There is a speciality from the viewpoint of both appearance (colorfulness and shape of tubers) and nutritional value (mainly the high content of antioxidants and pigments). This area has been, in the long term, intensively examined by Prof. Ing. Karel Hamouz, CSc. and his colleagues from the Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences (CULS) in Prague. Their studies are deepening the known information about these varieties (antioxidant activity, content of anthocyanin in raw and cooked tubers). It is possible to find between them perspective varieties usable for the consumption or processing (production of natural dye agents or syrups). To this group belongs variety Valfi, which originates in Czech Republic (violet variety bred in Potato Research Institute Havlíčkův Brod).

4. Innovations in cultivation techniques

4.1. Nutrition and fertilization

The need of nutrients, specifically the plant uptake, is given by the level of yield of tubers. Potatoes need, in average, 80–130 kg of Nitrogen per hectare (it is possible to count the uptake of 40–50 kg of Nitrogen, 8.8 kg of Phosphorus, 22 kg of Potassium, and 8.4 kg of Magnesium per 10 tonnes of tubers). This need is covered by applied barnyard manure, green manure, compost, cattle slurry, or digestate. Then the level of available nutrients depends on the level of biologic activity of the soil, i.e., mineralization conditions (which are supportable by hoeing). It is also possible to enhance the biological procedures in soil by many preparations on the basis of nitrogen fixators such as Azoter or AlgaSoil-natural organic fertilizer made of seaweed. These preparations were tested in small-plot experiments on CULS's land.

4.1.1. Experimental verification

Azoter was applied by spraying a dose of 10 liters per hectare to the furrows during hand-planting. AlgaSoil was applied to the furrows near tubers in a dose of 70 kg per hectare during planting. During vegetation, the content of chlorophyll was measured by hand using the Chlorophyll Meter SPAD 502 (in five terms from the 56th to the 100th day after planting), and in case of preparation, AlgaSoil leaf samples were taken twice for analyses of nitrogen and other nutrients. After harvest, tubers were sorted by size into two groups (tubers under 4 cm and over 4 cm).

The application of Azoter supported nitrogen fixation in the soil, thanks to the three genus of nonsymbiotic bacteria contained in this preparation (*Azotobacter chroococcum*, *Azospirillum*

braziliense, and *Bacterium megatherium*). This was also shown in plants with higher chlorophyll content in their leaves (Figure 1). The application of Azoter had positive effect on the yield of tubers that was higher by 1.1 t per hectare in comparison with untreated control (Figure 2).

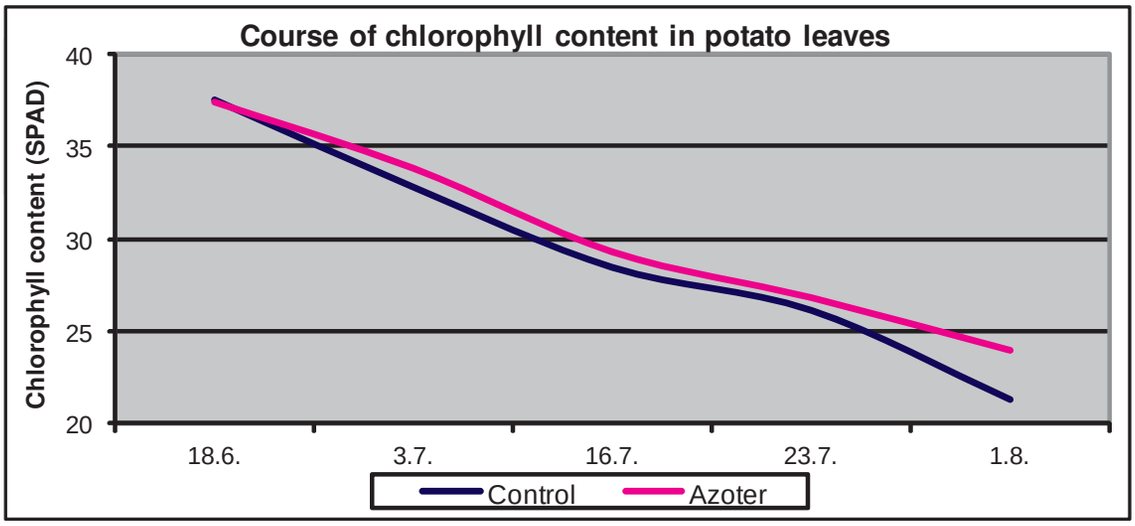

Figure 1. Chlorophyll content in potato leaves of Katka varieties in 2013 when measured by Chlorophyll Meter SPAD 502.

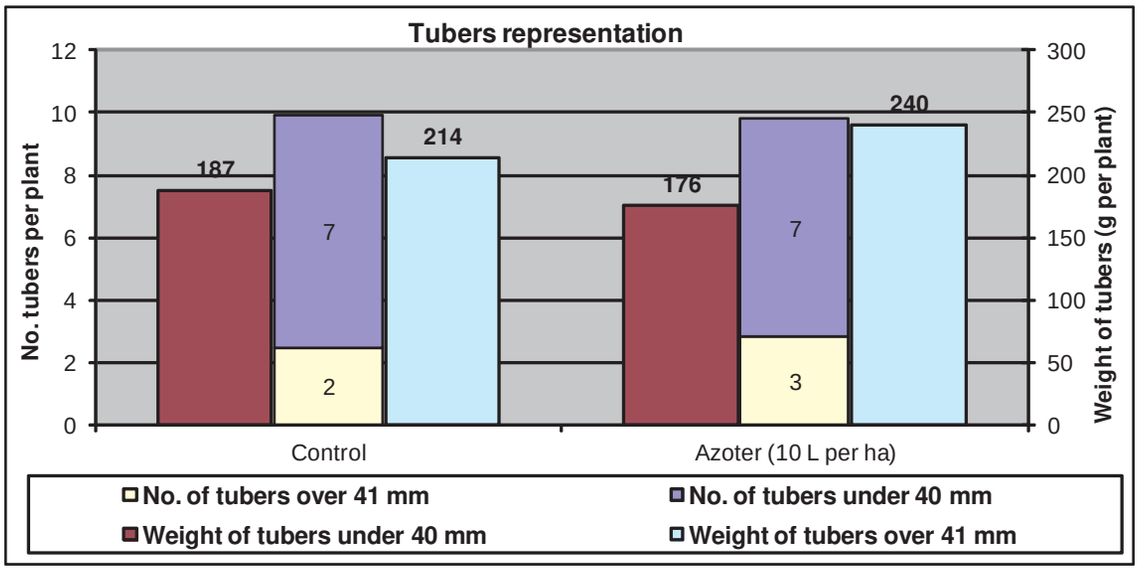

Figure 2. The final effect of Azoter on the numerical representation and weight of tubers under a clump of Katka variety in 2013.

AlgaSoil is a natural organic granulated fertilizer based on seaweed, which should work as a soil conditioner, ameliorate the soil structure, and increase the microbial activity and the utility of nutrients in soil. AlgaSoil also increased the chlorophyll content in leaves (Figure 3).

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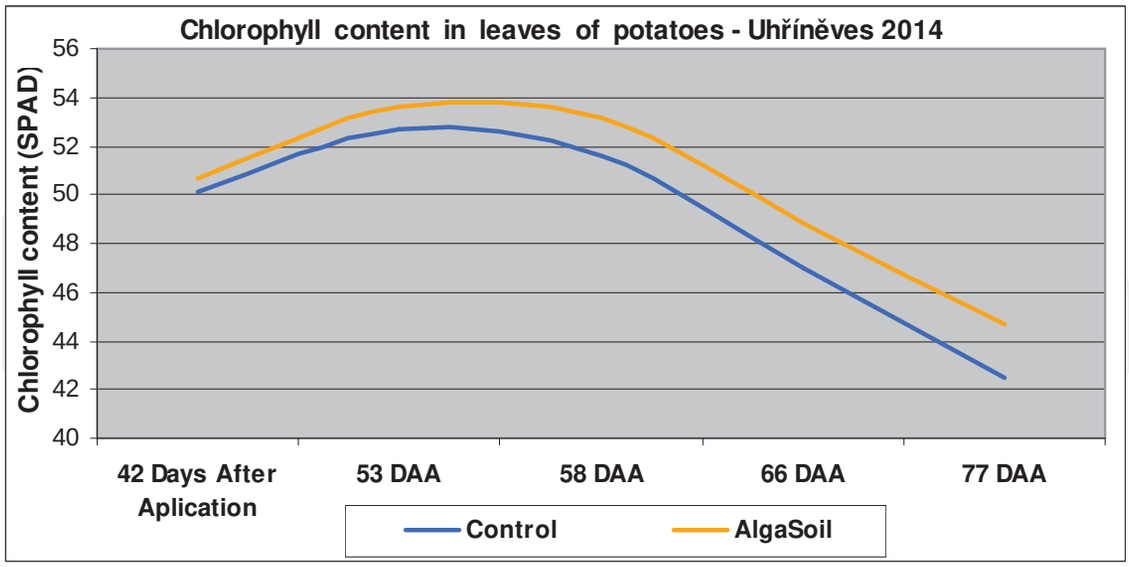

Figure 3. Course content of chlorophyll in the leaves after application of the fertilizer AlgaSoil.

There is known positive correlation between chlorophyll content and N content in plants [4]. The N content in variants treated by AlgaSoil (Figures 4 and 5) was 6% higher than in controls after first sampling (58th day after planting) and 24% higher after the second sampling (77th day after planting). Similarly, the chlorophyll content was higher on the 58th day by 3% as well as on the 77th day.

The AlgaSoil affected the size and final yield of tubers, which was higher by 3.6% (Figure 6).

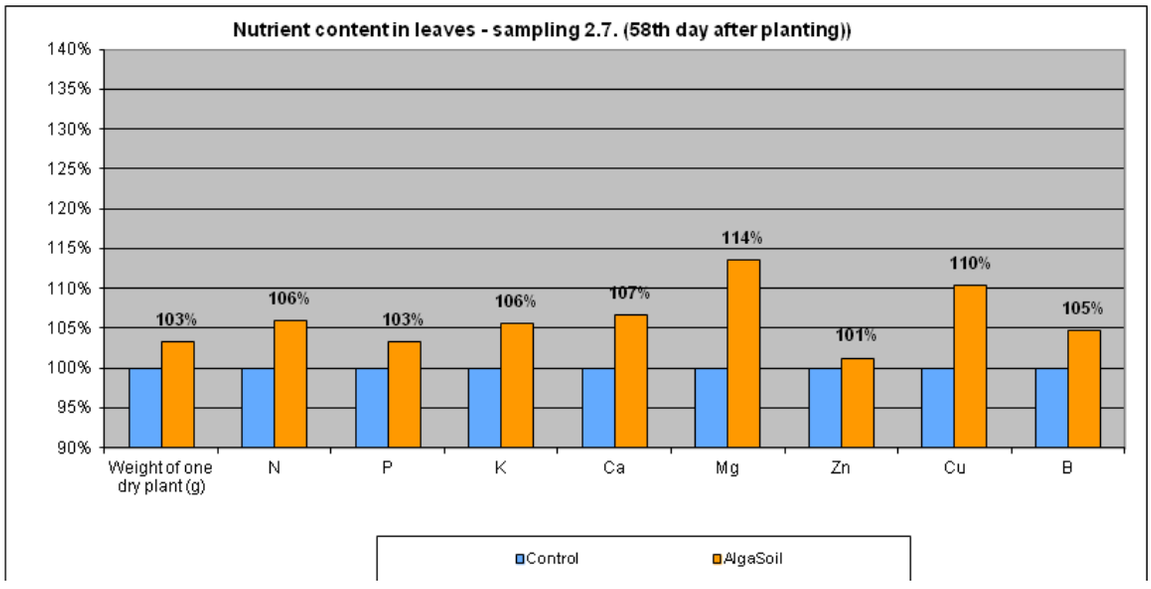

Figure 4. Results of laboratory analyses on the primary nutrients content in the leaves of potatoes on the 58th day after planting [14].

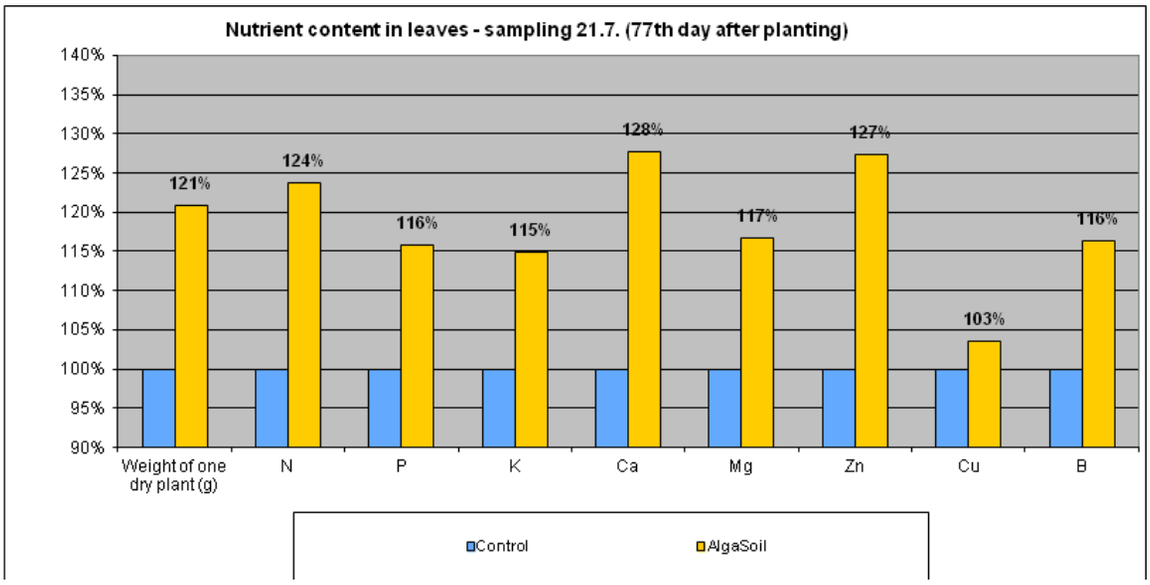

Figure 5. Results of laboratory analyses on the primary nutrients content in the leaves of potatoes on the 77th day after planting [14].

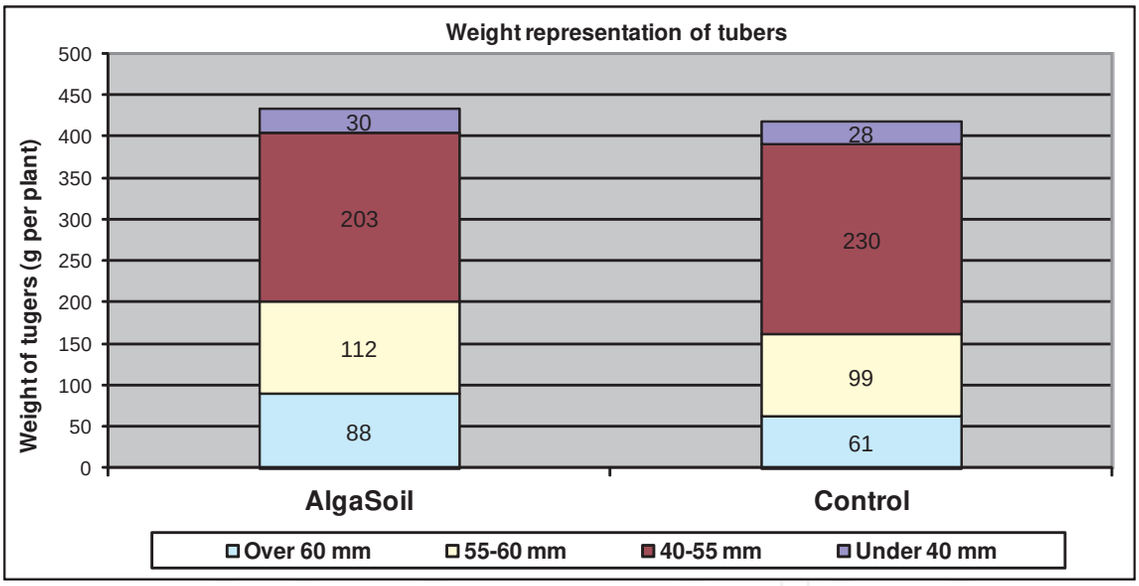

Figure 6. Size analysis under a clump of tubers after treatment with AlgaSoil.

5. Preparation of planting material and planting

The planting material intended for the conditions of organic farming is necessary to sprout or at least to bud. These procedures lead to lower sprout production, which means lower stalks production. This would express as lower tuber setting under the clump, but the tubers would

reach the consumption size sooner. So, by these methods, we can increase the earliness and partially anticipate the decrease of production as a consequence of late blight attack. In case of early term of harvest combined with sprouting, it is possible to count the increase of yield of consumption tubers by 7–8% [8]. The disadvantage of the procedure is the increase of work requirements during biological preparations both ensuring the sprouting or budding and planting. The sprouted tubers are possible to plant only with suitable technology (potato planter or disc planting mechanism).

5.1. Size sorting of planting material

Size sorting of planting material on desired size can influence the shortening of vegetation of very early varieties and their yield of tubers.

5.1.1. Experimental verification

In a precise field experiment, three sizes of planting material were compared: variant A (tubers 25 to 35 mm), variant B (tubers 40 to 60 mm), and variant C (65 to 85 mm) with the aim of finding the influence of tuber size on potato yield characteristics. In the experiment, a very early variety called Impala was used. Every variant was set in three repetitions under non-woven fleece textile (Pegas-agro 17 UV) and an uncovered variant was used as control. The harvest and evaluation of yield happened on the 56th to 68th day from planting.

From Table 1, we can recommend big sorting of planting material (variant C) for very early harvest of early potatoes (for regular vegetation and for vegetation covered with nonwoven fabric CFT). It was verified by papers dealing with the size of planting material [5–7] that big sorting of planting material has a marked effect on tuber yield, even on earliness of vegetation (quicker start, thanks to bigger content of energy storage molecules, and quicker ability of regeneration in case of frozen sprouts).

Variant	Yield of ware potatoes (tons per hectare)	Average weight of 1 consumer tubers (g)	Total no. of tubers per plant
	Without cover – control (C)		
AC	12.7^{a}	48.9^{a}	9.7^{a}
BC	15.8^{ab}	40.4^{b}	13.3^{b}
CC	19.3^{b}	52.9^{a}	13.3^{b}
$HSD_{0.05}$	*4.02*	*7.73*	*2.65*
	White fleece textile (FT)		
AFT	17.8^{a}	57.4^{a}	9.5^{a}
BFT	21.2^{ab}	60.2^{a}	10.2^{ab}
CFT	24.5^{b}	63.3^{a}	12.6^{b}
$HSD_{0.05}$	*5.91*	*11.25*	*2.72*

Table 1. Effect of seed tuber size on yield and yield characteristics in the stands that cultivated without cover (C) and cultivated under nonwoven fleece textile (FT) in 2005–2006

5.2. Pre-sprouting

The aim of pre-sprouting is the formation of 15 to 25 mm long, colored, and firm sprouts with basis of roots. It is an intensive procedure, which can hasten emergence, vegetation growth, and even harvest [1]. From the view-point of organic farming, prepared planting materials can ensure quicker emergence of vegetation, which means better concurrence against weed. Quicker emergence also reduces the appearance of black scurf of tubers and stem canker. Pre-sprouting is a suitable procedure to speed up tuber production, and in case of late blight and Colorado potato beetle, tubers are in late state of consumption (pre-sprouting increases the yield assurance).

5.3. Treatment of planting material before planting

In conditions of organic farming, the grower has the possibility to treat potato planting material with allowed agents (this can mainly ameliorate and speed up the emergence of potatoes, than protect it against pests and diseases as in conventional cultivation). For interest, it is possible to specify some preparations, which we have tested (Albit, Amalgerol, Galleko, Special, Polyversum, Softguard). It is possible to apply these preparations on tubers before planting (ultra-low volume pesticide application of tubers in pre-shooting room) or directly during planting on the potato planter. It even partially treated the soil nearby simultaneously [1].

6. Treatment before emergence

The treatment before emergence consists of ploughing and harrowing with full mechanical cultivation. The first operation after planting is blind ploughing after 7 to 10 days. In case of early potatoes, it is suitable for quicker emergence to cover less with soil or to start with harrowing (chain harrow or tine harrow for regulation of emerging weeds in phase of cotydelons). Harrowing also disturbs the soil crust, decreases the height of the top soil above the tubers (meaning warmer through the ridges), so they emerge quicker [8]. With ploughing, we destroy weeds in furrows and on the sides of ridges (it is done most frequently 7 to 10 days after harrowing).

For acceleration of vegetation and early harvest, it is possible to cover the vegetation after planting with white nonwoven fleece textile or perforated foil. The nonwoven fleece textile also provides protection against low temperature, but it limits mechanical cultivation and in case of temperatures higher than 22 °C, plants can be damaged under fleece. In an average of nine years, nonwoven fleece textile probably increased yield of tubers by 23.2% in average of years and varieties in early terms of harvest (ca. 60 days after planting) [9].

It is possible to apply mulching materials on the soil surface (on ridges) to improve soil and nutritional conditions. The main benefits of mulching materials are evaporation regulation, reduction of temperature fluctuation of the soil, and repression of weeds. They can be sources of nutrients and can limit erosion and occurrence of some pests. The right choice of suitable mulching material is important for concrete stand.

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The first group are organic (herbal) mulch, such as straw, chopped grass, biomass of intercrops, or other plant material, that can be applied on the ridge surface and usually come directly from the farm. For their application, we recommend manure spreaders, separators of bales of straw, or bedding semi-trailer. The straw is used as mulch mainly abroad. It is easy to store, so it is available during the whole vegetation time [10].

The second big group of mulching materials are plastic products or other waste materials (for example, paper). Considering the origin of plastic and the impact of its application on large-area agriculture, it is necessary to reduce this material and suitably replace it. The use of biodegradable foil or black nonwoven textile can bring certain easement in this area. Targeted processing and recycling of waste paper is possible to produce paper mulching matting with different firmness and durability. The firm VUC Services (www.ekocover.cz) is engaged in this processing and production in the Czech Republic.

In connection with mulch application, it is necessary to mention that mechanical cultivation during vegetation is not possible because of the mulching fabric or foil or it may be limited (in case of plant material). However, past studies imply that the absence of cultivation has no negative effect on tuber yield.

6.1. Application of mulching material

The experiments with herbal mulch, wheat straw, and black textile mulch (weight 50 g/m^2) conducted from 2008 to 2012 brought many answers in the area of temperature change, soil humidity, level of material degradation, biomass of weeds, chlorophyll content in leaves, occurrence of Colorado Potato Beetle (CPB), and Late Blight on tubers and size representation of tuber under clumps [11]. In 2014, we enlarged the experiment by other materials: biodegradable foil and two types of paper matting EkoCover (short-time matting with weight 270 g/m^2 and medium-term matting with weight 800 g/m^2).

6.1.1. Experimental verification

It was found that herbal mulch functions as an isolation and during tracked time decreased the soil temperature by 0.8 °C. Mulch also affected soil humidity conditions when the lowest soaking pressure of soil (that means the highest humidity of soil) was registered at mulching textile. Soil humidity with herbal mulch was in average of years comparable to the unmulched control.

The changed humidity and temperature conditions of soil influence even the nutrient availability in soil [12] and the whole nutritional state of vegetation within it. The source of nutrients for plants can even be its own herbal mulch. The chlorophyll content in leaves was higher by 3.7% in the case of chopped grass applied after planting or before emergence, and it was higher by 2.3% in the case of control (Figure 7). We found the lowest content of chlorophyll in leaves after using black mulching textile and straw (Figure 7 and 8). From known correlation of chlorophyll content and nitrogen content in plants [13, 14], it is possible to deduce that this vegetation had lower nitrogen content in leaves (nitrogen in soil was probably used in straw decomposition not by plants). Other mulching materials (such as paper mulching matting,

biodegradable foil) applied after planting (Figure 8) induced lower chlorophyll content in leaves.

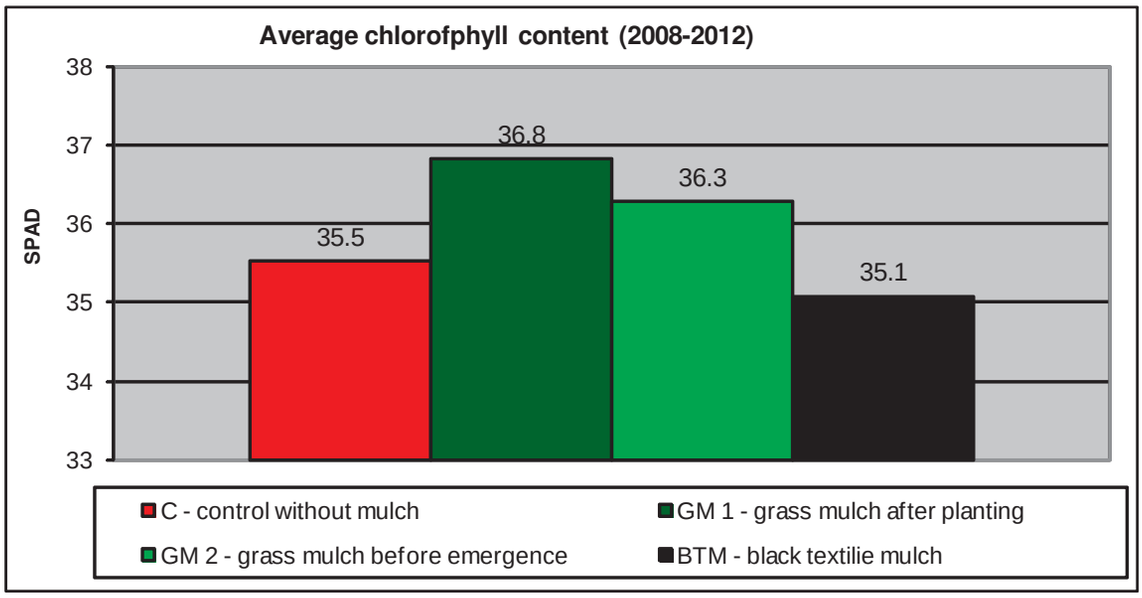

Figure 7. The chlorophyll content (SPAD in units) for each variant of mulch.

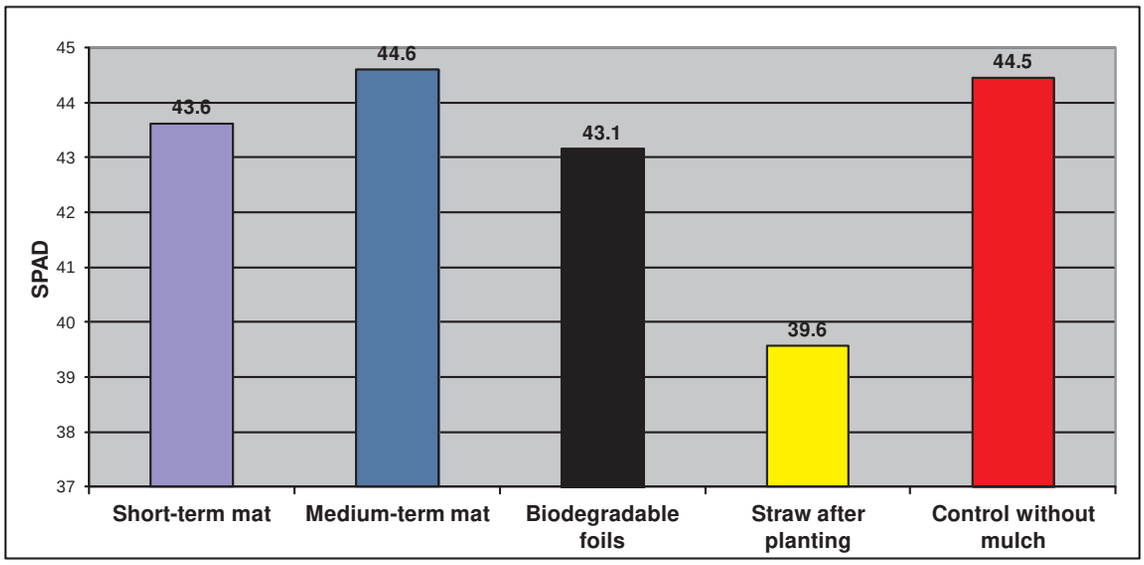

Figure 8. Chlorophyll content in experiments with biodegradable materials (Uhříněves, 2014).

Positive humidity and nutritional conditions affect even growth and biomass of weed and its regulation is ensured only by mulching fabric, biodegradable foil, and paper matting. The application of mulch (or the present weed biomass) is an effective way of soil protection against erosion because the soil is most vulnerable since the planting [15].

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The mulch also affects the occurrence of CPB and the following damage of vegetation by the larvae of CPB. Chopped grass reduced the occurrence of CPB (Figure 9) and on the contrary, black mulch textile increased its attack (probably because of higher temperature of soil). The lowest occurrence was found on plots with applied straw. Similarly in 2014, the lowest occurrence of larvae was on straw and foil (Figure 10).

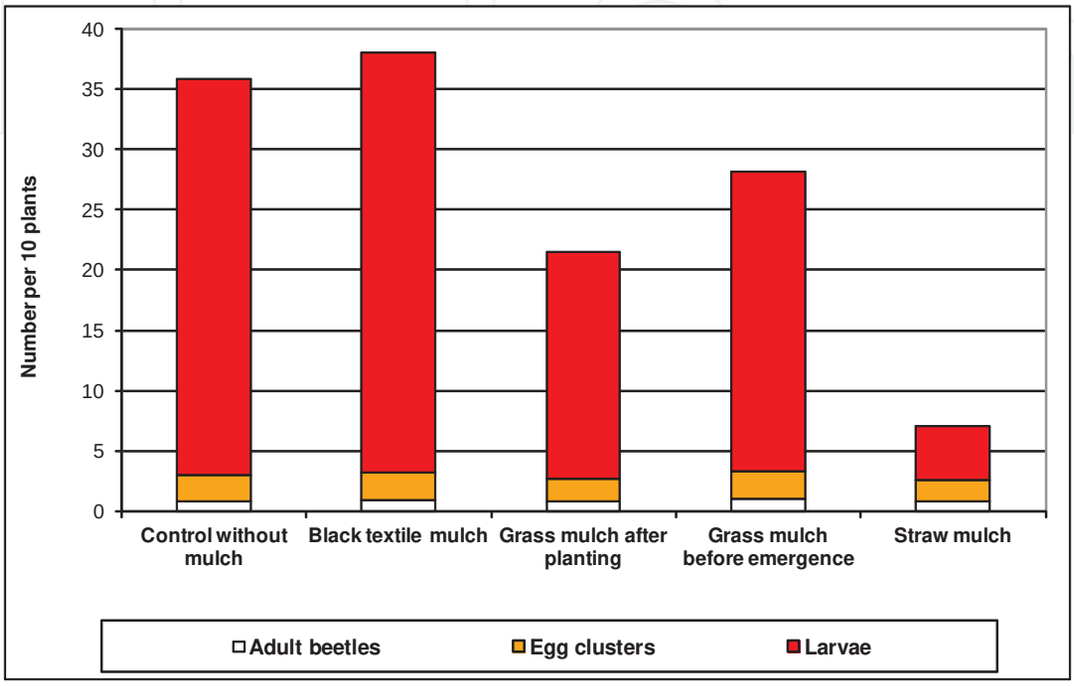

Figure 9. Dependence of the occurrence of beetles, nests with eggs and larvae of CPB on used mulching materials on station Uhříněves (2008–2012).

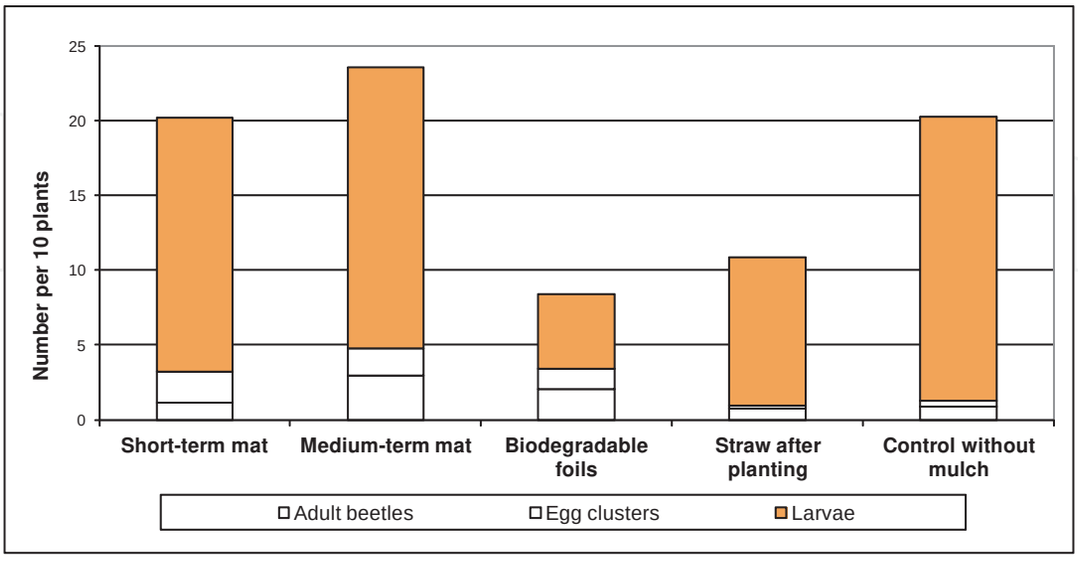

Figure 10. Dependence of occurrence of beetles, nests with eggs and larvae of CPB on used mulching materials (Uhříněves, 2014).

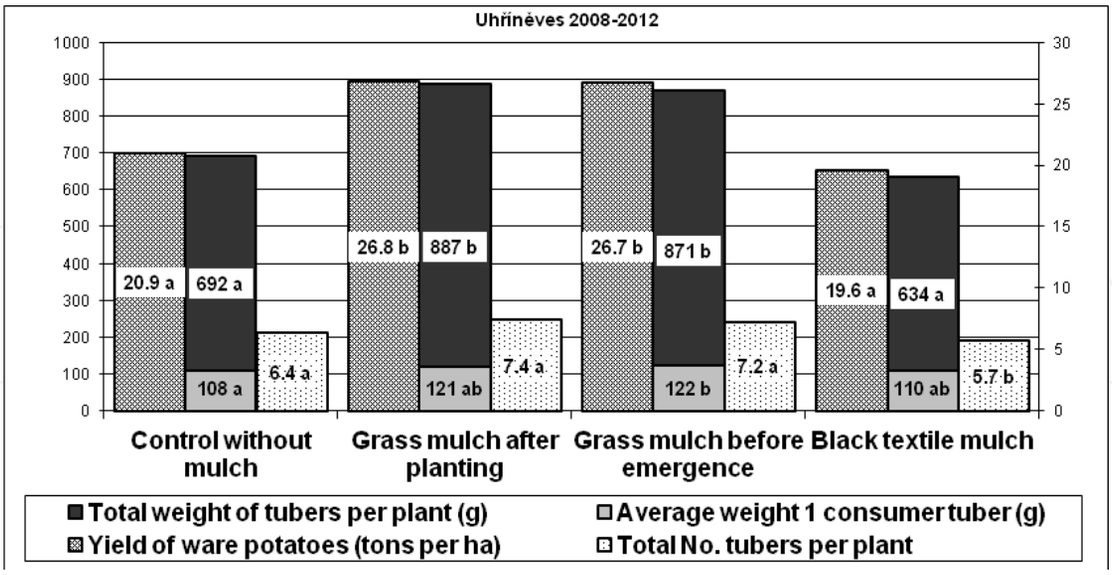

Figure 11. Total weight of tubers, number of tubers, and yield of ware potatoes at various ways to mulching in Uhříněves (different letters for average mean statistically significant differences at the 95% confidence level).

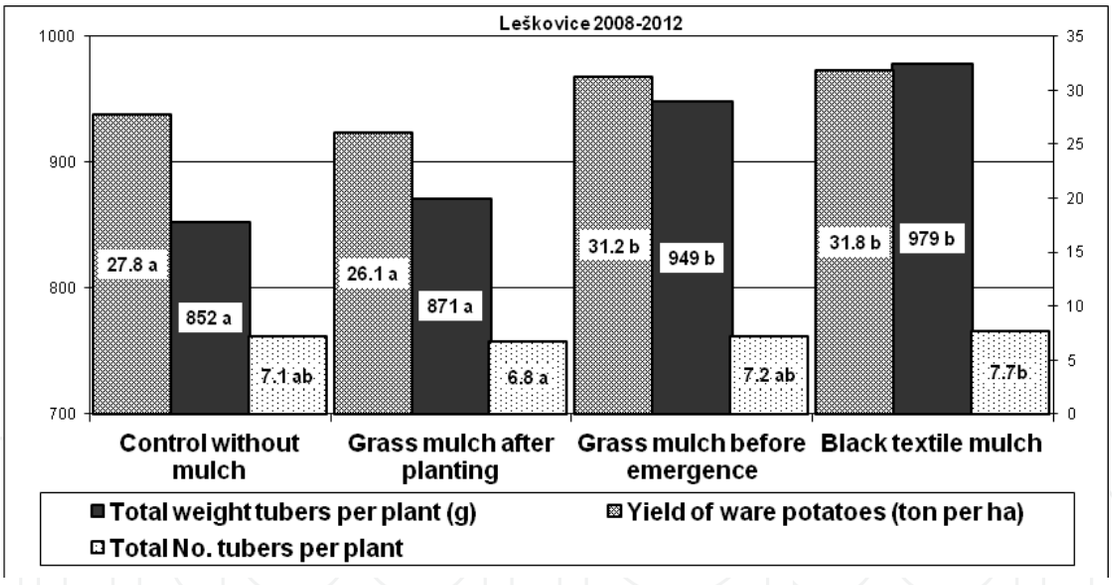

Figure 12. Total weight of tubers, number of tubers, and yield of ware potatoes at various ways to mulching in Leškovice (potato growing region).

The abovementioned factors affect consequent tuber production (Figures 11, 12 and 13). The higher yield of consumption tubers was after the application of chopped grass. Yield of tubers in Uhříněves was lower after the use of black textile mulch than at non-mulched control because of the great attack and damage of vegetation by larvae of CPB. On the contrary, the positive result was achieved with textile mulch on site in the potato processing area where the occurrence of CPB was not high. Black textile mulch positively increased the temperature of the soil and water content in the soil. It produced better conditions for growth and on this site

was the highest yield of consumption tubers with textile mulch (higher by 4 t/ha against control).

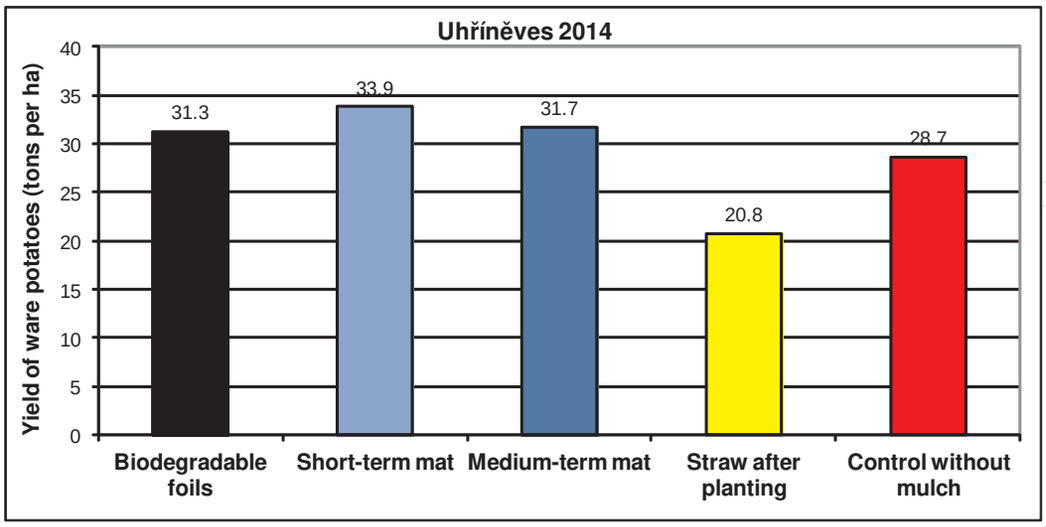

Figure 13. Yield of ware potatoes depending on the selected mulching material.

7. Treatment after emergence

After emergence of vegetation, we continue in mechanical cultivation, which consists of ploughing (eventually the use of weeder) and careful harrowing. Freshly emerged stalk is sensitive on damage, so we should practise harrowing only exceptionally. When the stalk is green and firm, harrowing is possible without great damage in the afternoon hours (when the stalks are withered). In that case, it is beneficial to use tine harrow. It damages stalks lesser than the chain harrow.

According to the need, ploughing (eventually harrowing) is repeated approximately 3 to 4 times until the full canopy closure [8]. The last cultivation intervention should be made until the formation of flower buds when they pile up the ridges as a precaution for transition of late blight from stalk to tubers.

In case the plant height reaches approximately 20 cm, it is suitable to apply (on the leaf or partially also on the soil) supportive preparations (Albit, Alga 600, Alginure, Amalgerol Premium, Ferbiflor, Lignohumate B, PRP-EBV and others).

8. Regulation of pests and diseases

Potatoes can have many diseases (i.e. viral, bacterial, or fungal). For the major part, it is possible to only apply preventive procedures. Direct intervention is possible only in case of fungal diseases.

Potato pests attack mainly stalks and tubers. Some of them are also transferring agents of diseases (for example, aphides transfer plant viruses).

8.1. Late blight (Phythophora infestans)

Late blight is a serious disease on the worldwide scale. If the conditions are favorable, it spreads quickly, and after three weeks, it is able to totally defoliate vegetation [16]. Its regulation in conditions of organic farming is very difficult. The grower must maximally use available preventive methods of pathogen regulation. The assumption is to use known pathogen biology including his weakness.

Varieties of potatoes show marked differences in susceptibility to the late blight. The choice of variety is deciding, because the possibilities of direct crop protection are limited in organic farming. Abroad are already known resistant varieties (Defender, Jacqueline Lee) or varieties with high resistance against it (Sapro Mira, Bionta).

Early term of planting and biological preparation of planting material reduce mainly the risk of yield loss because the later the epidemic shows up (in later stage of plant development), the bigger the tubers are and the lower the losses of yield.

For regulation of late blight, it is possible to use methods that decrease the time of moistening. In case of irrigation need, it is preferable to use the drop irrigation than the spray irrigation (it also saves water). Time-controlled irrigation can markedly decrease the time of moistening. The best time of irrigation is early in the morning, during dew [17]. Unambiguously, it is not suitable to irrigate in late afternoon hours when the stalks cannot dry up before sun-down and usually stay moistall night, which leads to wetting for a very long time and to higher risk of diseases.

The recommended methods of regulation of late blight are suitable organization of vegetation (spacing and row orientation). Orientation of rows is recommended for dominant air circulation. Wide rows (80 to 90 cm) can enhance air circulation and wider rows (90 to 120 cm) prevent canopy closure, which assure longer time of air circulation and makes vegetation dry faster after precipitation. But after, there is lower soil shading and higher concurrence of weeds. Weed occurrence in potato vegetation decreases air circulation and increases the infection risk. In addition, those weeds can be hosts to late blight (*Solanaceae*).

It is also possible to introduce some plants in the vegetation that can reduce the risk of late blight. These new plants form a barrier against the spreading of spores. Some studies mention positive effects of intercropping potatoes with wheat. Potatoes are planted diagonally to dominate air circulation and wheat is sowed in the furrows. Another alternative method verified in the project Blight-MOP with positive result was alternate (band) cultivation of varieties resistible and sensitive to the late blight on one site or cultivation of more varieties in one row. This mixture of varieties can improve control over pathogen, but induce practical problems with harvest and variety separation [18].

Balanced plant nutrition including microelements decreases the possibility of late blight infection of potatoes [1]. Overdose of nitrogen fertilizer forms less tubers and lots of stalks that

dry up slower, which increases the infection risk. More resistant are mature "older" stalks [16] well-supplied with potassium [1].

In case of occurrence of late blight in the vegetation (when preventive methods did not work), it is possible to alternatively approach the destruction of the first infected plants on site. It can stop or slow down the spreading of the disease to the rest of the site. We have to eliminate not only the visibly ill plants, but also the plants around the focus point because they may be infected though without any symptoms. The appearance of symptoms takes around three days to one week (depending on environmental conditions). Results of these methods are the elimination of many apparently healthy plants, which are enclosed by the infected plants. For these purposes, it is possible to use, for example, a propane-butane burner, which can ensure the destruction of spores.

Opinions on the use of preparations on the basis that copper is markedly different (grower to grower, state to state) is mainly dependent on legislation. In some states, copper fungicide was limited. According to the EU, they determined a boundary of 6 kg of Cu/ha/year. In Scandinavia, copper fungicides cannot be used at all. Growers there are trying to use alternative products, but with smaller success. In present conditions, the ban of copper fungicide could destabilize the production of organic potatoes because there are no other effective alternatives for blight regulation.

In our experiments from 2009 to 2011, solutions of plant and animal origin were tested and supplemented with five hopeful commercial preparations (Figure 14). First, preventive spraying was always done before occurrence of blight, and consequent treatment was done according to prognostics and signalization. The site, where the experiment occurred, was typical for lower blight attack on stalks and tubers, so even the use of alternative spraying had satisfactory results compared with copper fungicide. We also observed mild phytotoxicity of preparation with the extract from walnut tree (*Juglans regia* L.), which probably had an effect on tuber yield.

Treatment	Late Blight on the leaves (1–9)	Tuber blight		Tuber yield (tons per ha)
		Number (%)	Weight (%)	
Kuprikol 50	7.6	0.4	0.3	26.1
5% solution of biomilk	7.5	0.6	0.5	23.3
10% extract from *Juglans R.*	7.6	1.0	0.9	22.6
MycoSin VIN*	7.6	1.1	0.3	28.0

*Note:** Only years 2010–2011, 9 points – without challenge

Table 2. Incidence of Late Blight on the leaves and tubers of potato (expressed in % of infected leaves and infected tubers)

Another comparison of commercial preparations is represented in Figure 14. Surprisingly, the best results on blight regulation were observed with preparations against Colorado potato beetle (Neem Azal T/S and safety net). It affirmed the recent finding that regulation of CPB in organic farming (regulation of leaf damage) has a positive effect on the decrease of blight in potato vegetation.

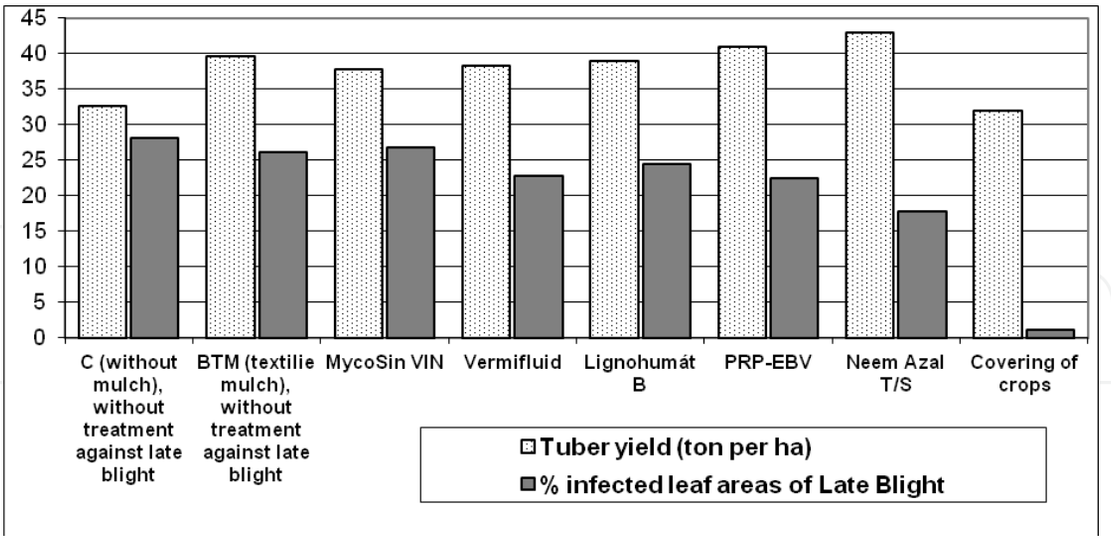

Figure 14. Results of applications support preparations in average varieties (Monika, Jelly, and Red Anna) on station Uhříněves (2009–2011).

8.2. Colorado potato beetle (Leptinotarsa decemlineata)

CPB is a pest of potatoes, which after overpopulation induce serious damage of vegetation and decrease of tuber yield [1]. The biggest damage is caused by its larvae. Their overpopulation can lead to clean-eating, leading to the destruction of vegetation. This pest should not be undermined.

From preventive precaution, it is possible to recommend pre-sprouting and early planting, not place the potatoes on near-by sites (easily admissible for beetles), aim for support of natural enemies (lady-bugs, heteroptera, earwig, and birds such as blackbird, pheasant, or partridge), and application of mulch. From variety experiments are some possible different attacks (attractiveness of varieties for Colorado beetle). The deciding factor can be the content of glycoalcaloids or trichomes on leaves.

Direct crop protection on large area consists of applications of biological insecticide. Currently registered in the Czech Republic are two effective substances: azadirachtin (in Neem Azal T/S) and spinosad (in Spintor). In some states, it is possible to use biological preparation Novodor FC on the basis of bacteria *Bacillus thuringiensis* var. *tenebrionis.*

On smaller areas, it is possible to use labor-intensive way of hand collecting (mainly of spring beetles), which aims to prevent the laying of eggs. Uniquely, it is possible to find special shakers or blowers (eventually vacuums), but they are usually homemade machines or prototypes.

9. Preparation of harvest and harvest methods

Removing stalks happens usually early in organic farming because of late blight (with the removal of stalks, we follow the regulation of inoculum and spread of infection on tubers). In

case of very early potatoes, we remove stalks mainly for simplification of harvest and hardening of the peel (in this case 2 to 3 weeks before planed harvest). To remove the stalks, we use a mechanical stalk crusher in organic farming.

In case of production of planting material, stalk removal is necessary and unavoidable mainly from the point of view of viral regulation (eventually the pass of aphids). A more efficient procedure (mainly with planting material) is thermic removal of stalks (fire, vapor, or nitrogen).

On certain conditions it is possible to use even the tweezers of stalks (only with erect vegetation on consistent soil so it would not tear out the tubers). These machines are not available in the Czech Republic, so there are not even used [19].

10. Conclusion

Existing knowledge and experiences in the technology of cultivation of organic potatoes are continuously innovated and specific issues of growers are addressed. Especially valuable are the findings in the field of soil treatment and processing as they affect the soil state and the soil edaphon, which has an irreplaceable role in the system of ecological agriculture. Adequate soil treatment and application of organic materials, combined with biological preparations, have positive impact on the nutritional state of vegetation and are effective ways of how to balance nutrients in organic farming. In our experiments, the nutritional state of vegetation and the tuber yield improved by using soil preparations of Azoter (yield increased by 1.1 t/ha) and AlgaSoil (increase by 0.9 t/ha). The growers solved the nutrient deficit found during vegetation only marginally. Even here, the supply is growing and the organic grower already can apply liquid or organomineral fertilizers with quick nitrogen effect on the basis of actual nutritive state of plants. Another big group of preparation is the so-called supplemental plant preparations. We had the chance to verify some preparations of this group (Albit, Alga 600, Amalgerol, Lignohumate B, PRP-EBV, or Softguard) with positive results. Another benefit of these preparations is their possible effect on the health of plants.

The health, even the tuber yield, of potatoes is possible to influence with some other operation such as the choice of variety, size sorting of planting material, and treatment of plant material. The use of greater size sorting and of tubers of overplanting size increased the tuber yield in combination with early harvest. It is necessary in organic farming to perform biological preparation of planting material (pre-sprouting) because of late blight. Consequential growth of roots and vegetation vitality is possible to support with treatment of planting material before planting or application during planting (on potato planter).

The protection of soil and soil life is also important. The application of mulching material on top of ridges can help in this area (also as anti-erosion precaution). Another benefit of mulch is that it can be used in the regulation of CPB or aphids (mainly if we use herbal mulch or buffer strip), weed regulation (weed biomass was regulated by black mulching fabric and partially by grass mulch applied before emergence), the possibility of temperature and humidity regulation, and also the increase of tuber yield. The tuber yield was largely affected

by concrete use of mulching material (the right choice of mulching material unrolls from concrete site and soil conditions).

Initial treatment of potato vegetation happens according to concrete environmental conditions of the year and the grower's experiences. We gain many valuable results about plant extracts of *Azadirachta indica* L., eventually Neem Azal and other plant extracts (*Juglans regia* L., *Pelargonium zonale* L.) as protection against late blight and CPB. However, they are not usable in practise because of their changing effectivity. The main regulation procedure includes: 1. choice and use of resistant varieties; 2. pre-sprouting of planting material and early planting; 3. suitable irrigation regime; 4. interchange of crops; 5. removal of stalks or use of copper fungicide.

Aimed liquidation of stalks stops not only the blight spread, but also its transition to the soil and on tubers. Another area using stalk removal is the regulation of maturation (tuber size) and regulation of viruses (in propagation vegetation). Experimental results indicate, that even after stronger pass of aphids, it is possible to use preventive methods (early varieties, pre-sprouting, early planting, buffer strip, or mulching) in organic farming and regulate the occurrence of viral diseases. Production of planting material is possible even in conditions of organic farming. It demands good knowledge and maximal usage of all regulation methods and procedures.

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