THE INFLUENCE OF UNDERSOWN CROPS AND STRAW BIOMASS ON YIELD AND NUTRITIONAL VALUE OF POTATO TUBERS

WPŁYW BIOMASY WSIEWEK MIĘDZYPLONOWYCH I SŁOMY NA PLON ORAZ WARTOŚĆ ODŻYWCZĄ BULW ZIEMNIAKA

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ABSTRACT

The paper presents the results of research carried out over 2001-2003 which aimed at describing the influence of undersown crops and spring barley straw fertilization on chemical composition of table potato tubers. Two factors were examined. I - undersown crops fertilization: control variant (without undersown crops fertilization), farmyard manure, black medic (Medicago lupulina), black medic (Medicago lupulina) + Italian ryegrass (Lolium multiflorum), Italian ryegrass (Lolium multiflorum). II – straw fertilization (subblock without straw, subblock with straw). Obtained results allow to conclude that, fertilization with mixture of black medic with Italian ryegrass and black medic in combinations without straw or with straw in terms of size and quality of yield of potato tubers it equals or it even exceeds the farmyard manure fertilization. The increase of starch, vitamin C and true protein content in comparison with control variant was noted in potato tubers fertilizerd with undersown crops biomass and straw.

Key words: undersown crop, straw, potato, yield, nutritive value of tubers.

STRESZCZENIE

W pracy przedstawiono wyniki badań z lat 2001-2003 mające na celu określenie wpływu nawożenia wsiewkami międzyplonowymi i słomą jęczmienia jarego na skład chemiczny bulw ziemniaka jadalnego. W doświadczeniu badano dwa czynniki. Pierwszy czynnik – nawożenie wsiewką międzyplonową: obiekt kontrolny (bez nawożenia wsiewką), obornik, lucerna chmielowa, lucerna chmielowa + życica wielokwiatowa, życica wielokwiatowa. Drugi czynnik – nawożenie słomą: podblok bez słomy, podblok ze słomą. Otrzymane wyniki badań pozwalają stwierdzić, iż nawożenie mieszanką lucerny chmielowej z życicą wielokwiatową oraz lucerną chmielową w kombinacjach bez słomy lub ze słomą pod względem wielkości i jakości plonu bulw ziemniaka dorównuje, a nawet przewyższa nawożenie obornikiem. Wzrost zawartości skrobi, witaminy C i białka właściwego w porównaniu z obiektem kontrolnym odnotowano w bulwach ziemniaka nawożonego biomasą wsiewek międzyplonowych i słomą.

Słowa kluczowe: wsiewka międzyplonowa, słoma, ziemniak, plon, wartość odżywcza bulw.

DETAILET ABSTRACT

Ziemniak przeznaczony do bezpośredniego spożycia powinien charakteryzować się jak najlepszymi cechami jakościowymi. O jakości bulw decyduje ich skład chemiczny silnie modyfikowany przez czynniki agrotechniczne, a zwłaszcza przez nawożenie. Zauważa się tu korzystne oddziaływanie nawożenia organicznego. Jednak niewiele jest danych eksperymentalnych określających oddziaływanie międzyplonów na wartość odżywczą bulw ziemniaka. Stąd wyłania się potrzeba prowadzenia tego typu badań. Celem przeprowadzonych badań było określenie wpływu nawożenia wsiewkami międzyplonowymi i słomą na skład chemiczny bulw ziemniaka jadalnego. Eksperyment polowy przeprowadzono w latach 2001-2003, na glebie kompleksu żytniego bardzo dobrego. W doświadczeniu badano dwa czynniki. Pierwszy czynnik – nawożenie wsiewką międzyplonową: obiekt kontrolny (bez nawożenia wsiewką), obornik, lucerna chmielowa, lucerna chmielowa + życica wielokwiatowa, życica wielokwiatowa. Drugi czynnik – nawożenie słomą: podblok bez słomy, podblok ze słomą. Wsiewki międzyplonowe wsiewano w jęczmień jary uprawiany na ziarno. W pierwszym roku po zastosowaniu nawożenia organicznego uprawiano ziemniaki jadalne. Podczas zbioru ziemniaka, na każdym poletku określono plon handlowy. W pobranych próbach bulw oznaczono zawartość: skrobi, witaminy C i białka właściwego.

W przeprowadzonym eksperymencie wykazano istotny wpływ badanych czynników doświadczenia i ich interakcji na plon handlowy bulw ziemniaka. Największy plon handlowy bulw ziemniaka otrzymano z kombinacji nawożonej mieszanką lucerny chmielowej z życicą wielokwiatową. Również plon handlowy bulw ziemniaka nawożonego lucerną chmielową i słomą był istotnie wyższy od odnotowanego na oborniku. Na pozostałych obiektach nawożonych wsiewkami międzyplonowymi i słomą, z wyjątkiem życicy wielokwiatowej plon handlowy bulw ziemniaka kształtował się na zbliżonym poziomie, jak na oborniku. Nawożenie organiczne wpływa nie tylko na wysokość ale i na jakość plonu, a więc na ilość i wzajemny układ składników występujących w bulwach ziemniaka. Nawożenie międzyplonami i słomą stymulowało koncentrację składników odżywczych w bulwach ziemniaka. Najwyższą zawartość skrobi odnotowano w bulwach ziemniaka nawożonego życicą wielokwiatową oraz życicą wielokwiatową ze słomą, a witaminy C i białka właściwego w bulwach ziemniaka nawożonego lucerną chmielową oraz lucerną chmielową ze słomą.

W podsumowaniu należy podkreślić, iż nawożenie mieszanką lucerny chmielowej z życicą wielokwiatową oraz lucerną chmielową w kombinacjach bez słomy lub ze słomą pod względem wielkości i jakości plonu bulw ziemniaka, dorównuje a nawet przewyższa nawożenie obornikiem. Wzrost zawartości skrobi, witaminy C i białka właściwego w porównaniu z obiektem kontrolnym odnotowano w bulwach ziemniaka nawożonego biomasą wsiewek międzyplonowych i słomą.

1. INTRODUCTION

Potato tubers make a valuable and healthy sustenance for people [5]. About quality of potato and its consumption value decides chemical composition of tubers, which depends on genetic conditioning and interaction of different factors of environment [3, 5, 11]. Among environmental and cultivable factors importaut influence on yield quality has fertilization. Advantageous interaction of organic fertilization is noticed here [1, 2, 3, 5, 6, 10]. Majority of works from this range concerns mainly manure fertilization, and also green fertilizers and straw of cereal, which are used as alternative sources of biomass can have significant influence on change of chemical composition of potato tubers. So there is a requirement of carrying out such researches which aim is to determine the influence of undersown crops fertilization and spring barley straw fertilization on chemical composition of table potato tubers.

2. MATERIALS AND METHODS

Field experiment was carried out in 2000–2003 at the Experimental Station in Zawady, belonging to the University of Podlasie in Siedlce. The experiments were carried out on a soil which was rated to autogenic soil, russet soil order, fawn soil type made from hard sandy loam. The arable layer of soil characterized with ph 6.5 and assimilable forms: P 50.4 mg·kg^{-1}, K 112.9 mg·kg^{-1} and Mg 53.8 mg·kg^{-1}. The humus content was 1,33%. The experiment was a three-replicate split blocks design. Two factors were examined: I - undersown crops fertilization: control variant (without undersown crops fertilization), farmyard manure (30 t ha^{-1}), black medic-Medicago media (20 kg ha^{-1}), black medic-Medicago media + Italian ryegrass-Lolium multiflorum (10+15 kg ha^{-1}), Italian ryegrass-Lolium multiflorum (30 kg ha^{-1}). II – straw fertilization: subblock without straw, subblock with straw.

Undersown crops were sown into spring barley by the seeder across the rows in a day of protective plant. At harvest straw yield was defined. On plots with straw, the crushed straw was left and on fields without straw, the straw was taken away from the field. In all the combinations with straw, except for companion crop of

black medic, the balancing nitrogen dose was applied at the amount of 7 kg per 1 t of straw. In autumn, on every plot the fresh matter yield was taken in order to define together with their root mass from 30 cm soil layer. The average yield for black medic, black medic – Italian ryegrass mixture and Italian ryegrass amounted: 21.7, 32.4 and 33.0 t ha^{-1}, respectively. Next for defined plots cattle manure was applied and pre-winter plough was made down.

In the first year after organic fertilization, table potatoes were cultivated. In early spring mineral fertilization was used: 90 kg N, 39.6 kg P and 99.6 kg K per 1 ha. Mineral fertilizers were mixed with soil by using a cultivator combined with a harrow. Potatoes were planted in the third decade of April and harvested in the second decade of September. During the potato harvest commercial yield (the yield of tubers whose diameter was larger than 40 mm) was recorded. Next, 5-to-7 kg samples were collected from each plot to carry out chemical analyses. In fresh matter of potato tubers the starch content was determined by Reimann method [15] and vitamin C by Pijanowski method [12]. The true protein content was determined in tuber dry mass by means of the Kjeldahl method [4] which was applied after trichloracetic acid precipitation. Each of the characteristics was subjected to analysis of variance according to the split-block linear model. Means for significant sources of variation were compared by the Tuckey test.

3. RESULTS

The statistical analysis indicated significant effects of the investigated factors and their interaction on potato tuber commercial yield (Table 1). The highest potato tuber yield was recorded for black medic and Italian ryegrass mixture. The tuber commercial yield of potato fertilized with black medic was no different than the yield recorded for farmyard manure-fertilized potato. However, the yield of potato which was fertilized with Italian ryegrass and from control object was significantly lower than the yield from farmyard manure. Straw fertilization differentiated potato tuber yields, too. The potato commercial yield recorded for straw –fertilized plots was on average by 6.4% higher than the yield obtained on non-straw-fertilized plots. An interaction was found to be significant and it indicated that the highest potato tuber yield was recorded for the plots fertilized with black medic and Italian ryegrass mixture, whereas the lowest yield was

Table 1: The commrecial yield of potato tubers, in t·ha^{-1} (means from 2001-2003)
Tabela 1: Plon handlowy bulw ziemniaka, w t·ha^{-1} (średnie z lat 2001-2003)

Underplant fertilization Nawożenie wsiewką międzyplonową	Straw fertilization Nawożenie słomą		
	Subblock without straw Podblok bez słomy	Subblock witch straw Podblok ze słomą	Means Średnie
Control object Obiekt kontrolny	18.5	33.8	26.2
Farmyard manure Obornik	38.4	36.9	37.7
Black medic Lucerna chmielowa	37.8	40.0	38.9
Black medic + Italian ryegrass Lucerna chmielowa + Życica wielokwiatowa	42.6	39.8	41.2
Italian ryegrass Życica wielokwiatowa	34.7	32.5	33.6
Means Średnie	34.4	36.6	-
$LSD_{0.05}$-$NIR_{0,05}$			
Underplant fertilization Nawożenie wsiewką międzyplonową			1.2
Straw fertilization Nawożenie słomą			0.9
Interaction Interakcja			1.4

Table 2: The content of starch in potato tubers, in % (means from 2001-2003)
Tabela 2: Zawartość skrobi w bulwach ziemniaka, w % (średnie z lat 2001-2003)

Underplant fertilization Nawożenie wsiewka miedzyplonową	Straw fertilization Nawożenie słomą		
	Subblock without straw Podblok bez słomy	Subblock witch straw Podblok ze słomą	Means Średnie
Control object Obiekt kontrolny	13.5	14.3	13.9
Farmyard manure Obornik	14.4	14.5	14.5
Black medic Lucerna chmielowa	14.0	14.3	14.2
Black medic + Italian ryegrass Lucerna chmielowa + życica wielokwitowa Italian ryegrass Życica wielokwiatowa	14.5	14.6	14.6
	14.7	14.6	14.7
Means Średnie	14.2	14.5	-
$LSD_{0.05}$-$NIR_{0,05}$			
Underplant fertilization Nawożenie wsiewką międzyplonową			0.2
Straw fertilization Nawożenie słomą			0.2
Interaction Intrakcja			0.3

found on control variant, without undersown crops fertilization.

Potato tuber chemical composition was significantly influenced by the experimental factors and their interaction (Table 2, 3, 4). The starch content in the tubers of undersown crops fertilized potato, with exception of black medic was not significantly different from the content determined for farmyard manure-fertilized potato. Only for the control variant and after using black medic the starch content in potato tubers was significantly lower than the content for farmyard-manure fertilized potato. Straw fertilization increased starch concentration in potato tubers. The interaction of the factors indicates that potatoes fertilized with Italian ryegrass contained the most starch, and the least potatoes from control variant. The highest vitamin C content was determined in the tubers of black medic-fertilized potato and in tubers of black medic and Italian ryegrass mixture-fertilized potato. The content of vitamin C in potato tubers which were fertilized with Italian ryegrass was insignificantly different from the values determined in the farmyard manure fertilized potato tubers. Also, straw fertilization facilitated vitamin C accumulation in potato tubers. An interaction was found and it indicated that the highest vitamin C contents were accumulated in the tubers of black medic and straw, but the least farmyard manure fertilized potatoes, without undersown crops fertilization.

Statistic analysis indicates that potatoes fertilized with black medic characterize with the highest content of true protein. On the rest objects which were fertilized with undersown crops the content of true protein in potato tubers was not significantly different from the values recorded for the farmyard manure fertilized potatoes. Straw fertilization also modified the concentration of true protein in potato tubers. An interaction of the examined factors indicated that black medic and black medic and straw mixture have the biggest influence on concentration of true protein in potato tubers. Whereas, the least concentration of true protein was typical of the control variant.

4. DISCUSSION

The development of integrated production of potato induces to fill the crop rotation with intercrops, which may substitute farmyard manure and have a positive impact on the soil environment. A special attention ought to be paid to undersown crops. Another source of biomass

Table 3: The content of vitamin C in potato tubers, in mg% (means from 2001-2003)
Tabela 3: Zawartość witaminy C w bulwach ziemniaka, w mg% (średnie z lat 2001-2003)

Underplant fertilization Nawożenie wsiewką międzyplonową	Straw fertilization Nawożenie słomą		
	Subblock without straw Podblok bez słomy	Subblock witch straw Podblok ze słomą	Means Średnie
Control object Obiekt kontrolny	20.9	22.0	21.5
Farmyard manure Obornik	22.2	22.1	22.2
Black medic Lucerna chmielowa	22.7	22.9	22.8
Black medic + Italian ryegrass Lucerna chmielowa + życica wielokwiatowa	22.5	22.6	22.6
Italian ryegrass Życica wielokwiatowa	22.3	22.4	22.4
Means Średnie	22.1	22.4	-
$LSD_{0..05}$-$NIR_{0,05}$			
Underplant fertilization Nawożenie wsiewką międzyplonową			0.2
Straw fertilization Nawożenie słomą			0.2
Interaction Interakcja			0.3

might be also straw which stay at field after cereal harvest. Nowak [8] points to a clear advantage of green manures over farmyard manure. It follows from the fact that nutrients contained in green manure are in general more available than farmyard manure components, as a result of the faster rate of organic matter decomposition. The present study has confirmed this finding. The highest commercial yield of potato tubers was obtained from the treatment which had been fertilized with a mixture of black medic and Italian ryegrass, and the combination of black medic and straw. However, the effect of black medic was markedly poorer. The possible explanation of the fact is that the decomposition of legumes can be accompanied by substantial nitrogen losses. The losses depend on temperature, humidity and decomposition duration and can amount to as 50%. In order to prevent the losses, one should add carbon-rich material, e.g. grass or straw, to the decomposing legume biomass in order to increase the C:N ratio [8].

Undersown crops and straw fertilization not only increases the yields but also improves their quality, so it conditions the reciprocal relation of the elements found in the potato tuber. In the current work, the highest starch content was determined in the tubers fertilized with Italian ryegrass and the potato fertilized with a mixture of black medic and Italian ryegrass, both with and without straw application. But in tubers fertilized with black medic its concentration was significantly lower than in potatoes fertilized with farmyard manure. It should be explained by the fact that natural fertilizer, which contains more nitrogen (black medic), stimulates the concentration of protein, but it does not stimulate the concentration of starch in potato tubers. It agrees with the findings of Peshin and Shing [9], and Ceglarek and Płaza [2]. But it is in disagreement with the reports by Mazur and Jułkowski [7] who point to a beneficial response of potato, in terms of the starch content, to fertilization with a legume, compared with farmyard manure. Under the conditions of the discussed study, undersown crops fertilization, black medic in particular and mixture of black medic and Italian ryegrass stimulated vitamin C accumulation in potato tubers. Also, straw fertilization favourably influenced the aforementioned characteristic. Similar conclusions were formulated by many authors [1, 2, 5, 11, 13, 14]. They also mentioned the correlation between organic fertilization and vitamin C content in potato tubers. In the works by Mazur and Jułkowski

Table 4: The content of the true protein in potato tubers, in % d.m. (means from 2001-2003)
Tabela 4: Zawartość białka właściwego w bulwach ziemniaka, w % s.m. (średnie z lat 2001-2003)

Undreplant fertilization Nawożenie wsiewką międzyplonową	Straw fertilization Nawożenie słomą		
	Subblock without straw Podblok bez słomy	Subblock witch straw Podblok ze słomą	Means Średnie
Control object Obiekt kontrolny	3.78	4.84	4.31
Farmyard manure Obornik	5.11	5.32	5.22
Black medic Lucerna chmielowa	5.94	6.05	6.00
Black medic + Italian ryegrass Lucerna chmielowa + życica wielokwiatowa Italian ryegrass Życica wielokwiatowa	5.28	5.37	5.33
	4.96	5.02	4.99
Means Średnie	5.01	5.32	-
$LSD_{0.05}$-$NIR_{0,05}$			
Underplant fertilization Nawożenie wsiewką miedzyplonową			0.23
Straw fertilization Nawożenie słomą			0.14
Interaction Interakcja			0.25

[7], Płaza et al. [10] and in the present study an increase in the true protein content was observed in the tubers of organically fertilized potatoes. An application of black medic in combination with straw and black medic only most positively influenced the above-mentioned characteristic. Also, Peshin and Shing [9] point to the reduced starch content and increased protein content in potato tubers following an addition of nitrogen-rich material. It results from the fact that nitrogen from the legume biomass undergoes gradual mineralization and is gradually made available for the potato plant, the process assuring that all the mineral nitrogen is converted into proteinaceous nitrogen. As a result it should be claimed that undersown crops and undersown crops and straw fertilization have beneficial influence on nutritive value of potato tubers.

5. CONCLUSION

Received results of researches allow to ascertain that the highest tuber commercial yield was obtained for the treatment fertilized with a mixture of black medic and Italian ryegrass, and black medic and straw. Undersown crops and straw fertilization stimulated starch, vitamin C and true protein concentration in potato tubers in comparison to concentration of those components which were observed on control variant, without undersown crops fertilization. Fertilization with mixture of black medic and Italian ryegrass, and black medic in combinations without or with straw, it completely substitutes farmyard manure in cultivation of table potato. Firstly, the commercial yield and nutritive value of potato tubers are higher than yield and nutritive value of farmyard manure fertilized potato tubers. Secondly, undersown crops and straw, also farmyard manure exert next operation, they enrich soil to organic substance, preclude leaching of nutritional components to deeper layers of soil and groundwater, what have great importance in protection of agricultural environment.

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