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TUBER YIELD AND QUALITY OF POTATO FERTILISED WITH INTERCROP COMPANION CROPS AND STRAW

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ABSTRACT

The paper presents the results of research carried out over 1997-2000 which aimed at examining the possibility of replacing manure in potato fertilisation with intercrop companion crops and straw, without decreasing the tuber yield and its quality. In the experiment two factors were studied: I – fertilisation with intercrop companion crop (control, manure, birdsfoot trefoil, birdsfoot trefoil + Italian ryegrass, Italian ryegrass), II – straw fertilisation (without straw, with straw). In the first year after organic fertilisation table potatoes 'Ania' were cultivated. It is a mid-late cultivar, very high-yielding, of large high tubers, of multipurpose culinary use, and good taste. Out of all the intercrop companion crop combinations researched, the greatest amount of biomass was introduced into soil by Italian ryegrass, significantly less – by a mixture of birdsfoot trefoil and Italian ryegrass, and the least – birdsfoot trefoil. Potato fertilisation with intercrop companion crops increased the content of dry matter, starch, vitamin C and true protein, and decreased the content of glycoalkaloids in tubers. Potatoes fertilised with straw showed a higher content of dry matter and vitamin C, and lower content of glycoalkaloids than potato tubers which were not fertilised with straw.

Key words: manure, intercrop companion crop, straw, potato, yield, tuber quality

INTRODUCTION

Potato is undoubtedly one of the most precious crops. High yields require both organic and mineral fertilisation. The most basic organic fertiliser applied in potato cultivation is manure [2,8,10,16]. Decreasing manure production caused by a decrease in animal farm numbers and organic farming development call for other alternative solutions. In that situation green fertilisers are becoming more and more important [2,3,6,8,10].

Introducing intercrops means not only biomass production; they are also a sorbent which prevents nutrients leaching out into deeper soil layers and ground waters, which is of significant importance in soil environment protection [8,22,23,24]. Out of all the intercrops, the cheapest sources of organic substance are companion crops [2,3,6,21]. The second replacement biomass source can be cereals straw applied together with green fertilisers [1,7,8,13,21].

Organic fertilisers significantly affect potato plant growth, development and yielding [9]. Potato cultivar for direct consumption should show a high tuber yield, of possibly highest quality parameters [14,15]. In most countries of Western Europe certified potato production is being introduced to ensure high quality tubers while limiting the content of substances harmful for humans and the natural environment [5,24]. The agronomic factor which shows a favourable effect on these features is organic fertilisation [3,6,8,11]. Most papers covers mainly manure fertilisation whereas green fertilisers from intercrop companion crops and straw, applied as alternative forms of organic fertilisation can show a significant effect on potato tuber yield size and quality. Unfortunately the problem has not been thoroughly analysed, which is seen by a low number of applicable papers. The working hypothesis assumes that intercrop companion crops and straw application in different combinations with companion crops will show a similar effect on tuber yield and their quality as traditional manure application. The aim of the present research was to check the possibility of replacing manure in potato fertilisation with intercrop companion crops and straw, without decreasing the tuber yield size and quality.

MATERIAL AND METHODS

The field experiment was carried out over 1997-2000 at Zawady Agricultural Experiment Station of the University of Podlasie in Siedlce. The research was carried out on a very good rye complex soil of neutral reaction, a low richness in phosphorus, potassium and magnesium. The content of humus was 1.15%.

The experiment was set up as a split-block design, in three replications, on plots of the harvest area of 15 m^2.

Two factors were studied:

I – intercrop companion crop fertilisation:
- control (without organic fertilisation),
- manure (dose of 30 $t \cdot ha^{-1}$),
- birdsfoot trefoil (seeding rate of 18 $kg \cdot ha^{-1}$),
- birdsfoot trefoil + Italian ryegrass (seeding rate of 9 + 15 $kg \cdot ha^{-1}$),
- Italian ryegrass (seeding rate of 30 $kg \cdot ha^{-1}$);

II – straw fertilisation:
- – without straw,
- – with straw.

The cover crop for intercrop companion crops was constituted by spring barley cultivated for grain. Barley with companion crops was cultivated after oat. In early spring mineral fertilisers were applied whose amount per 1 ha was as follows: N – 60 kg, P_2O_5 – 90 kg and K_2O – 120 kg. Spring barley 'Start' was sown in the first decade of April. Intercrop companion crops were sown on the day of sowing cover crop, compliant with the experiment methodology. Birdsfoot trefoil 'Skrzeszowicka' and Italian ryegrass 'Gran' were cultivated. Spring barley was harvested at full grain ripeness (the third decade of July). 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 birdsfoot trefoil, the balancing nitrogen dose was applied at the amount of 7 kg per 1 t of straw. In autumn (the third decade of October), prior to intercrop plough-in in randomly selected spots of each plot, mean samples of mass and post-harvest residue of companion crops together with their root mass from 30 cm soil layer were taken in order to define the fresh matter yield. Next for defined plots cattle manure was applied and pre-winter plough was made down to the depth of 20 cm.

In the first year after organic fertilisation, table potatoes 'Ania' were cultivated. It is a mid-late cultivar, very high-yielding, of big tubers, of multipurpose culinary use, which tastes good. In early spring, prior to planting out of potatoes mineral fertilisation was used: N – 90 $kg \cdot ha^{-1}$, P_2O_5 – 90 $kg \cdot ha^{-1}$ and K_2O – 120 $kg \cdot ha^{-1}$. Potatoes were planted out in the third decade of April, at the row spacing of 62.5 x 30 cm. On the potato plantation mechanical-and-chemical cultivation was made. Until plant emergence every 7 days hilling and harrowing were carried out, and immediately prior to potato emergence Afalon 450 SC was applied at the dose of 2 $dm^3 \cdot ha^{-1}$, while after emergence (at 15-20 cm plant growth), when weed infestation with monocotyledonous weeds was

observed, Fusilade Super 125 EC herbicide was used at the dose of 2 $dm^3 \cdot ha^{-1}$. Colorado beetle was controlled with Fastac 10 EC preparation (0.1 $dm^3 \cdot ha^{-1}$) and potato blight with Ridomil MZ 72 WP fungicide (2 $dm^3 \cdot ha^{-1}$). Potatoes were harvested in the second decade of September. At harvest on each plot tuber fresh matter yield was defined, and then 5-7 kg tuber samples were taken for chemical analysis. In tuber fresh matter the following were determined: the content of dry matter with the oven-drying and gravimetric method [20], of starch with the Reimann method [27], of vitamin C with the Pijanowski method [20] and of glycoalkaloids with the Bergers method [4]. In tuber dry matter the content of true protein was defined with the Kjeldahl method after precipitation with trichloric acid [12]. The results obtained were statistically verified.

Table 1. Weather conditions over the research period (1997-2000)

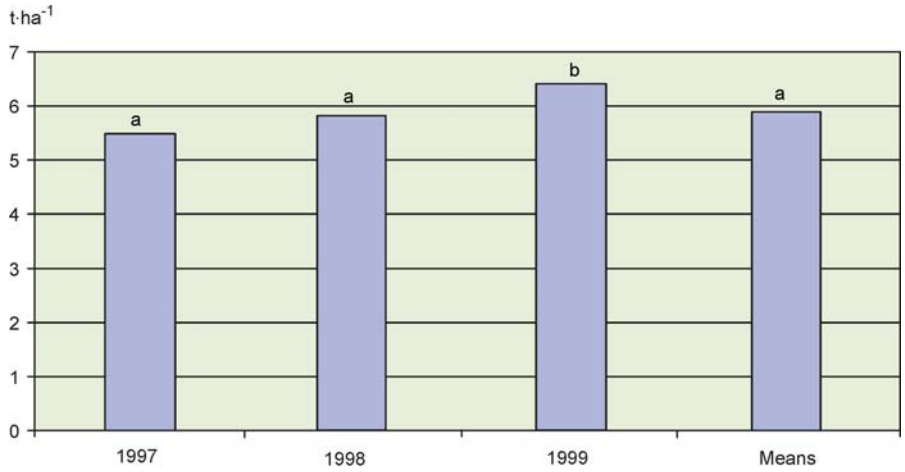
Year	Month							Mean
	April	May	June	July	August	September	October	
Temperature, °C								
1997	5.1	14.9	17.7	19.9	20.4	13.9	5.6	13.9
1998	9.3	15.9	18.8	18.8	17.4	13.1	7.4	14.4
1999	9.9	12.9	20.5	21.8	18.7	16.1	8.0	15.4
2000	12.9	16.4	19.5	19.0	19.1	11.8	11.7	15.8
Mean for 1951-1990	7.2	13.2	16.2	17.6	16.9	12.7	8.0	13.1
Precipitation, mm								Total
1997	21.5	24.5	51.5	191.3	5.7	11.5	26.6	332.6
1998	42.6	73.1	48.7	63.3	58.5	36.5	26.2	348.9
1999	87.3	26.4	121.7	21.9	77.4	27.8	11.6	374.1
2000	47.5	24.6	17.0	155.9	43.6	61.1	3.2	352.9
Total for 1951-1990	29.4	54.3	69.3	70.6	59.8	48.2	32.0	363.6

The four-year research period showed changeable weather conditions in respective vegetation periods (Table 1). The annual rainfall was not evenly distributed in time and showed a various intensity, which showed a direct effect on growth, development and yielding of spring barley, intercrop companion crops and potato cultivated directly after companion crops and barley straw plough-in.

RESULTS AND DISCUSSION

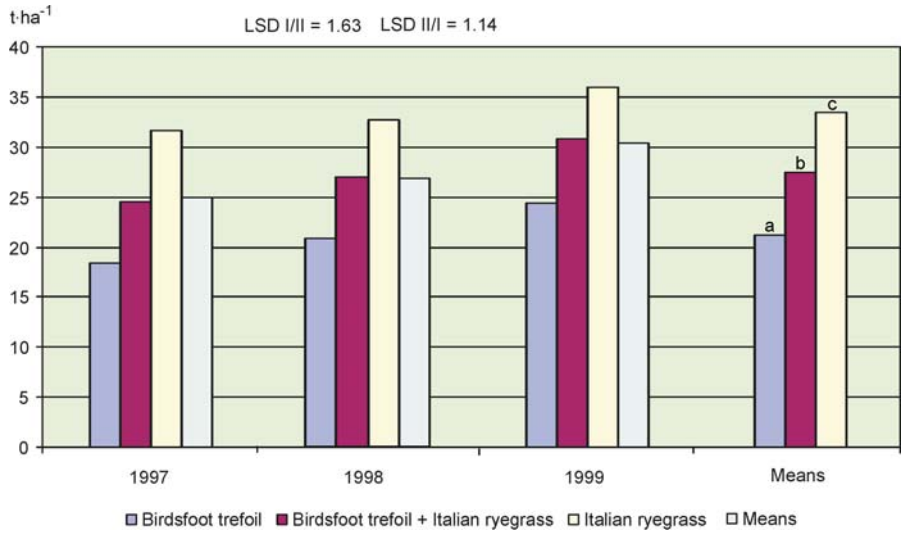
In potato fertilisation manure can be substituted with straw remaining in the field after cereals harvest. According to Mazurek [18], changeable weather conditions in respective years affect considerably the cereal plant growth and development as well as the availability and use of nutrients and the effectiveness of photosynthesis, which results in substantial annual fluctuations of the assimilation area and their photosynthetic efficiency leading to a varied yielding. All that observations were confirmed in the present research. Significantly highest straw yield was recorded in 1999 which was favourable for spring barley cultivation. Significantly lower yields were recorded in 1998 and 1997 of unfavourable weather conditions (rainfall deficit) over the vegetation period (Fig. 1).

Fig. 1. Barley straw yield (means followed by the same letters did not differ significantly at α= 0.05)



The second replacement biomass source in potato cultivation can be offered by green fertilisers from intercrop companion crops. The applicability of the intercrop kind depends on the biomass productivity. The total intercrop fresh matter yield (cut mass + post-harvest residue) varied and depended strictly on the species selection, conditions of the vegetation period and their interaction (Fig. 2). The year 1999 showed most favourable conditions for companion crop cultivation, while 1997 – unfavourable in which rainfall deficit occurred throughout the vegetation period, except for July. The rainfall deficit showed an unfavourable effect on the amount of intercrop biomass and hence the yield of potatoes cultivated after its ploughing-in. Out of all the intercrop companion crop combinations, significantly highest fresh matter yield was obtained from Italian ryegrass. A high grass biomass production is also shown by the results reported by Gromadziński [10], Hoekstra [11], Sadowski [21] and Witkowicz [26]. The addition of Italian ryegrass to birdsfoot trefoil significantly increased its yield as compared with the yield of papilionaceous plant cultivated in pure stand. According to Batalin et al. [2], Bawolski [3] and Witkowicz [26], mixtures yield similarly as grasses and their yields show smaller fluctuations due to weather conditions. Additionally they create a favourable root system which has an exceptionally favourable effect on soil. In the present experiment birdsfoot trefoil yielded lowest because papilionaceous plants, as compared with grasses, show a slower growth rate and produce less biomass. Even if they do not grow adequately, they always form a well-developed root system, and so they show a favourable effect on aftercrop yielding, which is confirmed by Batalin et al. [2], Gromadziński [10] and Witkowicz [26].

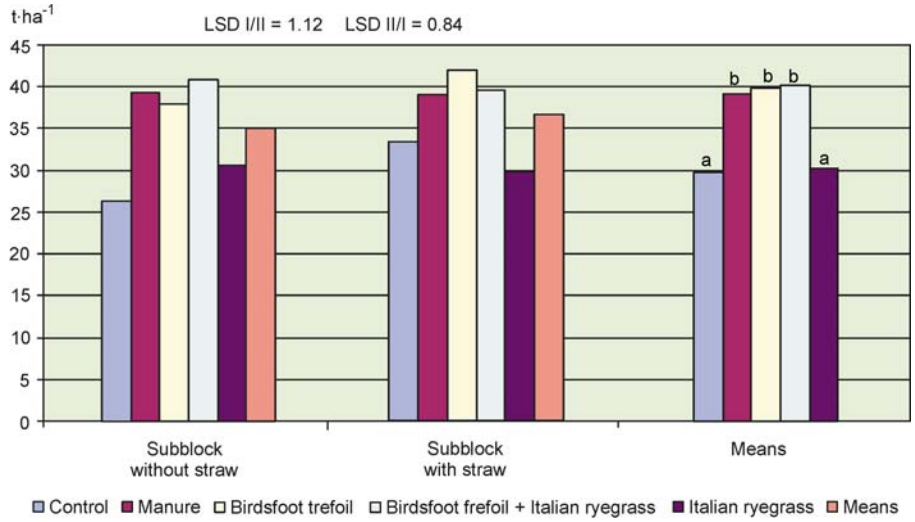
Fig. 2. Intercrop companion (I) crop fresh-matter yield over research years (II) (means followed by the same letters did not differ significantly at α= 0.05)



The fresh matter yield of potato tubers was significantly modified by fertilisation with intercrop companion crop, straw fertilisation and their interaction (Fig. 3). Tuber fresh matter yield of potato fertilised with birdsfoot trefoil, as well as with the mixture of birdsfoot trefoil and Italian ryegrass did not differ significantly from the tuber

yield of potato fertilised with manure. Similarly Batalin et al. [2], Bawolski [3] and Gromadziński [10] report on the fertilisation value of intercrop companion crops and their mixtures with grasses reaching that of manure. In the present experiment the lowest effect of fertilisation was attributed to Italian ryegrass but also in this case tuber fresh matter yield was slightly higher that that from the control. An increase in tuber yield after grasses plough-in was also reported by Hoekstra [11] and Sadowski [21], however these yields were significantly lower than when manure was applied, which is due to the fact of introducing a considerable amount of biomass of a low content of macroelements into soil. Besides grasses show a wide C : N ratio and in such case less nitrogen, used mainly by soil microorganisms, is mineralised.

Fig. 3. Mean potato tuber fresh-matter yield depending on intercrop companion (I) and fertilization with straw (II) (means followed by the same letters did not differ significantly at α= 0.05)



The second factor significantly modifying tuber yields was straw fertilisation. Cereals straw shows the lowest fertilisation value, however the increase in the yield of plants cultivated on straw does not result from its fertilisation effect but it is indirectly stimulated by processes of stimulating soil bioactivity [1,7,13]. The tuber fresh matter yield of potato fertilised with straw was significantly higher than that of tuber fresh matter of potato cultivated without straw. There was also shown an interaction which revealed that the highest tuber yield had been obtained from the object fertilised with birdsfoot trefoil with straw, while the lowest from the control, without organic fertilisation. Similarly Dzienia and Szarek [7] and Sadowski [21] recommend a combined application of green fertilisers with straw. According to Nowak [19], over the decomposition of papilionaceous plants high nitrogen losses can occur. Depending on the temperature, moisture and decomposition time, nitrogen losses can reach up to 50%. In order to prevent that, one should add material rich in carbon, e.g. straw, to the papilionaceous plants mass undergoing decomposition in order to increase the C : N ratio.

The chemical composition of potato tubers was significantly modified by fertilisation with intercrop companion crop, straw and their interaction. In the present experiment, similarly as in the reports by Ceglarek and Płaza [6], Gleń et al. [8], Leszczyński [14] and Sawicka and Kuś [22], organic fertilisation showed a favourable effect on chemical composition of potato tubers. The highest content of dry matter was recorded in potato fertilised with a mixture of birdsfoot trefoil and Italian ryegrass or manure (Table 2). Potato fertilisation with birdsfoot trefoil and Italian ryegrass significantly decreased the content of dry matter in potato tubers, as compared with manure fertilisation. The second factor which significantly modified the content of dry matter in potato tubers was straw fertilisation. In combinations with straw there was recorded a significant increase in the content of dry matter in tubers, as compared with the combination without straw. The interaction of the factors studied shows that the highest concentration of dry matter was shown in potatoes fertilised with a mixture of birdsfoot trefoil and Italian ryegrass and straw as well as manure and straw, and the lowest - tubers of the control.

Table 2. Content of dry matter in potato tubers, % (means for 1998-2000)

Fertilisation with intercrop companion crop (I)	Straw fertilisation (II)		
	Without straw	With straw	Mean
Control	21.7	22.5	22.1 a
Manure	23.2	23.3	23.3 c
Birdsfoot trefoil	22.6	22.8	22.7 b
Birdsfoot trefoil + Italian ryegrass	23.3	23.5	23.4 c
Italian ryegrass	22.4	22.6	22.5 ab
Mean	22.6 A	22.9 B	22.7
$LSD_{0.05}$ for:			
interaction: I x II	0.34		
II x I	0.22		

Means followed by the same capital letters in rows and small ones in columns did not differ significantly at α= 0.05

The concentration of starch in potatoes fertilised with Italian ryegrass as well as with a mixture of birdsfoot trefoil and Italian ryegrass did not differ significantly from its content in tubers of potato fertilised with manure (Table 3). However in potatoes fertilised with birdsfoot trefoil it was significantly lower than in tubers of potato fertilised with manure. A different opinion is represented by Mazur and Jułkowski [16] who claim that potato fertilisation with green matter of yellow lupin shows a more favourable effect on the content of starch than manure fertilisation. In the present experiment, similarly as reported by Gleń et al. [8], fertilisation with straw did not show a significant effect on the content of starch in potato tubers. An interaction was proven which shows that the highest concentration of starch was reported in potatoes fertilised with Italian ryegrass with straw, mixture of birdsfoot trefoil and Italian ryegrass and straw as well as manure with straw, while the lowest – potatoes cultivated without organic fertilisation.

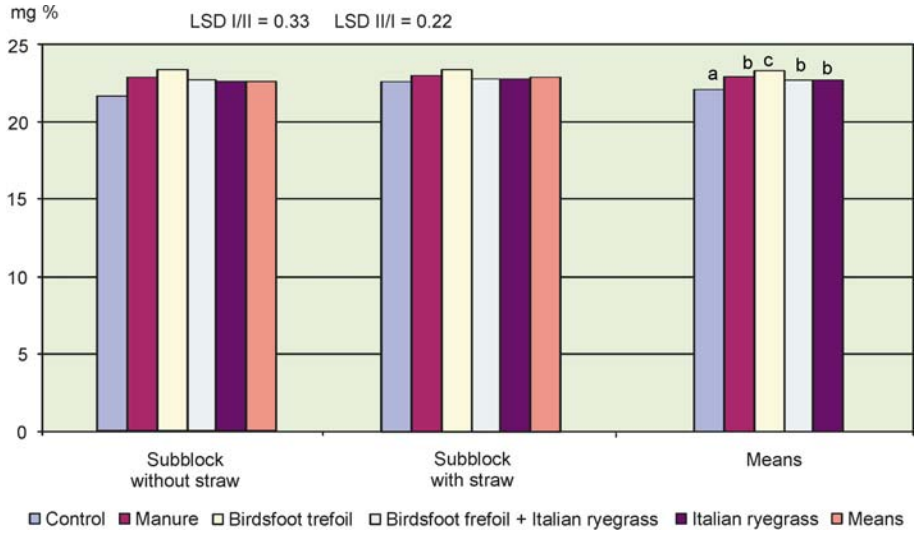
Table 3. Content of starch in fresh matter of potato tubers, % (means for 1998-2000)

Fertilisation with intercrop companion crop (I)	Straw fertilisation (II)		
	Without straw	With straw	Mean
Control	14.1	14.7	14.4 a
Manure	15.2	15.4	15.3 c
Birdsfoot trefoil	14.7	15.0	14.9 b
Birdsfoot trefoil + Italian ryegrass	15.3	15.5	15.4 c
Italian ryegrass	15.5	15.6	15.6 c
Mean	15.0 A	15.2 A	15.1
$LSD_{0.05}$ for:			
interaction: I x II	0.21		
II x I	0.11		

Means followed by the same capital letters in rows and small ones in columns did not differ significantly at α= 0.05

Out of all the intercrop companion crop combinations researched, birdsfoot trefoil showed most favourable to the content of vitamin C in potato tubers (Fig. 4). The content of vitamin C in potato tubers fertilised with a mixture of birdsfoot trefoil and Italian ryegrass and Italian ryegrass did not differ significantly from that in tubers of potatoes fertilised with manure. In the control only, with no organic fertilisation, the content of vitamin C in potato tubers was significantly lower than in potatoes fertilised with manure. Straw fertilisation showed also a favourable effect on the accumulation of vitamin C in potato tubers. The interaction of the factors studied shows that significantly highest content of vitamin C was recorded in potatoes fertilised with birdsfoot trefoil with straw, while significantly lowest in control potato tubers. Similarly the results reported by Ceglarek and Płaza [6], Leszczyński [14,15], Sawicka and Kuś [22] and Weber and Putz [25] show a positive correlation between organic fertilisation, and the content of vitamin C in potato tubers.

Fig. 4. Mean content of vitamin C in potato tuber fresh-matter depending on intercrop companion (I) and fertilization with straw (II) (means followed by the same letters did not differ significantly at α= 0.05)



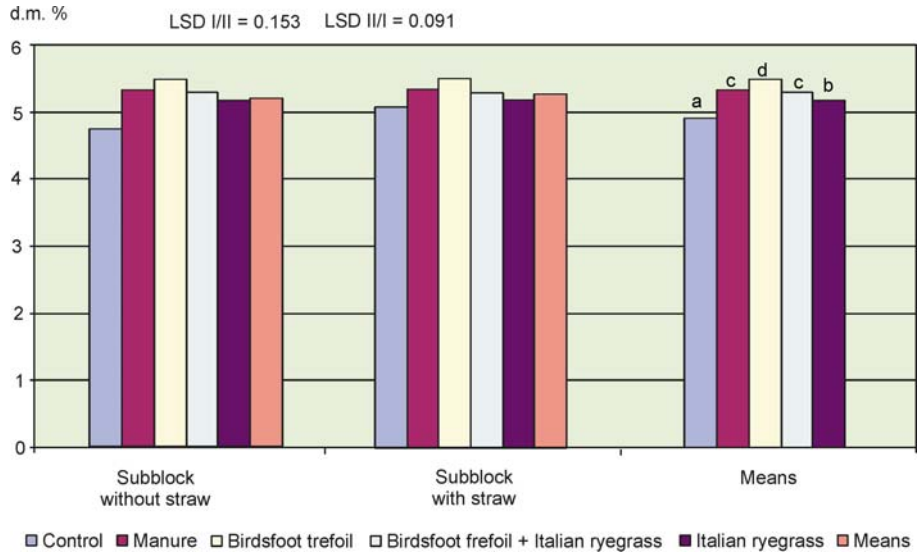
Potato fertilisation with manure, intercrop companion crops and straw significantly decreased the content of glycoalkaloids in tubers, as compared with their content recorded in potatoes cultivated without organic fertilisation (Table 4). The most favourable effect on the feature discussed was attributed to the fertilisation with birdsfoot trefoil with straw. According to Głuska [9] and Leszczyński [15], organic fertilisers decrease the content of harmful substances in potato tubers. They enrich the soil with organic substance, inhibit the process of synthesis of glycoalkaloids, and increase the accumulation of nutrients in potato tubers. In the present research significantly highest content of glycoalkaloids was noted in control potatoes, without organic fertilisation, of the highest share of small tubers in yield. According to Mazurczyk [17], small tubers show a greater share of the surface layer (most glycoalkaloids is located in peel or under it), and hence a greater content of glycoalkaloids than big tubers.

Table 4. Content of glycoalkaloids in potato tubers, mg·kg^{-1} of fresh matter (means for 1998-2000)

Fertilisation with intercrop companion crop (I)	Straw fertilisation (II)		
	Without straw	With straw	Mean
Control	32.8	32.0	32.4 c
Manure	31.7	31.4	31.6 b
Birdsfoot trefoil	31.2	31.0	31.1 a
Birdsfoot trefoil+ Italian ryegrass	31.4	31.2	31.3 ab
Italian ryegrass	31.8	31.5	31.7 b
Mean	31.8 B	31.4 A	31.6
$LSD_{0.05}$ for:			
interaction: I x II	0.33		
II x I	0.20		

Means followed by the same capital letters in rows and small ones in columns did not differ significantly at α= 0.05

Fig. 5. Mean content of true protein in potato tubers depending on intercrop companion (I) and fertilization with straw (II) (means followed by the same letters did not differ significantly at α= 0.05)



In the present research, similarly as reported by Mazur and Jułkowski [16] and Sawicka and Kuś [22], organic fertilisers increased the concentration of true protein in potato tubers (Fig. 5). A special attention must be paid to fertilisation with birdsfoot trefoil; after its plough-in potato tubers observed the highest content of true protein. However after plough-in of Italian ryegrass, the amount of true protein in tubers was significantly lower than in potatoes fertilised with manure. An interaction was also proved which shows that the highest concentration of true protein was attributed to potatoes fertilised with birdsfoot trefoil with straw and the lowest – tubers cultivated without organic fertilisation due to the fact that potatoes cultivated on the stand fertilised with papilionaceous plants intake a greater amount of nitrogen than on the stand fertilised with grasses or without organic fertilisation. The papilionaceous plant biomass shows the highest content of nitrogen and gets mineralised fast. To prevent that one has to add material rich in carbon, e.g. cereals straw. Then nitrogen from the biomass ploughed-in is freed gradually and evenly made available to potato plants throughout the vegetation period, which ensures a complete transformation of mineral nitrogen uptaken by potato plants into protein nitrogen [16,19].

CONCLUSIONS

1. Out of all the intercrop companion crop combinations researched, the greatest amount of biomass was introduced into soil by Italian ryegrass, significantly less by a mixture of birdsfoot trefoil and Italian ryegrass, and the least – by birdsfoot trefoil.
2. The highest yields of potato tuber fresh matter were obtained from the combinations fertilised with birdsfoot trefoil with straw, and also with a mixture of birdsfoot trefoil and Italian ryegrass which fully replaces manure.
3. Potato fertilisation with birdsfoot trefoil companion crop, a mixture of birdsfoot trefoil and Italian ryegrass and with Italian ryegrass increased the content of dry matter, starch, vitamin C and true protein and decreased the content of glycoalkaloids in potato tubers.
4. Fertilisation with straw, irrespective of the other organic fertilisers, increased the content of dry matter and vitamin C and decreased that of glycoalkaloids, however it did not differentiate the content of starch and true protein in potato tubers.

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