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The Influence of Intercrops Biomass and Barley Straw on Yield and Quality of Edible Potato Tubers

Anna Płaza, Feliks Ceglarek, Danuta Buraczyńska
and Milena Anna Królikowska
University of Natural Sciences and Humanities in Siedlce
Poland

1. Introduction

Potatoes destined for direct consumption should be distinguished by a high trade yield with the best qualities. (Leszyński, 2002; Boligłowa and Gleń, 2003; Płaza and Ceglarek, 2009). In most European countries schemes for the verifiability of the potato product are introduced. The aim is to obtain good quality of potatoes, ensuring the reduction of harmful substances to human health and the natural environment (Spiertz et al., 1996). The beneficial effects of organic fertilization is noted here (Leszczyński, 2002; Boligłowa and Gleń, 2003; Makaraviciute, 2003; Płaza et. al., 2009).
Farmyard manure is a basic manure applied in potato cultivation (Batalin et.al., 1968; Kalembasa and Symanowicz, 1985; Rozrtopowicz, 1989). For many years its amount covered the demand, but now the situation has negatively affected due to the decline in livestock, especially cattle. Decreasing amount of farmyard manure, low profitability and the rationale for a system of integrated agriculture, tend to seek alternative, energy-efficient sources of biomass. As a result, a significant role is being attributed to green manures (Grześkiewicz i Trawczyński, 1997; Zając, 1997; Ceglarek et. al., 1998; Karlsson-Strese et. al., 1998; Płaza i in., 2009).
Green fertilizers were mentioned many times in literature. Batalin et. al. (1968), Roztropowicz (1989), Gruczek (1994), Dzienia and Szarek (2000) emphasize that the advantage of using this type of fertilization is high labor and energy saving in relation to its amount spent on works related to the application of farmyard manure. Estler (1991), Stopes et. al. (1995), Spiertz et. al. (1996), Karlsson-Strese et. al. (1998) and Songin (1998) show that the intercrops introduction into the cultivation is not only the production of biomass. They are also a kind of absorbent material to prevent leaching of nutrients into the deeper layers of soil and groundwater, which is important in protecting the agricultural environment.
From manuscripts connected with green fertilizers it is clear that among catch crops, undersown crops seem to be the cheapest source of organic matter because it does not require any additional costs associated with the cultivation and preparation of the soil before sowing, which is particularly troublesome in the cultivation of stubble crops (Ceglarek et. al., 1998). Seed cost is also low. As undersown the legumes are recommended to cultivate. The Renaissance intercrops from legumes is linked to the multilateral noticing

them, valuable, but not fully used advantages of agronomic and biological properties. The rediscovery of these plants is associated with current global trends in agricultural techniques, aiming towards the promotion of proecological and ecological agriculture (Stopes et.al., 1995; Spiertz et.al., 1996; Karlsson-Strese et. al., 1998; Duer, 1999). White clover is distinguished by a high capacity of fixing atmospheric nitrogen, and a wide range of crops to allow its existence in a very different soil conditions have long been interested for researchers across Europe (Frye et. al., 1988). In Poland, there is little experimental data determining the suitability of this species to cultivation as undersown, designed for plowing, as a green manure in integrated potato cultivation. Researches of many authors (Batalin et. al., 1968; Gromadziński and Sypniewski, 1971; Zając, 1997; Ceglarek et. al., 1998) show that undersown legumes are quite unreliable in yielding. More similar are legume mixtures with grasses (Gromadziński and Sypniewski, 1971; Bowley et. al., 1984; Ceglarek et al,. 1998; Witkowicz, 1998; Płaza et. al., 2009). Reliable in yielding also are grasses grown in pure sowing. As a fast-growing plants and easily shading the soil interact with the position by weed reduction (Szymona et. al., 1983/1984; Sadowski, 1992; Karlsson-Strese et. al., 1998; Majda and Pawłowski, 1998; Kuraszkiewicz and Pałys, 2002).

An alternative source of biomass can also be stubble crops, which were mentioned in literature many times (Sadowski, 1992; Roztropowicz, 1989; Boligłowa and Dzienia, 1996; Grzeskiewicz and Trawczyński, 1997; Dzienia and Szarek, 2000). Recently, there has been an interest of the possibility of entering non-legume plants with a short growing season. It is recommended to sow fast-growing species, with good ability of shading, and not able to produce too large, aboveground woody mass. The most common are: white mustard, oil radish and phacelia (Allson and Amstrong, 1991; Boligłowa and Dzienia, 1997; Grześkiewicz and Trawczyński, 1997; Gutmański et. al., 1998). Among non-legume plants cultivated in stubble crop phacelia is distinguished by rapid growth, it produces a soft aboveground mass, easily frozen in winter. Is a phytosanitary plant. In Poland, previously carried out researches on fertilizing position of phacelia only in sugar beet cultivation (Nowakowski et. al., 1997; Gutmański et.al., 1999), still there is no experimental data evaluating its usefulness in the fertilization of potatoes.

Intercrops can be plowed down in autumn or left till spring in the form of mulch. The beneficial effects of intercrops plants left till spring in the form of mulch is to: protect the soil against wind and water erosion, gathering water from rainfall, slowing the process of mineralization of organic matter and prevent from nutrients leaching into the soil, reducing the cost of cultivation by eliminating plowing (Hoyt et. al., 1986; Gutmański et. al., 1999). It should be noted that the green fertilizers left till spring in the form of mulch causes a slight decrease in yield, but the improvement of the quality characteristics of the fertilized plants compared to fertilization applied in the traditional form.

Another substitute source of biomass can also be the straw left on the field after harvest of cereals (Szymankiewicz, 1993; Gruczek, 1994; Śnieg and Piramowicz, 1995; Dzienia and Szarek, 2000), especially used in combination with green fertilizers. Its addition to the legume biomass, not only does not reduce nitrogen losses, but also extends the period of green fertilizers acting (Nowak, 1982). In the case of non-legume plants effect of combined application of these forms of fertilization is not always positive (Dzienia, 1989; Sadowski, 1992). In Poland, there is little on this experimental data. Thus emerges the need for research aimed at comparing the impact of intercrops biomass, stubble crops both plowed down in autumn and left till spring in the form of mulch in combinations with straw or without straw, farmyard manure fertilization on yielding and chemical composition of edible potato tubers.

2. Material and methods

A field experiment was carried out in the years 2004-2007 at the Zawady Experimental Farm whose owner is the University of Natural Sciences and Humanities in Siedlce. The experimental site was Stagnic luvisol characterised by an average availability of phosphorus, potassium and magnesium. The experimental design was a split-block design with three replicates. Two factors were examined: I - intercrop fertilization: control object (without intercrop fertilization), farmyard manure (30 t ha^{-1}), undersown crop – biomass plowed down in autumn (white clover 18 kg ha^{-1}, white clover + Italian ryegrass 9 + 15 kg ha^{-1} , Italian ryegrass 30 kg ha^{-1}), stubble crop – biomass plowed down in autumn (phacelia 12 kg ha^{-1}), stubble crop – biomass left in the form of mulch until spring (phacelia 12 kg ha^{-1}). II. Straw fertilization: subblock without straw, subblock with straw.
Undersown crops were sown after planting spring barley cultivated for grain whereas stubble catch crops were planted after barley harvest. During spring barley harvest, on each plot straw yield was determined, and then the average its tests were taken in order to determine the content of macroelements (N – by Kjeldahl method, P – vanadium-molybdenum method, K and Ca – by flame photometry and Mg – by atomic absorption spectrometry) (Kerłowska-Kułas, 1993). In sub-block with straw fragmented straw was left and on sub-block without straw, straw was collected and brought out from field. On every plots with straw, with the exception of white clover undersown, compensatory dose of nitrogen was applied in the amount of 7 kg per 1 tonne of straw. Phacelia cultivated in stubble crop was sown in mid-August.
In the autumn, in random locations from each intercrop plot, the average sample of hay weight collected hay and crop residues of plants including their root mass, with a 30 cm layer to determine the yield of fresh weight. In collected plant material the content of dry matter was analyzed (by drier-weight method), and macroelements (N, P, K, Ca and Mg). Then on designated plots the cattle manure was transported, earlier the average sample was taken to determine the chemical composition.
In the first year following organic manuring edible potatoes Syrena cultivar was cultivated. In early spring mineral fertilizers were distributed, at the rates of 90 kg N, 39 kg P and 100 kg K per 1 ha. In the plots which had been ploughed in the autumn, mineral fertilizers were mixed with the soil using a cultivator equipped with a harrow whereas in the mulched plots, an application of a disc harrow was followed by a cultivator. Potatoes were planted in the third decade of April. In the integrated production system, a combination of mechanical and chemical control was applied. Until emergence, potato rows were earthed up and harrowed every 7 days; then just before emergence the herbicide mixture Afalon 450 SC in amount of 2 dm^3 ha^{-1} was sprayed, but after emergence (in the phase of 15-20 cm), when the weed infestation was noted herbicide Fusilade Super 125 EC in amount of 2 dm^3 ha^{-1} was sprayed. The Colorado potato beetle was and potato blight were controlled using, respectively, Fastac 10 EC (0.1 dm^3 ha^1) and the fungicide Ridomil MZ 72WP (2 dm^3 ha^{-1}). Potatoes were harvested in the second decade of September. During potato harvest, total and marketable yields were recorded in each plot, assuming that the marketable yield includes only healthy tubers with a diameter of more than 40 mm. Then 5-to-7-kg samples were collected from each plot to carry out their chemical analysis. In fresh mass the

following contents were determined: dry mass by drier-weight method, starch by the Reiman (Zgórska and Czerko, 1981), vitamin C using the Pijanowski method, reducing sugars and total sugar by Luffa-Schoorl method, nitrates by using an ion selective nitrate electrode and silver-silver chloride reference electrode (Rutkowska, 1981) and the content of glycoalkaloids by using the method of Bergersa (Bergers, 1980). Consumption value of potato tubers, ie the darkening of the raw and cooked tubers flesh, was evaluated according to the color plates in an inverted 9-point Danish scale, number 9 - marked the flesh intact, and the number one - the flesh is black. Changes in raw tubers flesh was evaluated after 4 hours from the time of slice potatoes and boiled at 24 hours. Flavor ratings were made using a 9-point scale, with scores 9 assumed to be very good, and a 1 as very poor (Zgórska and Frydecka-Mazurczyk, 1985). 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 (Trętowski and Wójcik, 1991).

3. Results

3.1 Dry matter yield of researched organic fertilizer and the accumulation of macroelements

Amount of dry matter introduced into the soil by researched organic fertilizers was significantly differentiated (table 1). The biggest amount of the dry matter applied farmyard manure using jointly with straw and undersown intercrops with straw. Phacelia in combination with straw, irrespectively of its application introduced into the soil similar amount of dry matter as farmyard manure. However, intercrops and straw supplied the soil significantly less dry matter than farmyard manure.

Statistic analysis showed significant influence of the type of organic fertilizer on the amount of macroelements introduced into the soil (table 1). Indeed, the biggest amount of nitrogen supplied farmyard manure in combination with straw, white clover with straw and the mixtures of white clover mixed with Italian ryegrass also with the addition of straw. The amount of nitrogen supplied by white clover and the mixture of white clover with Italian ryegrass did not differ significantly from the amount of nitrogen supplied by farmyard manure. Other organic fertilizers introduced significantly less nitrogen than farmyard manure. Analyzing the amount of phosphorus applied by researched organic fertilizers, showed that only farmyard manure with straw provided that macroelement tha most. Comparable amount of phosphorus, as farmyard manure supplied white clover with straw, mixture of white clover with Italian ryegrass in combination with straw, and phacelia with straw. Other organic fertilizers introduced into the soil significantly less phosphorus than farmyard manure. The greatest amount of potassium supplied farmyard manure with straw and all intercrops also in combination with straw. Intercrops without straw supplied to the soil significantly less potassium than farmyard manure. Among researched organic fertilizer provided the most calcium applied farmyard manure with straw, white clover with straw, a mixture of white clover with Italian ryegrass and straw and phacelia with straw. Italian ryegrass in combination with straw provided a comparable amount of calcium, as farmyard manure. However, intercrops provided significantly less calcium than farm yard manure. Significantly more magnesium than farmyard manure provided farmyard manure used in combination with straw. However, intercrops in combinations without straw and with straw introduced into the soil significantly less magnesium than farmyard manure. The largest number of macroelements straw introduced into the soil.

Organic fertilization	Dry mass	Macroelements				
		N	P	K	Ca	Mg
Farmyard manure	7.8	162.0	48.3	132.6	63.8	40.2
White clover	5.3	157.7	32.0	112.4	49.3	24.1
White clover + Italian ryegrass	5.9	158.0	30.8	115.6	47.7	18.4
Italian ryegrass	6.3	114.5	26.9	109.1	35.3	13.6
Phacelia	4.4	112.8	37.8	92.7	43.8	21.0
Phacelia-mulch	4.5	112.9	38.0	92.9	43.9	21.2
Straw	4.2	32.8	11.2	76.4	27.0	9.9
Farmyard manure + straw	12.0	194.8	59.5	209.0	90.8	50.1
White clover + straw	9.5	190.5	43.2	188.8	76.3	34.0
White clover + Italian ryegrass + straw	10.1	190.8	42.4	192.0	74.7	28.3
Italian ryegrass + straw	10.5	147.8	38.1	185.5	62.3	23.5
Phacelia + straw	8.6	145.6	49.0	169.1	70.8	30.9
Phacelia-mulch + straw	8.7	145.7	49.2	169.3	70.9	31.1
$LSD_{0.05}$	1.0	11.7	5.9	10.7	5.5	3.2

Table 1. The amount of dry mass (t ha^{-1}) and macroelements (kg ha^{-1}) introduced into the soil by researched organic fertilizers (means from years 2000-2006)

3.2 Potato tubers yield

3.2.1 Total yield

Total yield of potato tubers was significantly modified by the examined factors and their interaction (table2). The highest yields of potato tubers were harvested from the objects

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	27.4	36.2	31.8
Farmyard manure	42.8	41.7	42.3
White clover	43.0	46.2	44.6
White clover + Italian ryegrass	47.3	44.8	46.1
Italian ryegrass	37.4	36.3	36.9
Phacelia	44.7	43.0	43.8
Phacelia-mulch	42.6	44.2	43.4
Means	40.7	41.8	-
$LSD_{0.05}$			
Catch crop ferilization			1.0
Straw fertilization			0.9
Interaction			1.2

Table 2. Total field of potato tubers, t ha^{-1} (means from yaers 2005-2007)

fertilized with a mixture of white clover with Italian ryegrass, white clover, and phacelia both plowed down in autumn, and left till spring in the form of mulch. Only after Italian ryegrass applying total yield of potato tubers was significantly lower than recorded on control object. Straw fertilization also significantly modified the yield of potato tubers. At the sub-block with straw, potato tuber yield was significantly lower than recorded at the sub-block without straw. An interaction has been noted, which shows that the highest yield of potato tubers were obtained from the object fertilized with a mixture of white clover with Italian ryegrass and white clover with straw, and the smallest from control object, without intercrop fertilization.

3.2.2 Marketable yield

Statistical analysis showed a significant influence of examined factors and their interaction on the commercial yield of potato tubers (table 3). The highest yields were obtained from objects fertilized white clover, a mixture of white clover and Italian ryegrass and phacelia both plowed in the autumn, and left till spring in the form of mulch. Only on object fertilized with Italian ryegrass and on control object marketable yield of potato tubers was significantly lower than that recorded in farmyard manure. Straw fertilization also significantly differentiate commercial yield of potato tubers. At the sub-block with straw marketable yield of potato tubers was significantly higher than obtained in the sub-block without straw. An interaction has been noted, which shows that indeed the highest marketable yield was obtained from the object fertilized with a mixture of white clover with Italian ryegrass and white clover with straw, and the smallest from the control object without organic fertilization.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	17.8	27.0	22.4
Farmyard manure	38.6	37.2	37.9
White clover	39.4	45.6	42.5
White clover + Italian ryegrass	46.8	43.5	45.2
Italian ryegrass	28.9	28.1	28.5
Phacelia	43.9	41.2	42.6
Phacelia-mulch	38.4	42.0	40.2
Means	36.3	37.8	-
$LSD_{0.05}$			
Catch crop ferilization			0.9
Straw fertilization			1.0
Interaction			1.3

Table 3. Marketable field of potato tubers t ha^{-1} (means from years 2005-2007)

3.3 The quality of potato tubers

3.3.1 The dry matter content in potato tubers

The dry matter content in potato tubers was significantly differentiated by the intercrop fertilization, straw fertilization and their interaction (table 4). The highest concentration of

dry matter characterized potato tubers fertilized with white clover, a mixture of white clover with Italian ryegrass and phacelia both plowed down in the autumn, as left till spring in the form of mulch.
The dry matter content in potato tubers fertilized with Italian ryegrass was significantly lower than in potatoes fertilized with farmyard manure. On control object, without organic fertilization dry matter content in potato tubers was significantly lower. Straw fertilization also significantly modified dry matter content in potato tubers. At the sub-block with straw potatoes distinguished by a higher concentration of dry matter than the tubers at sub-block without straw. From the interaction of researched factors showed that the highest content of dry matter was noted in potato tubers fertilized with white clover with straw, a mixture of white clover with Italian ryegrass in combinations without straw and with straw, phacelia in combination with straw, and phacelia used in the form of mulch with a straw or without the straw, and the lowest in potato tubers harvested from control object without organic fertilization.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	19.5	21.1	20.3
Farmyard manure	21.4	21.6	21.5
White clover	21.7	22.0	21.9
White clover + Italian ryegrass	22.1	22.3	22.2
Italian ryegrass	21.0	21.1	21.1
Phacelia	21.7	22.2	22.0
Phacelia-mulch	22.2	22.4	22.3
Means	21.4	21.8	-
$LSD_{0.05}$			
Catch crop ferilization			0.3
Straw fertilization			0.2
Interaction			0.4

Table 4. Dry matter content in potato tubers, % (means from years 2005-2007)

3.3.2 Dry matter yield of potato tubers

Dry matter yield of potato tubers was significantly modified by the intercrop fertilization, straw fertilization and their interaction (table 5). The highest dry matter yield of potato tubers was collected from the object fertilized with a mixture of white clover with Italian ryegrass, white clover and phacelia used in the form of mulch. Dry matter yield of potato tubers fertilized with phacelia did not differ significantly from the yield recorded on the farmyard manure. Only after the application of Italian ryegrass dry matter yield of potato tubers was significantly lower than that recorded on the farmyard manure. However, in this case, dry matter yield was significantly higher than that obtained on control object, without intercrop fertilization. Straw fertilization also significantly differentiate dry matter yield of potato tubers. On objects with straw dry matter yield of potato tubers was greater than on the objects without straw. There has been an interaction, which shows that the highest dry matter yield of potato tubers were obtained from the object fertilized with a mixture of white clover with Italian ryegrass in combinations without straw and with straw, white clover in combination with straw, and phacelia used in the form of mulch and also in combination with straw, and the smallest on control object, without intercrop fertilization.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	5.34	7.64	6.49
Farmyard manure	9.16	9.01	9.09
White clover	9.33	10.16	9.75
White clover + Italian ryegrass	10.45	9.99	10.22
Italian ryegrass	7.85	7.66	7.76
Phacelia	9.70	9.55	9.63
Phacelia-mulch	9.46	9.90	9.68
Means	8.76	9.13	-
$LSD_{0.05}$			
Catch crop ferilization			0.56
Straw fertilization			0.27
Interaction			0.59

Table 5. Dry matter yield, t ha^{-1} (means from years 2005-2007)

3.3.3 Starch content in potato tubers

Statistical analysis showed a significant effect of examined factors and their interaction on starch content in potato tubers (table 6). Intercrops fertilization of potato, with the exception

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	13.2	13.9	13.6
Farmyard manure	14.0	14.1	14.0
White clover	13.7	14.0	13.9
White clover + Italian ryegrass	14.2	14.3	14.2
Italian ryegrass	14.4	14.5	14.4
Phacelia	14.5	14.7	14.6
Phacelia-mulch	14.6	14.8	14.7
Means	14.1	14.3	-
$LSD_{0.05}$			
Catch crop ferilization			0.2
Straw fertilization			0.1
Interaction			0.3

Table 6. Starch content in potato tubers, % (means from years 2005-2007)

of white clover caused a significant increase of starch content in potato tubers in comparison with farmyard manure fertilization. The starch content in potato tubers fertilized with white clover did not differ significantly from that observed in potato tubers fertilized with farmyard manure. However, on control object starch concentration in potato tubers was significantly lower than in tubers fertilized with farmyard manure. An interaction has been noted, which shows that the highest concentration of starch was noted in potato tubers fertilized with phacelia both plowed down in the autumn, and left till spring in the form of mulch in combination without straw and with straw and Italian ryegrass in combination with straw, and the lowest in potato tubers cultivated on control object.

3.3.4 Starch yield

Statistical analysis showed a significant effect of examined factors in experience on the starch yield of potato tubers (table 7). Intercrop fertilization caused a significant increase of starch yield in comparison with starch yield of potato tubers from the control object. The highest starch yield was obtained from the object fertilized with a mixture of white clover with Italian ryegrass, white clover, phacelia plowed down in autumn and left till spring in the form of mulch. Only after the application of Italian ryegrass the starch yield of potato tubers fertilized with Italian ryegrass was significantly lower than that recorded in the farmyard manure. Straw fertilization also modified the starch yield. At the sub-block with straw starch yield of potato tubers was significantly higher than at the sub-block without straw. An interaction has been shown that intercrop fertilization with straw fertilization, which shows that the highest yield of starch was obtained from the object fertilized with a mixture of white clover with Italian ryegrass and phacelia used in the form of mulch in combination with straw, and the smallest from control object, without intercrop fertilization.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	3.62	5.03	4.33
Farmyard manure	5.99	5.88	5.94
White clover	5.89	6.47	6.18
White clover + Italian ryegrass	6.72	6.41	6.57
Italian ryegrass	5.39	5.26	5.33
Phacelia	6.48	6.32	6.40
Phacelia-mulch	6.22	6.54	6.38
Means	5.76	5.99	-
$LSD_{0.05}$			
Catch crop ferilization			0.20
Straw fertilization			0.14
Interaction			0.21

Table 7. Starch yield, t ha^{-1} (means from years 2005-2007

3.3.5 Reducing sugars content in potato tubers

Statistical analysis showed a significant effect of examined factors on reducing sugars content in potato tubers (table 8). The highest concentration of reducing sugars noted in potato tubers harvested from control object. The highest concentration of reducing sugars noted in potato tubers harvested from control object. Intercrop fertilization significantly decreased reducing sugars content in potato tubers in comparison with their concentrations recorded in potatoes tubers harvested from control object. Indeed, the lowest content of reducing sugars was noted in potato tubers fertilized with phacelia both plowed down in the autumn, and left till spring in the form of mulch. Straw fertilization also significantly differentiate the concentration of reducing sugars in potato tubers. Higher its content was noted in potato tubers in the sub-block without straw than on the sub-block with straw.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	0.34	0.26	0.30
Farmyard manure	0.24	0.21	0.23
White clover	0.23	0.20	0.22
White clover + Italian ryegrass	0.17	0.15	0.16
Italian ryegrass	0.21	0.19	0.20
Phacelia	0.17	0.16	0.17
Phacelia-mulch	0.16	0.14	0.15
Means	0.22	0.19	-
$LSD_{0.05}$			
Catch crop ferilization			0.03
Straw fertilization			0.02
Interaction			n.s.

Table 8. Reducing sugars content in potato tubers, % (means from years 2005-2007)

3.3.6 The total sugar content in potato tubers

The total sugar content in potato tubers was significantly modified by intercrop fertilization and straw fertilization (table 9). Intercrop fertilization significantly decreased the concentration of total sugars in potato tubers. The lowest its content was recorded in potato tubers fertilized with a mixture of white clover with Italian ryegrass and phacelia plowed down in the autumn and left till spring in the form of mulch. The content of reducing sugars in potato tubers fertilized with white clover and Italian ryegrass did not differ significantly from their concentrations observed in tubers fertilized with farmyard manure. However, on control object, the content of total sugars in potato tubers was significantly higher than in the potato fertilized with farmyard manure. Straw fertilization also significantly modified the content of total sugars in potato tubers. At the sub-block without straw content of total sugars in potato tubers was significantly lower than at the sub-block with straw.

3.3.7 Vitamin C content in potato tubers

The vitamin C content in potato tubers was significantly differentiated by the examined factors of experiment and their interaction (table 10). Intercrop fertilization in comparison with control object caused a significant increase of vitamin C content in potato tubers. Indeed, the highest concentration of vitamin C were characterized in potato tubers fertilized with phacelia in the form of mulch and white clover. The vitamin C content in potato tubers fertilized with a mixture of white clover with Italian ryegrass and phacelia developed at a similar level as in the potato fertilized with farmyard manure. Straw fertilization also significantly differentiate the concentrations of vitamin C in potato tubers. On objects with straw the content of vitamin C in tubers was significantly higher than on the objects without straw. From the interaction between studied factors shows that the highest concentration of vitamin C were characterized by potato tubers fertilized with phacelia both plowed down in the autumn, and left till spring in the form of mulch, in combination without straw and with straw, and white clover and white clover with straw, and the lowest in potato tubers from control object.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	0.63	0.56	0.60
Farmyard manure	0.54	0.52	0.53
White clover	0.53	0.51	0.52
White clover + Italian ryegrass	0.48	0.42	0.45
Italian ryegrass	0.50	0.51	0.51
Phacelia	0.47	0.46	0.47
Phacelia-mulch	0.46	0.44	0.47
Means	0.52	0.49	-
$LSD_{0.05}$			
Catch crop ferilization			0.04
Straw fertilization			0.02
Interaction			n.s.

Table 9. The total sugar content in potato tubers, % (means from years 2005-2007)

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	203.4	217.6	210.5
Farmyard manure	218.6	217.3	218.0
White clover	222.5	224.2	223.4
White clover + Italian ryegrass	219.4	222.5	221.0
Italian ryegrass	217.7	218.4	218.1
Phacelia	220.6	221.7	221.2
Phacelia-mulch	223.4	224.8	224.1
Means	217.9	220.9	-
$SLD_{0.05}$			
Catch crop ferilization			3.2
Straw fertilization			1.8
Interaction			4.3

Table 10. Vitamin C content in potato tubers, g kg^{-1} dry matter (means from years 2005-2007)

3.3.8 The total protein content in potato tubers

Statistical analysis showed a significant effect of examined factors and their interaction on total protein content in potato tubers (table 11). Intercrop fertilization significantly increased the concentration of total protein in potato tubers in relation to its content recorded in potatoes harvested from control object. Indeed, the highest concentration of total protein were characterized by potato tubers fertilized with white clover and with phacelia both plowed down in the autumn and left till spring in the form of mulch. The content of total protein in potato tubers fertilized with a mixture of white clover with Italian ryegrass did not differ significantly from that observed in potato tubers fertilized with farmyard manure. However, fertilization of potato with Italian ryegrass caused a significant decrease in total protein content in potato tubers in comparison with farmyard manure fertilization. Straw fertilization also significantly modified the concentration of total protein in potato tubers. On objects with straw total protein content in potato tubers was significantly higher on objects without straw. An interaction has been noted, which shows that the highest concentration of total protein was characterized by a potato fertilized with white clover, white clover with straw, and phacelia both plowed down in the autumn, and left till spring in the form of mulch, in combination, without straw and with straw, whereas the lowest potato tubers collected from the control object without intercrop fertilization.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	8.16	9.23	8.69
Farmyard manure	9.42	9.48	9.45
White clover	10.46	10.53	10.50
White clover + Italian ryegrass	9.45	9.56	9.51
Italian ryegrass	8.89	9.00	8.95
Phacelia	10.33	10.45	10.39
Phacelia-mulch	10.08	10.15	10.12
Means	9.54	9.77	-
$LSD_{0.05}$			
Catch crop ferilization			0.27
Straw fertilization			0.14
Interaction			0.43

Table 11. The content of total protein in potato tubers, % dry mass (means from years 2005-2007)

3.3.9 The content of true protein in potato tubers

The content of true protein in potato tubers was significantly differentiated by the intercrop fertilization, fertilization with straw and their interaction (table 12). The highest concentration of true protein in potato tubers was noted in potato tubers fertilized with phacelia and white clover both plowed down in the autumn, and left till spring in the form of mulch. The concentration of true protein in potato tubers fertilized with a mixture of white clover with Italian ryegrass remained at a similar level, such as on farmyard manure.

However, true protein content in potato tubers fertilized with Italian ryegrass was significantly lower than in tubers fertilized with farmyard manure. Straw fertilization also significantly differentiate true protein content in potato tubers. At the sub-block with straw concentration of true protein in potato tubers was significantly higher than on sub-block without straw. Investigated the interaction of factors we can see that the highest true protein content had potato tubers fertilized white clover, white clover with straw, and phacelia both plowed down in the autumn, and left till spring in the form of mulch in combination without straw and with straw, and the lowest potato tubers harvested from control object, without intercrop fertilization.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	3.67	4.72	4.20
Farmyard manure	4.92	5.06	4.99
White clover	5.74	5.83	5.79
White clover + Italian ryegrass	5.03	5.18	5.10
Italian ryegrass	4.38	4.45	4.42
Phacelia	5.54	5.66	5.60
Phacelia-mulch	5.43	5.54	5.48
Means	4.96	5.21	-
$LSD_{0.05}$			
Catch crop ferilization			0.26
Straw fertilization			0.14
Interaction			0.43

Table 12. The content of true protein in potato tubers, % dry mass (means from years 2005-2007)

3.3.10 Nitrate content in potato tubers

Statistical analysis showed significant effects of intercrop fertilization and interaction between intercrop fertilization and straw fertilization on the nitrate content in potato tubers (table 13). The highest concentration of nitrates was recorded in tubers harvested from control object. Intercrop fertilization caused a significant decrease of nitrate content in potato tubers. The lowest their concentration was noted in potato tubers fertilized with white clover, a mixture of white clover and Italian ryegrass and phacelia both plowed down in the autumn, and left till spring in the form of mulch. The nitrates content in potato tubers fertilized with Italian ryegrass, did not differ significantly from the concentrations observed in potato tubers fertilized with farmyard manure. An interaction has been noted which shows that the lowest content of nitrates was recorded in tubers fertilized with white clover and phacelia both plowed down in the autumn, and left till spring in the form of mulch, and the lowest on control object.

3.3.11 Glycoalkaloids content in potato tubers

The content of glycoalkaloids in potato tubers was significantly modified for examined factors and their interaction (table 14). Intercrop fertilization caused a significant decrease of glycoalkaloids in potato tubers in comparison with its concentrations observed in the potato from control object. The lowest content of glycoalkaloids was noted in potato tubers fertilized with white clover, a mixture of white clover with Italian ryegrass, phacelia both plowed down in the autumn, and left till spring in the form of mulch. The concentration of glycoalkaloids in potato tubers fertilized with Italian ryegrass did not differ significantly from that recorded in the potatoes fertilized with farmyard manure. Straw fertilization also significantly modified the content of glycoalkaloids in potato tubers. At the sub-block with

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	147.0	141.2	144.1
Farmyard manure	109.2	122.2	115.7
White clover	92.3	84.9	88.6
White clover + Italian ryegrass	99.7	102.3	101.0
Italian ryegrass	108.3	118.6	113.5
Phacelia	88.2	107.4	97.8
Phacelia-mulch	95.4	88.6	92.0
Means	105.7	109.3	
$LSD_{0.05}$			
Catch crop ferilization			7.2
Straw fertilization			n.s.
Interaction			7.5

Table 13. Nitrate content in potato tubers, mg kg^{-1} of dry mass (means from years 2005-2007)

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	63.9	58.2	61.1
Farmyard manure	54.4	54.2	54.3
White clover	46.3	44.1	45.2
White clover + Italian ryegrass	52.1	40.8	46.5
Italian ryegrass	55.2	54.6	54.9
Phacelia	47.5	46.6	47.1
Phacelia-mulch	47.2	45.7	46.5
Means	52.4	49.2	-
$LSD_{0.05}$			
Catch crop ferilization			3.1
Straw fertilization			0.4
Interaction			3.9

Table 14. Glycoalkaloids content in potato tubers, mg kg^{-1} of dry mass (means from years 2005-2007)

straw the concentration of glycoalkaloids in potato tubers was significantly lower than that recorded in the tubers of the sub-block without straw. Investigated the interaction of factors that were characterized it shows that the lowest content of glycoalkaloids in potatoes fertilized with white clover, white clover with straw, and phacelia both plowed down in the autumn, and left till spring in the form of mulch in combination without straw and with straw, and the highest potato tubers collected from the control object.

3.4 Consumption value of potato tubers

3.4.1 The darkening of raw potato tubers flesh

Statistical analysis revealed significant effects of intercrop fertilization and interaction of intercrop fertilization with straw fertilization on the darkening of raw potato tubers flesh (table15). Potatoes cultivated after intercrops showed less tendency to darkening of raw potato tubers flesh than tubers cultivated on control object. On control object fertilized with white clover, and with phacelia left till spring in the form of mulch noted significantly the lowest degree of darkening of raw potato tubers flesh. The darkening of tubers flesh fertilized with a mixture of white clover and Italian ryegrass, Italian ryegrass and phacelia plowed down in autumn remained at a similar level as the darkening of tubers flesh fertilized with farmyard manure. Differences between particular objects are within the limits of experimental error. There was an interaction, which shows the lowest degree of darkening of raw potato flesh was recorded in the object fertilized with phacelia in the form of mulch and white clover with straw, and the highest on control object.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	6.0	6.2	6.1
Farmyard manure	6.9	7.1	7.0
White clover	7.4	7.5	7.5
White clover + Italian ryegrass	7.0	7.1	7.1
Italian ryegrass	6.6	6.8	6.7
Phacelia	7.0	7.1	7.1
Phacelia-mulch	7.6	7.7	7.7
Means	6.9	7.1	-
$LSD_{0.05}$			
Catch crop ferilization			0.3
Straw fertilization			n.s.
Interaction			0.4

Table 15. The darkening of raw potato tubers flesh after 4 hours (means from years 2005-2007)

3.4.2 The darkening of cooked potato tubers flesh

The darkening of cooked potato tubers flesh was significantly modified by intercrop fertilization and the interaction of intercrop fertilization with straw fertilization (table16). The degree of darkening of cooked potato tubers fertilized with white clover, and phacelia left till spring in the form of mulch was the lowest. Darkening of cooked potato tubers flesh fertilized with a mixture of white clover with Italian ryegrass, Italian ryegrass and phacelia plowed down in the autumn did not differ significantly from the darkening of potato tubers flesh fertilized with farmyard manure. Only on control object the level of darkening of cooked potato tubers flesh was significantly lower than that recorded on the farmyard manure. An interaction of researched factors was noted, which shows that the lowest degree of darkening of cooked potato tubers flesh were recorded on the object fertilized with white clover, white clover with straw, and phacelia left till spring in the form of mulch with straw, and the highest on control object.

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	7.0	7.1	7.1
Farmyard manure	7.8	7.9	7.9
White clover	8.1	8.3	8.2
White clover + Italian ryegrass	7.9	8.0	8.0
Italian ryegrass	7.6	7.7	7.7
Phacelia	7.7	7.9	7.8
Phacelia-mulch	8.1	8.2	8.2
Means	7.7	7.9	-
$LSD_{0.05}$			
Catch crop ferilization			0.2
Straw fertilization			n.s.
Interaction			0.4

Table 16. The darkening of cooked potato tubers flesh after 24 hours (means from years 2005-2007)

Catch crop fertilization	Straw fertilization		Means
	Subblock without straw	Subblock with straw	
Control object	5.4	5.5	5.5
Farmyard manure	6.3	6.4	6.4
White clover	8.0	8.2	8.1
White clover + Italian ryegrass	7.0	7.2	7.1
Italian ryegrass	6.5	6.6	6.6
Phacelia	7.1	7.2	7.2
Phacelia-mulch	7.5	7.7	7.6
Means	6.8	7.0	-
$LSD_{0.05}$			
Catch crop ferilization			0.2
Straw fertilization			n.s.
Interaction			0.3

Table 17. Savoriness of potato tubers, points (means from years 2005-2007)

3.4.3 Savoriness of potato tubers

Statistical analysis revealed significant effects of intercrop fertilization and interaction between intercrop fertilization and straw fertilization on savoriness of potato tubers (table17). Intercrop fertilization improved the savoriness of potato tubers in comparison with savoriness of potato tubers harvested from control object. The best savoriness had potato tubers fertilized with white clover, the mixture of white clover with Italian ryegrass, and phacelia both plowed down in the autumn, and left till spring in the form of mulch. Savoriness of potato tubers fertilized with Italian ryegrass did not significantly differ from savoriness of potato tubers fertilized with farmyard manure. There has been an interaction which shows that the best savoriness had potato tubers fertilized with white clover in combination without straw and with straw, and the worst potato tubers from control object.

4. Discussion

Shortage of farmyard manure due to the decline in farm animal stocks, low profitability and the rationale for integrated production tend to look for alternative and efficient ways of potato fertilization. The most important here are green fertilizers from undersown crops and stubble crops and straw left on field after cereal harvest. Selection of underplant crops as alternative sources of biomass, dictated the results of Batalina et al. (1968) and Ceglarka (1982). Batalin et al. (1968) initiated studies to evaluate the fertilizer value of underplant crops legumes, and Ceglarek (1982) conducted a thorough research on the determination of yield and chemical composition of crop residues of underplant crops. However Gutmański et al. (1998) have evaluated the value of fertilizer of oil radish, white mustard and phacelia used in sugar beet cultivation, which became the motivation for taking this type of research in potato cultivation. Under the conditions of this experiment, from the group of underplant crops yielding on the highest level was Italian ryegrass and a mixture of white clover with Italian ryegrass. The high biomass production of grasses also show results of Gromadziński and Sypniewski (1971), Zając and Witkowicz (1996), Ceglarka et al. (1998), Witkowicz (1998) and Kuraszewicza and Palys (2002). In own researches, phacelia grown in stubble intercrop yielded at a similar level as white clover cultivated as an intercrop. This is consistent with the results of Gromadziński and Sypniewski (1971), Witkowicz (1998), Trawczyński and Grześkiewicz (1997) and Nowakowski et. al. (1997), Ceglarek and Płaza, 2000). In the experiment the addition of straw to the intercrops caused a significant increase of the amount of dry matter and macronutrients.

Nowak (1982) indicates a predominance of green manure on the farmyard manure. This follows from the fact that the nutrients contained in green manure are generally more easily absorbed than the components of farmyard manure, due to rapid decomposition of organic matter. In this experiment, among intercrops the highest value of fertilizing showed undersown: a mixture of white clover with Italian ryegrass and white clover. Batalin et. al. (1968) the highest yields of potato tubers received after plowing the undersown of red clover and serradella, and Ceglarek et al. (1998) after plowing the mixtures of legume with Italian ryegrass. These differences are due to different rates of mineralization used forms of fertilization and the fact that the introduction into the soil with a mixture of larger amounts of biomass and macronutrients. According to Nowak (1982), during the decomposition of legumes may occur high losses of nitrogen. Depending on the temperature, humidity and time of decomposition, nitrogen losses could amount up to 50%. To prevent it, to the decomposing mass of legumes material rich in carbon should be added, such as grasses, in order to increase the C:N. In this experiment yields of potato tubers fertilized with Italian ryegrass were significantly smaller than in farmyard manure. However, in this case, tuber yields were significantly higher than those obtained on control object, without intercrop fertilization. The increase of tuber yield after plowing down the grass also found Sadowski (1992), Spiertz et al. (1996), Duer and Jończyk (1998) and Reust et al. (1999), but yields were lower than on the farmyard manure. This is because the introduction into the soil a large amount of biomass, with a low content of macronutrients (Sadowski 1992; Duer and Jończyk 1998). In addition, grasses have a wide ratio C:N. In this case, the less nitrogen mineralization, which is used primarily by soil microorganisms. In own research, the value of stubble crop fertilizer from phacelia plowed down in autumn and left till spring in the form of mulch equal the fertilizer value of farmyard manure. This is understandable because of non-legume stubble crops biomass of this plant was notable for its high content of macronutrients. This is confirmed by results of Dzienia (1989), Trawczyński and Grześkiewicz (1997) and Nowakowski, et al. (1997) and Różyło (2002).

In potato fertilization of stubble crops can also be used in the form of mulch. However, thus fertilizing the position, with the exception of phacelia, in terms of fertilizer could not match with farmyard manure. This is confirmed by research of Boligłowa and Dzienia (1996) and Dzieni and Szarka (2000) on potato fertilization by mulch from white mustard. In the system of integrated agriculture can recommend this method of fertilization, especially with phacelia mulch, while significantly reducing of costs. The beneficial effects of intercrops plants left on the field in the form of mulch slows the mineralization of organic matter, does not allow for leaching of nitrogen, stored water from the autumn-winter rainfalls, improves soil structure and enriches it in organic matter (Hoyt et al. 1986; Frye et al., 1988; Dzienia and Boligowa, 1993; Gutmański et al., 1999).

In that experiment fertilization with spring barley straw gave a lower effect than farmyard manure fertilization. This is consistent with the results of Sadowski (1992), Szymankiewicz (1993), Śnieg and Piramowicza (1995) and Ceglarek et al. (1998). However, its use combined with intercrop undersown of white clover and stubble crop left till spring in the form of mulch clearly strengthened its fertilising value. Potato tubers yields of after fertilization of these forms were comparable, in the case of white clover yields higher than those recorded on farmyard manure. Also Ceglarek et al. (1998) recommend the combined use of legumes as undersown.

Intercrops fertilization with straw affects not only for the amount of received yieldss, but also on quality, so reciprocal arrangement of the components involved in potato tubers (Roztropowicz, 1989; Grześkiewicz and Trawczyński, 1997; Boligłowa and Gleń 2003). The dry matter content and starch in potato tubers depends on the genetic factor, the distribution of rainfall and temperatures during the growing season and on agronomic factors, mainly from fertilizer (Rostropowicz, 1989; Grześkiewicz and Trawczyński 1997; Ceglarek et al., 1998; Dzienia and Szarek, 2000; Leszczyński 2002; Płaza and Ceglarek 2009; Makaraviciute 2003). In own studies, intercrop fertilization stimulated the content and dry matter yield of potato tubers and starch content and yield. The highest concentration of dry matter were characterized potatoes fertilized with mixture of white clover with Italian ryegrass and with phacelia plowed down in the autumn and left till spring in the form of mulch, and starch - potatoes fertilized with Italian ryegrass and phacelia plowed down and left till spring in the form of mulch. Research of Ceglarek et al. (1998) showed that potatoes fertilized with legume mixtures with Italian ryegrass include the most dry matter and Italian ryegrass fertilized include the most starch. Boligłowa and Gleń (2003) have not indicated significant differences between the starch content in potatoes fertilized with farmyard manure, and white mustard both plowed down in the autumn, as left till spring in the form of mulch. a Different view present Mazur and Jułkowski (1982) claiming that potato fertilization with legumes works better on the percentage starch content than with farmyard manure fertilization. In own studies, potato fertilization with stubble intercrop in the form of mulch increased the concentration of dry matter and starch in potato tubers as compared to that of intercrops plowed down in autumn. A similar relationship, but in sugar beet cultivation proved Gutmański et al. (1998). However Dzienia and Szarek (2000) and Boligłowa and Gleń (2003) found no significant differences between the starch content in potato tubers fertilized with farmyard manure, and white mustard both plowed down in the autumn, and left till spring in the form of mulch. Under the conditions of this experiment straw fertilization increased starch content in potato tubers, and in studies Gleń et al. (2002) did not decrease significantly the concentration of this component. Consumption potato tubers should contain about 0.3% reducing sugar, and 1% of total sugars. With increased content of total sugars, potatoes taste sweet (Głuska 2000; Leszczynski, 2000, 2002). In own studies, fertilization of potato with intercrop and straw caused a significant decrease in reducing sugars and total sugars in potato tubers as compared to the control object, without intercrop fertilization. Also, according to Leszczyński (2002) and Makaraviciute (2003) organic fertilizers reduce the concentration of sugars in potato tubers. However, the studies of Mondy and Munshi (1990) showed that enrichment of soil in substance abounds in nitrogen reduces the starch content and increases the sugar content in potato tubers. In own studies, potato fertilization with white clover did not result in significant differences in the amount of reducing sugars and total sugars as compared to farmyard manure fertilization.

In light of these studies used forms of organic fertilization stimulated the concentration of vitamin C in potato tubers. The highest concentrations of vitamin C were characterized in potatoes fertilized with white clover and phacelia both plowed down in the autumn, and left till spring in the form of mulch in combination without the straw and with straw. Also, the findings of other authors (Garwood et al. 1991; Weber and Putz 1999; Leszczyński 2002; Sawicka and Kuś 2002; Hamouz et al. 2005, 2007; Płaza and Ceglarek 2009) indicate a positive correlation between organic fertilization and vitamin C content in potato tubers.

In own researches, intercrop fertilization preferably affected on protein content in potato tubers. Also in the researches of Mazur and Jułkowskiego (1982), Sawicka (1991), Leszczyński (2002) and Sawicka and Kuś (2002) saw an increase in concentration of true protein in potato tubers cultivated in organic fertilizers. Most preferably, the discussed feature influenced white clover fertilization, also phacelia both plowed down in the autumn, and left till spring in the form of mulch in combination, without straw and with straw. A similar relationship has proved Wiater (2002). Potatoes cultivation in the position fertilized with legume plants and phacelia plants take larger amounts of nitrogen from soil than potatoes cultivated in position fertilized with green fertilizers. Nitrogen contained in the biomass of white clover and phacelia, is gradually mineralization is evenly shared to the potato crop, leading to total conversion of protein nitrogen. In own stuies, the lowest nitrate content was reported in potato tubers fertilized with white clover and phacelia both plowed down in the autumn and left till spring in the form of mulch. Only after Italian ryegrass applying nitrate content in potato tubers did not differ significantly from that recorded in potatoes fertilized with farmyard manure. The above relationship is explained by the fact that the biomass of white clover, or phacelia outside the higher content of nitrogen contained a few fibers which ensured its rapid degradation. Thanks to this all nutrients, including nitrogen available to potatoes plant are evenly distributed, allowing the total conversion of mineral nitrogen in protein nitrogen. This is consistent with the results of Dzienia et al. (2004) and Boligłowy and Gleń (2003), who showed that potato tubers fertilized with white mustard and rye straw contained significantly less nitrates than potatoes fertilized with farmyard manure. According to Leszczyński (2002) use of farmyard manure, whose chemical composition is not controlled, may increase for example nitrogen and other components content in the plant. However Boligłowa and Gleń (2003) showed that the nitrate content in potato tubers fertilized with white mustard developed at a similar level as in the potatoes fertilized with farmyard manure. In own studies the highest concentration of nitrates reported in potato tubers from the control object, only with mineral fertilization. This is due to the fact that mineral fertilizers, especially nitrogen increased the content of nitrogen compounds, mainly non-protein, including free amino acids, amines, ammonium nitrogen and nitrate nitrogen and reduces the share of protein in general (Wiater, 2002).

In this experiment the lowest concentration of glycoalkaloids in potatoes fertilized with white clover, a mixture of white clover and Italian ryegrass and phacelia both plowed down in the autumn, and left till spring in the form of mulch. According to Rudella et al. (2005) intercrop cultivation with a favorable ratio of carbon to nitrogen regenerates the soil environment, increases the humus content, the number of microorganisms, enzymes and other biologically active compounds in the soil, which inhibits the accumulation of harmful substances in potato tubers. In the experiment only after the applying of Italian ryegrass the concentration of glycoalkaloids in potato tubers was at the similar level as in the potato fertilized with farmyard manure. However, in this case the content of glycoalkaloids in tubers was significantly lower than that in potatoes cultivated without intercrop fertilization. Leszczyński (2002) shows that organic fertilizers reduce the harmful substances content in potato tubers by enriching the soil with organic substance which inhibits the synthesis process of glycoalkaloids. In own studies, straw fertilization also significantly differentiate the content of glycoalkaloids in potato tubers. On objects with straw the content of glycoalkaloids in potato tubers was significantly lower than on objects without straw. This is consistent with the results of research of Płaza et al. (2010). In this experiment the highest concentration of glycoalkaloids in potato tubers has been harvested from the control object, only with mineral fertilization. Also, the studies of Mondy and Munshi (1990), Hamouz et al. (2007), Kołodziejczyk et al. (2007) and Rytel et al. (2008) mineral fertilization increased the content of glycoalkaloids (solanine and chakoniny) in potato tubers. However, it should be noted that the potato in comparison with other crops have little ability to accumulate harmful substances for human. Moreover, the use of green manure and straw greatly reduces their concentration in comparison to traditional farmyard manure.

5. Conclusion

1. Among researched organic fertilizers the highest amount of dry matter and macroelements introduced into the soil farmyard manure with straw, white clover and straw and the mixture of white clover with Italian ryegrass and straw.
2. The largest potato yields were obtained from a combinations fertilized with a mixture of white clover with Italian ryegrass and white clover with straw.

3. Fertilization with straw from white clover undersown, and with phacelia left till spring in the form of mulch significantly increased potato tuber yield compared to the intercrop fertilization.
4. Intercrop and straw fertilization increased in potato tubers dry matter content, starch, total protein, true protein and vitamin C, and decreased the content of reducing sugars, total sugars, nitrates and glycoalkaloids.
5. Farmyard manure can be fully replaced in potato fertilization with substitutes, such as a mixture of white clover with Italian ryegrass, white clover and phacelia both plowed down in the autumn, and left till spring in the form of mulch in combinations without straw and with straw.

6. References

Allison, M. & Amstrong, M. (1991). The nitrate leaching problem – are catch crop the solution. *Br. Sugar Beet Rev.,* No. 3, pp. 8-11.

Batalin, M.; Szałajda, R. & Urbanowski, S. (1968). Wartość zielonego nawozu z poplonowych wsiewek roślin motylkowatych. *Pam. Puł.,* Nr 35, ss. 37-51.

Bergers, W. 91980). A rapid quantitative assai for solanidine glycoalkaloids In potatoes and industrial potato protein. *Potato Research*, No. 23, pp. 105-110.

Boligłowa, E. & Dzienia, S. (1996). Wpływ nawożenia organicznego i sposobu uprawy roli na plonowanie i jakość bulw ziemniaka. *Zesz. Nauk. AR Szczecin, Roln. LXII*, Nr 172, ss. 37-42.

Boligłowa, E. & Dzienia , S. (1997). Tendencje zmian w agrotechnice ziemniaka. Mat. konf. nauk. nt. „Nawozy roślinne w integrowanym systemie produkcji rolniczej". *AR Kraków*, ss. 51-56.

Boligłowa, E. & Gleń, K. (2003). Yielding and quality of potato tubers depending on the kind of organic fertilization and tillage methods. *Elec. Jour. Pol. Agroc. Univ. Ser. Agron.,* Vol. 1, No. 6, www.ejapau

Bowley, S. R..; Taylor, N.L. & Dougherty C.T. (1984). Physiology and morphology of red clover. *Adv. Agron.,* No. 37, pp. 317-347.

Ceglarek, F. (1982). Uprawa wsiewek międzyplonowych w zbożach. Cz. III. Ocena resztek pożniwnych wsiewek plonowych i ich wpływ na plon pszenicy jarej. *Zesz. Nauk. WSRP Siedlce, Ser. Rol.,* Nr 1, ss. 101-114.

Ceglarek, F.; Płaza, A.; Buraczyńska D. & Jabłońska-Ceglarek R. (1998). Alternatywne nawożenie organiczne ziemniaka jadalnego w makroregionie środkowo-wschodnim. Cz. II. Wartość odżywcza i konsumpcyjna ziemniaka. *Rocz. Nauk Rol.,* Ser. A. T. 113, Z. 3-4, ss. 189-201.

Ceglarek, F. & Płaza, A. (2000). Wartość konsumpcyjna bulw ziemniaka w zależności od rodzaju nawożenia organicznego. *Biul. IHAR*, Nr 213, ss. 117-123.

Dzienia, S. (1989). Wpływ masy organicznej na plonowanie roślin i chemiczne właściwości gleby lekkiej. *Zesz. Probl. Post. Nauk Rol.*, Nr 377, ss. 155-160.

Dzienia, S. & Boligłowa, E. (1993). Rola mulczowania w podnoszeniu żyzności i urodzajności gleby. *Post. Nauk Rol.*, Nr 1, ss. 107-111.

Dzienia, S. & Szarek, P. (2000). Efektywność uprawy bezpłużnej oraz międzyplonów i słomy w produkcji ziemniaka. *Zesz. Probl. Post. Nauk Rol.*, Nr 470, ss. 145-152.

Dzienia, S.; Szarek, P & Pużyński , S. (2004). Yielding and quality of potato tubers depending on the soil tillage systems and organic fertilization. *Zesz. Probl. Post. Nauk Rol.*, No. 500, pp. 235-242.

Duer, I. (1999). Plon suchej masy kilku odmian koniczyny uprawianej w ekologicznym i integrowanym systemie produkcji oraz akumulacja azotu w glebie. *Zesz. Nauk. AR Kraków,* Nr 347, ss. 69-77.

Duer, I & Jończyk, K. (1998). Potato fertilization cultivated in ecological farms. *Fragm. Agron*., No. 1, pp. 85-95.

Estler, M. (1991). Conservation of soil and water by using a new tillage system for row crop. In: Cover crops for clean water. The proceedings of an international conference. *Jacson, Terenssee*, pp. 34-36.

Frye, W.W.; Bleviens, R.L.; Smith, M.S.; Corak, S.J. & Varco, J.J. (1988). Role of annual legume cover crops in efficient use water and nitrogen. No. 51, *Am. Soc. Agronom*. Medison.

Garwood, T.; Davles, D. & Hartley, A. (1999). The effect of winter cover crops on yielding of the following spring crops and nitrogen balance in a calcareous loam. *J. Agric. Sci*. Cambridge, No 132, pp. 1-11.

Gleń, K.; Boligłowa, E. & Pisulewski, P. (2002). Wpływ różnego rodzaju nawożenia organicznego na jakość bulw ziemniaka. Mat. konf. nauk. nt. „Ziemniak spożywczy i przemysłowy oraz jego przetwarzanie. Perspektywy ekologicznej produkcji ziemniaka w Polsce". *AR Wrocław*, ss. 100-101.

Głuska, A. (2000). Wpływ agrotechniki na kształtowanie jakości plonu ziemniaka. *Biul IHAR*, Nr 213, ss. 173-178.

Gruczek, T. (1994). Gospodarka bezobornikowa na glebie lekkiej. *Fragm. Agron*., Nr 2, ss. 72-82.

Gromadziński, A. & Sypniewski, J. (1077). Przydatność różnych roślin do uprawy jako wsiewka poplonowa w żyto na ziarno i po życie na zielonkę. *Pam. Puł*., Nr 68, ss. 93-103.

Grześkiewicz, H. & Trawczyński, C. (1997). Poplony ścierniskowe jako nawóz organiczny w uprawie ziemniaka. *Biul. Inst. Ziemn.,* Nr 48, ss. 73-82.

Gutmański, I.; Kostka-Gościniak, D.; Nowakowski, M.; Szymczak-Nowak, J. & Banaszak, K. (1998). Plonowanie i jakość przemysłowa buraka cukrowego w warunkach stosowania siewu w mulcz z międzyplonu. *Rocz. AR Poznań, CCCVII, Rol*., Nr 52, ss. 255-262.

Gutmański, I.; Kostka-Gościniak, D.; Szymczak-Nowak, J.; Nowakowski, M. & Sitarski, A. (1999). Stan zachwaszczenia plantacji buraka cukrowego uprawianego z siewu w mulcz. *Folia Univ. Agric. Stetin. 195, Agric*., Nr 74, ss. 105-114.

Hamouz, K; Lachman, J.; Dvořăk, P. & Pivec, V. (2005). The effect of ecological growing on the potatoes yielding and quality. *Plant Soil Environ*., No. 51, pp. 397-402.

Hamouz, K; Lachman, J.; Dvořăk, P.; Duskova, O. & Cizek, M. (2007). Effect of conditions of locality, variety and fertilization on the content of ascorbic acid in potato tubers. *Plant Soil Environ*., No. 53, pp. 252-257.

Hoyt, G.D. & Hargrove W.L. (1986). Legume cover crop for improving crop and soil management in the Southern United States. *Hortic. Sci*., No. 21, pp. 34-39.

Jansen, G.; Flamme, W.; Shűller, K. & Vandrey, M. (2001). Tuber and starch quality of wild and cultivated potato species and cultivars. *Potato Res*., No. 44, pp. 137-146.

Kalembasa, S. & Symanowicz, B. (1985). Wpływ nawożenia organicznego i mineralnego na plon i skład chemiczny wybranych odmian ziemniaków. *Zesz. Nauk. WSRP Siedlce, Ser. Rol*., Nr 3, ss. 67-76.

Karlsson-Strese, E.M.; Rydberg, I.; Becker H.C. & Umaerus M. (1998). Strategy for Catch Crop Development. II. Screening of Species Undersown in Spring barley (*Hordeum* *vulgare* L.) with respect to catch crop Growth and Grain Yield. *Acta Agric. Scand., Sec. B. Soli and Plnat Sci.*, No. 48, pp 26-33.

Kerłowska-Kułas, M. (1993). Researches of the quality of food productions. *PWE, Warszawa.*

Kołodziejczyk, M.; Szmigiel, A.& Kiełbasa, S. (2007). Yielding and chemical composition of potato tubers in chageable conditions of fertilization. *Fragm. Agron.*, Nr 2, ss. 142-150.

Kuraszkiewicz, R. & Pałys, E. (2002). Wpływ roślin ochronnych na plon masy nadziemnej wsiewek międzyplonowych. *Annaless UMCS, Sec. E,* Nr 57. Ss. 105-112.

Leszczyński, W. (2000). Kryteria oceny jakości ziemniaka konsumpcyjnego i skrobiowego. Mat. konf. nauk. nt. „Ziemniaka spożywczy i przemysłowy oraz jego przetwarzanie". *AR Wrocław*, ss. 41-49.

Leszczyński, W. (2002). Zależność jakości ziemniaka od stosowania w uprawie nawozów i pestycydów.. *Zesz. Probl. Post. Nauk Rol.*, Nr 489, ss 47-64.

Majda, J. & Pawłowski, F. (1988). Plonowanie wsiewek życicy wielokwiatowej w zależności od ilości wysiewu i dawek azotu. Cz. I. Wsiewki w żyto zbierane na ziarno. *Rocz. Nauk Rol., Ser. A, T. 107,* Nr. 3, ss. 109-119.

Makaraviciute, A. (2003). Effect of organic and mineral fertilizers on the yield and quality of different potato varieties. *Agron. Res.*, No. 1, pp 197-209.

Mazur, T. & Jułkowski, M. (1982). Wpływ nawożenia organicznego i mineralnego na plonowanie, cechy jakościowe dwóch odmian ziemniaka uprawianego na glebie lekkiej. *Zesz. Nauk. ART Olsztyn, Ser. Rol.,* Nr 34, ss. 187-194.

Mondy, N.I. & Munshi, C.B. (1990). Effect of nitrogen fertilization on glicoalcaloid and nitra te kontent of potatoes. *Jour. Agric. Foood Chem.*, No. 38, pp. 565-567.

Nowak, G. (1982). Przemiany roślinnej materii organicznej znakowanej izotopem C_{14} w glebach intensywnie nawożonych. *Zesz. Nauk. AR Olsztyn, Ser. Rol.*, Nr 35, ss. 3-57.

Nowakowaski, M.; Gutmański, J.; Kostka-Gościniak, D. & Kaczorowski, G. (1997). Międzyplony ścierniskowe odmian gorczycy białej, rzodkwi oleistej i facelii błękitnej jako nawozy zielone i czynniki ograniczające mątwika burakowego w glebie. *Biul. IHAR*, nr 202, ss. 201-211.

Płaza, A. & Ceglarek, F. (2009). Tuber quality of edible potato fertilized with catch crops and barley straw. *Annales UMCS, Sec. E,* No. 3, pp. 79-90.

Płaza, A.; Ceglarek F.; Królikowska M.A. & Próchnicka M. (2009). Nawożenie ziemniaka jadalnego biomasą międzyplonów w warunkach środkowo-wschodniej Polski. *Biul IHAR,* Nr 254, ss. 137-144.

Płaza, A.; Ceglarek F. & Królikowska M.A. (2010). The influence of intercrops and farmyard manure fertilization in changeable weather conditions on consumption value of potato tubers. *Jour. Centr. Europ. Agric.,* No. 1, pp. 47-54.

Roztropowicz, S. (1989). Środowiskowe, odmianowe i nawozowe źródła zmienności składu chemicznego bulw ziemniaka. *Fragm. Agron.*, Nr 1, ss. 33-75.

Różyło, K. (2002). Wstępna ocena walorów konsumpcyjnych odmiany ziemniaka Irga różnie nawożonej na glebie lekkiej i ciężkiej. Mat. konf. nauk. nt. „Ziemniaka spożywczy i przemysłowy oraz jego przetwarzanie. Perspektywy ekologicznej produkcji ziemniaka w Polsce". *AR Wrocław*, ss. 97-98.

Rudella, C.A.; Davenport, J.R.; Evans, R.G., Hattendorf, M.J.; Alva, A.K. & Boydston, R.A. (2005). Relating potato yield and quality to yield scale variability in soil characteristics. *Amer. Jour. Potato Res.*, No. 79, pp. 317-323.

Rutkowska, U. (1981). Seleccted methods of study of composition and nutritional value of food. PZWL, Warszawa.

Rytel, E.; Lisińska, G. & Kozicka-Pytlarz, M. (2008). Wpływ sposobu uprawy na jakość konsumpcyjną ziemniaka. *Zesz. Probl. Post. Nauk Rol.*, Nr 530, ss. 259-269.

Sadowski, W. (1992). Porównanie efektywności obornika, słomy, nawozów zielonych i biohumusu w uprawie ziemniaka. Mat. konf. nauk nt. „Produkcyjne skutki zmniejszenia nakładów na agrotechnikę roślin uprawnych". *ART Olsztyn*, ss. 216-222.

Sawicka, B. (1991). Próba ustalenia niektórych czynników środowiska i zabiegów agrotechnicznych na ciemnienie miąższu bulw ziemniaka. *Biul IHAR,* Nr 179, ss. 67-74.

Sawiska, B. &Kuś, J. (2002). Zmienność składu chemicznego bulw ziemniaka w warunkach ekologicznego i integrowanego systemu produkcji. *Zesz. Probl. Post. Nauk Rol.,* Nr 489, ss. 273-282.

Smith, O. (2007). Potato quality. *Amer. Jour. Potato Res.*, No. 28, pp. 732-737.

Songin, W. (1998). Międzyplony w rolnictwie proekologicznym. *Post. Nauk Rol.*, Nr 2, ss. 43-51.

Spiertz, J.H.J.; Haverkort, A.J. & Vereijken P.H. (1996). Enviromentally safe and consumerfriendly potato production in The Netherlands. 1. Development of ecologically sound production systems. *Potato res.*, No. 39, pp. 371-378.

Stopes, C.; Milington, S. & Woolward, L. (1996). Dry matter and nitrogen accumulation by three leguminous green manure species and the yield of a following wheat crop in an organic production system. *Agric. Ecos. and Envir.*, No. 57, pp. 189-196.

Śnieg, L. & Piramowicz, W. (1995). Wpływ sposobu nawożenia na plonowanie ziemniaka i zboża jarego w ogniwie zmianowania. *Rocz. Nauk. Rol. , Ser. A, T. 111*, Nr 1-2, ss. 127-134.

Szymankiewicz, K. (1993). Wpływ stosowania pod ziemniaka słomy na plon i jego strukturę ze szczególnym uwzględnieniem bulw dużych. *Biul. Inst. Ziemn.*, Nr 43, ss. 93-103.

Szymona, J.; Krupiński, A. & Malicki L. (1983/1984). Resztki pożniwne niektórych roślin uprawianych na rędzinie. *Annales UMCS, Sec E*, Nr 7, ss. 77-87.

Trętowski, J & Wójcik, A.R. (1991). Methodology of agrocultural experiments. *Siedlce, WSRP*.

Weber, L. & Putz, B. (1999). Witamin C content In potato. Proceding 14 th triennial Conference of the European Association for Potato research. *Sorento, Italy*, pp. 230-231.

Wiater, J. (2002). Wpływ współdziałania niektórych odpadów z roślinami motylkowatymi na ilość i jakość białka ziemniaka. *Zesz. Probl. Post. Nauk Rol.*, Nr 484, ss. 743-752.

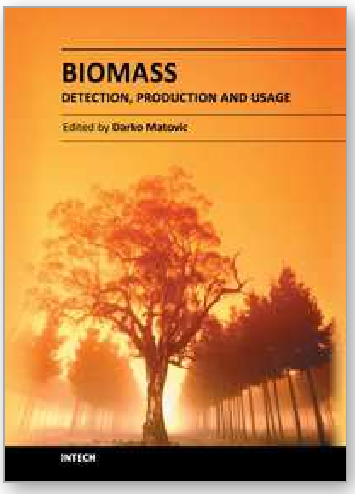
Witkowicz, R. (1998). Porównanie plonowania oraz wartości przedplonowej wsiewek roślin motylkowatych i traw na glebie lekkiej. *Rocz. AR Poznań, CCCVII, Ser. Rol.,* Nr 52, ss. 65-70.

Zając, T. (1997). Dobór roślin na nawozy zielone wraz z produkcyjna weryfikacją. Mat. konf. nauk. nt. „Nawozy roślinne w integrowanym systemie produkcji rolniczej". *AR Kraków*, ss. 5-12.

Zając, T. & Witkowicz, R. (1996). Skład chemiczny biomasy wsiewki koniczyny czerwonej na cele nawozowe. *Zesz. Nauk. AR Szczecin, Ser. Rol.*, Nr 172, ss. 553-559.

Zgórska, K. & Czerko, Z. (1981). Accurate and Simple metod of determining starch. Instrukcja wdrożeniowa. *Instytut Ziemniaka w Boninie.*

Zgórska, K. & Frydecka-Mazurczyk, A. (1985). Warunki agrotechniczne i przechowalnicze a cechy użytkowe bulw ziemniaka. *Biul. Inst. Ziemn.*, Nr 33, ss. 109-120.



Biomass - Detection, Production and Usage

Edited by Dr. Darko Matovic

ISBN 978-953-307-492-4
Hard cover, 496 pages
Publisher InTech
Published online 09, September, 2011
Published in print edition September, 2011

Biomass has been an intimate companion of humans from the dawn of civilization to the present. Its use as food, energy source, body cover and as construction material established the key areas of biomass usage that extend to this day. Given the complexities of biomass as a source of multiple end products, this volume sheds new light to the whole spectrum of biomass related topics by highlighting the new and reviewing the existing methods of its detection, production and usage. We hope that the readers will find valuable information and exciting new material in its chapters.