Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2003
Volume 6
Issue 1
Series AGRONOMY

BOLIGŁOWA E., GLEŃ K. 2003. YIELDING AND QUALITY OF POTATO TUBERS DEPENDING ON THE KIND OF ORGANIC FERTILISATION AND TILLAGE METHOD **Electronic Journal of Polish Agricultural Universities**, Agronomy, Volume 6, Issue 1.
Available Online http://www.ejpau.media.pl

YIELDING AND QUALITY OF POTATO TUBERS DEPENDING ON THE KIND OF ORGANIC FERTILISATION AND TILLAGE METHOD

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ABSTRACT

Over 1998-2000 field experiments were carried out to define the effect of various organic fertilisers and the tillage methods on the content of nitrogen in soil and yielding and the quality of 'Ibis' potato tubers. The research showed that fertilising the potato with manure or white mustard stubble intercrop enhanced the tuber yield and decreased their accumulation of nitrate nitrogen. Manure as compared with other fertilisers tested ensures also the best health status of tubers after harvest and after storage. However barley straw facilitates nitrate nitrogen liberation and its increase in tubers and deteriorates their storage life, causing an increase in rots. On the other hand, ploughless tillage (with cultivator) decreases the yield and causes tuber infection with common scab, increasing the nitrates in topsoil and in potato tubers and total losses after storage.

Key words: potato, organic fertilisers, tillage method, yielding, tuber quality

INTRODUCTION

So far potato cultivation commonly involved the use of manure as organic fertiliser. Currently there is observed a decrease in the production of this fertiliser, which forces farmers to search for other forms of organic fertilisation (green fertilisers, straw). A growing interest in the issue is related to cost-cutting in potato cultivation [5,11,14]. Introducing organic fertilisers into soil enhances its structure, decreases susceptibility to erosion, enhances the component balance, increases the soil bioactivity [1,3,6,8, 18,19] and the quality of potato tubers [4,15].

A need to protect the environment and the economic factors require also the use of pro-ecological tillage methods which protect the soil production potential. Ploughless technologies are less energy-consuming, and

under favourable conditions they allow for plant yields not lower than in traditional tillage [2,5,9,11]. On the other hand, ploughless tillage causes an excessive mineralisation of the organic matter, increases the susceptibility to erosion, its energy-consumption is high and depends on the course of weather [13,23]. Over the last years there has been recorded an increasing interest in pro-ecological plant cultivation methods. However the literature lacks unambiguous explanations of the effect of organic fertilisation, especially simplified tillage on yielding, quality and storage life of potato tubers. Ploughless tillage involves shallow mixing of organic matter with soil. For that reason this tillage method may affect a different dynamics of nutrients mineralization and their intake by the plant and potato tuber quality characteristics.

The aim of the present research was to compare the effect of various organic fertilisers (manure, stubble, barley straw, intercrop) and two methods of tillage (plough and ploughless tillage) on the content of nitrogen in soil and on the potato tuber yield and its quality.

MATERIAL AND METHODS

Field experiments were carried out over 1997-2000 at Boczkowice (the Małopolska Province) on good wheat soil suitability complex which in its topsoil contained, on average, in 100 g – 10.4 mg P_2O_5, 19.2 mg K_2O, 7.9 mg Mg and 1.65% of humus, and pH in 1 N KCl was 5.2. The two-factor experiment was set up with the split-block method in four replications:

- factor I – a kind of organic fertilisation – manure; stubble; spring barley straw; white mustard intercrop (‘Nakielska’ cultivar); barley straw + white mustard (‘Nakielska’ cultivar);
- factor II – tillage method - traditional plough tillage and ploughless tillage with cultivator.

Spring barley constituted the forecrop for potato. Every autumn the objects with manure and stubble were treated with phosphorus and potassium fertilisation; 80 kg of $P_2O_5 \cdot ha^{-1}$ and 120 kg of $K_2O \cdot ha^{-1}$, while the other objects – prior to mustard sowing. White mustard (intercrop) sowing, preceded by tillage, just like for stubble intercrop, coincided with the second decade of August. Before winter in plough objects organic fertilisers were covered with autumn ploughing and the ploughless ones were treated with cultivator. Spring tillage involved the use of aggregate composed of cultivator and harrow. Nitrogen fertilisation (80 kg of $N \cdot ha^{-1}$) in the form of ammonium nitrate (the same for all the objects) was applied in spring prior to tuber planting. Additionally, directly after harvest, the objects fertilised with straw were supplemented with carbamide; 1 kg of N per 100 kg of the straw.

‘Ibis’ potato tubers were planted in the first decade of April with planter for 30 x 62.5 cm spacing (53 thousand plants per ha). Up till plant emergence mechanical cultivation had been applied; harrowing twice and hilling. Then the newly hilled soil was treated with Afalon; 2 $kg \cdot ha^{-1}$ protecting plants against weed infestation. Over the vegetation period, potato was protected also against disease (*Phytophtora infestans* (Mont.) de Bary*)* applying Curzate twice (2.5 $kg \cdot ha^{-1}$) and against Colorado beetle (*Leptinotarsa decemlineata* Say), spraying the plants with Decis preparation (0.3 $l \cdot ha^{-1}$).

In each research year the total precipitation (414.5; 442.8; 475.9 mm) over the potato vegetation exceeded the precipitation considered optimal for that plant. A considerably excessive moisture was recorded in June 1999 (211.2 mm) and in July 2000 (218.9 mm). In general, the years 1998 and 2000 were warm, while 1999 was the coldest. Weather conditions in the Małopolska Region were favourable for the cultivation of stubble intercrops. The total precipitation in August through the end of October, in respective years, amounted to 224.4 mm; 188.0 mm; 175.5 mm and was optimal for white mustard intercrop.

In organic fertilisers total nitrogen was determined with the Kjeldahl method, phosphorus with the colorimeter and potassium with flame photometry. In spring in topsoil (0-30 cm), the contents of nitrate nitrogen and ammonium nitrogen were determined with the potentiometric method.

After harvest there were defined tuber yield, share of tubers in yield (fractions), content of starch and nitrates in the fresh matter of tubers with the colorimetric method. The percentages of black scurf -infected tubers *(Rhizoctonia solani* Kuehn*)* and tubers infected with common scab of potatoes (*Streptomyces scabies* (Thaxter) Waksman et Henrici) were determined in 10 kg samples, following the methodological instruction [22]. Then the tuber samples were stored for 6 months at 7°C at 92% relative air humidity and the natural and waste losses were determined as caused by dry-rot and soft rot. The results obtained were variance analysed and the significance was verified with the t-Student test at $\alpha_{0.05}$.

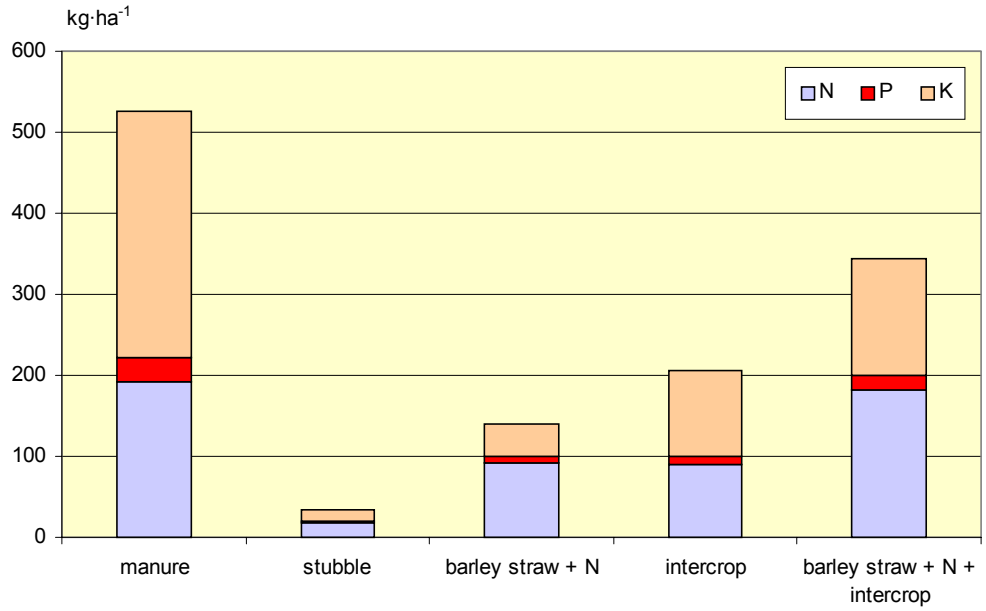
RESULTS AND DISCUSSION

The organic fertilisers tested differed both in the content of dry matter and chemical composition (Table 1). The highest content of dry matter was introduced into soil by a combined application of straw with stubble intercrop and manure. The lowest amount of organic matter was provided by fertilising soil with stubble and also with stubble intercrop (white mustard). Out of all the fertilisers compared, the greatest amount of macroelements (525 kg NPK·ha^{-1}) was introduced into soil with manure (Fig. 1). Also a combination of straw with nitrogen and intercrop turned out to be a favourable organic fertiliser, providing 344 kg of NPK·ha^{-1} into soil.

Table 1. Amount and quality of organic fertilisers introduced into soil (mean for 1998-2000)

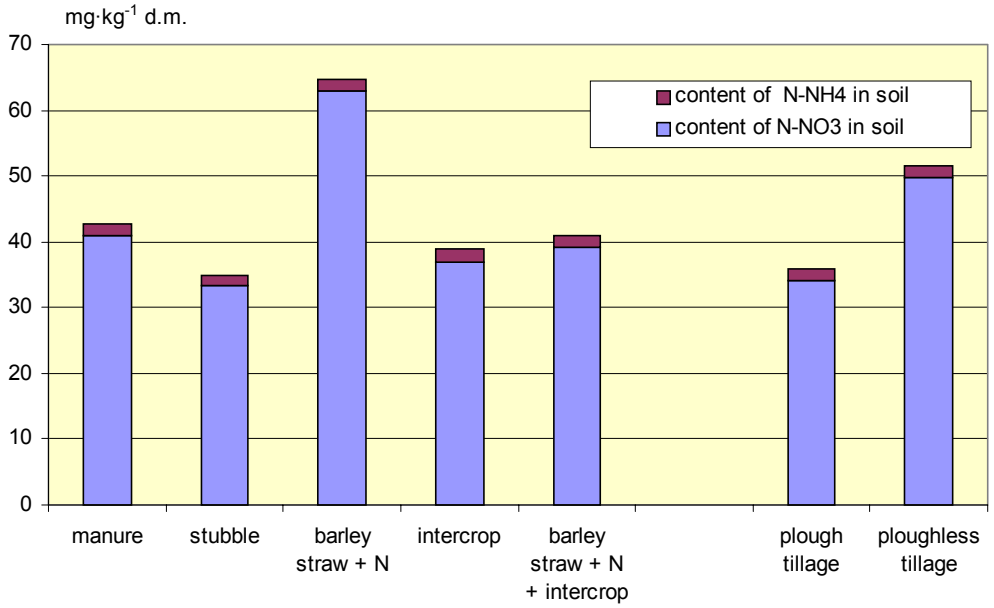
Organic fertiliser	Dry matter, t·ha^{-1}	Content in dry matter, %		
		N	P	K
Manure	7.03	2.72	0.45	4.31
Barley stubble	2.21	0.79	0.13	0.63
Barley straw + N	4.50	1.05	0.16	0.88
White mustard intercrop	2.98	3.01	0.35	3.52
Barley straw + N + white mustard intercrop	7.48	4.06	0.51	4.40

Fig. 1. Macroelements introduced into soil with organic fertilisation



The content of mineral nitrogen forms, especially nitrate nitrogen, in topsoil varied and depended on the kind of biomass and the method of tillage (Fig 2.). The rate of organic fertilisers mineralisation depend on numerous factors, including the grain size composition of soil, its moisture and temperature and the plant species introduced into soil and mixing it with soil [10,23]. The present research observed the greatest amount of liberated N-NO_3 in soil fertilised with barley straw. The soil fertilised with post-harvest residue (stubble) and with intercrop (white mustard) showed least rich in this component. The results obtained are also confirmed by other authors [10,16], showing that the amount of liberated nitrogen depends not only on the plant species but also on the amount of biomass introduced into soil. As shown by the results obtained, fertilising soil with manure, barley straw and straw combined with intercrop, as compared with other fertilisers tested, provided the plants with a high amount of nitrogen, including nitrate nitrogen (N-NO_3). Nitrogen generated as a result of organic matter mineralization should be used by growing plants as it comes, otherwise it can be leached out or excessively accumulated [1,20]. The present research recorded a relationship between the tillage method and the content of nitrogen in soil. Ploughless tillage increased nitrates in topsoil, which was due to shallow mixing of organic fertilisers with soil, and then a greater soil aeration, which resulted in accelerated biomass mineralization. A similar opinion is expressed by Duer [10] and Weber [23]. The content of ammonium nitrogen (N-NH_4) in soil was low and did not record such great changes as affected by the factors studied.

Fig. 2. Effect of organic fertilisation and tillage method on the content of $N\text{-}NO_3$ and $N\text{-}NH_4$ in soil



The present research showed that the tuber yield and its quality depended significantly on the kind of organic matter introduced into soil. The potato cultivation on manure or after white mustard intercrop ensured the highest yielding and, at the same time, it was not conducive to accumulation of nitrates ($N\text{-}NO_3$) in tubers (Table 2). Yielding value of stubble intercrop fertilisation, comparable with that of the manure, was also observed by Dzienia et al. [11] and Boligłowa and Dzienia [7]. Barley straw, on the other hand, introduced into soil, combined with intercrop lowered the tuber yield, which coincided with an increased share of tubers with symptoms of common scab of potatoes (*Streptomyces scabies*), which could have been due to a process of proteinization of the nitrogen surplus in soil. Fertilising with barley straw increased the contents of starch and nitrates (148 $mg \cdot kg^{-1}$ f.m.). However the content of this nitrogen form ($N\text{-}NO_3$) in tubers as affected by the organic fertilisers used was low and did not exceed the permissible standards [12]. Similarly other authors [4,15,21] report on a favourable effect of organic fertilisers on the quality of potato tubers. As for the fertilisers tested, as compared with manure, increased the incidence of such tuber diseases as black scurf and common scab of potatoes. The effects have been confirmed by Boligłowa et al. [6] and Grześkiewicz and Trawczyński [15]. The present results obtained indicate that fertilising with manure most considerably limited the occurrence of common scab of potatoes and black scurf-infected tubers, which coincides with reports by Heitefuss [17], as manure accelerated a microbiological decomposition of cellulose, and along with it – it decreases the survival of *Rhizoctonia solani* in soil, the agent causing black scurf.

Table 2. Potato tuber yielding and health status depending on the organic fertilisation

Organic fertilisation	Tuber yield $t \cdot ha^{-1}$	Content in tubers		Percentage of tubers with symptoms of	
		Starch %	nitrates $mg \cdot kg^{-1}$ f.m.	common scab	black scurf
Manure	48.8	13.8	90.0	78.9	21.3
Barley stubble	44.2	14.3	52.8	68.7	40.9
Barley straw + N	44.8	15.2	148.7	82.4	37.3
White mustard intercrop	47.2	14.8	90.9	82.1	41.8
Barley straw + N + white mustard intercrop	39.4	14.2	113.3	91.0	36.6
Mean	44.9	14.5	99.1	80.6	35.6
$LSD_{0.05}$	2.9	0.5	38.5	5.5	7.1

The tillage method significantly modified the potato tuber yielding and quality (Table 3). Ploughless tillage (with cultivator), contrary to plough tillage, decreased the tuber yield and the share of tubers with symptoms of common scab. Tillage with cultivator, on the other hand, increased the amount of liberated nitrate nitrogen, increasing also its content in tubers. There was also recorded a significant interaction of the factors analysed. Incorporating manure and stubble with cultivator increased the amount of nitrates in tubers. The reports by other authors [7,11] show that eliminating plough tillage and replacing it with cultivator does not lower potato yielding significantly. Neither does it cause changes in the content of starch in tubers, nor the number of black scurf-infected tubers.

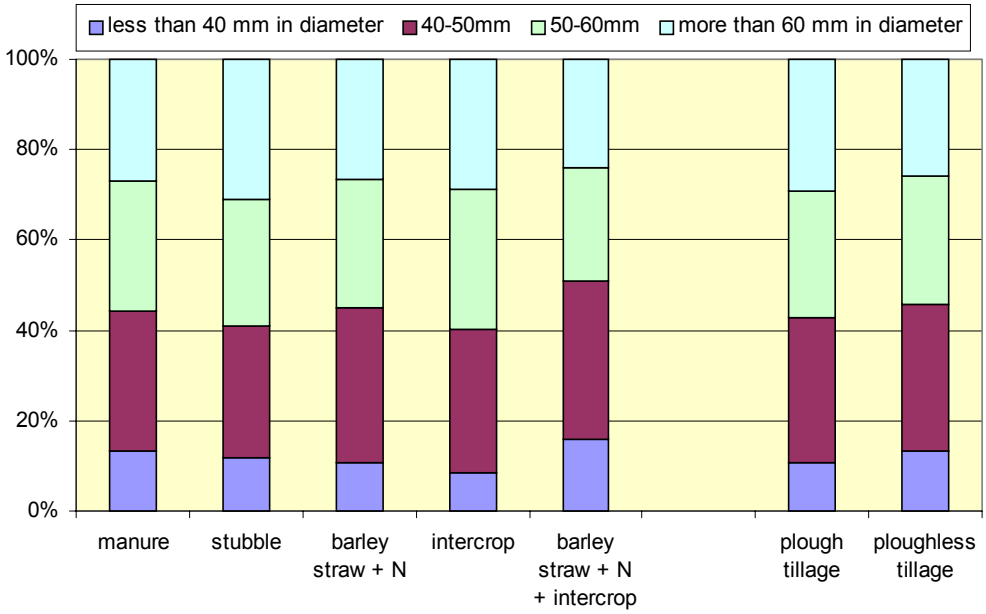
The results obtained show that the kind of organic fertilisation did not have a significant effect only on the share of tubers of a given fraction in the yield (Fig. 3).

Table 3. Potato tuber yielding and health status depending on the tillage method

Tillage method	Tuber yield $t \cdot ha^{-1}$	Content in tubers		Percentage of tubers with symptoms of	
		starch %	nitrates $g \cdot kg^{-1}$ f.m.	common cab	black scurf
Plough	46.5	14.4	94.3	84.5	33.2
Ploughless	43.3	14.5	104.0	77.6	37.5
$LSD_{0.05}$	2.2	ns	3.7	3.5	ns

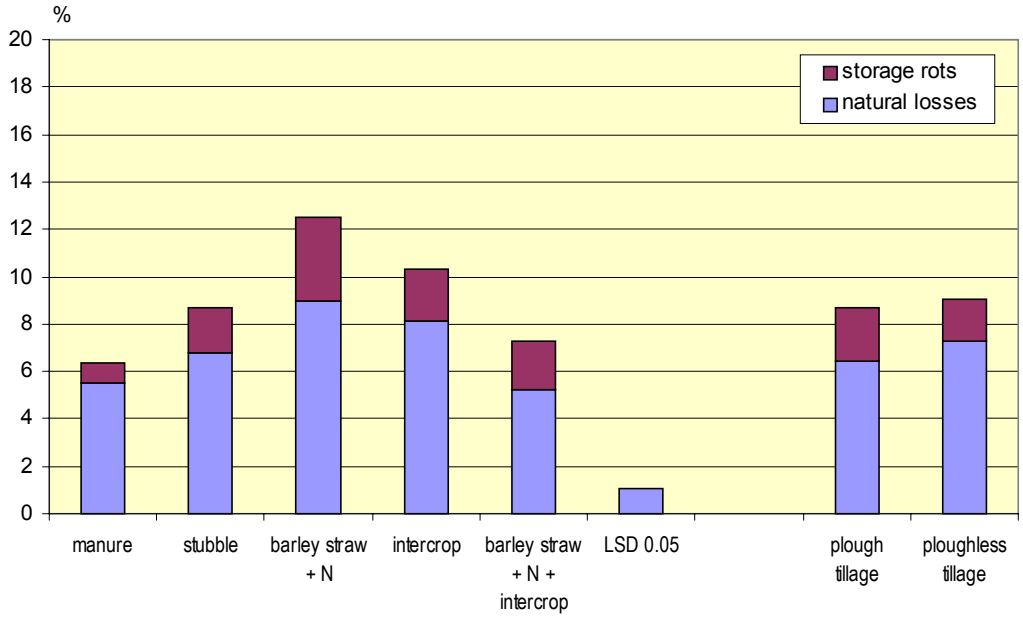
ns – not significant

Fig. 3. Effect of organic fertilisation and tillage method on the share of a given tuber fraction in the yield



Infection of tubers by pathogens over the vegetation period was conducive to secondary infections recorded over the storage period (dry-rot and soft rot in potato tubers), deteriorating the tuber storage life. Fertilising with straw or with white mustard significantly increased natural losses of the tuber weight due to transpiration and respiration (Fig. 4). Besides, introducing only straw into soil, and along with it the greatest amount of liberated nitrogen, enhanced the development of rots. Similar reports have been provided by Boligłowa et al. [6] and Kurzawińska [18]. The highest storage value was noted for tubers obtained from the object fertilised with manure. The problem has been explained by Benken [3] and Deryło [8], showing that manure increases the microbiological soil activity, especially antagonistic micoflora, neutralising toxins produced by post-harvest residue decomposition.

Fig. 4. Tuber weight losses after storage depending on the organic fertilisation and tillage method



The present research recorded also no significant effect of the tillage method on the content of starch in tubers, tuber size in the yield and the amount of natural and waste losses (rots) after storage. According to Boligłowa and Dzienia [4,7], traditional plough tillage on manure enhances the increase in the share of big tubers (over 60 mm in diameter) in the yield. Besides there was noted no significant correlation between organic fertilisation and tillage affecting the above potato tuber quality characteristics. The domestic and foreign literature lacks explanations of the effect of tillage simplifications as combined with organic fertilisation on diseases, including the potato tuber storage life.

Considering the tuber yielding and quality and aiming at cost-cutting and alleviating the negative effects on the environment, traditional tillage practises considered so far as indispensable in potato cultivation technology, can be omitted. Fertilising potato with intercrop (white mustard) can be an alternative in the manure-free economy. Pro-ecological tillage methods can be also recommended to farmers who search for more cost-effective energy-saving technologies.

CONCLUSIONS

1. The kind of organic fertilisation and the tillage method significantly modified the potato tuber yield and quality and the percentage of losses after storage.
2. As far as the expected yield and its quality are concerned, fertilising potato with manure can be replaced with intercrop (white mustard). The best tuber health status after harvest and after storage were recorded due to fertilising potato with manure.
3. Out of all the organic fertilisers tested, barley straw was inductive to liberation of nitrate nitrogen and its accumulation in potato tubers and deteriorated their storage life, increasing rots.
4. A simplified tillage (ploughless) can decrease tuber yield by 7%, which coincided with a deterioration of some quality tuber characteristics.

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