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Effect of different production systems on yield and quality of potato

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Abstract. In the experimental field of the Department of Field Crops and Grassland Husbandry the late maturing potato variety 'Ants' was grown in the following variants: conversion to organic, $N_0P_0K_0$, $N_{50}P_{25}K_{95}$, $N_{100}P_{25}K_{95}$ and $N_{150}P_{25}K_{95}$. Pesticides were used in mineral fertilizer variants. In $N_0P_0K_0$ and mineral fertilizers variants insecticide Fastac 50 was used. The total yield of tubers as well as the proportion of marketable tubers increased significantly with the use of mineral fertilizers ($N_{50}P_{25}K_{95}$, $N_{100}P_{25}K_{95}$ and $N_{150}P_{25}K_{95}$). Tubers from conversion to organic and $N_0P_0K_0$ variants had significantly higher starch content, compared to the variants where mineral fertilizers were used, but the overall yield of starch remained lower. Increasing the amount of nitrogen fertilizer is positively correlated with the nitrate content in the tubers. The number of tubers infected by potato brown rot and potato soft rot did not differ significantly, but there were fewer tubers infected with black scurf in conversion to the organic variant.

Key words: black scurf, brown rot, marketable yield, soft rot, *Solanum tuberosum,* starch content

INTRODUCTION

At present potato is one of the main food components in most European countries and therefore holds a strong position amongst the world's food crops. The wide acknowledgement of organic agriculture in the EU was initiated with the establishment of national subsidies and uniform requirements. Organic marketing holds a rather small share of the total food market but is growing fast. As with all organic production, higher prices can be asked for organically grown potatoes because of their healthfulness, rewarding the lower yields in organic farming (Luik et al, 2008).

Organically grown food is as attractive to scientists as it is to consumers (Hajšlová et al., 2005). The main focal point used in advertising organic food is its beneficial impact on human health (Heaton, 2001). The yield and quality of the tubers is related to the time and amount of nutrient application (Munoz et al, 2005). With lower fertilisation levels generally used in organic farming systems the yields and tubers remain smaller (Varis et al., 1996). It's necessary to know the factors influencing the nitrogen requirement for predicting the nutrient demand of crops to provide give the grower with reliable advice (Greenwood, 1982; van Keulen et al., 1989). Knowing the nitrogen demand is not only important from the economic viewpoint, but also from the environmental one, because an oversupply of nitrogen causes leaching of nitrates (Addiscott et al., 1991). Therefore knowledge about exact levels of nitrogen is a basis for ensuring maximum yields with good quality. There are significantly more nitrates in the tubers of conventionally grown potato compared to those from organic farming (Stopes et al., 1988; Rembialkowska, 1999; Guziur et al., 2000), thus it is considered a healthier product.

MATERIALS AND METHODS

Field trials with the late potato variety 'Ants' (bred in Jõgeva SAI) were carried out on the experimental fields of the Department of Field Crops and Grassland Husbandry, Estonian University of Life Sciences (EMU). There were five treatments – conversion to organic and $N_0P_0K_0$, $N_{50}P_{25}K_{95}$, $N_{100}P_{25}K_{95}$ and $N_{150}P_{25}K_{95}$. Fields were fertilized with different fertilizers: Kemira Grow How Power N:P:K – 5:14:28, and **AN 34.4** N:P:K **– 34:0:0.** The variants that had received $N_0P_0K_0$ and mineral fertilizers were sprayed with insecticide Fastac 50 (BASF Ag, Germany; the active ingredient alpha-cypermethrin 100 g l^{-1}). The experiments were laid out in four replications. The size of each test plot was 60 m^2. The distance between seed tubers was 25 cm and the distance between rows was 70 cm. Seed tubers with a diameter of 35–55 mm were used. The soil of the experimental field was *Stagnic Luvisol* by WRB (2002) classification (Deckers et al. 2002), the texture of which is sandy loam with a humus layer of 20–30 cm.

Table 1. Average monthly temperatures (ºC) and precipitation (mm) in Estonia during the vegetation period.

Month	Temperatures, °C		Precipitation, mm	
	2008*	Average of 1966–1998**	2008*	Average of 1966–1998**
May	10.6	11.6	27.4	55
June	14.5	15.1	110.6	66
July	16.1	16.7	53.8	72
August	15.8	15.6	117.8	79
September	9.8	10.4	45.6	66

* according to the Eerika weather station
** (Jaagus 1999)

Compared to the average temperatures of many years, 2008 was colder. May and June had less precipitation, but there was abundant rainfall in the first decade of August and September (Table 1).

The tuber yield was determined by weighing directly after harvest. The starch content was determined by Parov's weights (Viileberg, 1986). The starch yield was calculated according to starch content and tuber yield. The content of nitrates was analyzed in the plant biochemistry laboratory (EMU) by FiaStar 5000. Disease assessment of tubers was performed one month after the harvest by Rich (1983). For determination of the infection by black scurf, 100 tubers were taken from each treatment and the percentage of area damaged by black scurf was determined.

Experimental data were processed by Statistica 7.0 software (Anova, Fisher LSD test).

RESULTS AND DISCUSSION

The use of fertilizers on the potato field is based on the lack of nutrients in the soil for economically viable yields (Kuldkepp & Roostalu, 2002). Hence, the low yield of conversion to organically grown potato is the result of inadequate nutrient content in the soil.

Fertilization resulted in significantly higher tuber yield, compared to $N_0P_0K_0$ and conversion to organically grown potato (Table 2). Tubers more than 35 mm in diameter are considered as marketable yield. From Table 2 it can be concluded that marketable yields and their percentage of total yield is also higher in fertilized variants. In conversion to organic and $N_0P_0K_0$ variants the marketable and total yield is more than 50% lower than in $N_{100}P_{25}K_{95}$ and $N_{150}P_{25}K_{95}$ variants (Table 2). The percentage of marketable yield of the total yield in conversion to organic and $N_0P_0K_0$ variants is 8% lower than in $N_{100}P_{25}K_{95}$ and $N_{150}P_{25}K_{95}$.

Table 2. Tuber yield, marketable yield, percentage of marketable tubers, starch content and starch yield.

Variant	Yield, t ha^{-1}	Marketable tubers		Starch	
		yield, t ha^{-1}	%	content, %	yield, t ha^{-1}
Conversion to organic	20.1a	17.4a	86.3a	14.7a	3.0a
$N_0P_0K_0$	24.8a	21.7a	87.6a	14.5a	3.6ab
$N_{50}P_{25}K_{95}$	34.2b	31.7b	92.4b	12.7b	4.3bc
$N_{100}P_{25}K_{95}$	38.7b	36.6b	94.5b	12.8b	5.0c
$N_{150}P_{25}K_{95}$	38.0b	36.0b	94.7b	11.4c	4.3bc

Means followed by the different letter in the some column are significantly different ($P < 0.05$).

Starch is an important raw material for food and industrial applications. As a carbohydrate, starch stores energy in tubers and often influences their quality parameters (Jõudu, 2002). The starch content of tubers is affected by cultivar, maturity of tuber and climatic conditions during growth (Caldiz et al., 1996), and by cultivation methods, fertilization and storage conditions (Jõudu, 2002).

The results of our experiment showed that starch content was higher in conversion to organic and $N_0P_0K_0$ variants. The amount of nitrogen applied was negatively correlated with starch content (Table 2). Many researchers (Lampkin, 1990; Woese et al., 1995; Hajšlová et al., 2005) have found that the content of dry matter and starch are higher in organically grown potato than in the conventionally grown crop. In given conditions the starch content is determined by the total yield.

The tubers contain inorganic nitrogen compounds like ammonium, nitrates and, occasionally, nitrites in small amounts. The content of nitrates and the factors affecting its level are most often studied. Generally the content of nitrates is in the range of 40–250 mg kg^{-1} in raw material (Cieślik et al., 1990; Jõudu, 2002).

In our trials the highest content of nitrates was in $N_{100}P_{25}K_{95}$ (54.7 mg kg^{-1}) and $N_{150}P_{25}K_{95}$ (69.2 mg kg^{-1}) variants (Fig. 1). Generally the content of nitrates was higher in variants that received mineral nitrogen applications.

The tubers infected by potato brown rot (*Ralstonia solanacearum*) and potato soft rot (*Erwinia ssp.*) pathogens may start to decay in storage.

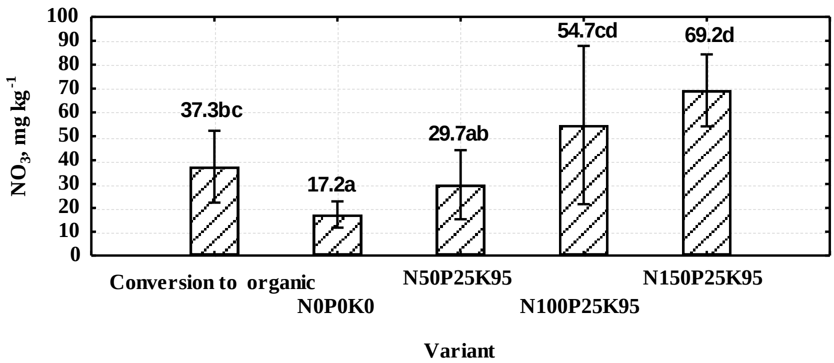

Fig. 1. The nitrate content in tubers, NO_3 mg kg^{-1}. Means followed by the different letter in the same row are significantly different (P < 0.05).

The infected tubers may also contaminate healthy tubers, which may result in enormous loss of yield and quality. Regarding the infection of tubers with potato brown and soft rot, no significant differences between variants were observed (Table 3).

Table 3. The percentage of number and weight of tubers infected with potato brown and soft rot.

Variant	The tubers infected with brown rot		The tubers infected with soft rot	
	number, %	weight, %	number, %	weight, %
Conversion to organic	3.4a	3.3a	2.0a	1.6a
$N_0P_0K_0$	1.8a	2.3a	1.2a	1.4a
$N_{50}P_{25}K_{95}$	3.4a	3.1a	1.0a	0.6a
$N_{100}P_{25}K_{95}$	2.5a	2.3a	2.2a	1.6a
$N_{150}P_{25}K_{95}$	2.0a	1.7a	2.1a	1.4a

Means followed by the different letter in the some column are significantly different (P < 0.05).

The damage caused by *Rhizoctonia solani* (the causal agent of black scurf) usually develops on the spot of mechanical injury on the tuber and is also affected by the handling of tubers. The injury is not necessarily visually detectable on the skin of the tubers. The probability of black scurf occurrence is higher during storage, when the tubers are experiencing stronger pressure and more injuries occur (Sawyer & Collin, 1960). The spread of black scurf is also favoured by abundant precipitation during growth and unsuitably high storage temperatures (Lõiveke, 2002).

It could be observed that all tubers in the experiment were infected by black scurf; its growth was especially favoured by abundant precipitation right before harvest (Table 1). Consequently, it can be concluded that various agrotechnical measures do not affect the spread of black scurf. Although all tubers were infected, the damaged area was only 2–12%. The area damaged by black scurf was smallest in conversion to organic and $N_{100}P_{25}K_{95}$ treatments and significantly larger in other treatments (Fig. 2).

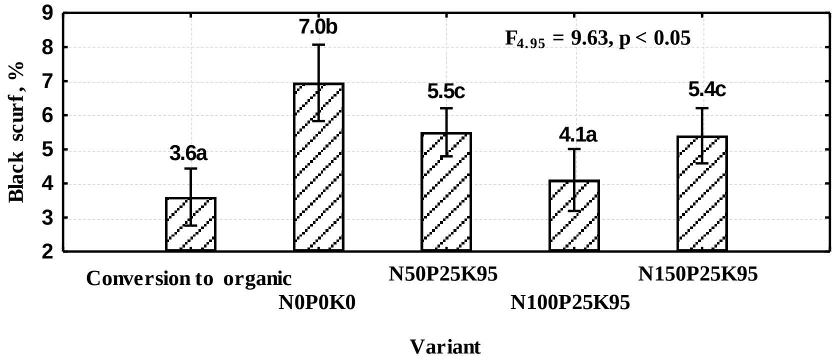

Fig. 2. The area of tuber peel infected by black scurf, %. Means followed by the different letter in the same row are significantly different ($P < 0.05$).

CONCLUSIONS

By using mineral fertilizers ($N_{50}P_{25}K_{95}$, $N_{100}P_{25}K_{95}$ and $N_{150}P_{25}K_{95}$), tuber yield, marketable yield as well as the percentage of marketable tubers increased significantly. The optimal amount of nitrogen for conventional farming is 100 kg ha^{-1}. The conversion to organic and $N_0P_0K_0$ variants had significantly higher starch content compared to variants where various levels of mineral fertilizers were used, but the starch yield remained lower. Increasing the amount of mineral fertilizers is positively correlated with nitrate content of the tubers. The number of tubers infected with potato brown or soft rot did not differ significantly between variants. Compared to other variants, the conversion to organic plot had the lowest percentage of tubers infected with black scurf. Therefore it could be concluded that while focusing on the quality and healthfulness of the product, potato should be grown via conversion to organic method. When higher yields are the main purpose, potato should receive adequate amounts of fertilizers.

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