# TUBER YIELD PARAMETERS IN ORGANIC POTATO PRODUCTION WITH GREEN MANURES AS PRECEDING CROP, CATCH CROP AND WITH FARMYARD MANURE

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## ABSTRACT

*The effect of different preceding crops, catch crops and manure application on the agronomic performance of potato was studied in two consequential years in an organic farming system. Within the study the effect of three different preceding crops: viz. lucerne, field pea and spring barley; incorporated catch crops as green manure: non-legume or mixture; and farmyard manure (30 tones ha$^{-1}$) are tested on subsequent potato yield and tuber size distribution. The catch crop treatments were studied in comparison to control bare fallow. The subsequent crop response to preceding crops was negligible since there was no indication of a greater tuber yields (fresh tuber, marketable and dry matter) after legume pre-crops compared to barley. Catch crops and manure effects both slightly increased tuber dry matter yield from 4.9 tones ha$^{-1}$ to 5.2 tones ha$^{-1}$ in 2010 only, on the contrary dry matter yield was not affected by catch crop and manure in 2011. The significant interaction effect was found between year and catch crop for fresh and dry matter tuber yield and non-standard small sized tubers. Catch crops had a positive effect on potato yield only in 2010 when mineral nitrogen availability was low. The catch crops significantly ($P < 0.01$) increased the percentage of large sized tubers (> 65 mm in diameter); however catch crops even negatively affected potato medium sized tuber yield and quality. Significant ($P < 0.01$) interaction effect was found between year and catch crop for small sized tubers, also.*

**KEY WORDS:** Organic potatoes, Green manures, Farmyard manures, Preceding crop, Catch crop

## INTRODUCTION

The potato is one of the staple foods of modern Civilization and it plays a greater role in many countries. It is grown in more than 125 countries and consumed almost daily by more than a billion people. In terms of production, potato (*Solanum tuberosum L.*) is the fourth most important food crop in the world ranking at 376.5 million tones (2013) [1]. Potato can be highly productive, but it has a relatively shallow root system and often requires substantial nutrient input to maintain tuber productivity and quality. Therefore, nutrient management of potato crop is very important. On the other hand, at this time, the negative influence of agriculture on the environment was receiving greater attention. Nowadays, organic farming is the most environmentally compatible form of agriculture. The role of preceding crop, catch crop and manure can be very important in organic potato farming since synthetic mineral fertilizers are not permitted [2]. Thereby the main nitrogen sources in most organic farming systems are biological $N_2$ fixation, crop residues, and manures.

Many potato farmers are converting from conventional agricultural management to sustainable organic farming in all the time. Nitrogen (N) stress is stated to be most limiting to tuber yield in organic potato cropping. As a consequence it has been suggested that organically cultivated potato crops may be risk of N stress, it can limit yield losses caused by tuber formation. This study was conducted to evaluate the effects of the preceding crop, catch crop and manure application on tuber dry matter yield, as well as total and graded tuber for marketing. The aim of this experiment was to investigate the growth of three different preceding crops followed by organic amendments (catch crop-green manure and animal manure) and their residual effects on a succeeding potato crop on a silty loam soil.

## MATERIAL AND METHODS

**Site description:** The field trial was carried out on the organically managed fields at research station of the University of Natural Resources and Life Sciences, Vienna (48°14′N, 16°35′E, and 153 m above sea level) in experimental area. Soils at the study site are *Calcaric Phaeozem* [3] with a high water holding capacity, a comparably high soil organic matter (2.2 % total organic carbon) and a pH $CaCl_2$ of 7.6 in the Ap horizon [4]. Soil texture is silty loam [5]. The mean annual temperature is 9.6 °C; the average precipitation is 520 mm. The experiment was performed under rain-fed condition.

**Experimental design and management:** The study was established within a backset in three consecutive years 2009-2011. The trial was laid out as randomized complete block design (RCBD) with a split-split plot arrangement within the four replications (Blocks). The twelve treatments comprised a factorial arrangement of three different preceding crops (PC), green manure-catch crop management (CC) and farmyard manure (M) application (30 t ha$^{-1}$ or no manure control) using 48 plots 5.6 m × 6 m in size. The factors and the tested factor levels in the field trial are shown in Table **1**.

Table 1

Summary of experimental details

| Treatment | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009 & 2010 | PC | Lucerne | | | | Field Peas | | | | Spring barley | | | |
| | CC | bare fallow | | *non - leg. | | bare fallow | | *non - leg. | | bare fallow | | **mixture | |
| | M | no | yes | no | yes | no | yes | no | yes | no | yes | no | yes |
| 2010 & 2011 | Main crop | Pot | Pot | Pot | Pot | Pot | Pot | Pot | Pot | Pot | Pot | Pot | Pot |

**Legend:** *non-leg: oil radish + phacelia, (fallen peas); **mixture: oil radish + phacelia + common vetch + field peas; Pot: Potatoes. Ploughing of all treatments at the same time after harvest of peas and barley, there were in Mid. July 2009 and 2010. Catch crops were ploughed down in early November 2009 and 2010 to ca. 18 cm deep. Manure was applied in early November to the fields 30 tones ha$^{-1}$. All preceding crops and catch crops were grown using conventional technology. Main plots were three preceding crops: one-year mulched lucerne (*Medicago sativa,* L), field pea (*Pisum sativum,* L), and spring barley (*Hordeum vulgare,* L) in both years (2009 and 2010). The preceding crops were sown on April 14, 2009 and on April 11, 2010. All of three pre-crops aboveground biomass was harvested in the same time, mid. of July. The sub plots were with and without catch crop at the following pre-crops. The catch crops were sown in the 12 plots on 24$^{th}$ August, 2009 and 11$^{th}$ August, 2010, after legume pre-crops, non-legumes (oil radish (*Raphanus sativus* L.) + Phacelia (*Phacelia tanacetifolia* L.) and after spring barley, a mixture (oil radish + Phacelia + common vetch (*Vicia sativa* L.) + field pea) were sown. The sub-sub plots were with and without farmyard manure at 30 t ha$^{-1}$ rates and the plot size was 33.6 m$^2$. Cattle manure was applied 1 or 2 days before ploughing down to one of the treatments with or without the green manure as a catch crop. Succeeding main crop potatoes were planted in this field at a seed tuber rate 40,000 ha$^{-1}$ at the end of the first decade of April in 2010 and in 2011. Potato of the Austrian variety "Ditta" was used. Potatoes were harvested on 26 August 2010 and 9 September 2011 by hand using a crotch.

**Assessment of tuber yield parameters:** The yield parameters such as total, marketable and dry matter yield data is taken per plot at stage of potato maturation. Potato fresh weight yields were measured from 11.2 m$^2$ taken from the center row in each plot. The harvested potato tubers were graded and sized into the following three class sizes for medium size is class: the diameter of tuber is greater than 3.5 cm and less than 6.5 cm; large size is class: the diameter is greater or equal to 6.5 cm; and small size is class: smaller or equal to 3.5 cm tuber in diameter. Marketable yield was defined as tubers with diameters greater than 3.5 cm and without visible blemishes. Tuber dry matter yield was calculated as fresh tuber yield multiplied by the DM content.

**Statistical analysis:** Data for each parameter were evaluated by analysis of variance based on a Split Plot design with the main factor pre-crop (PC) and the sub factors catch crop (CC) and manure (M) using a General Linear Model of the statistical software SPSS (Version 18.0). The replication (Rep) was considered as random effect. Differences between individual treatment and significant interaction means were determined using Tukey's HSD test.

## RESULTS AND DISCUSSION

**Seasonal rainfall and temperature:** In growing season 2010, precipitation was approx. 60% above; an average temperature was nearly $1^0$C lower than long-term mean. Whereas in the same period 2011, weather condition was convenient for potato crop; precipitation was approx. 20% above and air temperature was $2^0$C warmer than the long-term mean.

**Tuber fresh and dry matter yield:** Total tuber yield ranged from 23.0 to 28.8 tones $ha^{-1}$ and from 40.0 to 43.6 tones $ha^{-1}$ in 2010 and 2011, respectively. The significance levels of the main factors preceding crop, catch crop and manure, their interaction effects on potato total tuber (TT) yield of two years average values are presented in Table 2. The overall yields remained significantly ($P > 0.01$) less in 2010 compared to 2011. The comparatively higher tuber yield in 2011 was probably caused by the relatively high temperatures and rainfall during growing season.

This present study suggests that both quantity and quality of potato yield influenced by weather conditions of growing years, it could be caused that relatively high soil temperature influenced to strongly release N from organic amendments or from soil organic matter to subsequent potato (in 2011), other one possibility is may be great amount of soil nitrate N leaching to subsoils (in 2010) by strongly rainfall. That result matches with previous study by Macak et al. [6], who found that a highly significant differences between certain years (weather condition) in potato tuber yield and quality parameters. Several authors reported that the potential benefits of growing legumes prior to potatoes [7-11]. This was not found in the present study; our finding indicates that catch crop treatment had no effect for tuber yield, whereas manure treatment increased a negligible amount for tuber dry matter yield (Table 2).

Table 2

Significance levels for fixed factors and their interactions for potato tuber yield, average of two years (2010 - 2011)

| Parameters effects | TTY ($t\ ha^{-1}$) | MTY ($t\ ha^{-1}$) | DMY ($t\ ha^{-1}$) | DM conc. (%) | Ø < 35 mm (%) | Ø = 35 -65 mm (%) | Ø > 65 mm (%) |
|---|---|---|---|---|---|---|---|
| Y | ** | ** | ns | ** | ** | ** | ns |
| PC | ns | ns | ns | ns | ns | ns | ns |
| CC | ns | ns | ns | ns | ns | ** | ** |
| M | ns | ns | ** | ns | ns | ns | ns |
| PC*Y | ns | ns | ns | + | ns | ns | ns |
| CC*M | ns | ns | ns | ns | ns | ns | ns |
| CC*Y | ** | + | ** | ns | ** | ns | ns |
| PC*CC | ns | ns | ns | ns | ns | ns | ns |
| M*Y | ns | ns | ns | ns | ns | ns | ns |
| PC*M | ns | ns | ns | ** | ns | ns | ns |
| PC*CC*Y | ns | ns | ns | ns | ns | ns | ns |
| PC*M*Y | ns | ns | ns | ns | + | ns | ns |
| CC*M*Y | ns | ns | ns | ns | ns | ns | ns |
| PC*CC*M | ns | ns | ns | ns | ns | ns | ns |
| PC*CC*M*Y | ** | ns | + | ns | ns | ns | ** |

Legend: TTY: Total tuber yield; MTY: Marketable yield; DMY: Dry matter yield; DM conc.: DM concentration; Ø: tuber diameter; Y: Year; R: Replicate; PC: Preceding crop; CC: Catch crop; M: Manure; PC*Y, CC*M, PC*CC, M*Y, PC*M: Two-way interactions between fixed factors; PC*CC*Y, PC*M*Y, CC*M*Y: Three-way interactions between fixed factors; PC*CC*M*Y: Complete interaction between fixed factors; Treatment effects labeled with "ns" are not significant; **: significant at 1 % level of probability; +: significant trend at 10 % level of probability. In previous studies also recorded that the variability in potato yield is caused by rainfall [12] and temperature [13]. According to Macák et al. [6] green manure management did not influence potato yields significantly, that is also in agreement with our results, it could therefore be hypothesized that N in farmyard manure may be released too late to be fully utilized by the potato crop [14]. Moreover, Lynch et al. [15] found that an incorporated green manure or farmyard manure treatments increased a subsequent potato tuber yield by 22-25%, rather to combine of those two amendments, which increased a potato yield by 43%. That previous result did not verify in the present study, namely the combination of catch crop and manure application following different preceding crops had no such influence on tuber yield. It may be caused by the great N immobilization in manured soil, which consists high clay and silt contents, observed by Honeycutt et al. [16]. Based on averages, the pre-crops, catch crops and manure application did not affect potato total and marketable fresh tuber yields. A significant ($P$ < 0.01) interaction between catch crop and year was found for total tuber yield and tuber dry matter yield. In addition, four-way interaction effect (PC*CC*M*Y) (Figure 1) was observed for total tuber yield (Table 2). Therewith, manure and catch crop combination had a positive effect on tuber yield after lucerne and field pea in 2010, and no influence in 2011. After spring barley, catch crops influenced tuber yield also in 2010 only (Figure 1).

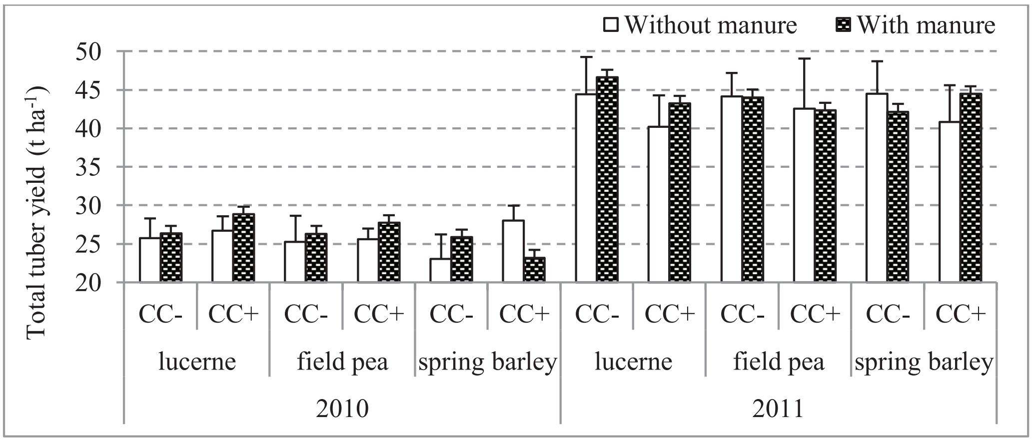


Figure 1 Potato tuber fresh matter yield affected by preceding crop, catch crop, manure and year

After lucerne, the potato tuber yield was significantly less with catch crop treatment in 2011, but in 2010 not. In manure applied plots, a total and marketable tuber yield varied from 33.1 tones ha$^{-1}$ to 34.9 tones ha$^{-1}$ and 26.5 - 28.5 tones ha$^{-1}$ and from 32.4 to 34.3 and 26.3 - 28.4 tones ha$^{-1}$ in 2010 and 2011, respectively. The mean yields following the various preceding crop, catch crop and manure application are shown in table 3.

Table 3

Effect of experimental factors preceding crop, catch crop and manure on potato tuber yield and size distribution (2010 - 2011)

| Parameters / Effects | TTY (t ha$^{-1}$) | MTY (tha$^{-1}$) | DMY (t ha$^{-1}$) | Tuber size classification Ø ≤ 35 mm (%) | Ø = 35 -65 mm (%) | Ø ≥ 65 mm (%) |
|---|---|---|---|---|---|---|
| PC: Lucerne | 35.2 ± 8.4$^{a}$ | 27.9 ± 5.0$^{a}$ | 6.6 ± 1.5$^{a}$ | 15.7 ± 12$^{a}$ | 79.6 ± 13$^{a}$ | 4.8 ± 5.0$^{a}$ |
| Field pea | 34.7 ± 8.3$^{a}$ | 27.7 ± 4.9$^{a}$ | 6.6 ± 1.6$^{a}$ | 14.8 ± 11$^{a}$ | 80.5 ± 11$^{a}$ | 4.7 ± 3.3$^{a}$ |
| Spring | 34.0 ± 9.0$^{a}$ | 27.7 ± 5.8$^{a}$ | 6.5 ± 1.6$^{a}$ | 15.0 ± 11$^{a}$ | 80.8 ± 12$^{a}$ | 4.2 ± 4.9$^{a}$ |
| CC: Without | 34.9 ± 8.9$^{a}$ | 28.1 ± 5.9$^{a}$ | 6.6 ± 1.6$^{a}$ | 14.7 ± 10$^{a}$ | 81.8 ± 11$^{a}$ | 3.5 ± 3.1$^{a}$ |
| With | 34.4 ± 8.2$^{a}$ | 27.4 ± 4.5$^{a}$ | 6.5 ± 1.5$^{a}$ | 15.6 ± 12$^{a}$ | 78.8 ± 13$^{a}$ | 5.7 ± 5.2$^{b}$ |
| M: Without | 34.2 ± 8.7$^{a}$ | 27.4 ± 5.5$^{a}$ | 6.4 ± 1.6$^{a}$ | 15.2 ± 11$^{a}$ | 80.1± 12$^{a}$ | 4.7 ± 3.9$^{a}$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| With | 35.1 ± 8.4$^a$ | 28.1± 5.0$^a$ | 6.7 ± 1.5$^a$ | 15.0 ± 11$^a$ | 80.5 ± 12$^a$ | 4.5 ± 5.0$^a$ |
| Y: 2010 | 26.0 ± 2.7$^a$ | 21.5 ± 2.6$^a$ | 5.1 ± 0.6$^a$ | 4.7 ± 1$^a$ | 91.3 ± 4$^b$ | 4.0 ± 4.4$^a$ |
| 2011 | 43.3 ± 4.4$^b$ | 34.0 ± 4.5$^b$ | 8.0 ± 1.0$^b$ | 25.6 ± 5$^b$ | 69.3 ± 5$^a$ | 5.1 ± 4.4$^a$ |
| Mean | 34. 6± 8.5 | 27.8 ± 5.2 | 6.6 ± 1.5 | 15.1± 11 | 80.3 ± 12 | 4.6 ± 4.4 |

**Legend:** See table 2; the values with the same letters within a column are not significantly ($P < 0.05$) different.

**Tuber size distribution:** The percentage of tuber yield in diameter less than 35 mm size class, in diameter between 35 mm and 65 mm size class and in diameter more than 65 mm size class ranged from 3.5 to 27.7%, from 66.0 to 93.0%, and from 0.4 to 9.8%, respectively. The year and catch crop effects significantly ($P < 0.01$) influenced tuber size classes. Differences among years were significant ($P < 0.01$) for small (Ø < 35 mm)) and medium sized (Ø = 35 - 65 mm) tubers. The percentage of large tubers was influenced by catch crop, with a significantly greater percentage (5.7 %) of tubers for within catch crop, compared to the without catch crop (3.5 %) treatment (Table 3) This may be due to the additional nutrient input with the applied organic matter by catch crop and manure were for maintaining plant growth throughout the cooler early season (2010) under enough soil water supplement. The positive influence of the nitrogen supply by legumes or manure on the yield of the following potato crops is described by several author [7, 8]. However, the current study showed that pre-crop, catch crops and manure application had no significant effect on the tuber productivity (Table 2). Likewise, Rinnofner et al. [4] found no benefit of green manure crop effects for the first following crop potato at dry weather conditions on the same site. Furthermore, according by Macák et al. [6] green manure management did not influence potato yields significantly, that is in agreement with our results also. In present study, catch crop treatment had no effect whereas manure treatment increased a negligible amount for tuber yield (Table 3). One reason could be N from the catch crop residue was released late in the development of the potatoes to provide any yield benefit [17]. On the contrary, previous researchers reported that catch crops increased potato total tuber yield and quality under organic farming condition [10, 11, 18]. Essah et al. found a cover crops have the potential to increase potato tuber yield and quality, as measured by tuber size and appearance. In current case, the small sized tubers tended to be higher in 2011, probably due to delayed plant maturity and tuber fill as a result of excessive N availability in the more fertile soil.

## CONCLUSSION

On the basis of the results it can be concluded that:

1. Precipitation distribution and temperature fluctuation in growing season may be limited use of soil mineral nitrogen for potato tuber yield and quality, because yield varied from season to season.
2. Results show clearly that catch crop and farmyard manure did not consistently enhance the potato tuber yield and quality in a soil with high fertility during a wet year.
3. Potato size distribution in both years was related to the cultivation of catch crops whereat small potato size was negatively and large potato size positively affected by the catch crop treatment. The percentage of large and small tubers could be increased by applying catch crops as green manures.

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