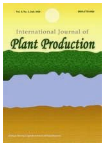


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# Yield and chemical composition of spring triticale grain depending on cropping and tillage systems

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## Abstract

A field experiment was conducted to evaluate the yield and chemical composition of triticale grain in different crop rotation and tillage systems. The first experimental factor was the cropping system – a) crop rotation and b) monoculture and the second factor was the tillage system – 1) conventional (CT), 2) reduced (RT) and 3) no-tillage (NT). The spring triticale yield was found to be 15.4% higher for crop rotation than for monoculture and 19.4-22.4% higher in CT than in RT and NT. Crop rotation also increased the content of starch in the grain, as well as that of phosphorus (P), calcium (Ca) and iron (Fe), with respect to monoculture. Triticale grain from the CT plots contained more starch, magnesium (Mg), manganese (Mn) and iron (Fe) than grain from RT and NT. Crude fibre content, however, was higher in the grain harvested from the monoculture than in the case of crop rotation. Higher fibre content was also noted in the grain from NT and RT than from CT.

***Keywords:*** Crop rotation; Monoculture; Tillage; Macroelements; Microelements; Protein; Starch, Crude fibre.

## Introduction

The dominant share of cereals in the total acreage occupied by crops, together with advances in farm machinery and equipment, has led to the development of ploughless tillage (Lahmar, 2010). Ploughless systems have many advantages, including counteracting soil erosion (Jordan et al., 2000), increasing organic carbon in the soil (West and Marland, 2002; Tabaglio et al., 2008), stabilization of the soil structure (Madari et al., 2005; Celik et al., 2012) and protection of the biological diversity of the soil (Uri et al., 1999). Despite these benefits, however, many studies indicate that crop yield is lower in ploughless systems than in conventional systems (Gruber et al., 2012; Woźniak, 2013; Woźniak and Kwiatkowski, 2013). According to De Vita et al. (2007) and Montemurro and Maiorana (2014), in warm, dry regions cereal yields are higher in ploughless systems than conventional ones, but in moderate moisture conditions better effects are achieved with conventional tillage (Lahmar, 2010; Gruber et al., 2012; Woźniak and Soroka, 2014). Research by Woźniak and Makarski (2012, 2013) suggests that cropping system and tillage also affect the quality and chemical composition of grain. However, according to Morris et al. (2009), Ranhort et al. (1995) and Ruibal-Mendieta et al. (2005), the chemical composition of grain is largely determined by weather conditions during maturation of the cereals.

The aim of the study was to evaluate the effect of cropping and tillage systems on the yield and chemical composition of spring triticale grain.

## Materials and Method

A field experiment with cropping and tillage systems was conducted in the years 2011-2013 at the Uhrusk Experimental Station (51° 18' 10" N, 23° 36' 44" E) of the University of Life Sciences in Lublin, Poland. The experiment was set up in a randomized split-plot design (8 m × 25 m) with three replications. The first experimental factor was the cropping system: a) crop rotation and b) monoculture; and the second factor was the tillage system: 1) conventional (CT), 2) reduced (RT) and 3) no-tillage (NT). In the crop rotation, the succession of crops was pea – spring wheat – spring triticale and in the monoculture it was spring triticale – spring triticale – spring triticale (a multi-species monoculture in its 23$^{th}$ to 25$^{th}$ year). In the CT system, harvest of the forecrop was followed by skimming (to a depth of 10-12 cm) and harrowing and in the autumn deep ploughing (25-30 cm). In the RT system a cultivator was used twice (10-15 cm), while in NT only glyphosate was applied (4 L ha$^{-1}$). Spring tillage in all plots involved the use of a tillage unit consisting of a cultivator and a roller (10-12 cm). The soil on which the experiment was conducted was Rendzic Phaeozem, according to the classification of IUSS Working Group WRB (2006). This soil is rich in available forms of phosphorus (110 mg P kg$^{-1}$) and potassium (190 mg K kg$^{-1}$) and has a slightly alkaline pH value ($pH_{KCl}$ =7.2). The total nitrogen (N) content in the soil is at 1.10 g kg$^{-1}$ and that of organic carbon (C-organic) is at 7.79 g kg$^{-1}$.

The total annual precipitation in the study area (data from 1963-2010) was 578 mm, of which 352 mm fell during the period from sowing of triticale to harvest (from March to August). In the years of the experiment the greatest total precipitation during the triticale growing season was in 2013 and the highest mean monthly air temperature in 2012.

The 'Milkaro' variety of spring triticale was sown in each year of the experiment in the first 10 days of April at a density of 500 seeds m$^{-2}$. Mineral fertilization of the soil was as follows: 26 kg P ha$^{-1}$, 83 kg K ha$^{-1}$ and 90 kg N ha$^{-1}$. Phosphorus and potassium fertilizers were applied before sowing and nitrogen twice – 45 kg N before sowing and 45 kg N at the stem elongation stage. To protect the plants against fungal diseases the following fungicides (active substances) were applied: flusilazole (125 g L$^{-1}$) + carbendazim 250 g L (1 L ha$^{-1}$) and propiconazole (125 g L$^{-1}$) + fenpropidin 275 g L (1 L ha$^{-1}$). For weed control a herbicide was applied: mecoprop + MCPA + dicamba (1.5 L ha$^{-1}$).

In the experiment the following were evaluated for each plot: grain yield, spike number per m$^2$, grain weight per spike (mean from 30 spikes), 1,000 grain weight (2 × 500 grains) and content in the grain of total protein, starch, crude fibre, minerals (P, K, Mg, Ca, Zn, Mn, Fe and Cu) and phytate P. Nitrogen content in the grain was determined by the Kjeldahl method and converted to total protein (N × 6.25). Starch content was determined by shaking seed samples with TRIS buffer (pH = 9.2) until the protein was completely dissolved. The remaining sediment was dissolved in hot water. Starch was determined by spectrophotometry ($\lambda$=660 nm) in the form of a complex with iodine. Crude fibre was determined using a Fibertec TM 2010 system for measuring dietary fibre according to AOAC, AACC and AOCS standards. The method was based on the manufacturer's instructions (FOSS TECATOR).

Content of minerals in the triticale grain was determined following dry mineralization of samples at 600 °C. The ash was dissolved in 5 mL 6M HCL and then redistilled water was added to attain a volume of 50 ml. Measurements were made by Atomic Absorption Spectrometry in an acetylene-air flame with a Unicam 939 spectrometer (Woźniak and Makarski, 2012; Woźniak and Makarski, 2013).

The data were analysed statistically using analysis of variance (ANOVA) and the means were compared by *F*-test protected LSD values calculated for P<0.05.

## Results

Spring triticale sown in the crop rotation system produced significantly higher yield than in the monoculture (Table 1). The higher yields were due to higher spike numbers per $m^2$ and grain weight per spike than in monoculture. The 1,000 grain weight where crop rotation was used was also significantly higher than in the monoculture. Higher yields were also noted for CT than RT and NT, which resulted from higher spike number per $m^2$, grain weight per spike and 1,000 grain weight. Analysis of variance components (*F*-Value) showed that triticale yield depended more on the cropping system than the tillage system. The interaction of the tillage system with the cropping system also significantly influenced yield (Table 2).

Table 1. Grain yield of spring triticale and its components.

| Cropping system (CS) | Tillage system (TS) | | | Mean |
|---|---|---|---|---|
| | [a]CT | RT | NT | |
| | Grain yield (t $ha^{-1}$) | | | |
| Crop rotation | 4.90 | 3.89 | 4.05 | 4.28 |
| Monoculture | 4.35 | 3.10 | 3.40 | 3.62 |
| Mean | 4.63 | 3.50 | 3.73 | - |
| | $LSD_{0.05}$ for CS = 0.46, TS = 0.54, CS × TS = 0.63 | | | |
| | Spike number $m^{-2}$ | | | |
| Crop rotation | 420 | 330 | 355 | 368 |
| Monoculture | 326 | 210 | 267 | 268 |
| Mean | 373 | 270 | 311 | - |
| | $LSD_{0.05}$ for CS = 24, TS = 37, CS × TS = 55 | | | |
| | Grain weight per spike (g) | | | |
| Crop rotation | 1.35 | 1.05 | 1.21 | 1.20 |
| Monoculture | 1.12 | 0.81 | 1.01 | 0.98 |
| Mean | 1.24 | 0.93 | 1.11 | - |
| | $LSD_{0.05}$ for CS = 0.09, TS = 0.11, CS × TS = ns | | | |
| | 1,000 grain weight (g) | | | |
| Crop rotation | 50.3 | 41.5 | 44.6 | 45.5 |
| Monoculture | 42.0 | 35.5 | 38.0 | 38.5 |
| Mean | 46.2 | 38.5 | 41.3 | - |
| | $LSD_{0.05}$ for CS = 2.2, TS = 2.7, CS × TS = 3.3 | | | |

[a]CT - conventional tillage; RT - reduced tillage; NT – no tillage; ns - not significant P<0.05.

Table 2. Analysis of variance for grain yield and its components, P<0.05.

| Effects | Grain yield | Spike number | Grain weight per spike | 1,000 grain weight |
|---|---|---|---|---|
| | *F*-Value | | | |
| [a]CS | 33.2 | 21.7 | 19.1 | 16.2 |
| TS | 18.9 | 37.1 | 18.3 | 17.1 |
| CS × TS | 21.3 | 15.3 | 2.1 | 8.8 |

[a]CS - Cropping System, TS - Tillage System.

The cropping and tillage systems significantly affected the content of starch and crude fibre in the grain (Table 3). The grain from the crop rotation plots contained significantly more starch than the grain from monoculture. CT also increased starch content in the grain with respect to RT and NT. However, crude fibre content was greater in the grain harvested in monoculture than in the case of crop rotation. Fibre content in the grain was also higher for NT and RT than for CT.

Table 3. Quality parameters of spring triticale grain.

| Cropping system (CS) | Tillage system (TS) | | | Mean |
|---|---|---|---|---|
| | [a]CT | RT | NT | |
| Total protein (g $kg^{-1}$ dm) | | | | |
| Crop rotation | 150.0 | 151.5 | 149.8 | 150.4 |
| Monoculture | 148.7 | 145.8 | 145.2 | 146.6 |
| Mean | 149.4 | 148.7 | 147.5 | - |
| $LSD_{0.05}$ for CS = ns, TS = ns, CS × TS = ns | | | | |
| Starch (g $kg^{-1}$ dm) | | | | |
| Crop rotation | 746.5 | 711.0 | 699.4 | 718.9 |
| Monoculture | 701.8 | 669.7 | 658.0 | 676.5 |
| Mean | 724.2 | 690.4 | 678.7 | - |
| $LSD_{0.05}$ for CS = 21.1, TS = 23.0, CS × TS = ns | | | | |
| Crude fibre (g $kg^{-1}$ dm) | | | | |
| Crop rotation | 19.1 | 26.9 | 29.8 | 25.3 |
| Monoculture | 24.9 | 35.3 | 38.6 | 32.9 |
| Mean | 22.0 | 31.1 | 34.2 | - |
| $LSD_{0.05}$ for CS = 2.2, TS = 3.0, CS × TS = ns | | | | |

Legend as in Table 1.

Content of minerals in the triticale grain also depended on the cropping system and the tillage system (Table 4). The grain from the crop rotation plots contained more phosphorus (P) than the grain from the monoculture. NT also increased P content in the grain in comparison with CT and RT. A substantial proportion of the P in the grain was in the form of phytate. This form of phosphorus accounted for 75% of total P in the case of crop rotation and over 85% in the monoculture. Phytate P content was also higher in the grain from NT than from CT. Potassium (K) content in the grain was significantly higher in the monoculture than in the crop rotation system. NT also increased K content in comparison to RT and CT. Magnesium (Mg) content, however, was affected only by the tillage method and was significantly higher in CT than in NT. In contrast, calcium (Ca) content in the grain was only influenced by the cropping system; it was significantly higher in the case of crop rotation than in the monoculture. Monoculture of triticale increased the grain content of zinc (Zn) and manganese (Mn) in comparison with crop rotation (Table 5). An increase in the content of these elements in the grain was also observed in RT and CT (for Zn) and CT (for Mn) in comparison to NT. Iron (Fe) content in the grain was higher in the crop rotation than in the monoculture and higher for CT than for RT and NT. Content of copper (Cu) in the grain was influenced by the tillage system and was higher in the grain collected from RT and CT plots than for NT.

Table 4. Content of macroelements and phytate P in spring triticale grain.

| Cropping system (CS) | Tillage system (TS) | | | Mean |
|---|---|---|---|---|
| | CT* | RT | NT | |
| Phosphorus (g P $kg^{-1}$ dm) | | | | |
| Crop rotation | 4.08 | 4.09 | 4.18 | 4.12 |
| Monoculture | 4.02 | 4.06 | 4.14 | 4.07 |
| Mean | 4.05 | 4.08 | 4.16 | - |
| $LSD_{0.05}$ for CS = 0.04, TS = 0.06, CS × TS = ns | | | | |
| Phytate-P (g $kg^{-1}$ dm) | | | | |
| Crop rotation | 3.01 | 3.19 | 3.12 | 3.11 |
| Monoculture | 3.10 | 3.30 | 3.99 | 3.46 |
| Mean | 3.06 | 3.25 | 3.56 | - |
| $LSD_{0.05}$ for CS = 0.14, TS = 0.19, CS × TS = 0.24 | | | | |
| Potassium (g K $kg^{-1}$ dm) | | | | |
| Crop rotation | 3.82 | 4.00 | 4.07 | 3.96 |
| Monoculture | 3.90 | 4.11 | 4.56 | 4.19 |
| Mean | 3.86 | 4.06 | 4.32 | - |
| $LSD_{0.05}$ for CS = 0.13, TS = 0.16, CS × TS = ns | | | | |
| Magnesium (g Mg $kg^{-1}$ dm) | | | | |
| Crop rotation | 1.30 | 1.26 | 1.19 | 1.25 |
| Monoculture | 1.34 | 1.24 | 1.23 | 1.27 |
| Mean | 1.32 | 1.25 | 1.21 | - |
| $LSD_{0.05}$ for CS = ns, TS = 0.09, CS × TS = ns | | | | |
| Calcium (g Ca $kg^{-1}$ dm) | | | | |
| Crop rotation | 0.25 | 0.24 | 0.24 | 0.24 |
| Monoculture | 0.21 | 0.20 | 0.22 | 0.21 |
| Mean | 0.23 | 0.22 | 0.23 | - |
| $LSD_{0.05}$ for CS = 0.02, TS = ns, CS × TS = ns | | | | |

Legend as in Table 1.

Table 5. Content of microelements in spring triticale grain.

| Cropping system (CS) | Tillage system (TS) | | | Mean |
|---|---|---|---|---|
| | CT | RT | NT | |
| Zinc (mg Zn $kg^{-1}$ dm) | | | | |
| Crop rotation | 36.81 | 39.05 | 33.20 | 36.35 |
| Monoculture | 40.28 | 40.35 | 34.90 | 38.51 |
| Mean | 38.55 | 39.70 | 34.05 | - |
| $LSD_{0.05}$ for CS = 2.11, TS = 3.34, CS × TS = ns | | | | |
| Manganese (mg Mn $kg^{-1}$ dm) | | | | |
| Crop rotation | 29.00 | 22.15 | 22.51 | 24.55 |
| Monoculture | 33.62 | 30.45 | 25.14 | 29.74 |
| Mean | 31.31 | 26.30 | 23.83 | - |
| $LSD_{0.05}$ for CS = 1.92, TS = 2.62, CS × TS = 4.13 | | | | |
| Iron (mg Fe $kg^{-1}$ dm) | | | | |
| Crop rotation | 20.21 | 18.91 | 16.12 | 18.41 |
| Monoculture | 19.22 | 17.76 | 16.00 | 17.66 |
| Mean | 19.72 | 18.34 | 16.06 | - |
| $LSD_{0.05}$ for CS = 0.71, TS = ns, CS × TS = ns | | | | |
| Copper (mg Cu $kg^{-1}$ dm) | | | | |
| Crop rotation | 5.70 | 5.81 | 4.76 | 5.42 |
| Monoculture | 5.76 | 5.69 | 4.84 | 5.43 |
| Mean | 5.73 | 5.75 | 4.80 | - |
| $LSD_{0.05}$ for CS = ns, TS = 0.12, CS × TS = ns | | | | |

Legend as in Table 1.

## Discussion and Conclusions

Monoculture of cereals leads to reductions in grain yield (Struik and Bonciarelli, 1997) and this phenomenon is aggravated by ploughless tillage (Woźniak and Soroka, 2014). In our study, grain yield depended more on the cropping system than the tillage system. In addition, RT and NT carried out in monoculture decreased the triticale grain yield to a greater degree than in the case of crop rotation, as a result of the significantly lower spike number per $m^2$ on these plots. Similar correlations were observed in studies by Struik and Bonciarelli (1997), Gruber et al. (2012) and Woźniak and Kwiatkowski (2013).

The cropping and tillage systems also influenced the chemical composition of the grain. Grain from the crop rotation plots contained more starch than in the monoculture, but less crude fibre. Higher starch content and lower crude fibre content were also noted in the grain from the CT plots than the RT and NT plots. In both cases this can be presumed to result from greater plumpness of the grain (1,000 grain weight) in the crop rotation than in the monoculture and in the conventional tilling in comparison with RT and NT. In a study by Woźniak and Makarski (2012, 2013) the cropping and tillage systems also differentiated the chemical composition of wheat grain. Triticale grain from the crop rotation plots contained more P, Ca and Fe than grain from the monoculture and grain from RT and NT contained more P, phytate P, K and Zn than grain from conventional tillage (CT).

To sum up, the yield of spring triticale was higher in the crop rotation than in the monoculture and higher in CT than RT and NT. Cultivation of triticale in the crop rotation system also increased the grain content of starch, phosphorus (P), calcium (Ca) and iron (Fe) in comparison with the monoculture. The triticale grain from the CT plots contained more starch, magnesium (Mg), manganese (Mn) and iron (Fe) than the grain from RT and NT. Crude fibre content, however, was higher in the grain from the monoculture than for crop rotation. Fibre content was also higher in the grain from NT and RT than from CT.

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