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# THE CONSEQUENCES OF ABANDONING NITROGEN FERTILISATION IN THE CULTIVATION OF THREE FORMS OF OAT, DEPENDING ON THE WATER CONDITIONS

*Summary*

*The article presents the results of strict experiments which were conducted between 2010 and 2013 in plots of the Gorzyń Experimental and Educational Station in Złotniki, Department of Agronomy, Poznań University of Life Sciences, Poland. The aim of the study was to assess the consequences of abandoning nitrogen fertilisation in the cultivation of three forms of oat, depending on diversified water conditions. The following factors were researched: the water variant (non-irrigated, irrigated), the form of oat (tall husked, dwarf husked, hulless) and two variants of nitrogen fertilisation (0 and 100 kg N·ha$^{-1}$). The research revealed that irrigation resulted in a greater increase in the yield of oat grains in the tall husked and hulless forms and a smaller increase in the dwarf form. The abandonment of nitrogen fertilisation resulted in the greatest decrease in the yield of tall husked oat grains in both water variants.*
***Key words**: oat form, nitrogen, water variant, grain yield*

# SKUTKI ZANIECHANIA NAWOŻENIA AZOTEM W UPRAWIE TRZECH FORM OWSA W ZALEŻNOŚCI OD WARUNKÓW WODNYCH

*Streszczenie*

*W pracy przedstawiono wyniki ścisłych doświadczeń polowych przeprowadzonych w latach 2010-2013 w Katedrze Agronomii, Uniwersytetu Przyrodniczego w Poznaniu, na polach Zakładu Doświadczalno-Dydaktycznego Gorzyń, Stacja Złotniki. W badaniach oceniano biologiczne skutki zaniechania nawożenia azotem w uprawie trzech form owsa w zależności od zróżnicowanych warunków wodnych. Czynniki badawcze stanowiły wariant wodny (niedeszczowany, deszczowany), forma owsa (oplewiony wysoki, oplewiony karłowy, nagi) oraz dwa poziomy nawożenia azotem (0 i 100 kg N·ha$^{-1}$). Na podstawie uzyskanych wyników stwierdzono, że większy przyrost plonu ziarna owsa pod wpływem nawadniania wykazano u formy oplewionej wysokiej i nagiej, a niższy u formy karłowej. Spośród porównywanych form najwyższym spadkiem plonu ziarna na skutek zaniechania nawożenia azotem w obu wariantach wodnych charakteryzowała się forma oplewiona wysoka.*
***Słowa kluczowe:** forma owsa, azot, wariant wodny, plon ziarna*

## 1. Introduction

In recent years the area of oat (*Avena sativa* L.) plantations in Poland has reached 500,000 ha. The share of the species in the cereals structure amounts to about 7% [5]. Oat is characterised by a high nutritional value because it contains digestible protein with a favourable amino acid composition and fat with high content of unsaturated fatty acids. It is valuable nourishment both for people and animals [1, 2]. The breeding of hulless cultivars broadened the perspectives of using this cereal to feed monogastric animals and in the food industry [13].

Oat also has a very important role – it is a phytosanitary plant, which is particularly valuable in crop rotation with a high share of cereals. Therefore, oat is a particularly recommended species for organic farming, where industrial means of production, such as synthetic fertilisers, are banned [3].

The yield of cereals largely depends on the weather conditions and nitrogen fertilisation [7, 10].

The aim of the study was to assess the biological consequences of abandoning nitrogen fertilisation in the cultivation of common and hulless oat, depending on irrigation.

## 2. Material and methods

Field experiments were conducted between 2010 and 2013 in plots of the Gorzyń Experimental and Educational Station in Złotniki, Department of Agronomy, Poznań University of Life Sciences, Poland (N: 52° 29' 0" E: 16° 49' 53"). The research was conducted on lessive soil classified as IVa and IVb in the soil valuation system. According to the agricultural suitability system, the soil was classified as part of complex 4 (very good rye complex) and 5 (good rye complex). It was characterised by the pH value of 5.7 (in 1 M KCl), high content of phosphorus (8.3 mg P·100 g$^{-1}$ of soil), medium content of potassium (9.4 mg K·100 g$^{-1}$ of soil) and magnesium (3.5 mg Mg·100 g$^{-1}$ of soil), and the humus content of 1.1%. The experiments were conducted in a randomised complete block design (split-plot), with 4 replicates. The following factors were researched: the water variant (unirrigated, irrigated), the form of oat (tall husked, dwarf husked, hulless) and two variants of nitrogen fertilisation (0 and 100 kg N·ha$^{-1}$).

When the soil moisture dropped below 70% field capacity, soil was irrigated by means of a system with semi-fixed NAAN 233/91 sprinklers with the nozzle diameter of 7 mm and water efficiency of 5 mm·h$^{-1}$. In consecutive years of the study the following doses of water were applied by irrigation: 40, 200, 160 and 155 mm. The following oat cultivars were sown: Bingo (tall husked oat), STH 6106 (dwarf husked oat), Polar (hulless oat) in 2010 and 2011 and Maczo (hulless oat) in 2012 and 2013.

The crops were fertilised with nitrogen in the form of ammonium nitrate, which was applied at two terms: 50 kg N·ha$^{-1}$ before sowing and 50 kg N·ha$^{-1}$ at the tillering phase (BBCH 21) in respective variants. Oat was grown after winter triticale in a four-field crop rotation system, where the share of cereals amounted to 50%. Before sowing the soil was fertilised with phosphorus (34.9 kg P·ha$^{-1}$) and potassium (83 kg K·ha$^{-1}$). Between 2010 and 2012 oat was sown in late March. Only in 2013 it was sown in early April due to unfavourable weather conditions. The number of seeds to be sown was decided according to their quality, i.e. 350 seeds·m$^2$. Other treatments were applied according to the agrotechnical recommendations for this species.

The results were statistically assessed by means of analysis of variance. The detailed Tukey's test was conducted, where the confidence limit was P = 0.95. The coefficients of variation (CV) of the analyzed features were calculated from the formula: CV = S / X · 100% where:
S - standard deviation,
X - arithmetic mean.

Satisfactory and stable yield depends on the weather conditions during the growth season [9, 12]. According to Hisira et al. [6], the temperature in May and June is particularly significant to the oat yield. The Greater Poland region is characterised by considerable changeability and diversity of weather due to the influence of maritime polar and maritime continental air masses. Records of the weather conditions during the experiments confirmed this tendency (Table 1). During the research period the average annual temperature ranged from 8.6 to 9.8°C, whereas the long-term average temperature was 8.6°C. In most months during the oat vegetation season the temperature was higher than the long-term average temperature in this period, except March and April 2013, May 2010, June 2012 and July 2011. The annual rainfall in the consecutive years of the research amounted to: 774.8, 525.3, 678.3 and 580.9 mm and it was higher than the long-term average rainfall (508.5 mm). During the oat growth season the highest rainfall was recorded in 2012 (368.6 mm), whereas the lowest rainfall was noted in 2013 (284.4 mm). The long-term average rainfall during this period was 245.7 mm.

## 3. Results and discussion

The irrigation applied in the experiment increased the average yield of oat grains by 0.9 t·ha$^{-1}$ (36.9%) in the combination without nitrogen fertilisation and by 1.51 t·ha$^{-1}$ (15.5%) in the variant fertilised with nitrogen at a dose of 100 kg N·ha$^{-1}$ . Similarly, in an earlier study by Panasiewicz et al. [11], the abandonment of nitrogen fertilisation decreased the yield of grains of the Roma winter wheat cultivar by 1.5 t·ha$^{-1}$ (41%) when the plants were grown under natural conditions. When they were irrigated, the yield dropped by 2.03 t·ha$^{-1}$ (52%).

In our study the tall husked oat gave the highest yield of grains in both water variants, regardless of the amount of nitrogen fertilisation (Table 2). However, the abandonment of nitrogen fertilisation in this oat form caused the greatest decrease in the yield of grains. The elimination of nitrogen from the unirrigated variants caused similar decreases in the yield of the other oat forms, i.e. 1.34-1.38 t·ha$^{-1}$. As far as the irrigated variants are concerned, the yield of the dwarf husked form dropped more than that of the hulless form. Panasiewicz et al. [11] assessed the effect of abandonment of nitrogen fertilisation in winter wheat and they noted that the yield of grains dropped by 1.5 t·ha$^{-1}$ (41%) when the crop was grown under natural conditions. When it was irrigated, the yield dropped by 2.03 t·ha$^{-1}$ (52%). The study by Feledyn-Szewczyk and Jończyk [4] showed that in the organic system the yield from husked cultivars was higher than from the hulless ones (by 66% on average). The authors indicated that the differences were caused by lesser density of plants and panicles.

The analysis of yield components showed that the abandonment of nitrogen fertilisation caused the greatest decrease in the density of panicles in the tall husked oat form, especially in the irrigated variant (218 pieces per m$^2$), and in the dwarf husked form grown without irrigation (108 pieces per m$^2$).

Table 1. Weather conditions at Meteorological Station at Złotniki in the years 2010-2013
*Tab. 1. Warunki pogodowe w Stacji Meteorologicznej Złotniki w latach 2010-2013*

| Months | Years | | | | Many-year average |
|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | |
| Temperature | | | | | |
| I | -6.5 | 0.6 | 2.2 | -2.4 | -1.5 |
| II | -0.5 | -1.7 | -1.4 | -0.3 | -0.5 |
| III | 4.2 | 4.5 | 5.6 | -2.3 | 3.3 |
| IV | 10.5 | 12.7 | 9.0 | 8.0 | 8.3 |
| V | 12.0 | 15.3 | 15.1 | 14.4 | 13.9 |
| VI | 19.2 | 18.4 | 15.8 | 17.3 | 17.2 |
| VII | 23.0 | 17.5 | 19.0 | 19.6 | 18.8 |
| VIII | 19.6 | 18.9 | 18.3 | 18.7 | 18.1 |
| IX | 13.4 | 15.0 | 14.1 | 12.4 | 13.5 |
| X | 6.9 | 9.1 | 8.3 | 10.3 | 8.9 |
| XI | 4.9 | 3.7 | 5.2 | 4.9 | 3.6 |
| XII | -4.0 | 3.3 | -1.5 | 2.6 | 0.0 |
| Average | 8.6 | 9.8 | 9.1 | 8.6 | 8.6 |

| Months | Years | | | | Many-year average |
|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | |
| Rainfall | | | | | |
| I | 34.4 | 22.1 | 86.6 | 43.6 | 28.3 |
| II | 22.8 | 36.0 | 52.0 | 41.3 | 26.5 |
| III | 33.8 | 15.2 | 11.8 | 33.8 | 29.8 |
| IV | 38.5 | 4.1 | 25.0 | 17.4 | 31.4 |
| V | 134.6 | 17.5 | 58.0 | 81.0 | 48.5 |
| VI | 26.6 | 62.4 | 124.4 | 106.0 | 59.6 |
| VII | 100.9 | 214.8 | 149.4 | 46.2 | 76.4 |
| VIII | 132.4 | 38.0 | 56.4 | 44.2 | 53.2 |
| IX | 68.5 | 28.6 | 30.4 | 74.8 | 46.0 |
| X | 7.2 | 21.8 | 32.8 | 16.4 | 34.4 |
| XI | 115.0 | 3.2 | 28.6 | 47.4 | 35.4 |
| XII | 60.1 | 61.6 | 22.9 | 28.8 | 39.0 |
| Sum | 774.8 | 525.3 | 678.3 | 580.9 | 508.5 |

*Source: own work / Źródło: opracowanie własne*

Table 2. The yield of oat forms and its components depending on irrigation and nitrogen fertilisation

*Tab. 2. Plon ziarna form owsa i jego komponenty w zależności od deszczowania i nawożenia azotem*

| Form of oat | Nitrogen fertilisation (kg N·ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | Non irrigation | | Reduction 2-3 | Irrigation | | Reduction 5-6 |
| | 100 | 0 | | 100 | 0 | |
| Grain yield (t·ha$^{-1}$) | | | | | | |
| Tall husked | 5.14 | 3.13 | 2.01 | 6.59 | 3.59 | 3.00 |
| Dwarf husked | 3.81 | 2.47 | 1.34 | 5.40 | 2.63 | 2.77 |
| Hulless | 3.32 | 1.94 | 1.38 | 4.82 | 2.48 | 2.34 |
| Average | 4.09 | 2.51 | 1.58 | 5.60 | 2.90 | 2.70 |
| Number of ears per 1m$^2$ | | | | | | |
| Tall husked | 612 | 430 | 182 | 688 | 470 | 218 |
| Dwarf husked | 493 | 385 | 108 | 486 | 388 | 98 |
| Hulless | 588 | 503 | 85 | 533 | 438 | 95 |
| Average | 564 | 439 | 125 | 569 | 432 | 137 |
| Number of grains per panicle | | | | | | |
| Tall husked | 28.6 | 22.7 | 5.9 | 30.9 | 19.3 | 11.6 |
| Dwarf husked | 35.9 | 30.9 | 5.0 | 46.3 | 30.2 | 16.1 |
| Hulless | 31.2 | 25.5 | 5.7 | 38.6 | 25.3 | 13.3 |
| Average | 31.9 | 26.4 | 5.5 | 38.6 | 24.9 | 13.7 |
| 1000 grain weight (g) | | | | | | |
| Tall husked | 39.5 | 34.2 | 5.3 | 39.1 | 38.1 | 1.0 |
| Dwarf husked | 36.4 | 35.6 | 0.8 | 35.8 | 32.1 | 3.7 |
| Hulless | 25.2 | 23.3 | 1.9 | 30.3 | 29.9 | 0.4 |
| Average | 33.7 | 31.0 | 2.7 | 35.1 | 33.4 | 1.7 |

*Source: own work / Źródło: opracowanie własne*

The elimination of nitrogen fertilisation caused the smallest decrease in the density of hulless oat panicles per m$^2$, where it amounted to 85 pieces per m$^2$ in the unirrigated variant and 95 pieces per m$^2$ in the irrigated variant. Apart from that, the elimination of nitrogen fertilisation from the unirrigated variant caused a greater decrease in the number of grains per panicle and in the thousand grain weight in the tall husked oat form. In the irrigated variant the greatest decrease in the same parameters was observed in the dwarf husked oat.

Koziara et al. [8] studied spring barley and proved that the abandonment of nitrogen fertilisation reduced the density of panicles and, to a lesser extent, it also reduced the thousand grain weight. The authors explained their observations with the effect of interdependence between the basic yield components.

Sykut-Domańska [14] compared 8 husked oat cultivars and 14 hulless cultivars and proved that the hulless ones were characterised by smaller 1000 grain weight and hectolitre weight than the husked ones. Tobiasz-Salach et al. [15] noted that the dwarf form was characterised by a significantly smaller thousand grain weight, smaller number of grains per panicle and greater panicle density than the tall form.

In our study the highest values of standard deviation and coefficient of variation were noted in the dwarf husked form in both water variants (Table 3). The calculations of the oat yield characteristics showed that the values of standard deviation and coefficient of variation increased when nitrogen fertilisation at a dose of 100 kg N·ha$^{-1}$ was applied in the unirrigated variants to the tall husked and dwarf husked oat forms and when it was applied to the hulless form in the irrigated variant. The irrigation of the tall husked and dwarf husked oat forms caused a decrease in the values of these characteristics. Koziara et al. [8] observed that when spring barley and spring triticale were grown without irrigation, the values of standard deviation and coefficient of variation in the grain yield increased when nitrogen fertilisation was applied at a dose of 100 kg N·ha$^{-1}$.

In all the oat forms nitrogen fertilisation at a dose of 100 kg N·ha$^{-1}$ under natural rainfall conditions reduced the values of standard deviation and coefficient of variation referring to the number of grains per panicle and the thousand grain weight and increased the panicle density in the dwarf husked oat form and the hulless one. When irrigation was applied, the same parameters increased for the thousand grain weight.

On average, during the research period the yield of oat grains in the unirrigated variant without nitrogen fertilisation ranged from 1.56 to 3.76 t·ha$^{-1}$ for the tall husked form, from 0.98 to 3.49 t·ha$^{-1}$ for the dwarf husked form and from 1.04 to 2.29 t·ha$^{-1}$ for the hulless form. On the other hand, the same conditions of oat cultivation where nitrogen fertilisation was applied resulted in the yield ranging from 2.97 to 7.38 t·ha$^{-1}$ for the tall husked form, from 1.17 to 6.0 t·ha$^{-1}$ for the dwarf husked form and from 2.68 to 3.96 t·ha$^{-1}$ for the hulless form. As far as irrigated variants without nitrogen fertilisation are concerned, the yield ranged from 2.33 to 4.68 t·ha$^{-1}$ for the tall husked form, from 1.41 to 3.47 t·ha$^{-1}$ for the dwarf husked form and from 2.20 to 2.64 t·ha$^{-1}$ for the hulless form. The yield of oat grains in the irrigated variants with nitrogen fertilisation at a dose of 100 kg N·ha$^{-1}$ ranged from 5.99 to 7.27 t·ha$^{-1}$ for the tall husked form, from 3.75 to 6.30 t·ha$^{-1}$ for the dwarf husked form and from 4.12 to 5.99 t·ha$^{-1}$ for the hulless form.

Brunava et al. [2] assessed two husked oat cultivars and two hulless cultivars and proved that the yield of the husked forms ranged from 4.31 to 5.30 t·ha$^{-1}$, whereas the yield of the hulless forms ranged from 3.20 to 3.69 t·ha$^{-1}$.

The straight-line correlation coefficients indicate that the yield of tall husked oat grains in the unirrigated variant without nitrogen fertilisation exhibited the strongest correlation with the plant density and thousand grain weight. In the irrigated variant there was the strongest correlation between the yield and the number of grains per panicle. As far as the variants fertilised with nitrogen at a dose of 100 kg N·ha$^{-1}$ are concerned, there was the strongest correlation between the yield and the number of grains per panicle in the plots without irrigation. In the irrigated plots there was the strongest correlation between the yield and the thousand grain weight and a negative correlation with the plant density.

The analysis of the correlation between the yield and its components depending on the water variant and nitrogen fertilisation in the dwarf husked oat form showed that the cultivation of this form in both water variants without fertilisation was the strongest correlated with the number of grains per panicle and the density of plants (Table 4). When nitrogen fertilisation was applied, the cultivation of the dwarf husked oat form the strongest correlated with the number of grains per panicle, but this correlation was negative in the irrigated variant.

The coefficients of correlation between the yield and its components in the hulless form showed that when nitrogen fertilisation was abandoned and no irrigation was applied, the yield was most strongly correlated with the number of grains per panicle and the number of plants per 1 m$^2$. When irrigation was applied, the yield was most strongly correlated with the thousand grain weight. When nitrogen fertilisation was applied (100 kg N·ha$^{-1}$) in the cultivation of this form without irrigation, there was the strongest correlation between the yield and the density of plants. As far as the irrigated variants are concerned, there was the strongest negative correlation between the yield and the thousand grain weight.

Table 3. Variation of oat features for non N fertilization and fertilization dose of 100 kg N·ha$^{-1}$ depending on irrigation
*Tab. 3. Zmienność cech owsa uprawianego bez nawożenia N i nawożonego dawką 100 kg N·ha$^{-1}$ w zależności od deszczowania*

| Form of oat | Figure | Fertilization (kg N·ha$^{-1}$) | Range | | Standard deviation (SD) | Variation coefficient (CV) |
|---|---|---|---|---|---|---|
| | | | min | max | | |
| Tall husked | Non irrigated | | | | | |
| | Grain yield (t·ha$^{-1}$) | 100 | 2.97 | 7.38 | 1..86 | 36..1 |
| | | 0 | 1..56 | 3..76 | 1..05 | 33..7 |
| | Number of ears per 1m$^2$ | 100 | 405 | 616 | 114 | 22..4 |
| | | 0 | 225 | 607 | 193 | 45..1 |
| | Number of grains per panicle | 100 | 18..9 | 40..8 | 9..52 | 33..2 |
| | | 0 | 13..0 | 37..6 | 10..9 | 48..1 |
| | 1000 grain weight (g) | 100 | 33..8 | 41..9 | 3..82 | 9..69 |
| | | 0 | 28..7 | 39..5 | 5..71 | 16..7 |
| | Irrigated | | | | | |
| | Grain yield (t·ha$^{-1}$) | 100 | 5.99 | 7.27 | 0.63 | 9.55 |
| | | 0 | 2.33 | 4.68 | 1.02 | 28.4 |
| | Number of ears per 1m$^2$ | 100 | 436 | 730 | 136 | 21.4 |
| | | 0 | 337 | 557 | 103 | 22.0 |
| | Number of grains per panicle | 100 | 24.3 | 41.5 | 7.39 | 23.9 |
| | | 0 | 16.0 | 20.8 | 2.23 | 11.6 |
| | 1000 grain weight (g) | 100 | 27.7 | 44.0 | 7.61 | 19.5 |
| | | 0 | 28.1 | 42.6 | 6.73 | 17.7 |
| Dwarf husked | Non irrigated | | | | | |
| | Grain yield (t·ha$^{-1}$) | 100 | 1.17 | 6.00 | 2.07 | 54.3 |
| | | 0 | 0.98 | 3.49 | 1.06 | 42.9 |
| | Number of ears per 1m$^2$ | 100 | 357 | 597 | 99.7 | 20.2 |
| | | 0 | 336 | 486 | 68.4 | 17.7 |
| | Number of grains per panicle | 100 | 22.9 | 52.9 | 13.2 | 36.8 |
| | | 0 | 18.1 | 51.2 | 14.8 | 48.0 |
| | 1000 grain weight (g) | 100 | 31.6 | 39.4 | 3.41 | 9.38 |
| | | 0 | 23.7 | 42.3 | 8.28 | 23.3 |
| | Irrigated | | | | | |
| | Grain yield (t·ha$^{-1}$) | 100 | 3.75 | 6.30 | 1.15 | 21.3 |
| | | 0 | 1.41 | 3.47 | 0.89 | 33.7 |
| | Number of ears per 1m$^2$ | 100 | 399 | 587 | 89.9 | 18.5 |
| | | 0 | 336 | 426 | 45.0 | 11.6 |
| | Number of grains per panicle | 100 | 36.2 | 58.5 | 9.21 | 19.9 |
| | | 0 | 20.2 | 40.9 | 8.53 | 28.2 |
| | 1000 grain weight (g) | 100 | 33.9 | 39.1 | 2.32 | 6.50 |
| | | 0 | 31.2 | 34.4 | 0.89 | 4.90 |
| Hulless | Non irrigated | | | | | |
| | Grain yield (t·ha$^{-1}$) | 100 | 2.68 | 3.96 | 0.69 | 20.9 |
| | | 0 | 1.04 | 2.29 | 0.60 | 31.0 |
| | Number of ears per 1m$^2$ | 100 | 243 | 635 | 182 | 37.3 |
| | | 0 | 303 | 666 | 168 | 33.5 |
| | Number of grains per panicle | 100 | 24.3 | 40.7 | 6.86 | 22.0 |
| | | 0 | 15.6 | 30.0 | 6.68 | 26.1 |
| | 1000 grain weight (g) | 100 | 20.8 | 27.6 | 3.04 | 12.1 |
| | | 0 | 17.9 | 25.9 | 3.71 | 15.9 |
| | Irrigated | | | | | |
| | Grain yield (t·ha$^{-1}$) | 100 | 4.12 | 5.99 | 0.82 | 16.9 |
| | | 0 | 2.20 | 2.64 | 0.19 | 7.94 |
| | Number of ears per 1m$^2$ | 100 | 356 | 672 | 136 | 28.2 |
| | | 0 | 185 | 645 | 189 | 45.8 |
| | Number of grains per panicle | 100 | 30.8 | 44.0 | 6.13 | 15.9 |
| | | 0 | 22.3 | 29.8 | 3.29 | 13.0 |
| | 1000 grain weight (g) | 100 | 25.1 | 42.7 | 8.28 | 27.3 |
| | | 0 | 22.0 | 36.4 | 7.28 | 24.3 |

*Source: own work / Źródło: opracowanie własne*

Table 4. Correlation coefficients of grain yield and yield components of oat forms for non N fertilization and fertilization dose of 100 kg N·ha$^{-1}$
*Tab. 4. Współczynniki korelacji plonu ziarna i komponentów plonowania form owsa uprawianych bez nawożenia N i nawożonych dawką 100 kg N·ha$^{-1}$*

| Form of oat | Fertilization (kg N·ha$^{-1}$) | Variable | Ear number per 1 m$^2$ (1) | Grain number in spike (2) | 1000 grain weight (g) (3) | Grain yield (t·ha$^{-1}$) (4) |
|---|---|---|---|---|---|---|
| Tall husked | | | Non irrigated | | | |
| | 100 | 1 | 1.000 | | | |
| | | 2 | 0.201 | 1.000 | | |
| | | 3 | 0.540 | 0.440 | 1.000 | |
| | | 4 | 0.070 | 0.989* | 0.324 | 1.000 |
| | 0 | 1 | 1.000 | | | |
| | | 2 | 0.896 | 1.000 | | |
| | | 3 | 0.573 | 0.822 | 1.000 | |
| | | 4 | 0.595 | 0.472 | 0.586 | 1.000 |
| | | | Irrigated | | | |
| | 100 | 1 | 1.000 | | | |
| | | 2 | 0.122 | 1.000 | | |
| | | 3 | -0.138 | 0.320 | 1.000 | |
| | | 4 | -0.682 | 0.541 | 0.656 | 1.000 |
| | 0 | 1 | 1.000 | | | |
| | | 2 | 0.816 | 1.000 | | |
| | | 3 | -0.623 | -0.295 | 1.000 | |
| | | 4 | 0.650 | 0.907 | 0.105 | 1.000 |
| Husked dwarf | | | Non irrigated | | | |
| | 100 | 1 | 1.000 | | | |
| | | 2 | 0.250 | 1.000 | | |
| | | 3 | 0.727 | -0.483 | 1.000 | |
| | | 4 | 0.436 | -0.524 | 0.040 | 1.000 |
| | 0 | 1 | 1.000 | | | |
| | | 2 | 0.831 | 1.000 | | |
| | | 3 | 0.208 | -0.320 | 1.000 | |
| | | 4 | 0.609 | 0.686 | -0.459 | 1.000 |
| | | | Irrigated | | | |
| | 100 | 1 | 1.000 | | | |
| | | 2 | 0.729 | 1.000 | | |
| | | 3 | -0.337 | -0.494 | 1.000 | |
| | | 4 | -0.168 | 0.410 | 0.300 | 1.000 |
| | 0 | 1 | 1.000 | | | |
| | | 2 | 0.715 | 1.000 | | |
| | | 3 | 0.528 | -0.187 | 1.000 | |
| | | 4 | 0.696 | 0.954* | -0.081 | 1.000 |
| Hulless | | | Non irrigated | | | |
| | 100 | 1 | 1.000 | | | |
| | | 2 | 0.275 | 1.000 | | |
| | | 3 | -0.115 | -0.974* | 1.000 | |
| | | 4 | 0.850 | -0.263 | 0.394 | 1.000 |
| | 0 | 1 | 1.000 | | | |
| | | 2 | 0.840 | 1.000 | | |
| | | 3 | 0.171 | -0.383 | 1.000 | |
| | | 4 | 0.761 | 0.976* | -0.503 | 1.000 |
| | | | Irrigated | | | |
| | 100 | 1 | 1.000 | | | |
| | | 2 | -0.972* | 1.000 | | |
| | | 3 | -0.341 | 0.511 | 1.000 | |
| | | 4 | -0.371 | 0.322 | -0.496 | 1.000 |
| | 0 | 1 | 1.000 | | | |
| | | 2 | -0.220 | 1.000 | | |
| | | 3 | -0.692 | 0.370 | 1.000 | |
| | | 4 | 0.040 | -0.354 | 0.535 | 1.000 |

*Source: own work / Źródło: opracowanie własne*

## 4. Concluding remarks

The research proved significant dependence between the yield of oat grains and irrigation, oat form and nitrogen fertilisation. In all the years of the research irrigation resulted in higher yield, regardless of the other factors. There was a greater increase in the yield of oat grains in the tall husked and hulless forms and a smaller increase in the dwarf form.

The abandonment of nitrogen fertilisation resulted in the greatest decrease in the yield of tall husked oat grains in both water variants. In the unirrigated variant the yield of grains was reduced by 2.01 t·ha$^{-1}$, whereas it was reduced by 3.0 t·ha$^{-1}$ when irrigation was applied.

## 5. References


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