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YIELD OF WINTER CULTIVARS OF SPELT WHEAT (*Triticum aestivum* ssp. *spelta* L.) CULTIVATED UNDER DIVERSIFIED CONDITIONS OF MINERAL FERTILIZATION AND CHEMICAL PROTECTION

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Abstract. The field experiment was carried out in years 2008-2010 on rendzina soil. The aim of the research was to determine the effect of the chemical protection level on the yield of two winter spelt cultivars – Schwabenkorn and Spelt I.N.Z. cultivated under different conditions of mineral fertilization. Chemical protection levels included: A) control, B) Mustang 306 SE, Stabilan 750 SL, C) Mustang 306 SE, Attribut 70 WG, Stabilan 750 SL, D) Mustang 306 SE, Attribut 70 WG, Alert 375 SC, Stabilan 750 SL. Mineral fertilization was as follows (in kg of pure component per hectare): lower level N – 60, P – 26.2, K – 83, and higher level N – 80, P – 34.9, K – 99.6. Significantly higher grain yields were obtained from Spelt I.N.Z. cultivar compared with Schwabenkorn cv. Application of higher rates of mineral fertilizers significantly increased the number of ears per 1 m^2 as well as the grain yield of spelt wheat but had no effect on the weight of 1000 grains, and the number and weight of grains per ear. Chemical protection of Schwabenkorn cultivar caused significantly higher grain yield, from 29.8 to 33.7%, compared with control without chemical protection.

Key words: fungicide protection, growth regulator, NPK rates, Schwabenkorn, Spelt I.N.Z., weed control

INTRODUCTION

Spelt wheat (*Triticum aestivum* ssp. *spelta* L.) is one of the oldest cereals cultivated by man. For a long time it fulfilled a significant role in the nutrition of old Europe, especially the Roman Empire. It was very popular in the Middle Ages. Later, it gave way to other more fertile wheat cultivars, and the area of its cultivation gradually decreased [Kalinowska-Zdun 2005, Tyburski and Żuk-Gołaszewska 2005]. For some time, spelt wheat was a forgotten cereal but in the past 20 years it has enjoyed its

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revival. It is connected with the development of ecological agriculture and with the high nutritional value of this cereal. It has been proved that systematic consumption of spelt wheat regenerates the whole body, increases its immunity and helps in the treatment of cancerous diseases. It can be consumed by people allergic not only to wheat flour but also to rye flour [Campbell 1997, Majewska et al. 2007, Sulewska et al. 2008b]. Grain of spelt wheat contains more protein than grain of bread wheat, it is also richer in easily available gluten than bread wheat grain. Moreover, it contains more zinc, copper and selenium as well as vitamins A, E and D. It is also a rich source of fiber [Grela et al. 1993, Pałys and Łabuda 1997, Achremowicz et al. 1999].

Today, spelt wheat is mainly cultivated in German-speaking countries, but also in Italy, France, and since the 1990s also in the Czech Republic, Hungary and Slovakia. In Poland interest in this cereal has been gradually growing, therefore more and more often the research is conducted which aims at developing proper agricultural techniques of spelt wheat cultivation under Polish soil-climatic conditions [Tyburski and Żuk-Gołaszewska 2005, Tyburski and Babalski 2006, Sulewska et al. 2008a].

The aim of this paper was to determine effect of the level of chemical protection on the yield of two winter cultivars of spelt wheat, Schwabenkorn and Spelt I.N.Z., cultivated under conditions of diversified mineral fertilization.

MATERIAL AND METHODS

Field experiments were carried out in the years 2008-2010 on an Experimental Farm in Bezek near Chełm (51°19' N; 23°26' E). The experiment was set up on mixed rendzina soil formed in the cretaceous age, of granulometric composition of medium silty clay (granulometric fraction content: 1-0.1 mm – 24 g·100 g^{-1}; 0.1-0.02 mm – 36 g·100 g^{-1}; <0.02 mm – 40 g·100 g^{-1}). This soil is included in minute soils. According to bonitation classification, it belongs to class IIIb, however according to agricultural suitability, it belongs to the defective wheat complex. It was characterized by alkaline reaction (pH in 1 mole KCl – 7.35), high content of phosphorus (117.8 mg·kg^{-1} of soil) and potassium (242.4 mg·kg^{-1} of soil) and very low magnesium content (19.0 mg·kg^{-1} of soil). The organic carbon content was 2.47%.

According to the 6-level scale of soil pollution with heavy metals elaborated by the Institute of Soil Science and Plant Cultivation in Puławy, the content of some trace metals in the ploughing layer of the soil 0-30 cm was located on the zero level of soil pollution, which denotes the natural content of these elements. It was (mg·kg of $soil^{-1}$): Cd – 0.24, Pb – 6.9, Ni – 7.2, Zn – 41.8, Cu – 9.0 [Collective work 1995].

The experiment was set up in a randomized block design in 3 replications, on plots of the area of 8 m^2. The scheme of the experiment included 2 spelt wheat cultivars (Schabenkorn and Spelt I.N.Z.), 2 levels of mineral fertilization and 4 levels of plant protection. The forecrop of spelt wheat was common wheat. Cultivation treatments were applied according to the generally accepted agricultural recommendations for the form of common winter wheat. Spelt wheat ears were sown in mid-October at a rate of 350 kg per hectare. Mineral fertilization was as follows (in kg of a pure component per hectare):

I level: N – 60 (20 + 40), P – 26.2, K – 83,

II level: N – 80 (20 + 40 + 20), P – 34.9, K – 99.6.

Phosphorous and potassic fertilizers and 20 kg $N \cdot ha^{-1}$ were applied before sowing spelt wheat. In spring, at the stage of shooting (BBCH 32-34), on both levels of fertilization, 40 kg $N \cdot ha^{-1}$ were applied. Additionally, on the second level, at the stage of earing (BBCH 52-55), 20 kg $N \cdot ha^{-1}$ was also sown.

Levels of plant protection included:

A) control object (without chemical protection);

B) Mustang 306 SE, Stabilan 750 SL;

C) Mustang 306 SE, Attribut 70 WG, Stabilan 750 SL;

D) Mustang 306 SE, Attribut 70 WG, Alert 375 SC, Stabilan 750 SL.

Herbicides Mustang 306 SE (florasulam 6.25 $g \cdot dm^{-3}$; 2.4-D EHE 300 $g \cdot dm^{-3}$) and Attribut 70 WG (propoxycarbazone 70%; 2-benzoic acid methyl ester sodium salt) were applied at the stage of tillering (BBCH 23-25) at the following rates: 0.4 $dm^3 \cdot ha^{-1}$ and 60 $g \cdot ha^{-1}$. Fungicide Alert 375 SC (flusilazole 125 $g \cdot dm^{-3}$; carbendazim 250 $g \cdot dm^{-3}$) at a rate of 1 $dm^3 \cdot ha^{-1}$, and growth regulator Stabilan 750 SL (CCC 750 $g \cdot dm^{-3}$) at a rate of 2 $dm^3 \cdot ha^{-1}$ were applied at the stage of shooting (BBCH 32-34).

Before harvesting spelt wheat, the height of 30 randomly chosen plants in a canopy was measured and the number of ears on the area of 1 m^2 was calculated on each plot, and also the length of 30 randomly selected ears per plot was determined. After manual weeding of grains, the number and weight of grains per 1 ear was determined as well as the weight of 1000 grains. Obtained results were elaborated statistically with the analysis of variance for triple classification, and the smallest significant differences were calculated with the use of Tukey's honestly significant difference test with 5% risk of error. Calculations, were carried out with the use of ARStat program from the Information Technology Center of the University of Life Sciences in Lublin. The results have been presented as the means from the three years of research.

Weather conditions at the time of experiment are presented in Table 1. The rainfall total from April to July in the first year of research reached a similar value as in the long-term period, however in the subsequent years it was higher than the long-term mean by 31 and 37%, respectively. Average air temperature, however, was in all years of research higher compared with the mean from the long-term period.

RESULTS AND DISCUSSION

Independent of the level of mineral fertilization and chemical protection, compared spelt wheat cultivars were characterized by similar plant height and ear length (Table 2). Tendency to a greater number of ears per 1 m^2 was observed in Spelt I.N.Z. cultivar (on average 493 plants compared with 480 plants of Schwabenkorn cultivar). Feledyn-Szewczyk and Duer [2006] in an experiment with spelt wheat cv. Schwabenkorn, obtained a comparable number of ears per area unit. In the research of Sulewska et al. [2010], however, value of this trait for Schwabenpelz cultivar was in the range from 334 to 481 plants, while for Badengold cultivar from 392 to 558 plants per 1 m^2. Rachoń and Szumiło [2009], evaluating the yield of winter lines of spelt wheat, obtained ear density on the level of 544-658 plants$\cdot m^{-2}$.

Greater grain ripeness was characteristic of Spelt I.N.Z. cultivar. The number and weight of grains per ear as well as the weight of 1000 grains of this cultivar were significantly higher than for Schwabenkorn cultivar. Slightly lower weight of 1000 grains of spelt wheat than in the discussed experiment was obtained by Pałys and

Kuraszkiewicz [2003] as well as by Sulewska et al. [2008a]. In the research of Pałys and Łabuda [1997] and Rachoń and Szumiło [2009], the weight of 1000 grains of spelt wheat oscillated between 40.6-50.4 g.

Table 1. Rainfall and air temperature from April to July in the years 2008-2010 compared with the long-term period (1974-2003) according to the Meteorological Station in Bezek
Tabela 1. Sumy opadów atmosferycznych i średnia temperatura powietrza w okresie od kwietnia do lipca w latach 2008-2010 w zestawieniu ze średnimi wieloletnimi (1974-2003) według Stacji Meteorologicznej w Bezku

Year – Rok	Month – Miesiąc				Sum – Suma
	April – kwiecień	May – maj	June – czerwiec	July – lipiec	
	Rainfall – Opady, mm				
2008	47.9	74.2	38.4	93.9	254.4
2009	10.1	86.8	180.5	50.8	328.2
2010	20.4	72.4	94.4	156.0	343.2
Mean from 1974-2003 Średnia z lat 1974-2003	40.1	53.0	77.6	80.3	251.0
	Temperature – Temperatura, °C				Mean – Średnia
2008	9.1	12.7	17.4	18.3	14.4
2009	11.2	13.0	16.2	19.9	15.1
20110	9.0	14.5	17.6	20.8	15.5
Mean from 1974-2003 Średnia z lat 1974-2003	7.6	13.6	16.2	17.9	13.8

Table 2. Yield components of spelt wheat cultivars
Tabela 2. Komponenty plonu odmian pszenicy orkisz

Trait – Cecha	Schwabenkorn	Spelt I.N.Z.	$LSD_{0.05}$ – $NIR_{0,05}$
Height of plants, cm Wysokość roślin w łanie	112	113	ns – ni
Number of ears per 1 m^2 Liczba kłosów na 1 m^2	480	493	ns – ni
Lenght of ear, cm Długość kłosa	10.9	11.1	ns – ni
Number of grains per ear Liczba ziaren w kłosie	19.2	20.8	0.93
Weight of grains per ear, g Masa ziaren z kłosa	0.86	0.98	0.049
Weight of 1000 grains, g Masa 1000 ziaren	44.6	46.8	0.81

ns – ni – non-significant differences – różnice nieistotne

According to Podolska and Mazurek [1999], availability of nitrogen in the soil favorably affects formation of traits of yield structure and proper architecture of the cereal canopy. In the conducted research, plants fertilized with NPK rates of 80 : 34.9 : 99.6 kg·ha^{-1} were significantly higher and developed significantly more ears per 1 m^2 than those fertilized with NPK rates on the level of 60 : 26.2 : 83 kg·ha^{-1}. Ear length, weight and number of grains per ear as well as the weight of 1000 grains did not change significantly in relation to the level of mineral fertilization (Table 3). Similar tendency was observed in the research of Podolska [2008] and Stankowski et al. [2004], who

proved that diversity of the rates of nitrogen fertilizers is a factor of no significant meaning in the variation of grain ripeness of common wheat.

Table 3. Yield components of spelt wheat depending on the mineral fertilization level
Tabela 3. Komponenty plonu pszenicy orkisz w zależności od poziomu nawożenia mineralnego

Trait – Cecha	NPK 60 : 26.2 : 83	NPK 80 : 34.9 : 99,6	$LSD_{0,05}$ – $NIR_{0,05}$
Height of plants, cm Wysokość roślin w łanie	109	117	3.3
Number of ears per 1 m^2 Liczba kłosów na 1 m^2	448	526	27.8
Lenght of ear, cm Długość kłosa	11.1	10.9	ns – ni
Number of grains per ear Liczba ziaren w kłosie	20.0	20.0	ns – ni
Weight of grains per ear, g Masa ziaren z kłosa	0.91	0.92	ns – ni
Weight of 1000 grains, g Masa 1000 ziaren	45.5	45.9	ns – ni

ns – ni – non-significant differences – różnice nieistotne

Chemical protection of plants, independent of the cultivar and level of mineral fertilization, caused a significant increase in the number of ears per 1 m^2 – on mean from 54 to 81 plants, i.e. from 12.4 to 18.7%, compared with the control variant without protection (Table 4). In the research of Rachoń and Szumiło [2009], increase of the value of this trait after application of comprehensive chemical protection of spelt wheat was 11.4%. In the discussed experiment, best results were obtained on plots with a full chemical protection, including application of two herbicides, fungicide and growth regulator, and next in combination, where Mustang 306 SE and Stabilan 750 SL were applied.

Table 4. Yield components of spelt wheat depending on the chemical protection level
Tabela 4. Komponenty plonu pszenicy orkisz w zależności od poziomu chemicznej ochrony

Traits – Cecha	A*	B	C	D	$LSD_{0.05}$ – $NIR_{0,05}$
Height of plants, cm Wysokość roślin w łanie	115	114	114	109	ns – ni
Number of ears per 1 m^2 Liczba kłosów na 1 m^2	434	510	488	515	51.9
Lenght of ear, cm Długość kłosa	10.9	10.8	11.1	11.2	ns – ni
Number of grains per ear Liczba ziaren w kłosie	19.9	20.3	20.4	19.4	ns – ni
Weight of grains per ear, g Masa ziaren z kłosa	0.91	0.93	0.94	0.89	ns – ni
Weight of 1000 grains, g Masa 1000 ziaren	45.5	45.3	46.1	45.9	ns – ni

A* – control object (without chemical protection) – obiekt kontrolny (bez ochrony chemicznej)
B – Mustang 306 SE, Stabilan 750 SL
C – Mustang 306 SE, Attribut 70 WG, Stabilan 750 SL
D – Mustang 306 SE, Attribut 70 WG, Alert 375 SC, Stabilan 750 SL
ns – ni – non-significant differences – różnice nieistotne

In the experiment, no significant effect of chemical protection on the plant height and ear length of spelt wheat was found. Also the number and weight of grains per ear and the weight of 1000 grains did not differ significantly. Other dependences occurred in the research of Rachoń and Szumiło [2009], in which comprehensive protection of spelt wheat, including application of seed dressing, two herbicides, fungicide, insecticide and growth regulator, significantly increased the number and weight of grains per ear by 8.6 and 9.2%, respectively, however it had no effect on the weight of 1000 grains.

Independently of the level of mineral fertilization and chemical protection, significantly higher yields were obtained from Spelt I.N.Z. cultivar (on average by 9.3% compared with Schwabenkorn cultivar) (Fig. 1). Grain yields of Schwabenkorn cultivar were similar to the ones obtained by this cultivar in the research of Feledyn-Szewczyk and Duer [2006], and visibly higher than in the experiments of Pałys and Łabuda [1997] as well as of Pałys and Kuraszkiewicz [2003]. It probably resulted from a different plant density, cultivation and soil conditions.

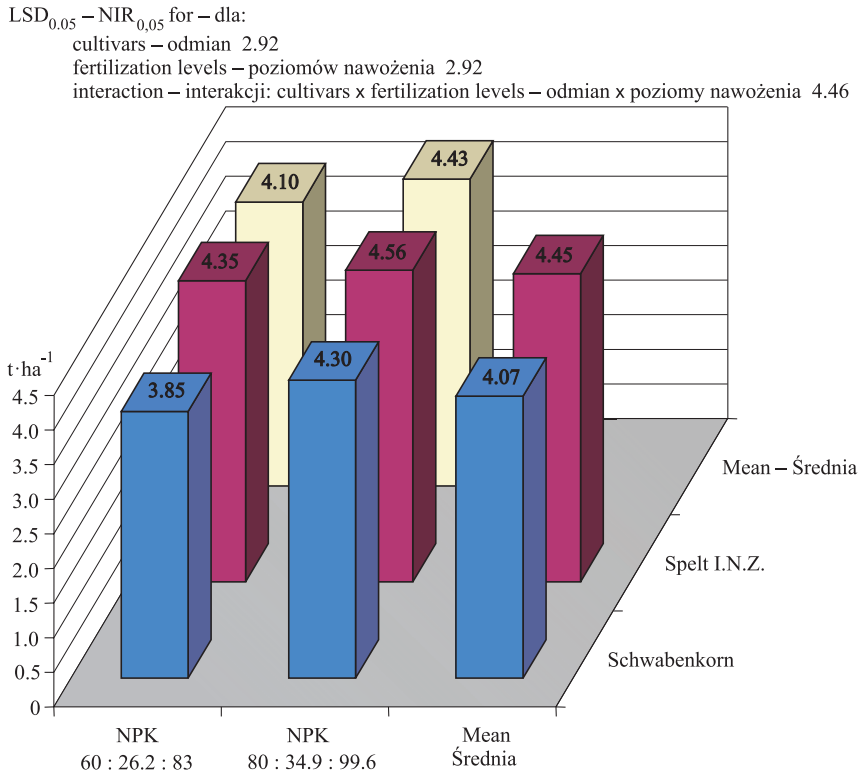

Fig. 1. Effect of mineral fertilization level on the yield of spelt wheat cultivars
Rys. 1. Wpływ poziomu nawożenia mineralnego na plony ziarna porównywanych odmian pszenicy orkisz

In the available literature there is no detailed research evaluating the effect of the level of mineral fertilization on the yield height of spelt wheat grain. The only known fact is that it is a plant of a lower nitrogen requirement, and at the same time of a similar

phosphorus and potassium requirement as common wheat, which is characterized by a better use of nutrients [Sulewska et al. 2010]. Sulewska et al. [2010] are convinced that manure fertilization is beneficial for spelt wheat at a rate of 15 t·ha^{-1}. However, from the previous research of Sulewska [2004], it follows that introduction of nutrients into mineral fertilizers is the most effective method of increasing spelt wheat yields. In own research, independent of cultivar and chemical plant protection, visibly more beneficial was application of higher rates of mineral fertilizers which affected the 8.0% yield increase (Fig. 1).

Experiments conducted with a great number of cultivars of spring and winter cereals indicate various reaction of cultivars to nitrogen fertilization. It is genetically conditioned and is connected with a different metabolism of each cultivar and with diverse nutritional requirements [Podolska and Mazurek 1999, Sułek et al. 2007]. Obtained interaction between cultivars and levels of fertilization allows to say that significant differences in the yield concerned only Schwabenkorn cultivar (increase by 11.7%), however increase of the grain yield of Spelt I.N.Z. cultivar under the effect of increased rates of NPK was slight (4.8%) and statistically insignificant.

According to many authors [Woźnica et al. 2004, Pałys et al. 2007], winter wheat is a cereal which strongly reacts to chemical protection. In the conducted experiment, independently of other factors, grain yields from plots with chemical protection were higher than from the control plots, on average by 13.2% to 14.0%, although obtained differences were statistically insignificant (Fig. 2). In the research of Rachoń et al. [2009], winter lines of spelt wheat with the comprehensive protection yielded by 17.7% higher than those under minimum protection.

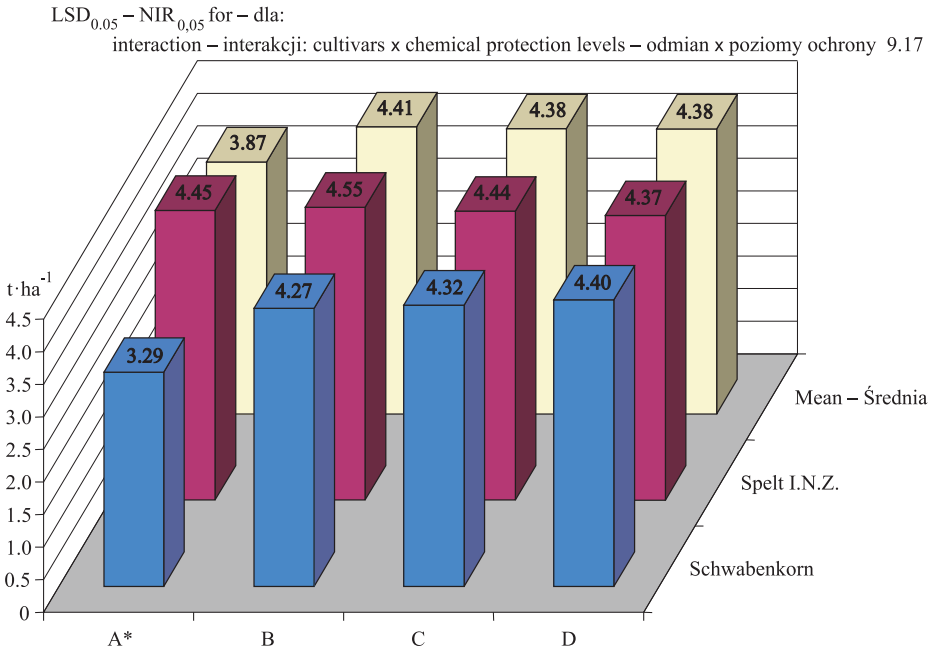

Fig. 2. Effect of chemical protection level on the yield of spelt wheat cultivars
Rys. 2. Wpływ poziomu chemicznej ochrony zasiewów na plony ziarna porównywanych odmian pszenicy orkisz

Statistical analysis of obtained results confirmed interaction between the levels of chemical protection and spelt wheat cultivars. Schwabenkorn cultivar, on each level of chemical protection produced significantly higher grain yields than in the control variant without protection. Chemical protection of Spelt I.N.Z. cultivar had no significant effect on the grain yield.

CONCLUSIONS

1. Under conditions of the conducted experiment, spelt wheat yielded on the level from 4.07 to 4.45 $t \cdot ha^{-1}$. Levels of crop chemicalization and rates of mineral fertilization diversified the level of grain yield of Schwabenkorn cultivar, however they had no effect on the yield of Spelt I.N.Z. cultivar.

2. Independent of the level of mineral fertilization and chemical protection, spelt wheat of Spelt I.N.Z. cultivar was characterized by a higher number of ears per area unit, higher number and weight of grains per ear and higher weight of 1000 grains than Schwabenkorn cultivar. As a result, grain yields of Spelt I.N.Z. cultivar were higher than the ones of Schwabenkorn cv.

3. Application of increased rates of mineral fertilizers increased the grain yield and number of ear-bearing culms per 1 m^2, however it had no effect on the ear length, number and weight of grains per ear and the weight of one thousand grains.

4. Independent of the cultivar and level of mineral fertilization, chemical protection of plants increased the number of ears per area unit compared with the control object, although they did not differentiate other components of yield of spelt wheat.

5. Schwabenkorn cultivar, on each level of chemical protection, produced higher grain yields than in the control variant without protection. Chemical protection of Spelt I.N.Z. cultivar had no effect on the grain yield.

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PLONOWANIE OZIMYCH ODMIAN PSZENICY ORKISZ (*Triticum aestivum* ssp. *spelta* L.) UPRAWIANYCH W ZRÓŻNICOWANYCH WARUNKACH NAWOŻENIA MINERALNEGO I OCHRONY CHEMICZNEJ

Streszczenie. Doświadczenie polowe przeprowadzono w latach 2008-2010 na rędzinie mieszanej. Celem badań było określenie wpływu poziomu chemicznej ochrony zasiewów na plonowanie dwóch ozimych odmian pszenicy orkisz (Schwabenkorn i Spelt I.N.Z.) w warunkach zróżnicowanego nawożenia mineralnego. Poziomy ochrony roślin obejmowały: A) obiekt kontrolny, B) Mustang 306 SE, Stabilan 750 SL, C) Mustang 306 SE, Attribut 70 WG, Stabilan 750 SL, D) Mustang 306 SE, Attribut 70 WG, Alert 375 SC, Stabilan 750 SL. Nawożenie mineralne przedstawiało się następująco (w kg czystego składnika na hektar): niższy poziom N – 60, P – 26,2, K – 83 oraz wyższy poziom N – 80, P – 34,9, K – 99,6. Istotnie większe plony ziarna wydała odmiana Spelt I.N.Z. w porównaniu z odmianą Schwabenkorn. Zastosowanie zwiększonych dawek nawozów mineralnych istotnie zwiększyło liczbę kłosów na 1 m^2 i plon ziarna, nie miało natomiast wpływu na liczbę i masę ziaren z kłosa oraz MTZ. Jedynie odmiana Schwabenkorn na każdym obiekcie chronionym chemicznie dawała plony ziarna istotnie większe niż w wariancie kontrolnym bez ochrony.

Słowa kluczowe: dawki NPK, ochrona fungicydowa, regulator wzrostu, Schwabenkorn, Spelt I.N.Z., zwalczanie chwastów

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