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EVALUATION OF WINTER RYE CULTIVATION TECHNOLOGY ON PRODUCTION PLANTATIONS IN THE ŁÓDŹ VOIVODESHIP DEPENDING ON PLANTATION AREA

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ABSTRACT

Background. The aim of the study was an evaluation of the suitability of the winter rye production technology used at production plantations in the Łódź Voivodeship, and identification of scale and types of errors allowed by farmers in cultivation of this crop depending on plantation area.

Material and methods. In the years 2009-2012 in the Łódź Voivodeship surveys were conducted at 307 winter rye production plantations. During three-interview sorties with farmers, the level of agrotechnical factors used at the plantations were identified. In the evaluation of the applied agro-techniques the plantations were divided into two groups, depending on their area: group I with areas up to 2.0 ha (179 plantations) and group II: 2.0 ha and more (128 plantations).

Results. The plantations with areas ≥2.0 were characterized by larger grain yield by 0.2 $Mg \cdot ha^{-1}$ (7.4%) compared to plantations with areas <2.0 ha. No significant differences in the rye agrotechnology were noted in either of the plantation groups. The production technology complexity index (W_k) for plantations ≥2.0 ha was 44.8% and for plantations <2.0 ha it was 42.8%. The most common discrepancies in agrotechnology, regardless of plantation area, were related to the sowing of an excessive norm of not qualified and undressed sowing material, to the application of insufficient dosages of nitrogen as well as of phosphorus and potassium, and to no application of foliar fertilization, of fungicides, of insecticides or of growth regulators.

Conclusion. Cultivation of winter rye in the Łódź Voivodeship was characterized by a low level of agrotechnology that was independent of plantation area. At over 70.0% of the investigated plantations, the level of use of qualified sowing material, seed dressing, sowing norms, tramlines, potassium dosage, and foliage fertilization did not conform to local agrotechnical recommendations for winter rye cultivation.

Key words: cultivation technology, production plantations, production technology complexity index, winter rye

INTRODUCTION

Rye has the lowest soil requirements among all grains and its use enables the full utilize of poor and very poor soils, which in turn accounts for much of the cultivated area in Poland (Górski *et al*., 1999; Kus and Filipiak, 2001). Moreover, rye has lower climate requirements and has a large tolerance for unfavorable weather conditions and is suitable for simplified crop rotation or monoculture. Under high levels of agrotechnology rye exhibits a clear enhancement of grain yield (Deryło and Tracz, 2005; Jaskulski and Piasecka, 2007).

World winter rye production in 2014 was 15,337 thousand tons. The dominating producers of winter rye grain in the European Union are Germany and

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Poland. In Germany, winter rye production in 2014 was 3,854 thousand tons, while in Poland it was 2,792 thousand tons. The area of rye cultivation in Poland was 886.3 thousand ha with an average grain yield of 3.2 Mg·ha^{-1}. The larger winter rye grain production in Germany, despite a smaller cropping area of 662 thousand ha, was achieved due to the considerably larger yield of this crop, which was 5.8 Mg·ha^{-1}. Therefore, winter rye yield in Poland was only 54.1% of that obtained by the country's Western neighbor (GUS, 2015). The main reason behind this is the much lower level of agrotechnology in Poland.

The aim of the research was to evaluate the correctness of the production technology of winter rye at production plantations in the Łódź Voivodeship, and to identify the scale and types of discrepencies allowed by farmers in cultivation of this crop depending on plantation area. The following working hypothesis was adopted: large-scale winter rye production plantations are characterized by a higher level of agrotechnology and a higher grain yield.

MATERIAL AND METHODS

The source material is the results of interviews conducted at 307 individual farms in the Łódź Voivodeship. The research was conducted in the years 2009–2012 in the counties: brzeziński, łaski, pabianicki and zgierski. In the Łódź Voivodeship most of the soil is classified as Podzols (FAO, 2006), which is included in the IV and V class of soils. The amounts of rainfall were: 667 mm in 2009, 751 mm in 2010, 483 mm in 2011 and 521 mm in 2012 while the average multi-year amount of rainfall (1971––2000) was 569.5 mm. The average daily air temperature in each of the studied years was: 8.6°C in 2009, 7.5°C in 2010, 9.0°C in 2011 and 8.7°C in 2012. The average multi-year daily air temperature (1971–2000) in this region is 8.0°C.

The primary investigated unit was a winter rye plantation. Data acquired on the intensity of agrotechnical factor application was recorded in technological sheets prepared for each plantation. Investigated plantations were divided into two groups depending on their cropping area: group I consisting of plantations with areas <2.0 ha (179 plantations) and group II with areas of 2.0 ha and larger (128). We assumed that the larger area plantations would be present in larger farms, which would be better equipped technically and where agrotechnology would be more carefully and thoroughly applied. The evaluation of the correctness of production technology of winter rye in the defined groups of plantations was conducted in accordance with the cropping recommendations of the Institute of Soil Science and Plant Cultivation – IUNG-PIB in Puławy, as well as in the available literature on the topic. In order to quantify compliance with the technological requirements of rye cultivation, the production technology complexity index (W_{kt}) was used (Klepacki, 1990):

$$W_{kt} = Z_w \times 100 / Z_p \ (\%),$$

where:

Z_w – the number of actually performed treatments and satisfied requirements, as listed in the technology sheets,

Z_p – fully possible to independently define the number of treatments and quality requirements of the production technology.

Furthermore, margins and distributions of the occurrence of selected agrotechnical factors (soil class, forecrop, multicomponent mineral fertilization) in rye cultivation at the two defined groups of plantations were analysed.

RESULTS AND DISCUSSION

The farms included in the study are representative for rye cultivation in the region. Table 1 summarizes selected data on the production technology of winter rye at the investigated plantations. The evaluated plantations were established on soils of grading classes from IIIb to VI. Plantations on V class soils dominated and accounted for 50.3% of the total number of evaluated sites with areas of below 2.0 ha and 49.2% of plantations with areas 2.0 ha or more. The share of plantations established on the lowest grading class of soils VI was 27.9 and 28.1%, respectively, for the smaller and larger area plantations (Fig. 1).

Table 1. Main features of winter rye production technology on production plantations in the Łódź Voivodeship depending on their size in the years 2009–2012

Specification	Area of plantations	
	<2.0 ha	≥2.0 ha
Number of plantations, pcs.	179	128
Most frequent forecrop, %	rye (25.1)	rye (26.0)
Most frequent soil class	V (50.3)	V (49.2)
Most frequently cultivated cultivar, %	Dańkowskie Złote (58.8)	Dańkowskie Złote (43.9)
Mean rate of seed sowing, kg·ha^{-1}	198.1	194.8
Share of plantations with:		
- delayed sowing, %	41.6	43.0
- tramlines, %	0.0	0.0
- seed dressing, %	18.4	35.5
- mechanical treatment, %	0.0	0.0
Rates of mineral fertilizers, kg NPK·ha^{-1}:	111.3	128.5
- nitrogen, kg N·ha^{-1}	53.0	60.0
- phosphorus, kg P_2O_5·ha^{-1}	25.9	29.4
- potassium, kg K_2O·ha^{-1}	32.4	39.1
Plantations fertilized with nitrogen, %:		
- once	100.0	100.0
- twice or more	0.0	0.0
Share of plantations with foliar fertilization, %	11.0	10.9
Share of plantations with, %:		
- herbicides	71.8	66.7
- fungicides	5.5	0.8
- insecticides	0.6	0.0
- growth regulators	1.1	0.8
Share of plantations with combine-harvester, %	100.0	100.0
Grain yield, Mg·ha^{-1}	2.7	2.9

Preparation of the plots for sowing, punctuality of sowing and correct sequence of cultivation treatments were usually related to the variety and time of harvest of the forecrop. The evaluated plantations were usually established following cereal forecrops. This was true in the case of 72.6% of plantations below 2.0 ha and in the case of 81.9% of plantations with areas of 2.0 ha and more (Fig. 2). The share of cereals in the forecrops was 37.4 and 45.7%. respectively for plantations of the smaller and larger area, while the share of plantations after rye as a forecrop where 25.1 and 26.0% for the two groups of plantations. Despite rye having the largest

tolerance for a variety of forecrops among all of the cereals, its cultivation with itself as a forecrop usually results in a decreased yield (Dworakowski, 2001; Wojciechowski and Parylak, 2006; Jaskulski and Piasecka, 2007). The primary reason in increased rye grain yield is occurrence of blade base diseases and intensified weed growth (Adamiak *et al.*, 2005; Gawrońska-Kulesza *et al.*, 2005; Stupnicka-Rodzynkiewicz *et al.*, 2004). Research on compensation of unfavorable site conditions on rye cultivation, conducted by Deryło and Szymankiewicz (1999), indicated that higher levels of agrotechnology (full tillage and comprehensive care and protection of plants) has indeed improved the efficiency of this crop cultivated after cereal forecrops.

The amount of seed is among the key factors shaping the conditions of crop development in a canopy. This amount is chosen depending on analysis of a site and the agrotechnology to be used, as well as on the properties of a given variety. At a decreased density of plants per unit of area the proper density in a canopy can be achieved through increased tillering of plants, which in turn is mainly affected by the intensity of nitric fertilization (Grabiński and Mazurek, 1995; 2002; Szmidt *et al.*, 2000). The sowing norm was often larger than that recommended by IUNG-PIB Puławy (up to 170 kg·ha$^{-1)}$ and averaged 198.1 and 194.8 kg·ha^{-1}, respectively, on fields with the smaller and larger areas (<2.0 ha and ≥2.0 ha respectively). The investigated farms used either their own retained seeds or sowing material obtained from another farmer. The share of plantations sown with qualified sowing material was small and accounted for 18.4% plantation <2.0 ha and 35.5% of plantations ≥2.0 ha. In the considered region, rye sowing should be performed before 25th of September, that is for the plants to achieve full tillering before the resting winter period. The share of plantations with an optimal time of sowing for this crop was comparable in both groups of plantations, and was 49.4 and 43.0% (Fig. 3). According to Budzyński (2001) and Budzyński *et al.* (2003), among the factors potentially limiting the yield of rye, insufficient fertilization and delayed sowing time should be included.

The two evaluated groups of winter rye plantations differed in the intensity of mineral fertilization used. Larger dosages of NPK fertilizers were applied on average at the plantations with areas ≥2.0 ha (128.5 kg NPK·ha^{-1}), and smaller doses were used at plantations <2.0 ha (111.3 kg NPK·ha^{-1}). Mean dosages, specifically of phosphorus and potassium, were smaller than recommended and were 25.9 and 29.4 kg P_2O_5·ha^{-1} and 32.4 and 39.1 kg K_2O·ha^{-1}, respectively, for fields with smaller and larger area. Mean nitrogen doses were larger than recommended at, respectively, 53.0 kg and 60 kg N·ha^{-1} at fields <2.0 and ≥2.0 ha. Rye has the lowest sensitivity to phosphorus, potassium and microelements shortage among all crops (Dmowski, 1993; Krauze and Zawadzki, 1993). The share of plantations not subject to nitrogen, phosphorus and potassium fertilization was larger in the <2.0 ha area group, the specific shares were, respectively, 10.1; 27.9 and 30.2%; while in the group of plantations with area ≥2.0 ha this was, respectively, 0.9; 21.9 and 21.9% (Fig. 4). Doses corresponding to IUNG-PIB Puławy recommendations were observed for nitrogen in 40.8% of plantations, while for phosphorus and potassium this was 34.8 and 24.6% in fields with an area <2.0 ha and these values were 54.7; 43.0 and 32.8% in fields ≥2.0 ha. Nitrogen fertilization was applied in one dose prior to vegetation.

Protection against weeds and disease has an influence on the size and quality of obtainable grain yield of winter rye (Kraska and Pałys, 2002; Mazurek and Noworolnik, 2001). Moreover, Kraska (2005) has shown that intensification of chemical protection of the rye canopy results in increased grain yield, compared to the basic level of chemical protection. However, results reported by Grabiński (1998) indicated that an absence of chemical protection only marginally decreased grain yield, compared to fields under full chemical protection. Protection against pests at the investigated production plantations was related mainly towards weeds. Herbicides were applied at 71.8% of plantations <2.0 ha and at 66.7% plantations ≥2.0 ha. Protection against disease was based mainly on dressing of the seed (19.9% and 33.3% of plantations with smaller and larger area, respectively). Fungicides, insecticides and growth regulators in the vegetation period were only applied sporadically. Combine-harvesters were used at all plantations for harvesting the crop.

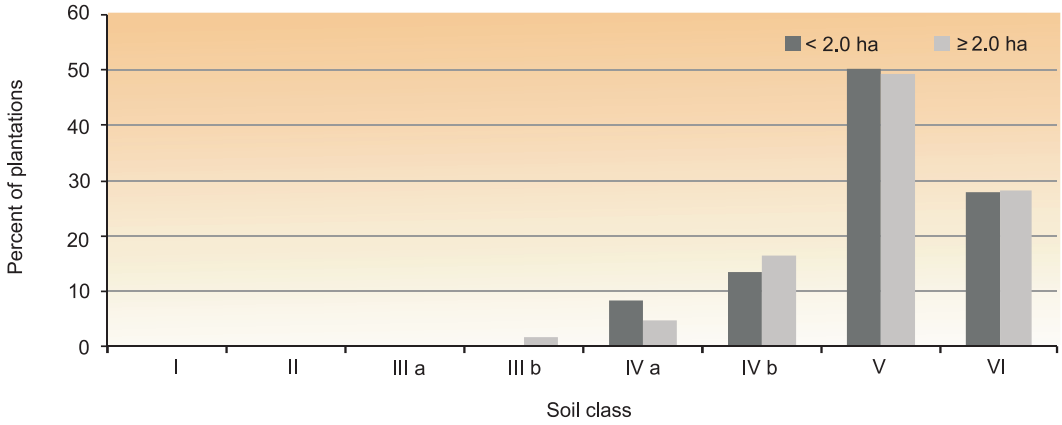

Fig. 1. Distribution of frequency of soil class on winter rye production plantations in the Łódź Voivodeship depending on their size in the years 2009–2012

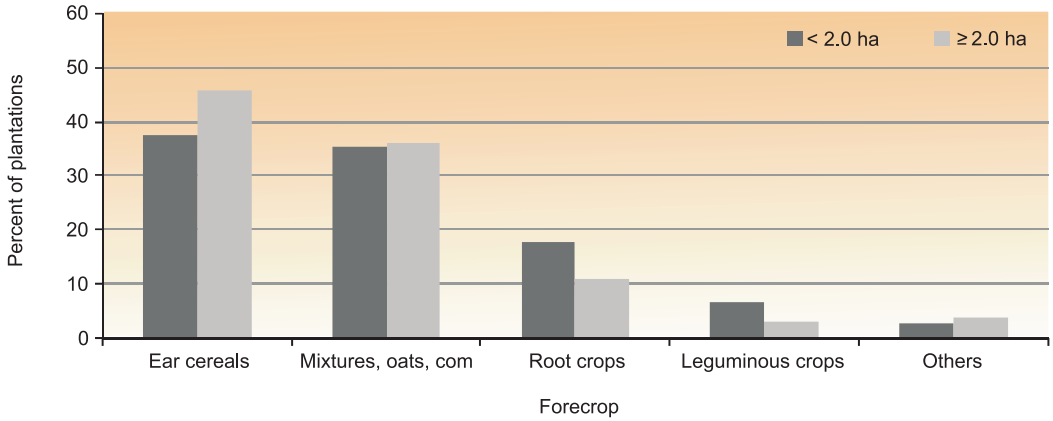

Fig. 2. Distribution of frequency of forecrop on winter rye production plantations in the Łódź Voivodeship depending on their size in the years 2009–2012

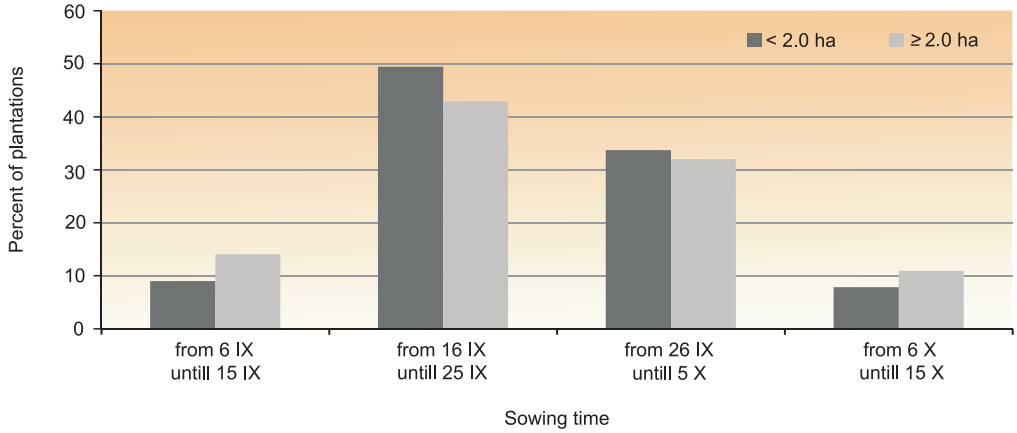

Fig. 3. Distribution of frequency of sowing time on winter rye production plantations in the Łódź Voivodeship depending on their size in the years 2009–2012

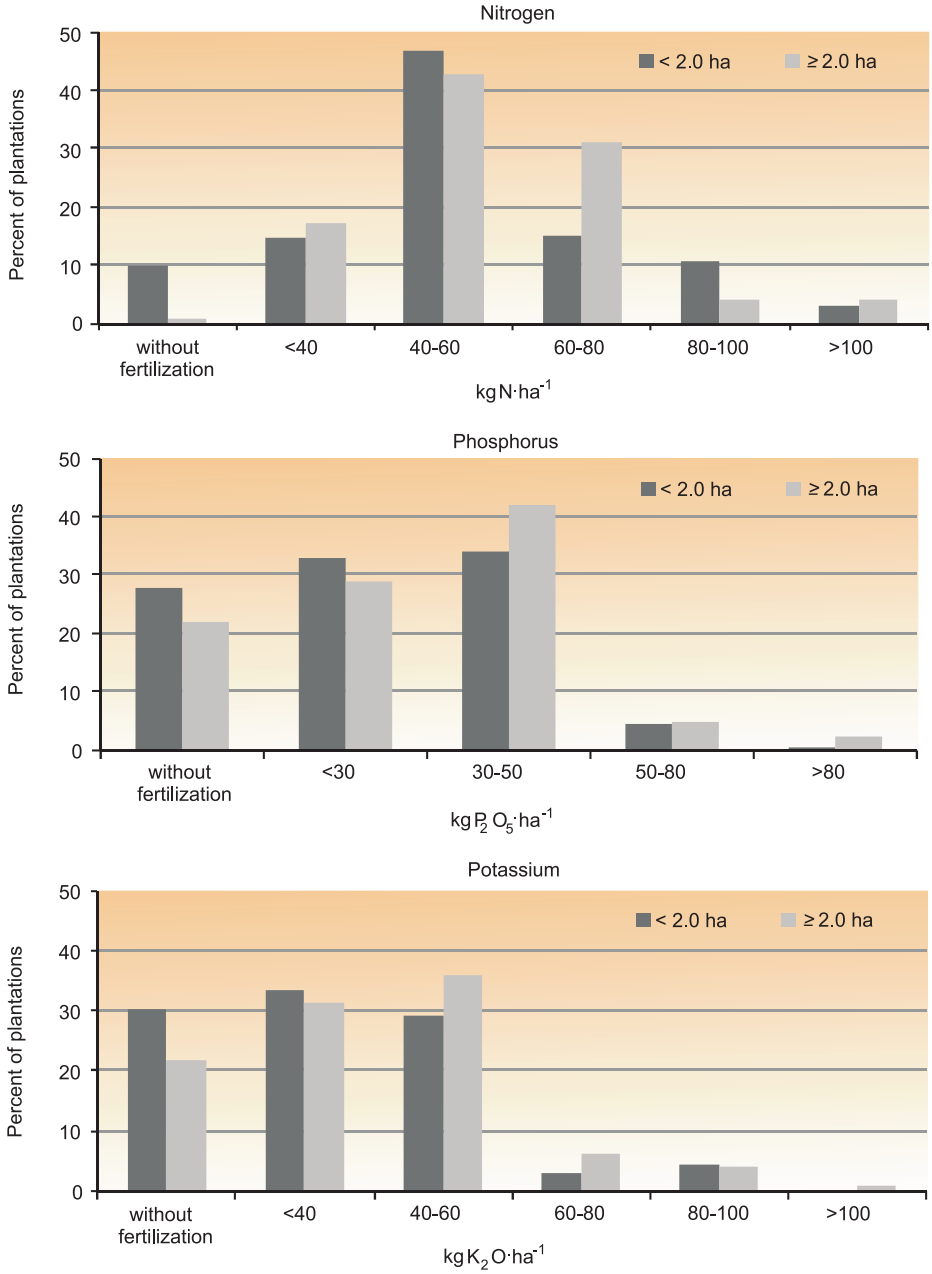

Fig. 4. Distribution of frequency of N, P, K fertilization applied to winter rye production plantations in the Łódź Voivodeship depending on their size in the years 2009–2012

Among the evaluated agrotechnical factors, the lowest number of deviations from recommendations were observed in the means of harvesting, nitrogen fertilization, selection of soil class and its pH, forecrop and knowledge of the cropped variety (Table 2). The most common variations were related to the norm used for sowing, the amount of recommended dose of NPK fertilizers, application of insecticides, fungicides, growth regulators and foliage fertilizers and the use of tramlines.

Table 2. Differentiation of features of winter rye production technology complexity index on production plantations in the Łódź Voivodeship depending on their size in the years 2009–2012

Name of feature	Share of right decision, %		
	area of plantations <2.0 ha	area of plantations ≥2.0 ha	average for all plantations
Soil class ≤IVb	91.6	93.8	92.5
Soil pH ≥5.5	75.0	67.2	71.7
Forecrop different than cereals	62.6	54.3	59.1
Known cultivar	86.5	82.0	84.6
Qualified sowing material	18.4	35.5	25.5
Seed dressing	19.9	33.3	25.5
Sown by 25 IX	57.8	56.6	57.3
Sowing norm up to 170 kg·ha^{-1}	10.5	9.3	10.0
Occurrence of tramlines	0.0	0.0	0.0
Application of nitrogen fertilization	89.9	99.2	93.8
Nitrogen rate ≥60 kg N·ha^{-1}	40.8	54.7	46.6
Division of nitrogen rate	0.0	0.0	0.0
Application of phosphorus fertilization	72.1	78.1	74.6
Phosphorus rate ≥40 kg P_2O_5·ha^{-1}	35.2	43.0	38.5
Application of potassium fertilization	69.8	78.1	73.3
Potassium rate ≥60 kg K_2O·ha^{-1}	24.6	32.8	28.0
Time of application of calcium fertilization in crop rotation	41.9	34.4	38.8
Application of foliar fertilization	11.0	10.9	11.0
Application of herbicide	71.8	66.7	69.7
Application of fungicide	5.5	0.8	3.5
Application of insecticide	0.6	0.0	0.3
Application of growth regulators	1.1	0.8	1.0
Harvesting with combine-harvester	100	100	100
Technological complexity index (W_k)	42.9	44.8	43.8

The technology complexity index of winter rye production at the investigated production plantations was on average 43.8%. These plantations are representative for rye cropping in the Łódź Voivodeship. The low value of this index indicates that farmers accept a large number of agrotechnical errors in the cultivation of this variety. The use of qualified sowing material, seed dressing, correct sowing norm, tramlines, potassium dosage, foliage fertilization – these are the factors for which the production

technology complexity index (W_k) was below 30.0%, which means that at over 70.0% of the plantations the intensity of these factors was not conforming to the agrotechnical recommendations for rye cropping. The production technology complexity index for the occurrence of tramlines and application of fungicides, insecticides and growth regulators was, respectively: 0.0; 3.5; 0.3; 1.0%. Plantations in this region are practically unprotected against plant disease and pests, and growth regulators are not used. Doses of mineral fertilizers equal to or larger than 60 kg N, 40 kg P_2O_5, 60 kg $K_2O \cdot ha^{-1}$ were on average applied, respectively, at 46.6; 38.5 and 28.0% of plantations. Compared to these expenditure factors, the main non-expenditure factor, the correct time of sowing – before the 25th of September, was observed at only 57.3% of the plantations.

No significant influence of plantation area on the level of the used rye agrotechnology was observed in the Łódź Voivodeship. The production technology complexity index for rye production in the larger area plantations was 44.8% and was higher by only 1.9% than its value for the smaller area plantations.

The mean grain yield at the larger area plantations was 2.9 $Mg \cdot ha^{-1}$ and was larger by 0.2 $Mg \cdot ha^{-1}$ or 7.4% than the yield typically obtained at fields with areas below 2.0 ha. The larger area plantations was the group in which qualified sowing material and seed dressing was more commonly used, along with dosages of nitrogen, phosphorus and potassium equal to or larger than 60 kg N, 40 kg P_2O_5, and 60 kg $K_2O \cdot ha^{-1}$.

Plantations in the below 2.0 ha group were characterized with a few percent larger share of fields in which a different than ear cereal forecrop had been cultivated, the soil pH was larger than 5.5 and herbicides and fungicides were applied more often. The lower share of fields with the correct intensity of these factors at plantations with larger area acted to decrease the positive effects of these plantations' mineral fertilization and better quality of sowing material.

It is to be noted, that the differences in intensities of various applied agrotechnical factors at the two investigated groups of rye plantations were not large and did not result in significant variability in the yield at the production plantations. Cropping of rye in the Łódź Voivodeship is characterized by a low level of agrotechnology, independent of plantation area, which directly explains the low grain yield in this region of the country.

CONCLUSIONS

1. Cultivation of winter rye in the Łódź Voivodeship was characterized by a low level of agrotechnology that was independent of plantation area. The production technology complexity index for this crop on plantations of 2.0 ha or larger was 44.8% and on plantations below 2.0 ha it was 42.3%.
2. Grain yield of winter rye from plantations of 2.0 ha and larger was 2.9 $Mg \cdot ha^{-1}$ and was larger by 0.2 $Mg \cdot ha^{-1}$, or by 7.4%, in comparison to plantations with areas below 2.0 ha.
3. At over 70.0% of investigated plantations, the level of use of qualified sowing material, seed dressing, norm of sowing, tramlines, potassium dosage, and foliage fertilization did not conform to the agrotechnical recommendations for winter rye cultivation.

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OCENA TECHNOLOGII PRODUKCJI ŻYTA OZIMEGO NA PLANTACJACH PRODUKCYJNYCH W WOJEWÓDZTWIE ŁÓDZKIM W ZALEŻNOŚCI OD POWIERZCHNI PLANTACJI

Streszczenie

W latach 2009–2012 w województwie łódzkim przeprowadzono badania ankietowe obejmujące 307 plantacji produkcyjnych żyta ozimego. Celem badań była ocena poprawności technologii produkcji żyta ozimego na plantacjach produkcyjnych w województwie łódzkim oraz rozpoznanie skali i rodzaju błędów popełnianych przez rolników w uprawie tego gatunku w zależności od powierzchni plantacji. Podczas trzykrotnych rozmów z rolnikami ustalono poziomy stosowanych czynników agrotechnicznych na badanych plantacjach. Plantacje celem oceny stosowanej agrotechniki podzielono w zależności od powierzchni na dwie grupy: I – do 2,0 ha (179 plantacji) i II – 2,0 ha i większe (128 plantacji). Plantacje o powierzchni ≥2,0 ha charakteryzowały się większym o 0,2 $Mg \cdot ha^{-1}$, tj. 7,4%, plonem ziarna w porównaniu z plantacjami o powierzchni <2,0 ha. Nie stwierdzono wyraźnych różnic w agrotechnice żyta w wydzielonych pod względem powierzchni dwóch grupach plantacji. Wartość wskaźnika kompleksowości technologii produkcji (W_k) dla plantacji o powierzchni ≥2,0 ha wynosiła 44,8%, a dla plantacji <2,0 ha powierzchni – 42,8%. Najczęściej popełniane błędy w agrotechnice niezależnie od powierzchni plantacji polegały na wysiewaniu w nadmiernej normie niekwalifikowanego i niezaprawionego materiału siewnego,

stosowaniu małych dawek azotu, a szczególnie fosforu i potasu, niestosowaniu nawożenia dolistnego, ochrony fungicydowej i insektycydowej oraz regulatorów wzrostu.

Słowa kluczowe: plantacje produkcyjne, technologia produkcji, wskaźnik kompleksowości technologii produkcji, żyto ozime