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TECHNOLOGICAL LEVEL AND THE YIELD OF WINTER MALTING BARLEY

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Abstract. The aim of the research was determination of the relationship between agrotechnical factors and the yield of winter malting barley cv. Corbie. Grain yield and its components were discussed. The source of results was field experiment carried out at the Experimental Station „Bałcyny Sp. z o.o." near Ostróda, under favourable weather conditions for winter barley in the years 2006-2008. 3^{5-2}(IV) fractional design was applied in two replications with 27 combinations in each one, in which at the same time 5 factors were tested (A, B, C, D, E) on three levels (0, 1, 2). Very high, though diversified in years, yield of winter barley cv Corbie was confirmed on the soil of the good wheat complex. During studies, the plants of this cultivar overwintered well, to a slight degree they lodged, and their infection with fungal diseases was low. Relationship between the yield and technological level was smaller than assumed in the working hypothesis. The highest grain yield was obtained from barley which was sown earliest (September 9-11th), at a rate of 450 grains$\cdot$m^{-2} with spring N fertilization at a rate of 60 kg N$\cdot$ha^{-1}. These were treatments protected with a dressing and 2 fungicide treatments at the time of growing and treated with regulator Retar 480 SL.

Key words: cultivar Corbie, growth regulation, N fertilization, protection against diseases, sowing date, sowing density

INTRODUCTION

For brewer's malt production spring barley grain is preferable (higher than winter barley's weight of grains, better homogeneity, higher grain density and extractivity, lower content of protein nitrogen) [Budzyński 2005]. Winter barley is a form used in brewing on a smaller scale than spring barley. It's advantage is lack of deep post-harvest dormancy and possibility to use it in the process of malting directly after harvest. Therefore, it is usually used directly after harvest before the spring grain obtains the proper germination energy. The advantage of winter barley is the yield level higher by up to 25% compared with the spring form. Winter barley cultivation in Poland in the last 3 years has been carried out on the area of 200,000 ha, compared with 1.61

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million ha of the total barley cultivation [Cereals market... 2010]. Polish agriculture does not sufficiently use barley's advantages, i.e. high yield of this form of barley [Budzyński and Szempliński 2003].

Grain yield and its brewing quality are conditioned by cultivar, however, badly suited level of agrotechnical factors may falsify the genetic potential of the yield and quality. In malting barley cultivation it occurs very often.

Conducted research was supposed to prove the relationship between the chosen agrotechnical variant and grain yield of winter barley cv. Corbie. These factors included time and density of sowing, level of nitrogen fertilization, level of protection against diseases and growth regulation at the time of growing.

MATERIAL AND METHODS

The results are the property of the Department of Agrotechnology and Crop Management of UWM in Olsztyn. The field experiment was carried out at the university's Experimental Station „Bałcyny Sp. z o.o." near Ostróda (53°90' N; 19°50' E), on the lessive soil, formed from sandy clay loam deposited on sandy loam, bonitation class IIIa, belonging to 2. good wheat complex. The soil was characterized by a high potassium content, average phosphorus and magnesium content, and its reaction was pH_{KCl} = 6.5. The research was carried out with winter barley cv. Corbie, cultivated on plots after winter rape. The field experiments were carried out in 3 subsequent years (2006-2008). 3^{5-2}(IV) fractional design was applied in two replications 27 combinations in each one, in which at the same time 5 factors were tested (A, B, C, D, E) on three levels (0, 1, 2) [Załuski and Gołaszewski 2006]. In the working hypothesis it was assumed that at least 1 of the levels of the studied agrotechnical factor would be close to optimum, and that quartile analysis of the results would allow for selection of the level for particular factors representing the highest yield, and would indicate the design of the level of factors responsible for the low yield.

Area for harvest of each plot was 15 m^2. Before sowing the following fertilizers had been applied: superphosphate 46% (26 kg $P \cdot ha^{-1}$), potassium salt 60% (75 kg $K \cdot ha^{-1}$) and magnesium (15 kg $Mg \cdot ha^{-1}$). Other agrotechnical treatments were applied according to the scheme (Table 1).

Distribution of weather conditions was described based on the data from Meteorological Station in Bałcyny. During the time of experiments, the number of plants was evaluated before winter. Overwintering, level of infection with diseases and lodging were evaluated with a 9-degree COBORU scale (Research Centre for Cultivar Testing, Poland), in which 9 denotes the most beneficial agriculturally condition. The number of yielding ears per m^2 was determined as well as the number of grains per ear and weight of one thousand grains (g). After harvest, grain yield was determined as well as the yield of winter barley straw. Obtained results were subjected to statistical analysis. All statistical calculations were carried out with the use of STATISTICA®8.0 package.

Weather conditions in the years of research

The research was carried out in years with favourable weather conditions for winter barley (Table 2). Only 2005/2006 winter was frosty (January, February, March), however a thick layer of snow protected the plants against winterkill, and the losses were no more than 5% of plants. Other winters were mild. Barley overwintered well.

Table 1. Experimental factors and their levels
Tabela 1. Czynniki doświadczenia i ich poziomy

Designation of variable factors – Oznakowanie czynników zmiennych		Factor level – description – Poziom czynnika – opis
A	sowing date – termin siewu	0 – September 9-11 – 9-11 września 1 – September 16-18 – 16-18 września (delay of 7 days – o 7 dni późniejszy) 2 – September 23-25 – 23-25 września (delay of 14 days – o 14 dni późniejszy)
B	sowing density (number of germinating grains·m^{-2}) gęstość siewu (liczba kiełkujących ziarniaków·m^{-2})	0 – 250 1 – 350 2 – 450
C	level of nitrogen fertilization in spring, kg·ha^{-1} poziom) nawożenia N wiosną, kg·ha^{-1} (BBCH 29-30)	0 – 40 1 – 60 2 – 80
D	level of protection against diseases poziom ochrony przed chorobami	0 – exclusively tebuconazole + triazoxid (dressing Dubelt J) – wyłącznie tebukonazol + triazoksid (zaprawa Dubelt J) 1 – as 0 + flusilazole+carbendazim – jak 0 + flusilazol + karbendazym (Alert 375 SC BBCH 32) 2 – as 1 + propiconazole + cyproconazole – jak 1 + propikonazol + cyprokonazol (Artea 330 EC BBCH 52)
E	growth regulation of plants (retardation) regulacja wzrostu roślin (retardacja)	0 – without regulation – bez regulacji 1 – trinexapac-ethyl – trineksapak etylu (Moddus 250 EC BBCH 32) 2 – ethephon – etefon (Retar 480 SL BBCH 32)

Table 2. Thermal and moisture conditions in the years of research (Meteorological Station in Bałcyny)
Tabela 2. Warunki termiczne i wilgotnościowe w latach badań (Stacja Meteorologiczna w Bałcynach)

Years – Lata	Month – Miesiąc										
	September wrzesień	October październik	November listopad	December grudzień	January styczeń	February luty	March marzec	April kwiecień	May maj	June czerwiec	July lipiec
	Mean daily air temperature – Średnia dobowa temperatura powietrza, °C										
2005/2006	18.1	10.5	5.2	-0.7	-8.7	-3.3	-2.5	7.8	12.5	16.0	21.0
2006/2007	15.7	10.1	5.6	4.2	2.4	-2.0	5.4	7.3	13.7	17.5	17.5
2007/2008	12.6	7.4	1.0	0.5	0.7	2.5	2.9	7.8	12.3	16.6	18.3
Long-term period Wielolecie (1961-2000)	12.6	8.1	2.8	-1.3	-3.5	-2.6	1.2	6.6	12.4	15.7	16.9
	Rainfall total – Suma opadów, mm										
2005/2006	17.9	19.3	31.1	82.9	15.3	26.7	3.1	24.2	93.2	83.5	27.1
2006/2007	105.6	34.3	107.3	60.0	110.2	14.6	27.9	26.8	79.7	60.8	176.5
2007/2008	65.4	48.9	50.0	25.2	30.8	33.9	47.1	33.8	48.4	27.8	47.0
Long-term period Wielolecie (1961-2000)	57.1	54.0	51.4	40.4	26.3	19.6	27.4	35.2	56.7	68.3	81.3
	Mean snow cover – Średnia pokrywa śnieżna, mm										
2005/2006			3.5	7.8	15.1	23.6	21.1				
2006/2007			22.0	0	1.6	0.5	0				
2007/2008			1.7	0.2	1.1	0.6	0.3				

Rainfall total in autumn and spring was really unstable: dry autumn occurred in the first research cycle, in the second one in 2006 there was a high rainfall in autumn. In 2007 spring growth and development occurred with an excessive moisture content, similar to the mean rainfall total in the first year and in the dry third year. The dry year was favourable for the yield, while a visible decrease in the yield was observed in the wet period of 2006/2007.

RESULTS

Emergence, plant infection with diseases and lodging

Barley emergence was not varied by the studied factors, and it should be estimated as quite even both within years and between treatments. Grain density diversified from 250 to 350 and 450 grains per 1 m^2 resulted in a difference between combinations from 40 to 84 plants before winter. This dependence occurred every year. Barley overwintered well (overwintering was classified to 9 degrees in the second and third research cycle and to 8 degrees in the first year) (Table 3).

According to the evaluation of plant infection with diseases (9-degree COBORU scale), plant health was very good (8-9°). Only in 2006 presence of powdery mildew and leaf stripe were observed on a small percentage of plants as well as the characteristic features for fungal infection with *Rhynchosporium secalis* and *Stagonospora nodorum*.

Barley lodging was observed only in the first cycle of research and it was relatively small (statistically insignificant variation). It is characteristic that growth regulator as well as protection method and sowing density did not affect this feature of stem. The most visible tendency of the lodging intensification was found with the latest sowing and under the effect of the highest nitrogen rate (80 $kg \cdot ha^{-1}$).

Yield components

The number of yielding ears of winter barley per 1 m^2 was modified mainly by weather factor (years). Mid-early sowing was favourable for a higher content of ears per canopy (Table 4). The number of yielding ears per 1 m^2 increased with the sowing density. Generally, increase of the ear number was less than proportional to the number of sown grains, though significant.

Beneficial effect of nitrogen on the ear development of winter barley was observed in all years of the experiment. Mean from the 3-year period indicates that 80 kg $N \cdot ha^{-1}$ affected the increase in the ear number per 1 m^2 by 10% compared with the rate which was by half lower. In the number of ear-bearing stems per 1 m^2 of canopy there occurred an interaction between years and N rate, between years and sowing density as well as between years and the sowing date (Table 4).

The applied protection against diseases, although it did not visibly vary intensity of the disease symptoms, it had a beneficial effect on the ear number in 2007 and 2008. The most beneficial appeared to be protection which included dressing and 1 treatment in the period of growing (increase in the ear number by 11 and 7%). Growth regulation with preparation Moddus caused decrease in the ear density in the period 2006/07 by 6.5%. This was not confirmed by the results obtained in other years of research.

Similarly as in the case of ear density, a significant modification of the grain number per winter barley ear was observed as a result of the effect of the weather factor. It is characteristic that the delay in the sowing date favourably affected the discussed feature. Early sowing increased productive tillering, while it decreased the grain number per ear.

Decrease in the grain number per ear was observed, as well as decrease in the weight of 1000 grains as a result of denser sowing. It confirms the principle that denser sowing is favourable for the occurrence of low stems with ears with finer grain, lower weight and number of grains per ear (Table 4).

Yields of grain and straw

High but diversified within years grain yields (by 23-37%) were harvested (Table 5). Dry year was favourable for the yield of this species. The highest yield was obtained when barley was sown on the earliest of the studied dates, that is on September 9-11. Sowing on later dates (by 7 and 14 days) decreased the yield within 3 years only by app. 0.30 $Mg \cdot ha^{-1}$. On average, from 3 years a high diversification in the sowing density did not affect the yield level (Table 5). In the 2006/07 cycle, sowing of 350 and 450 $grains \cdot m^{-2}$ resulted in an increase in the grain yield by app. 6 and 10%, compared with the sowing of 250 $grains \cdot m^{-2}$, however this difference was impossible to confirm statistically. Tendency towards grain yield increase under such conditions was observed also in the third cycle of research.

Significant diversification of the yield value was obtained as a result of interaction between the weather factor and nitrogen fertilization. In the second year of research, spring application of 60 kg $N \cdot ha^{-1}$, as well as of 80 kg N caused the yield increase by app. 17 and 27% respectively, compared with the treatments fertilized with a rate of 40 kg N. In other years of research, the effect of nitrogen fertilization, increased by 20 and 40 kg $N \cdot ha^{-1}$, was not that unambiguous, though it was also positive. On average, for 3 years the increase in the N rate from 40 to 60 kg caused the yield increase by 0.67 $Mg \cdot ha^{-1}$, that is by 33.5 kg of grain per each N kg.

Application of fungicides (Alert and Artea) in the growing period of barley caused a regular, though slight (~5%) and impossible to prove statistically increase in the grain yield. This tendency occurred despite a very low intensity of diseases in the years 2006--2008. The effect of stem retardation on the grain yield was variable in years, beneficial in dry years and unfavourable in the year with a high rainfall total.

In the results concerning grain yield, there occurred a small number of interfactorial interactions. Interaction between the sowing date, sowing density and nitrogen fertilization level in spring is presented in Table 6. Under conditions of late sowing, more beneficial (by 0.46 $Mg \cdot ha^{-1}$) was condensed sowing up to 450 grains per m^2. It is characteristic that also with the earliest sowing (on September 11th) a higher yield was obtained from treatment B_2 with the densest sowing. In this case, early sowing caused the highest growth of barley in autumn and its relatively highest thinning out in winter. From the interaction between factors A x C it follows that a significant yield increase in the first and second cycle of research on barley sown on September 11th and 18th occurred only up to the rate of N – 60, while in the third year with the latest sowing, even at a rate of N – 80 $kg \cdot ha^{-1}$.

Table 3. Values of selected features of winter barley
Tabela 3. Wartości wybranych cech roślin jęczmienia ozimego

Treatment symbol – Symbol obiektu															$\bar{x}$
A			B			C			D			E			
sowing date termin siewu			sowing density gęstość siewu			nitrogen fertilization in spring nawożenie azotem wiosną			protection against diseases ochrona przed chorobami			growth regulator regulator wzrostu			
September 9-11 9-11 września	+7 days +7dni	+14 days +14 dni	250	350	450	40	60	80	dressing zaprawa	dressing + 1 treatment zaprawa + 1 zabieg	dressing + 2 treatments zaprawa + 2 zabiegi	lack- brak	Moddus 250 EC – 0.6 dm^3	Retar 480 SL – 1.5 dm^3	
0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	
Mean number of plants before winter – Średnia liczba roślin przed zimą (2005-2007), szt.·m^{-2}															
334	339	337	295	335	379	327	333	350	324	363	323	346	333	331	336
Level of overwintering (9° scale)* – Stopień przezimowania (skala 9°)*															
7.5	8.0	8.1	8.1	8.1	7.7	8.1	8.0	8.0	8.1	8.1	7.9	8.0	8.0	8.1	8.0
Lodging (9° scale)* – Wyleganie (skala 9°)*															
8.9	8.8	8.3	8.8	8.6	8.7	8.9	8.7	8.4	8.8	8.7	8.6	8.6	8.8	8.7	8.7
Infection (9° scale) of flag leaves with – Porażenie (skala 9°) liści flagowych przez															
powdery mildew of cereals and grass (*Erysiphe graminis*)* – mącznika prawdziwego zbóż i traw (*Erysiphe graminis*)*															
8.0	7.8	8.3	8.1	8.1	7.9	7.9	8.1	8.1	7.9	7.9	8.3	8.0	8.2	7.9	8.0
leaf stripe (*Drechslera graminea*)* – pasiastość liści jęczmienia (*Drechslera graminea*)*															
8.2	8.3	8.3	8.4	8.3	8.1	8.0	8.1	8.8	8.1	8.1	8.3	8.1	8.2	8.6	8.3
scald (*Rhynchosporium secalis*)* – rynchosporiozę zbóż (*Rhynchosporium secalis*)*															
8.4	8.8	8.8	8.6	8.6	8.9	9.0	8.6	8.4	8.1	8.4	8.7	8.1	8.2	8.6	8.5
Infection (9° scale) of ears with – Porażenie (skala 9°) kłosów przez															
septoriozę plew (*Stagonospora nodorum*)*															
8.2	8.1	8.3	8.1	8.2	8.3	8.3	8.2	8.1	8.2	8.3	8.1	8.2	8.3	8.1	8.2

* only period 2005/2006 – wyłącznie sezon 2005/2006

Table 4. Values of yield components
Tabela 4. Wartości liczbowe elementów składowych plonu

Years Lata	Treatment symbol – Symbol obiektu															$\bar{x}$
	A			B			C			D			E			
	sowing date termin siewu			sowing density gęstość siewu			nitrogen fertilization in spring nawożenie azotem wiosną			protection against diseases ochrona przed chorobami			growth regulator regulator wzrostu			
	September 9-11 9-11 września	+7 days +7 dni	+14 days +14 dni	250	350	450	40	60	80	dressing zaprawa	dressing + 1 treatment zaprawa + 1 zabieg	dressing + 2 treatments zaprawa + 2 zabieg	lack brak	Moddus 250 EC – 0.6 dm^3	Retar 480 SL – 1.5 dm^3	
	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	
Number of yielding ears·m^{-2} – Liczba kłosów plonujących·m^{-2}																
2005/2006	574	570	598	554	588	600	550	576	616	582	554	606	570	589	583	581
2006/2007	774	770	741	675	768	842	693	787	806	722	801	762	774	723	789	762
2007/2008	978	846	834	824	881	953	862	895	901	854	917	887	896	870	892	886
$\bar{x}$	775	729	724	685	746	798	702	752	774	719	757	752	747	727	754	–
statistically significant effect of factors and interactions significantly varying results: factors A, B, C; interactions: years × A; years × B; years × C statystycznie istotny wpływ czynników i interakcje istotnie różnicujące wyniki: czynniki A, B, C; interakcje: lata × A; lata × B; lata × C																
Number of grains per ear – Liczba ziarniaków w kłosie																
2005/2006	19.3	19.9	19.5	19.8	19.7	19.2	18.8	20.1	19.8	19.8	19.5	19.6	19.7	19.5	19.6	19.6
2006/2007	21.3	22.4	22.0	22.9	21.6	21.3	21.6	22.0	22.2	22.7	21.5	21.5	22.0	22.2	21.7	21.9
2007/2008	19.1	19.9	22.5	21.0	20.5	20.0	20.1	20.8	20.5	20.2	21.1	20.2	21.4	20.7	19.4	20.5
$\bar{x}$	20.2	20.5	21.3	21.1	20.6	20.2	20.2	20.8	20.8	20.9	20.7	20.2	21.0	20.8	20.1	–
statistically significant effect of factors and interactions significantly varying results: factor A; interactions: years × A; years × C statystycznie istotny wpływ czynników i interakcje istotnie różnicujące wyniki: czynnik A; interakcje: lata × A; lata × C																
Weight of 1000 grains, g – Masa 1000 ziarniaków, g																
2005/2006	50.06	48.17	48.39	50.56	47.32	48.74	50.40	50.36	45.86	47.86	50.81	47.94	49.23	48.64	48.74	48.87
2006/2007	35.71	31.15	35.52	34.90	34.55	32.92	33.26	33.60	35.51	34.42	32.90	35.05	34.01	34.99	33.37	34.12
2007/2008	53.23	57.21	51.41	55.96	53.97	51.93	55.25	54.58	52.02	55.50	50.72	55.63	49.71	53.94	58.20	53.95
$\bar{x}$	46.33	45.51	45.11	47.14	45.28	44.53	46.30	46.18	44.46	45.93	44.81	46.21	44.32	45.86	46.77	–
statistically significant effect of factors and interactions significantly varying results: factor B; interactions: years × A; years × E; years × C × E statystycznie istotny wpływ czynników i interakcje istotnie różnicujące wyniki: czynnik B; interakcje: lata × A; lata × E; lata × C × E																

Table 5. Yield of grain and straw, $Mg \cdot ha^{-1}$
Tabela 5. Plon ziarna i słomy, $Mg \cdot ha^{-1}$

Years Lata	Treatment symbol – Symbol obiektu															$\bar{x}$
	A			B			C			D			E			
	sowing date termin siewu			sowing density gęstość siewu			nitrogen fertilization in spring – nawożenie azotem wiosną			protection against diseases ochrona przed chorobami			growth regulator regulator wzrostu			
	September 9-11 9-11 września	+7 days +7 dni	+14 days +14 dni	250	350	450	40	60	80	dressing zaprawa	dressing + 1 treatment zaprawa +1 zabieg	dressing + 2 treatments zaprawa +2 zabiegi	lack brak	Moddus 250 EC – 0,6 dm^3	Retar 480 SL – 1,5 dm^3	
	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	
	Grain yield – Plon ziarna															
2005/2006	7.85	7.71	7.79	7.77	7.77	7.82	7.40	8.00	7.96	7.63	7.82	7.91	7.61	7.88	7.86	7.79
2006/2007	6.67	6.16	6.47	6.12	6.46	6.71	5.60	6.55	7.14	6.37	6.45	6.47	6.56	6.35	6.39	6.43
2007/2008	10.44	10.20	9.85	10.02	10.14	10.34	9.97	10.45	10.07	9.87	10.22	10.40	10.08	9.98	10.43	10.16
$\bar{x}$	8.32	8.02	8.04	7.97	8.13	8.29	7.66	8.33	8.39	7.96	8.17	8.26	8.08	8.07	8.23	–
statistically significant effect of factors and interactions significantly varying results: factor A, C, E; interactions: years × A; years × C; years × E statystycznie istotny wpływ czynników i interakcje istotnie różnicujące wyniki: lata; A; C: E; interakcje: lata × A; lata × C; lata × E																
	Straw yield – Plon słomy															
$\bar{x}$	5.35	5.05	5.23	5.18	5.27	5.19	5.06	5.42	5.16	5.12	5.28	5.24	5.20	5.23	5.20	–
statistically significant effect of factors and interactions significantly varying results: factor A, C; interactions: A × B; A × C; years × A; years × C statystycznie istotny wpływ czynników i interakcje istotnie różnicujące wyniki: lata; A; C; interakcje: A × B; A × C; lata × A; lata × C																

Quartile analysis of the results allowed for the determination of treatments characterized by the highest and lowest grain yield (Table 7). Therefore, the highest grain yields were obtained from sowing barley on the earliest date (A_0), with a density of 450 grains·m^{-2} (B_2) with an average spring fertilization at a rate of 60 kg N·ha^{-1} (C_1). These were treatments protected with a dressing and two fungicide treatments in the period of growing (D_2), and treated with a regulator Retar 480 SL (E_2). Factors applied on other levels did not guarantee obtaining the highest grain yields (Table 6).

Straw yield was relatively low (grain-straw ratio for the 3 years was 1:0.6), and the so called harvest index, 0.60, was strongly modified by weather (years). It is characteristic that in the second wet cycle of research it was the lowest. There occurred a significant interfactorial interaction (Table 4), from which it follows that the range of the effect of agrotechnical factors was lower than of the weather.

Table 6. Grain yield, Mg·ha^{-1}; significant double interactions
Tabela 6. Plon ziarna, Mg·ha^{-1}; istotne interakcje podwójne

A		B			C			$\bar{x}$
sowing date termin siewu		sowing density gęstość siewu			nitrogen fertilization in spring nawożenie azotem wiosną			
		250	350	450	40	60	80	
		0	1	2	0	1	2	
September 11 – 11września	0	8.21	8.11	8.64	7.97	8.47	8.52	8.32
+7 days – +7 dni	1	7.97	8.09	8.02	7.54	8.26	8.27	8.03
+14 days – +14 dni	2	7.74	8.17	8.20	7.46	8.27	8.38	8.04
$\bar{x}$		7.97	8.13	8.29	7.66	8.33	8.39	–

Table 7. Technologies of high and low grain yields according to quartile result analysis
Tabela 7. Technologie wysokich i niskich plonów ziarna wg kwartylowej analizy wyników

Factor and its level – Czynnik i jego poziom					Grain yield – Plon ziarna			Mean Średnia (years – lata)
A	B	C	D	E	2006	2007	2008	
Quartile of high yields – Kwartyl wysokich plonów								
0	2	1	2	2	8.61	7.32	11.30	9.08
Quartile of low yields – Kwartyl niskich plonów								
2	0	0	0	0	6.94	5.42	9.48	7.28

DISCUSSION

The main reason of cereal yield variation is diversified within years distribution of climatic conditions. Research on spring barley in Bałcyny confirmed that under conditions of the increase in rainfall total by 40%, diversification of the barley grain yield reaches 30%, that is it reaches value similar to the one obtained under the effect of nitrogen fertilization [Mazur and Grabowski 2008]. Research carried out under climatic conditions of Lower Silesia indicates diversification in the winter barley yield within years, reaching 51% [Gandecki and Wacławowicz 2006], and in Kuyavian-Pomeranian Voivodeship up to 71% [Barczak *et al.* 1994]. Own research showed variations of winter barley yield in 2007 and 2008, reaching 37%, i.e. 3.73 $Mg \cdot ha^{-1}$. It should be emphasized that very high fertility of barley was obtained in this study.

Winter barley is characterized by a relatively low winter hardiness. Its main cultivation centers in Poland are in Greater Poland and in Lower Silesia [Budzyński and Szempliński 2003]. Pisulewska [2005] described the risk in its main cultivation areas as the lowest. The effect of the sowing date on overwintering of this species based on a large number of cultivar experiments in the Research Center for Cultivar Testing was described by Szymczyk [1996]. Research results indicate that barley overwinters better when sown after September 15 than when sown earlier. The risk of winterkill is mainly connected with weather conditions in autumn, and its effect on the development of vegetation matter and on plant hardening before winter dormancy [Noworolnik 2007c]. Large vegetation matter (early sowing) or a small amount of carbohydrates accumulated in aboveground organs (too late sowing) increase the risk of winterkill [Gut 2000, Leszczyńska *et al*. 2005].

In own research, overwintering of barley should be evaluated as very good (8 degrees in the first year, 9 degrees in other years). The effect of the sowing date and sowing density on this feature was smaller than it was assumed.

Sowing date was not the factor which varied the yield the most, however the highest yields were obtained regularly from the earliest sowing, i.e. September 9-11. Its delay of 7 days resulted in a decrease of grain yield by 0.30 Mg. Sowing in the 3rd decade of September (level 2) did not intensify the yield decrease. The results confirmed a significant interaction between the sowing date and density. In view of obtaining the highest yields from early sowing, N yield in these combinations was the most favourable (interaction between the sowing date x N rate). Noworolnik [2007c], however, indicated a strong dependence of the sowing date on climatic-soil conditions and cultivar selection. In the research of Leszczyńska and Noworolnik [2005], who compared reaction of two-row and multi-row winter barley cultivars to sowing date, the highest yield was obtained when barley was sown on September 7-9, provided that the plants overwintered well. Poorer overwintering of plants (infection with snow mold and smothering) significantly decreased the grain yield compared with the later sowing.

Under worse climatic-soil conditions, increase in the cereal sowing density is effective with regard to yield-formation [Noworolnik 2007b]. In own research, condensing sowing from 250 to 450 grains per 1 m^2 had a regularly beneficial effect on the main structural component of the yield, which is the ear number. And although it affected the decrease in the value of weight of 1000 grains, the grain yield in dense stands showed a regular increase tendency. Earlier, such dependences had been described in the papers of Noworolnik and Kozłowska-Ptaszyńska [1997], Kozłowska--Ptaszyńska and Pecio [1999] as well as of Szymczyk [1996], and also in well-documented papers concerning malting spring barley [Pecio 2002, Noworolnik 2007a].

In own research, the factor of N fertilization varied grain yield the most. The N effect was variable within years and in the wet year of 2007, the difference in the grain yield of plants fertilized with a rate of 40 and 80 kg was up to 1.54 $Mg \cdot ha^{-1}$, that is 27.5%. On average, within 3 years the increase in the yield of barley which was fertilized with a rate of 40 and 60 kg was 0.67 $Mg \cdot ha^{-1}$, and increasing the rate by the next 20 kg did not give yield increase. Beneficial effect of nitrogen on the yield was obtained above all in the increase in the ear number. It is confirmed by the research of Szmigiel [1998].

Also Noworolnik [2007b] indicates a great effectiveness of high nitrogen rates under conditions of delayed sowing (but also of a lower density or poorer soils). He explains that with nitrogen effect on plant tillering and interaction with other factors. In the presented experiment, mean grain yield from plots fertilized with nitrogen and sown 14 days later than control (level 0) was slightly higher than with the delay in sowing of 7 days, which may confirm a corrective role of nitrogen fertilization in relation to the delay in sowing.

The yield-protective effect of fungicides on the yield is realized mainly through increasing the weight of 1000 grains, and to a lesser degree through diversification of the grain number per ear. Barley requires early fungicide protection [Sowiński 1995], which is confirmed by Young *et al*. [2006], who explain that with necessity to prevent the decrease in inoculum production on lower leaves (application of a preparation against *Rhynchosporium secalis* before the occurrence of leaves, thus earlier than in winter wheat). In the research of Yang *et al*. [2000] the most yield-protective was double application of the preparations (on leaves and ears), which caused yield increase by 1.10 Mg. Beneficial effect of protection against diseases under epidemic conditions was confirmed by Young *et al*. [2006], who obtained an increase of approximately 1.00 Mg as a result of fungicide application at the beginning of the stage of shooting and of 0.50 Mg, when the treatments were carried out on other dates. Sowiński [1995] indicated the yield increase by 0.39 $Mg \cdot ha^{-1}$ as a result of fungicide application combined with herbicide, retardant and N fertilization.

In own research, despite low intensity of diseases in barley, there occurred a regular tendency of yield increase after application of one and two treatments. This increase compared with treatments protected only with a dressing was 0.21 $Mg \cdot ha^{-1}$ and 0.30 $Mg \cdot ha^{-1}$ respectively, and was impossible to prove statistically.

The yield-protective effect of growth regulators on the yield is usually in interaction with weather conditions. Their application may cause decrease in the grain weight, and sometimes even vary their number per ear. In own research, trinexapac and ethephon did not vary the ear number, but caused a tendency (especially in the dry year) towards increasing the weight of 1000 grains. This affected the yield increase, slight (0.15 $Mg \cdot ha^{-1}$) but statistically significant. Beneficial effect of ethephon on the grain development was observed in technological studies of Sowiński [1995]. The applied retardant caused an increase in the proportion of grain of the diameter >2.5 mm, on average by app. 8%, and increase in the grain yield by 0.44 $Mg \cdot ha^{-1}$, but in a combination with separate fertilization with nitrogen, herbicide and fungicides. In own research, application of ethephon more favourably affected value of the grain yield than growth regulation with the use of trinexapac-ethyl.

Cultivation technology of operations most beneficial for the yield value was provided by: early sowing carried out on September 9-11 at a density of 450 grains, rate of 60 kg N applied once in early spring and a full protection (BBCH 32 + Alert 375 SC, BBCH32 + Artea 330 EC, BBCH 52 + etefon BBCH 32). Intensive technology provided a very high yield of Corbie cultivar (>8.0 4.96 and 5.06 $Mg \cdot ha^{-1}$). Other authors using intensive technologies obtained yields of winter barley form on the level: 5.08 $Mg \cdot ha^{-1}$ [Szmigiel 1998], 6.83 $Mg \cdot ha^{-1}$ [Sowiński 1995], 4.96 and 5.06 $Mg \cdot ha^{-1}$ [Harasim and Noworolnik 1998].

The results concerning the effect of agrotechnical level on the brewing quality was presented in the paper of Załuski *et al*. [2012].

CONCLUSION

The yield of winter barley cv. Corbie cultivated on soil of the good wheat complex is very high, though diversified during years. During research (2005-2008) plants of this cultivar overwintered well, to a slight degree they lodged, and their infection with fungal diseases was low. The relationship between yield and technological level was lower than it had been assumed in the working hypothesis. Diversification in yield under the effect of: level of nitrogen fertilization was 0.73 $Mg{\cdot}ha^{-1}$, sowing density 0.32 $Mg{\cdot}ha^{-1}$, sowing date did not reach 0.30 $Mg{\cdot}ha^{-1}$ (3.5%), method of protection against diseases 0.30 $Mg{\cdot}ha^{-1}$ and stem retardation 0.16 $Mg{\cdot}ha^{-1}$. The highest malting grain yields were provided by technology which included: early (September 9-11) and condensed to 450 $grains{\cdot}m^{-2}$ sowing of barley, fertilization with a rate of 60 kg N per ha, intensive protection with fungicides and with a growth retardant. Delay in sowing of 2 weeks, sparce sowing (250 grains), low nitrogen rate (40 kg), and lack of chemical protection in the period of growing resulted in a grain yield lower by 1.80 $Mg{\cdot}ha^{-1}$.

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POZIOM TECHNOLOGII A PLONOWANIE OZIMEGO JĘCZMIENIA BROWARNEGO

Streszczenie. Celem badań było określenie związku pomiędzy czynnikami agrotechnicznymi a wydajnością browarnego jęczmienia ozimego odmiany Corbie. Omówiono plon ziarna i jego składowe. Źródłem wyników był eksperyment polowy zlokalizowany w ZPD „Bałcyny Sp. z o.o." koło Ostródy, w korzystnych pogodowo dla jęczmienia ozimego latach 2006-2008. Zastosowano układ frakcyjny typu 3^{5-2}(IV) w dwóch powtórzeniach po 27 kombinacji w każdym, w którym jednocześnie testowano 5 czynników (A, B, C, D, E) na trzech poziomach (0, 1, 2). Wykazano bardzo dużą, choć zmienną w latach wydajność jęczmienia ozimego odmiany Corbie na glebie kompleksu pszennego dobrego. W czasie badań rośliny tej odmiany zimowały dobrze, w niewielkim stopniu wylegały, a ich porażenie przez choroby grzybowe było małe. Związek wydajności z poziomem technologii był mniejszy niż zakładano w hipotezie roboczej. Najwyższe plony ziarna zapewniał wysiew jęczmienia w terminie najwcześniejszym (9-11 września), w ilości 450 szt. ziarniaków$\cdot$m^{-2} z wiosennym nawożeniem N w dawce 60 kg N$\cdot$ha^{-1}. Były to obiekty chronione zaprawą i 2 zabiegami fungicydowymi w czasie wegetacji oraz traktowane regulatorem Retar 480 SL.

Słowa kluczowe: gęstość siewu, nawożenie N, ochrona przed chorobami, odmiana Corbie, regulacja wzrostu, termin siewu

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