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THE EFFECT OF DIVERSE SOWING DENSITY ON THE YIELD AND STRUCTURAL YIELD COMPONENTS OF BROWN- AND YELLOW-HUSKED GENOTYPES OF OATS

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Abstract. The aim of the study was evaluation of the effect of various sowing density and the course of weather conditions in the growing season on the yield and structural yield components of chosen brown- and yellow-husked genotypes (cultivars and strains) of common oats. The two-factor field experiment was carried out in the years 2007-2010 at the Institute of Crop Production and Cultivation of Małopolska Plant Growing Company in Polanowice near Krakow. The first experimental factor were 6 cultivars/strains of common oats: 3 cultivars/strains of brown-husked cultivars (Gniady, CHD 2875/01, CHD 2833/02) and 3 yellow-husked cultivars (Bohun, Deresz and Cwał). The second factor were 3 sowing densities: 300, 400 and 500 germinating grains$\cdot$m^{-2}. The brown-husked (5.90 Mg$\cdot$ha^{-1}) and yellow-husked (6.13 Mg$\cdot$ha^{-1}) genotypes of oats which were compared in the study, did not differ significantly in the grain yield quantity, however, significant differences were observed between particular strains and cultivars (Gniady, CHD 2875/01, CHD 2833/02, Bohun, Deresz and Cwał) both in grain yields and in the number of grains developed per panicle, as well as in 1000 grain weight. The average oat yield obtained in the experiment was 5.6-6.4 Mg$\cdot$ha^{-1}, while the highest one was obtained from the brown-husked strain CHD 2833/02. Diversified sowing density had no effect on the grain yield quantity, however it significantly varied structural components of the yield. Increase in the density was directly proportional to the number of panicles developed per unit of area. The studied experimental factors had a significant effect on grain plumpness in the studied material. The highest yielding cultivars and strains (CHD 2833/02, Bohun, Deresz) were characterized by a higher proportion of small grains (<2.2 mm), and by a lower content of larger grains. The course of weather conditions in the years of research significantly diversified yield quantity, structural yield components and grain proportion of particular fractions. In 2008, under conditions favorable for growth and development of oat plants, the proportion of grains from fraction 2.5-2.7 mm was higher than in other years of research.

Key words: common oats, grain yield, husk color, sowing density, structural yield components

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INTRODUCTION

In previous studies on the effect of sowing density on oat yield, equivocal results were obtained. Based on numerous experiments concerning sowing density for husked oats, it is recommended to sow it within the range of 500-650 grains·m^{-2} [Noworolnik 1994, Peltonen-Sainio 1997, Walens 2003]. Dubis and Budzyński [2003] state that diversification of oat yield under the effect of different sowing quantities, is not very high, however in individual years may even reach 20%. According to Rybicki et al. [1991], opinions concerning an optimum sowing quantity in cereals change along with introducing new cultivars into agricultural practice, and with a progressing technical development in agriculture. Analysis of the combined effect of habitat and agricultural practices indicates that with a favorable course of weather conditions, production effect of increased sowing density is minor, while under unfavorable conditions, it is significantly greater [Ścigalska 1999]. Kozłowska-Ptaszyńska [1999], observed lack of the effect of increased sowing density on the yield quantity. At the same time, with an increase in the sowing density (from 400, 600 to 800 grains per m^2), panicle number increased per unit of area.

Ścigalska [1999] in her research found that husked cultivars of oats gave higher yields, when an increased sowing density was applied, i.e. 550 grains per m^2. This was confirmed in the studies of Pawłowska *et al*. [1996] according to which sowing density should be from 500-600 grains·m^{-2}. Świderska-Ostapiak and Stankowski [2006] observed that increasing sowing quantity from 400 to 790 grains per m^2 resulted in a slight, though significant, increase in the yield.

In the studies on common oats presented in this paper, it was assumed that: the new brown-husked genotypes of oats give higher yields compared with traditional cultivars, sowing density has a significant effect on the quantity and structural components of the yield, and that brown-husked forms are less susceptible to the unfavorable course of weather conditions in the growing season.

The aim of the study was evaluation of the effect of diverse sowing density of chosen yellow- and brown-husked cultivars and strains of oats on: 1) grain yield, 2) structural yield components and 3) proportion of grains of a diverse diameter in the yield. Additionally, the effect of weather conditions on the studied parameters was determined in the experimental years.

MATERIAL AND METHODS

The two-factor field experiment was carried out in the years 2007-2010 in the Institute of Crop Production and Cultivation of Małopolska Plant Growing Company in Polanowice near Krakow. The first experimental factor was the oat cultivar: 3 brown--husked cultivars/strains (Gniady, CHD 2875/01, CHD 2833/02) and 3 yellow-husked cultivars (Bohun, Deresz and Cwał). The second factor was sowing density: 300, 400 and 500 germinating grains·m^{-2}. The seed material of strains and cultivars came from Danko Plant Breeders Ltd. Phosphorus – potassium fertilizers were applied before sowing in all experimental years at doses of: 26.2 kg P·ha^{-1} and 74.7 kg K·ha^{-1} in the form of Polifoska 6. Nitrogen at a dose of 52 kg N·ha^{-1} was applied on two dates: 18 kg before sowing in the form of Polifoska, and 34 kg in the shooting stage in the form of ammonium saltpeter. The size of plots for harvest was 10 m^2. The soil on the experimental field was degraded chernozem formed from loess. Agricultural practices were carried out in accordance with the principles of oat cultivation. Every year, panicle number per unit of area was determined before harvest, while grain yield quantity (with 15% humidity) after harvest, as well as: grain number per panicle, 1000 grain weight, and also the proportion of grains of a diameter < 2.2; 2.2-2.5; >2.8 mm.

Statistical analysis was carried out with the use of AWAR program taking on a fixed-effect model. Tukey's test was used to determine differences between the means. With the significance level of $P \leq 0.05$, the null hypothesis was rejected.

The course of weather conditions in the experimental years is presented in Tables 1 and 2. In the first year of research (2007) rainfall throughout the growing season did not meet oat's requirements for water (Table 1). In the second experimental year (2008) water requirement of oats in the growing season (April – June), was significantly higher than the average rainfall in these periods (Table 1). In April rainfall constituted 69% compared with the long-term period. In May, rainfall did not meet water requirements of oats, either. A similar situation occurred in June, which also turned out to be very dry, the rainfall was even lower, constituting only 32% of the long-term mean. The difference between oat's requirement and the amount of rainfall that month was significant, and was up to 37.5 mm (Table 1).

After the long-term dry period, weather conditions in July underwent change. There occurred a more frequent and very intensive rainfall. The rainfall that month was over 142 mm, which constituted 190% of the mean rainfall in the long-term period. Weather conditions enabled oat's harvest in early August.

In the third year of research (2009) the mean rainfall total for particular months to a large degree fitted in with oat's requirement for water, except April, in which no rainfall occurred (Table 1). Throughout the growing season, it was in April that there occurred the least favorable weather conditions for plant growth and development. The highest rainfall occurred in June and it exceeded the long-term mean.

However, in the fourth year of research (2010), only in April the requirement for water was higher than the total rainfall that month (Table 1). In other months, the total rainfall was higher than oat's requirement. In May and July, the highest rainfall totals were observed.

Table 2 presents comparison of mean daily air temperatures in particular years of study with the long-term means. 2007 was cooler compared with the long-term period. The warmest months were June and July, while the coldest one was April with an average temperature of 5.4°C.

In 2008 the average air temperature in the growing season was 11.3°C, and was lower by app. 3°C than the long-term period temperature at that time (Table 2). The coolest months that year appeared to be April and May. In the studies carried out by Michalski *et al*. [1999], a dependence was found between oat yield and temperature in particular months, especially in May. The average temperature in those months was by nearly 4°C lower than the mean from the long-term period.

In the third year of research (2009) thermal conditions in particular months of the growing season were different. The warmest months were June and July, when mean daily temperatures were 15.8°C and 16.4°C. According to the criteria defined by Ziernicka [2001], April, May and June are classified as cold months, whereas July and August may be classified as very cold. The average temperature in the growing season in 2009 was lower than the mean from the long-term period. The highest average daily temperature occurred in July, while the lowest one in April (Table 2).

Table 1. Monthly rainfall totals in the period March-August in the years 2007-2010 compared with the rainfall means from the long-term period 1997-2007
Tabela 1. Miesięczne sumy opadów atmosferycznych w okresie marzec – sierpień w latach 2007-2010; na tle średnich opadów z wielolecia 1997-2007

Rainfall – Opady	Month – Miesiąc						Total rainfall in the growing season Suma opadów w okresie wegetacyjnym
	March marzec	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	
Rainfall distribution in 2007, mm Rozkład opadów w 2007 r.	34	26	28	75	45	47	254
Month's classification* Kwalifikacja miesiąca	BS	BS	BS	N	BS	BS	–
Rainfall distribution in 2008, mm Rozkład opadów w 2008 r.	38	34	27	35	107	38	279
Month's classification* Kwalifikacja miesiąca	BS	BS	BS	BS	N	BS	–
Rainfall distribution in 2009, mm Rozkład opadów w 2009 r.	54	0	73	159	83	43	411
Month's classification* Kwalifikacja miesiąca	S	SS	S	BW	N	BS	–
Rainfall distribution in 2010, mm Rozkład opadów w 2010 r.	17	28	186	130	180	152	691
Month's classification* Kwalifikacja miesiąca	SS	BS	BW	W	BW	BW	–
Long-term mean Średnia wieloletnia	16	50	65	80	75	22	–
Oat's requirement for water according to Dzieżyc**, mm Zapotrzebowanie owsa na wodę wg Dzieżyca	–	43	65	81	82	–	–
Differences between oat's requirement and the amount of rainfall – Różnice między zapotrzebowaniem owsa a ilością opadów							–
1st year of research – I rok badań	–	-17.4	-37.4	-5.9	-37.3	–	–
2nd year of research – II rok badań	–	-8.9	-38	-45.6	24.5	–	–
3rd year of research – III rok badań	–	–	8.2	77.5	0.9	–	–
4th year of research – IV rok badań	–	-15.3	120.6	49	97.5	–	–

* classification according to Kaczorowska [1962] – klasyfikacja wg Kaczorowskiej [1962]
** traditional oat's requirement according to Dzieżyc [1989] – zapotrzebowanie owsa tradycyjnego wg Dzieżyca [1989]
SS – extremely dry <25 – skrajnie suchy <25
BS – very dry 25-49 – bardzo suchy 25-49
S – dry 50-74 – suchy 50-74
N – average 75-125 – normalny 75-125
W – wet 126-150 – wilgotny 126-150
BW – very wet 151-200 – bardzo wilgotny 151-200
SW – extremely wet >200 – skrajnie wilgotny >200

2010 was the warmest year, with June and July having high temperatures, and the average daily temperature being 17.8°C and 18.3°C, respectively, which was higher than the mean from the long-term period. It should be highlighted that during panicle formation, oat has the highest heat requirements. April turned out to be the coldest month.

Table 2. Average daily air temperature in Polanowice in the period from March to August in the years 2007-2010 compared with the mean from the long-term period 1977-2007, °C
Tabela 2. Średnia dobowa temperatura powietrza w Polanowicach w okresie od marca do sierpnia w latach 2007-2010 w odniesieniu do średniej wieloletniej za okres 1977-2007, °C

Year Rok	Month – Miesiąc					
	March marzec	April kwiecień	May Maj	June czerwiec	July lipiec	August sierpień
2007	3.7	5.4	11.5	16.5	16.6	15.5
2008	1.5	4.6	9.8	15.2	15.5	14.8
2009	2	5.6	10.4	15.8	16.4	15.3
2010	-0.4	7.1	11.4	17.8	18.3	16.5
1977-2007	3.1	8.1	13.7	16.5	18.2	17.9

RESULTS AND DISCUSSION

In our research, from the compared oat cultivars/strains (Table 3), the highest yields were obtained from the brown-husked strain CHD 2833/02 (6.4 $Mg \cdot ha^{-1}$). Grain yield from the strain CHD 2833/02 did not differ significantly from the yield from cultivars Bohun and Deresz (Table 3). A significant difference (8%) in the yield of yellow--husked cultivars was observed between the two cultivars, Deresz and Bohun (6.3 $Mg \cdot ha^{-1}$), and the cultivar Cwał (5.8 $Mg \cdot ha^{-1}$).

Table 3. Grain yield of oat cultivars and strains depending on the studied factors, $Mg \cdot ha^{-1}$
Tabela 3. Plon ziarna odmian i rodów owsa w zależności od badanych czynników, $Mg \cdot ha^{-1}$

1st factor – cultivar/strain Czynnik I – odmiana/ród	2007	2008	2009	2010	Mean for cultivars Średnio dla odmian
Gniady	4.80	7.10	5.36	5.57	5.71
CHD 2875/01	4.63	6.51	4.97	6.17	5.57
CHD 2833/02	5.17	7.29	6.93	6.37	6.44
Bohun	5.44	7.84	5.33	6.63	6.31
Deresz	4.96	7.83	6.07	6.42	6.32
Cwał	5.08	7.16	4.84	5.97	5.76
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: cultivar/strain – odmiany /rodu	0.510***	0.479***	0.800***	0.814**	0.324***
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × cultivar/strain – lata × odmiana /ród	1.123***				–
2nd factor – sowing density Czynnik II – gęstość siewu	2007	2008	2009	2010	Mean for sowing density Średnio dla gęstości siewu
300	4.96	7.11	5.42	6.21	5.93
400	5.05	7.35	5.50	6.23	6.03
500	5.03	7.40	5.83	6.12	6.10
Mean – Średnia	5.01	7.28	5.58	6.18	6.02
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: density – gęstości	0.295	0.277*	0.462	0.470	0.188
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × density – lata × gęstość	ns – ni				–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat	0.239*				–

* $0.01 < \alpha < 0.05$; ** $0.001 < \alpha < 0.01$; *** $\alpha < 0.001$

In the studies carried out by Pisulewska *et al*. [2010], from among the 7 compared cultivars, the highest yields were obtained from the cultivar Rajtar (mean from 3 years 7.39 $Mg \cdot ha^{-1}$), followed by cultivars: Krezus (7.35 $Mg \cdot ha^{-1}$), Cwał (7.28 $Mg \cdot ha^{-1}$), Arab (7.23 $Mg \cdot ha^{-1}$), Bohun (7.15 $Mg \cdot ha^{-1}$), Furman (6.95 $Mg \cdot ha^{-1}$) and Deresz (6.87 $Mg \cdot ha^{-1}$). However, in the studies of Sulewska *et al*. [2010] carried out in the years 2006 – 2007, the highest yielding cultivar was Zuch, and its yield was by 0.39 $Mg \cdot ha^{-1}$ (by 8.2%) higher than yield of the standard cultivar Bohun (4.78 $Mg \cdot ha^{-1}$).

The applied sowing density, except 2008, did not vary significantly the yield level in the studied oat cultivars/strains. What was observed was a visible tendency towards yield increase under the effect of an increasing sowing density (Table 3). Also, the studies did not indicate any significant effect of oat genotypes and sowing density on the yield quantity (Table 4). The course of weather conditions in the experimental years had a significant effect on the yield of various oat forms (Table 3). The least favorable for the yield quantity was the first year of research (2007), in which only in June the total rainfall was similar to oat's requirement for water [Dzieżyc 1989], while other months, according to Kaczorowska's classification [1962], were very dry. In April, the rainfall was 25.6 mm, and in July 44.7 mm, while the oat's requirement for water in those months is 43 and 82 mm, respectively (Table 1).

Table 4. Grain yield of the studied oat cultivars/strains depending on the sowing density, $Mg \cdot ha^{-1}$
Tabela 4. Plony ziarna badanych odmian/rodów owsa w zależności od gęstości siewu, $Mg \cdot ha^{-1}$

Cultivar/strain – Odmiana/ród	Sowing density – Gęstość siewu	Grain yield – Plon ziarna
GNIADY	300	5.7
	400	5.8
	500	5.7
CHD 2833/02	300	6.5
	400	6.3
	500	6.6
CHD 2875/01	300	5.5
	400	5.8
	500	5.6
CWAŁ	300	5.7
	400	5.8
	500	5.8
DERESZ	300	6.2
	400	6.3
	500	6.5
BOHUN	300	6.2
	400	6.2
	500	6.5
$LSD_{0.05}$ – $NIR_{0.05}$ for – dla: genotype × density – genotyp × gęstość		ns – ni

The highest yields were obtained from the compared cultivars and strains in 2008, i.e. in the second year of research (Table 3). Although the total rainfall in the growing season (Table 1) was only by 25 mm higher than the total in 2007, the lower average daily air temperatures (Table 2) and a slightly better rainfall distribution in particular months turned out to be more beneficial for the oat's yield.

In oat cultivation, yield quantity is determined by: panicle number per unit of area, grain number per panicle, and by 1000 grain weight. In the conducted experiments, the average panicle number per unit of area was 441 panicles·m^{-2} (Table 5). In yellow-husked cultivars the average panicle number was 432 panicles·m^{-2}, while in brown-husked cultivars it was 449 panicles·m^{-2}. The greatest number of panicles (statistically not significantly) were developed by plants from the strain CHD 2833/02, which had a positive effect on grain yields (Table 3 and 5). The number of developed panicles was directly proportional to the sowing density and was significantly dependent on the course of weather conditions in particular years.

Table 5. Panicle number per unit of area depending on the studied factors, panicle·m^{-2}
Tabela 5. Liczba wiech na jednostce powierzchni w zależności od badanych czynników, szt.·m^{-2}

1st factor – cultivar/strain Czynnik I – odmiana/ród	2007	2008	2009	2010	Mean for cultivars Średnio dla odmian
Gniady	443	490	465	425	456
CHD 2875/01	443	504	335	453	434
CHD 2833/02	539	473	367	446	456
Bohun	485	480	343	422	433
Deresz	464	503	417	359	436
Cwał	458	478	388	391	429
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: cultivar/strain – odmiany /rodu	113.3	87.3	113.9*	95.9	50.0
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × cultivar/strain – lata × odmiana /ród	173.3**				–
2nd factor – sowing density Czynnik II – gęstość siewu	2007	2008	2009	2010	Mean for sowing density Średnio dla gęstości siewu
300	412	414	341	447	404
400	471	486	372	410	435
500	533	564	444	392	483
Mean – Średnia	472	488	386	416	441
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: density – gęstości	65.5***	50.4***	65.8***	55.4	29.0***
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × density – lata × gęstość	142.2***				–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat	36.8*				–

* $0.01 < \alpha < 0.05$; ** $0.001 < \alpha < 0.01$; *** $\alpha < 0.001$

The two highest yielding oat forms (strain CHD 2833/02 and cultivar Bohun) developed the largest number of panicles in the season of 2007, whereas other forms (Deresz, Cwał, Gniady and strain CHD 2875/01) in 2008. Response of the studied forms to the course of weather conditions in the experimental years was individual.

The obtained results, to a slight degree differ from the data obtained in the experiments of Wróbel *et al*. [2003], as well as Szarek and Klima [2006], in which panicle number per unit of area was 463-470 panicles·m^{-2} and 423 panicles·m^{-2}, respectively. Rudnicki and Gałęzewski [2006] with the sowing density of 280 grains·m^{-2} obtained 293 panicles·m^{-2}, while with the sowing density of 560 grains·m^{-2} – 448 panicles·m^{-2}. Dubis and Budzyński [2003] indicated that dense sowing, i.e. 800

grains·m^{-2}, provided a proportion of panicles higher by 46%, compared with the sparse sowing, i.e. 400 grains·m^{-2}. Increase in panicle density by 258 panicles·m^{-2} under the effect of an increased sowing density from 400-790 grains·m^{-2} was also observed by Świderska-Ostapiak and Stankowski [2006].

Another important structural yield component is grain number per panicle. In our research, grain number per panicle was directly proportional to sowing density, and was also dependent on cultivars and strains (Table 6). In the conducted experiment, the highest grain number per panicle was obtained in cultivar Bohun, and significantly lower in cultivar Gniady. Along with an increase in sowing density from 300-500 grains·m^{-2}, a significant decrease in grain number per panicle was observed (Table 6).

Table 6. Grain number per panicle of common oats depending on the studied factors
Tabela 6. Liczba ziaren w wiesze owsa siewnego w zależności od badanych czynników, szt.

1st factor – cultivar/strain Czynnik I – odmiana/ród	2007	2008	2009	2010	Mean for cultivars Średnio dla odmian
Gniady	63	77	67	73	70
CHD 2875/01	60	84	79	81	76
CHD 2833/02	65	74	86	71	74
Bohun	83	77	85	75	80
Deresz	74	75	84	72	76
Cwał	74	77	77	77	76
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: cultivar/strain – odmiany /rodu	15.6***	17.7	19.7	14.9	8.3*
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × cultivar/strain – lata × odmiana /ród	28.7*				–
2nd factor – sowing density Czynnik II – gęstość siewu	2007	2008	2009	2010	Mean for sowing density Średnio dla gęstości siewu
300	75	79	89	75	79
400	70	79	79	77	76
500	65	74	72	72	71
Mean – Średnia	70	77	80	75	75
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: density – gęstości	9.0*	10.2	11.3**	8.6	4.8***
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × density – lata × gęstość	ns – ni				–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat	6.1*				–

* $0.01 < \alpha < 0.05$; ** $0.001 < \alpha < 0.01$; *** $\alpha < 0.001$

1000 grain weight is also a factor affecting the yield. In our research, 1000 grain weight of cultivars and strains was within the range of 36.3 to 42.3 g. Generally, brown-husked forms developed plumper grains than yellow-husked cultivars. Diversity in 1000 grain weight depending on sowing density was low, and did not exceed statistical error (Table 7). Biskupski *et al.* [1984] state that the average value of 1000 grain weight in oats is 28.4 g. Śmiałowski [2006], while testing oat strains in a preliminary experiment carried out in various Experimental Stations, obtained grain with 1000 grain weight being 36.5 g. However, in the experiments of Deryło and Szymankiewicz [1999], the average 1000 grain weight was 30.4 g. In the studies of Noworolnik and Maj [2005], 1000 grain weight significantly decreased with sowing density of 650 grains·m^{-2}, and was lower by 1.8 g compared with the density of 350 grains·m^{-2}, amounting to the level of 37.8 g. An increasing sowing quantity in the studies of Świderska-Ostapiak and Stankowski [2006] had a significant effect on the decrease in 1000 grain weight. On the other hand, the research carried out by Kozłowska-Ptaszyńska [1999] indicated that increased sowing standard has no effect on 1000 grain weight. In the studies of Czubaszek [2003], a high 1000 grain weight was characteristic of grain of cultivar Sławko and Bajka (44.0 and 41.0 g), a lower one of cultivar Dragon and Skrzat (38.1 and 35.6 g).

A high diversity in 1000 grain weight between the study years, even higher than between the cultivars, was found by Zając *et al*. [1999], according to whom the yield under good soil conditions is determined mainly by panicle number per unit of area, while under mountain conditions, beside panicle number, also 1000 grain weight is of great importance. In the research carried out by Pisulewska et al. [2009] it was indicated that in the growing season of 2005, both the number of panicles developed per unit of area and grain number per panicle, as well as 1000 grain weight, were significantly higher, by 17, 16 and 32%, respectively, compared with 2006. To conclude, it may be stated that 1000 grain weight is a genetically conditioned trait, which is usually modified by agricultural practices and weather conditions. Results obtained in our research confirm this conclusion (Table 7).

Table 7. 1000 grain weight of common oats depending on the studied factors, g
Tabela 7. Masa tysiąca ziaren owsa siewnego w zależności od badanych czynników, g

1st factor – cultivar/strain Czynnik I – odmiana/ród	2007	2008	2009	2010	Mean for cultivars Średnio dla odmian
Gniady	44.1	37.1	38.6	41.5	40.3
CHD 2875/01	45.9	39.2	42.4	41.8	42.3
CHD 2833/02	44.2	33.4	36.8	41.2	38.9
Bohun	39.0	29.6	35.6	40.8	36.3
Deresz	42.3	34.2	36.8	40.1	38.4
Cwał	41.4	34.2	37.6	37.6	37.7
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: cultivar/strain – odmiany /rodu	5.7*	1.7***	1.7***	2.6***	1.6***
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × cultivar/strain – lata × odmiana /ród	5.7***				–
2nd factor – sowing density Czynnik II – gęstość siewu	2007	2008	2009	2010	Mean for sowing density Średnio dla gęstości siewu
300	43.6	34.0	37.8	40.4	38.9
400	43.9	34.9	38.0	40.2	39.3
500	40.8	35.0	38.1	40.8	38.7
Mean – Średnia	42.8	34.6	38.0	40.5	39.0
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: density – gęstości	3.3	1.0*	1.0	1.5	0.9
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × density – lata × gęstość	4.6**				–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat	1.2*				–

* $0.01 < \alpha < 0.05$; ** $0.001 < \alpha < 0.01$; *** $\alpha < 0.001$

All cultivars and strains significantly differed in the proportion of particular fractions in the grain yield (Tables 8-11). Cultivar Gniady and also strain CHD 2875/01 had the highest percentage of grain from the large fraction (≥2,8 mm) (Table 8). Statistical analysis confirmed that cultivars and strains (CHD 2833/02, Bohun, Deresz), which were characterized by the highest yield, had the lowest proportion of large grains (Tables 8, 9). Genotypes giving highest yields also had the highest proportion of small grains (<2.2 mm) (Table 11). A similar dependence was observed in the experiments of Pisulewska *et al*. [2010], in which cultivars of relatively high yield were characterized by quite a low proportion of grains from the large fraction, and the highest content of small grains and offal in the yield. The results of our studies confirm the literature data.

Table 8. Proportion of oat grain of a diameter ≥ 2.8 mm depending on the studied factors, %
Tabela 8. Udział ziarniaków owsa o średnicy ≥ 2,8 mm w zależności od badanych czynników, %

1st factor: cultivar/strain Czynnik I odmiana/ród	2007	2008	2009	2010	Mean for cultivars Średnio dla odmian
Gniady	51.8	10.8	24.6	3.5	22.7
CHD 2875/01	53.5	13.2	27.4	7.5	25.4
CHD 2833/02	24.1	2.5	14.9	2.1	10.9
Bohun	21.3	6.8	21.9	4.0	13.5
Deresz	19.7	3.6	12.2	3.1	9.6
Cwał	25.3	5.1	28.8	2.8	15.5
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: cultivar/strain – odmiany /rodu	7.1***	4.2***	7.8***	2.0***	2.8***
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × cultivar/strain – lata × odmiana /ród	9.7***				–
2nd factor: sowing density Czynnik II gęstość siewu	2007	2008	2009	2010	Mean for sowing density Średnio dla gęstości siewu
300	32.3	6.7	21.5	4.5	16.3
400	33.8	6.5	22.1	3.7	16.5
500	31.8	7.8	21.3	3.3	16.0
Mean – Średnia	32.6	7.0	21.6	3.8	16.3
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: density – gęstości	4.1	2.4	4.5	1.1*	1.6
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × density – lata × gęstość	ns – ni				–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat	2.0*				–

* $0.01 < \alpha < 0.05$; ** $0.001 < \alpha < 0.01$; *** $\alpha < 0.001$

In the research carried out by Czubaszek [2003], cultivar Sławko had the finest grain, and proportion of grain of a diameter above 2.8 mm constituted 47.2%. A lot of grains which were well-filled were also found in cultivar Bajka (24.1% of grain from the fraction over 2.8 mm, and 48.2% from the fraction 2.5-2.7 mm) and cultivar Dragon (16.5 and 53.8%, respectively).

In the research of Pisulewska *et al*. [2010], proportion of fraction with dehulled grain of a diameter 2.5-2.7 mm was within the range 7.4-14.5%, thus was significantly lower.

Table 9. Proportion of grains of a diameter 2.5-2.7 mm depending on the studied factors, %
Tabela 9. Udział ziarniaków o średnicy 2,5-2,7 mm w zależności od badanych czynników, %

1st factor – cultivar/strain Czynnik I – odmiana/ród	2007	2008	2009	2010	Mean for cultivars Średnio dla odmian
Gniady	6.8	64.6	56.3	33.8	40.4
CHD 2875/01	11.9	65.8	56.8	17.3	38.0
CHD 2833/02	8.8	53.7	55.2	24.5	35.5
Bohun	9.3	39.1	46.1	14.7	27.3
Deresz	12.3	47.2	50.7	12.7	30.7
Cwał	11.1	59.0	48.8	13.9	33.2
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: cultivar/strain – odmiany /rodu	6.2	10.4***	5.7***	8.6***	3.8***
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × cultivar/strain – lata × odmiana /ród	13.3***				–
2nd factor – sowing density Czynnik II – gęstość siewu	2007	2008	2009	2010	Mean for sowing density Średnio dla gęstości siewu
300	9.6	56.6	51.9	17.5	33.9
400	9.9	55.8	52.5	18.1	34.1
500	10.7	52.3	52.5	22.8	34.6
Mean – Średnia	10.1	54.9	52.3	19.5	34.2
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: density – gęstości	3.6	6.0	3.3	4.9*	2.2
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × density – lata × gęstość	10.9*				–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat	2.8*				–

* 0.01 < α < 0.05; ** 0.001 < α < 0.01; *** α < 0.001

The proportion of the fraction with small grains in the studied strains and cultivars was within the range 28.1-46.7%. However, in the research of Pisulewska *et al.* [2010], this proportion was much higher and amounted to 51.5%.

The difference between the results obtained in the experiments and literature data indicated that proportion of particular grain fractions is a genetically conditioned trait which may undergo changes depending on the course of weather conditions in the growing season. In the presented studies, no significant diversity in the proportion of the specified grain fractions was indicated in relation to sowing density (Tables 8-11).

Table 10. Proportion of grains of a diameter 2.4-2.2 mm depending on the studied factors,%
Tabela 10. Udział ziarniaków o średnicy 2,4-2,2 mm w zależności od badanych czynników, %

1st factor – cultivar/strain Czynnik I – odmiana/ród	2007	2008	2009	2010	Mean for cultivars Średnio dla odmian
1	2	3	4	5	6
Gniady	39.7	18.4	15.3	41.8	28.8
CHD 2875/01	32.9	16.9	12.8	49.7	28.1
CHD 2833/02	64.2	33.3	22.5	46.1	41.5
Bohun	65.8	39.5	22.4	50.1	44.5
Deresz	64.6	40.3	27.3	54.7	46.7
Cwał	60.7	26.9	17.8	52.1	39.4

Table 10 continue – cd. tabeli 10

1	2	3	4	5	6
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: cultivar/strain – odmiany /rodu	8.4***	7.7***	6.1***	9.4**	3.8***
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × cultivar/strain – lata × odmiana /ród		13.4***			–
2nd factor – sowing density Czynnik II – gęstość siewu	2007	2008	2009	2010	Mean for sowing density Średnio dla gęstości siewu
300	55.4	27.8	20.3	48.1	37.9
400	53.6	29.1	19.7	50.3	38.2
500	55.0	30.8	19.0	48.8	38.4
Mean – Średnia	54.6	29.2	19.7	49.1	38.1
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: density – gęstości	4.8	4.4	3.5	5.4	2.2
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × density – lata × gęstość		ns – ni			–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat		2.8*			–

* $0.01 < \alpha < 0.05$; ** $0.001 < \alpha < 0.01$; *** $\alpha < 0.001$

Table 11. Proportion of grains of a diameter <2.2 mm depending on the studied factors,%
Tabela 11. Udział ziarniaków o średnicy <2,2 mm w zależności od badanych czynników, %

1st factor – cultivar/strain Czynnik I – odmiana/ród	2007	2008	2009	2010	Mean for cultivars Średnio dla odmian
Gniady	1.7	6.1	4.1	20.9	8.2
CHD 2875/01	1.7	4.2	3.1	25.7	8.6
CHD 2833/02	2.9	10.8	7.5	27.3	12.1
Bohun	3.5	14.8	9.5	31.1	14.7
Deresz	3.4	9.2	9.7	29.5	12.9
Cwał	2.9	9.0	4.8	31.3	12.0
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: cultivar/strain – odmiany /rodu	0.5***	4.2***	5.1***	6.0***	2.1***
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × cultivar/strain – lata × odmiana /ród		7.5***			–
2nd factor – sowing density Czynnik II – gęstość siewu	2007	2008	2009	2010	Mean for sowing density Średnio dla gęstości siewu
300	2.8	9.0	6.4	29.9	12.0
400	2.7	8.8	5.9	27.9	11.3
500	2.6	9.3	7.0	25.2	11.0
Mean – Średnia	2.7	9.0	6.4	27.6	11.4
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: density – gęstości	0.3	2.4	2.9	3.4**	1.2
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: interaction – interakcji: years × density – lata × gęstość		6.2*			–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat		1.6*			–

* $0.01 < \alpha < 0.05$; ** $0.001 < \alpha < 0.01$; *** $\alpha < 0.001$

CONCLUSIONS

Based on the results obtained in the experiments carried out in the years 2007-2010, the following conclusions can be drawn:

1) the compared in the studies brown-husked (5.90 $Mg \cdot ha^{-1}$) and yellow-husked (6.13 $Mg \cdot ha^{-1}$) oat genotypes did not differ significantly in the grain yield quantity, though between particular strains and cultivars (Gniady, CHD 2875/01, CHD 2833/02, Bohun, Deresz and Cwał) significant differences were observed both in grain yields and in the number of grains developed per panicle, as well as in 1000 grain weight. The average oat yield obtained in the experiments was 5.6-6.4 $Mg \cdot ha^{-1}$, while the highest yields were obtained from the brown-husked strain CHD 2833/02;
2) diverse sowing density (300, 400, 500 $grains \cdot m^{-2}$) had no significant effect on the grain yield quantity in different studied oat forms, however it significantly varied panicle number and grain number per panicle;
3) the studied experimental factors (cultivars/strains and sowing density) significantly affected grain plumpness. The highest yielding cultivars and strains of oats (CHD 2833/02, Bohun, Deresz) were characterized by the highest proportion of small grains (<2.2 mm) and a lower content of large grains;
4) the course of weather conditions in the years of research significantly varied yield quantity, structural yield components and the proportion of grains from particular fractions. In 2008, under conditions favorable for plant growth and development, the proportion of grains from the fraction 2.5-2.7 mm was higher than in other years of experiments.

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WPŁYW ZRÓŻNICOWANEJ GĘSTOŚCI SIEWU NA PLON I ELEMENTY SKŁADOWE BRUNATNO- I ŻÓŁTOPLEWKOWYCH GENOTYPÓW OWSA SIEWNEGO

Streszczenie. Celem pracy była ocena wpływu różnych gęstości siewu oraz przebiegu warunków atmosferycznych w okresie wegetacji na plon i elementy składowe plonu wybranych brunatno- i żółtoplewkowych genotypów (odmian i rodów) owsa siewnego. Dwuczynnikowe doświadczenie polowe przeprowadzono w latach 2007-2010 w Zakładzie Hodowlano-Produkcyjnym Małopolskiej Hodowli Roślin w Polanowicach koło Krakowa. Pierwszy czynnik badawczy stanowiło 6 odmian/rodów owsa siewnego: 3 odmiany/rody brunatno- (Gniady, CHD 2875/01, CHD 2833/02) i 3 odmiany żółtoplewkowe (Bohun, Deresz i Cwał). Drugim czynnikiem były 3 gęstości siewu: 300, 400 i 500 kiełkujących ziaren$\cdot$m^{-2}. Porównywane w badaniach brunatno- (5,90 Mg$\cdot$ha^{-1}) i żółtoplewkowe (6,13 Mg$\cdot$ha^{-1}) genotypy owsa siewnego nie różniły się istotnie wielkością plonu ziarna, natomiast pomiędzy poszczególnymi rodami i odmianami (Gniady, CHD 2875/01, CHD 2833/02, Bohun, Deresz i Cwał) stwierdzono istotne różnice zarówno w plonach ziarna, jak i liczbie ziaren wykształconych w wiesze i masie 1000 ziaren. Średni plon owsa uzyskany w doświadczeniach wyniósł 5,6-6,4 Mg$\cdot$ha^{-1}, a najwyżej plonującym okazał się brązowoplewkowy ród CHD 2833/02. Zróżnicowana gęstość siewu nie miała wpływu na wielkość plonu ziarna, natomiast istotnie różnicowała elementy składowe plonu. Wzrost zagęszczenia był wprost proporcjonalny do liczby wiech wykształconych na jednostce powierzchni. Badane czynniki doświadczalne miały istotny wpływ na celność ziarna w badanym materiale. Najwyżej plonujące odmiany i rody (CHD 2833/02, Bohun, Deresz) cechowały się większym udziałem ziaren małych (<2,2 mm) i mniejszą zawartością ziaren dużych. Przebieg warunków pogodowych w latach prowadzenia badań istotnie różnicował wielkość plonu, elementy składowe plonu oraz udział ziarniaków poszczególnych frakcji. W korzystnych dla wzrostu i rozwoju roślin owsa warunkach 2008 roku, udział ziarniaków frakcji 2,5-2,7 mm był większy niż w pozostałych latach prowadzenia doświadczeń.

Słowa kluczowe: barwa plewki, elementy składowe plonu, gęstość siewu, owies siewny, plon ziarna

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