ISSN 1644-0625
ISSN 2300-8504 (online)
www.agricultura.acta.utp.edu.pl

Acta Sci. Pol. Agricultura, 14(3) 2015, 73-83

YIELD CHANGEABILITY OF WINTER WHEAT CULTIVARS IN DIVERSIFIED ENVIRONMENTS AND HERBICIDE VARIANTS

Renata Kieloch, Ryszard Weber, Andrzej Doroszewski, Leszek Purchała

Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy

Abstract. Yield size is the product of the genetic properties of the cultivar, environmental conditions, and the applied agrotechnics, including herbicide application. In agricultural practice, cultivars with high adaptation to changeable environmental conditions and tolerant in relation to many active substances of herbicides are preferred, as this ensures the obtainment of stable yield. The aim of the work was the evaluation of the effect of different herbicides on the yield changeability of winter wheat cultivars grown in diversified environmental conditions in Lower Silesia. In the years 2010-2013, field experiment was carried out on the yield changeability of four winter wheat cultivars (Boomer, Cubus, Nadobna, and Rapsodia) depending on the herbicide and environmental conditions. Studied environments were located in two towns in the vicinity of Wrocław, with diversified soil conditions (podsolic soil and chernozem). Three herbicides with different action mechanisms were applied: Panida 330 EC (pendimethalin), Snajper 600 SC (diflufenican + isoproturon), and Axial 100 EC (pinoxaden) with adjuvant Adigor 440 EC. Multivariate analysis of variance and discriminant analysis were used for the evaluation of the yield changeability of wheat cultivars in the particular environments. In order to group herbicides of similar effect, Ward's method of cluster analysis was applied. Cultivar Rapsodia was characterized by significantly higher yield, whereas Nadobna gave lower yield, in particular on chernozem. The studied variants of plant protection against weeds did not diversify the yield size of winter wheat cultivars. Cultivar Cubus was characterized by higher yield stability in comparison with the other cultivars. Herbicide Panida 330 EC contributed to the higher yield changeability of the studied cultivars. The chemical may contribute to the reduction in grain yield of some winter wheat cultivars in unfavourable environmental conditions.

Key words: cultivar, herbicide protection, genotype-environment interaction, soil type, winter wheat, yield stability

Corresponding author: dr inż. Renata Kieloch, Department of Weed Science and Tillage Systems of the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy, Orzechowa 61, 50-540 Wrocław, e-mail: r.kieloch@iung.wroclaw.pl

INTRODUCTION

Winter wheat is a species of the highest cultivation area in Poland and occupies the area of about 2 million ha. Every year new wheat cultivars are registered with diversified agricultural and functional characteristics, which may be cultivated in a given region or several regions of Poland or in the entire country. Adaptability to weather and soil conditions of a given region is the factor that decides about the usefulness of a given cultivar for growth in the particular region. Size of the obtained yield is affected first of all by the genetic properties of the cultivar, which may be modified by environmental conditions and the applied agrotechnics. One of the major factors that affect yield size is weather conditions during the growth season, in particular temperature and precipitation [Orzech *et al*. 2009, Rymuza *et al*. 2012]. Moreover, winter wheat cultivars are characterized by diversified tolerance to changeable environmental conditions, as well as to the applied agrotechnics [Oleksiak and Mańkowski 2007].

Protection of wheat sowing against weeds affects indirectly the yield size, since it prevents yield loss as a result of competitive effect of those agrophages. Increase in the intensification of plant production and simplifications in plant rotation contribute to the increase in winter wheat infestation. Rich offer of herbicides recommended for winter wheat weeding contains chemicals of diversified composition, characterized by different action mechanisms, and making it possible to eliminate many harmful weed species from the crop canopy. Some of them are not, however, fully safe for winter wheat cultivation and cause various kinds of plant damage, which may be a cause of yield decrease [Kong *et al*. 2009, Soltani *et al*. 2011, Singh *et al*. 2013].

Genotypic-environmental analyses of winter wheat cultivars concern interactions of certain genotypes with environment, whereas there is a lack of works that take into account the herbicide effect on yield changeability. The aim of the work was the evaluation of the effect of diversified herbicide protection on yield changeability of four winter wheat cultivars grown in diversified environmental conditions in Lower Silesia.

MATERIAL AND METHODS

Experiment performance

In the years 2010-2013, three series of field studies were carried out on the evaluation of yield changeability of four winter wheat cultivars (Boomer, Cubus, Nadobna, and Rapsodia) depending on the herbicide and environment. The study took into account the experiments carried out in the years 2009/2010, 2010/2011, and 2012/2013. Experiment was also set up in the 2011/2012 season but due to winter wheat freezing (description of the weather conditions can be found in the subchapter "Weather course") it was excluded from the research. The experiment was located in the vicinity of Wrocław, at two locations with diversified soil conditions. The experiment in Jelcz--Laskowice (51°1' N; 70°21' E) was set up on podsolic soil of poor rye complex, formed from weakly loamy sand, whereas the experiment in Turów (50°59' N; 17°3' E) took place on chernozem of very good wheat complex, formed from medium loam. The experiment was set up at split-block design in four repetitions, and the size of experimental plots was 12 m^2. In Jelcz-Laskowice, wheat was sown in early October at the density of 350 grains·m^{-2}, whereas at the other location, around the 20th October and due to a later sowing date at the higher density of 400 grains·m^{-2}. In order to eliminate the harmful effect of weeds on wheat, the experiments were set up in fields with low infestation, in which species of little competition for the plant dominated. In the experiment on podsolic soil, the following occurred: *Stellaria media* L. (8 plants·m^{-2}), *Capsella bursa-pastoris* L. (Medik.) (6 plants·m^{-2}), *Thlaspi arvense* L. (4 plants·m^{-2}), *Viola arvensis* Murr. (11 plants·m^{-2}), and *Veronica hederifolia* L. (7 plants·m^{-2}). At the other location, the following occurred: *Lamium purpureum* L. (8 plants·m^{-2}), *Lamium amplexicaule* L. (10 plants·m^{-2}), *Stellaria media* L. (13 plants·m^{-2}), *Thlaspi arvense* L. (11 plants·m^{-2}), and *Viola arvensis* Murr. (5 plants·m^{-2}). On the control , the weeds were removed manually. The following herbicides were applied in the experiments: Panida 330 EC (pendimethalin 330 g·dm^{-3}) at the dose of 4 dm^{-3}·ha^{-1}, Snajper 600 SC (diflufenican 100 g·dm^{-3} + chlorotoluron 500 g·dm^{-3}) at the dose of 1.5 dm^{-3}·ha^{-1}, and Axial 100 EC (pinoxaden 100 g·dm^{-3}) applied with adjuvant Adigor 440 EC at the doses of 0.3 dm^{-3}·ha^{-1} + 0.3 dm^{-3}·ha^{-1}. Herbicide Panida 330 EC was applied before emergence and the other herbicides at the stage of 2-3 leaves of winter wheat. The treatments were carried out using the knapsack sprayer "Gloria" with the constant pressure of 0.25 MPa and the utility liquid output of 250 dm^{-3}·ha^{-1}. At full ripeness, yield was collected using the combine harvester Nurserymaster Elite Z 035 and yield was determined as calculated per 14% grain humidity.

Statistical calculations

Calculations were conducted taking as a basis the yield obtained from every plot at the two locations for three years. Yield diversification of winter wheat cultivars in the studied environments under the effect of herbicides was evaluated with the use of three-factor analysis of variance. In order to evaluate the yield changeability of the analyzed wheat cultivars at the particular locations, multivariate analysis of variance was used (MANOVA), as well as the discriminant analysis method described by Morrison [1976], Caliński and Chudzik [1980] and Krzyśko [1990]. The above analysis makes it possible to evaluate the yield of wheat cultivars defined by eight variables: four herbicide variants and two environments, which the towns Turów and Jelcz-Laskowice were and which differed in regard to the soil conditions. In order to confirm the results obtained from the analysis of variance, canonical analysis of the studied variables was carried out. Value significance of the particular elements (canonical variates) was evaluated using the chi-square test. Real dimension of the discriminant space is determined by the first characteristic element that differs significantly from zero. On the other hand, Kaiser's criterion [1960] indicates that two canonical variates ought to be taken into account because their eigenvalues are higher than 1. In canonical variate interpretation, standardized coefficients and correlation values between the studied cultivars and canonical elements were applied. Comparison of the control with the herbicide ones was evaluated as squared Mahalanobis distance, which is the distance between two variants of plant protection in a given environments, in the space defined by four cultivars. Mahalanobis distance is similar to the standard Euclid distance but it additionally takes into account correlations between the studied variables. The higher the distance shown in the tables, the further from one another the analyzed herbicide variants are situated and the greater discriminant power is possessed by the presented model in the diversification of the yield of the studied cultivars. In order to compare the results obtained in the diversified herbicide variants, also Ward's method of cluster analysis [1963] was applied. The closer the location of the particular weeding methods, the higher intergroup similarity of the studied plots can be found. Statistical calculations were carried out using the program Statistica 6.0.

Weather course

Both locations were characterized by similar weather course in the particular research years (Table 1). Weather conditions in the spring of 2010 were characteristic for the studied period, when excessive precipitation in May led to the flooding of the experimental plots in Turów. Floods in this town were also related to the soil conditions, since chernozem is less permeable than podsolic soil at the other location. Also low temperatures for that time of the year were not favourable to wheat growth. Autumn of 2010 was characterized by precipitation shortage in October and low temperatures, which slowed down wheat emergence. Also inhibition of autumn growth occurred relatively early. Spring of 2011 was characterized by favourable weather course for winter wheat growth. It was warm and humid enough for wheat growth. In July, heavy precipitation occurred but only shortly before harvest and did not affect wheat yield. Season 2011/2012 was characterized by mild winter in December and January, whereas in early February heavy frost occurred (average air temperature – 11.2°C), which lasted for about 10 days. Such low temperatures, with the lack of snow cover, led to winter wheat freezing, so as a result that particular season was excluded from the research. In the following study season (2012/2013), the autumn was warmer in comparison with the previous year, which was conducive to wheat emergence and growth. Inhibition of autumn growth occurred in early December, and winter had a relatively mild course with heavy snowfall and short periods of low temperatures. Start of spring growth occurred relatively early (in early April). Spring of 2013 was cool, which slowed down wheat growth and development. Also high precipitation in the first ten days of June affected negatively the yield in that period.

RESULTS

No negative effect on the applied herbicides on the yield of the studied cultivars in the studied environments was found (Table 2). Rapsodia was distinguished by significantly higher yield at the studied locations, whereas Nadobna gave significantly lower yield, in particular in Turów. Significant interaction of herbicides with environments indicates a changeable effect of the studied active substances depending on thee soil and weather conditions.

Multivariate analysis of variance demonstrated significant yield diversification of the studied cultivars at the analyzed locations and herbicide variants (Table 3). Approximate value of the F test indicates that the hypothesis on the equality of four cultivar centroids ought to be rejected at the significance level of $P = 0.05$. Wilks partial lambda values, as well as the F test related to the individual input of a given variable (cultivar) to the discriminant power of the model indicate that the highest yield changeability in the studied protection and location variants was characteristic for cultivars Boomer and Nadobna. On the other hand, Cubus was characterized by high yield stability regardless of the studied environment and the herbicide.

Table 1. Weather conditions during the research period
Tabela 1. Warunki pogodowe w czasie prowadzenia badań

Years Lata	Weather characteristic Czynnik pogodowy	Month – Miesiąc											
		September wrzesień	October październik	November listopad	December grudzień	January styczeń	February luty	March marzec	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień
Turów													
2009/2010	T, °C	15.9	7.9	6.4	-0.4	-6.0	-1.2	4.2	9.5	12.5	17.6	21.2	19.2
	O, mm	6.8	72.5	30.5	34.2	28	7	40	41	128	34	90	98
2010/2011	T, °C	12.7	7.0	6.2	-4.4	0.2	-1.6	4.6	11.5	14.5	18.5	17.9	19.4
	O, mm	94.0	2.0	63.0	50.0	33.0	7.0	38.0	30.0	49.0	63.0	116.0	63.0
2012/2013	T, °C	14.9	8.9	5.9	-1.0	-1.6	0.1	-0.8	8.5	14.6	17.3	20.2	19.6
	O, mm	46	35	25	19	35.5	24.0	23.8	13.0	30.2	129.2	24.6	27.0
Laskowice													
2009/2010	T, °C	15.8	7.9	6.6	-0.5	-5.9	-0.7	4.0	9.2	12.6	17.6	21.7	19.4
	O, mm	6.1	73.0	30.1	33.7	29.1	7.3	39.3	45.4	127.1	40.4	116.8	83.4
2010/2011	T, °C	13.1	7.0	6.1	-5.3	0.4	-1.9	4.3	11.5	14.3	18.8	17.9	19.1
	O, mm	112.3	2.6	61.9	3.0	28.3	6.5	26.6	26.5	42.1	71.9	105.4	76.4
2012/2013	T, °C	14.6	8.8	5.6	-0.9	-1.7	0.0	-0.8	8.9	14.3	17.1	20.4	19.3
	O, mm	43.8	37.0	23.9	14.2	39.5	23.2	24.6	13.6	31.5	130.0	26.6	27.4

T – monthly mean temperature – średnia miesięczna temperatura powietrza
O – monthly precipitation sum – suma miesięczna opadu atmosferycznego

Table 2. Yield of winter wheat cultivars in the studied environments under the effect of herbicide – mean for three years, t·ha^{-1}
Tabela 2. Plonowanie odmian pszenicy ozimej w badanych siedliskach pod wpływem działania herbicydu – średnia z trzech lat, t·ha^{-1}

Herbicides Herbicydy	Dose Dawka	Cultivar – Odmiana				
		Boomer	Cubus	Nadobna	Rapsodia	mean średnia
		Jelcz – Laskowice				
Control – Kontrola	–	6.98	6.60	6.63	7.71	6.98
Panida 330 EC	4 dm^3·ha^{-1}	6.56	6.84	6.56	7.39	6.84
Axial 100 EC + Adigor 440 EC	0,3 dm^3·ha^{-1} + 0,3 dm^3·ha^{-1}	6.87	6.40	6.81	7.97	7.01
Snajper 600 SC	1.5 dm^3·ha^{-1}	6.88	6.82	6.84	7.88	7.11
Mean – Średnia	–	6.82	6.67	6.71	7.74	6.98
		Turów				
Control– Kontrola	–	6.68	6.32	5.45	6.93	6.35
Panida 330 EC	4 dm^3·ha^{-1}	6.47	6.06	5.17	6.92	6.16
Axial 100 EC + Adigor 440 EC	0,3 dm^3·ha^{-1} + 0,3 dm^3·ha^{-1}	6.89	6.53	5.40	7.28	6.53
Snajper 600 SC	1.5 dm^3·ha^{-1}	6.90	6.67	5.50	7.10	6.54
Mean – Średnia	–	6.74	6.39	5.38	7.06	6.39
General mean – Średnia ogólna	–	6.78	6.53	6.04	7.40	6.69

LSD – NIR for – dla:
environments – siedlisk 0.26
cultivars – odmian 0.48
interactions – interakcji:
cultivars × environments – odmiany × siedliska 0.64
cultivars × herbicides – odmiany × herbicydy 0.56

Table 3. Discriminant function analysis
Tabela 3. Analiza funkcji dyskryminacyjnej

Cultivar Odmiana	Wilks lambda Lambda Wilksa	Wilks partial lambda Cząstkowa lambda Wilksa	F	Level p Poziom p
Boomer	0.0924	0.0956	6.75	0.0257
Cubus	0.0226	0.3901	1.11	0.4681
Nadobna	0.0655	0.1348	4.58	0.0564
Rapsodia	0.0587	0.1505	4.03	0.0720

Wilks lambda – Lambda Wilksa 0.0088
approximate F – przybliżone F = 1.88; p < 0.0544

Canonical analysis made it possible to obtain four linearly independent functions in the form of characteristic elements. Those functions show multi-characteristic diversification of the yield of the studied cultivars in the area of canonical variables (Table 4). High absolute values of canonical coefficients and significant correlations between the studied variables and canonical elements indicate a high effect of the studied environments and chemical protection variants on the yield changeability of the particular winter wheat cultivars. Two first canonical variables explain in 99% mutual distances between the studied treatments. The participation of the other canonical variables is significantly lower. Results in Table 4 confirm that high input in the creation of first canonical variable is made by cultivars Boomer, Nadobna, and

Rapsodia. However, the analysis of structural coefficients indicates only significant correlations of cultivars Boomer and Nadobna with the first characteristic root. Therefore, it ought to be stated that the greatest effect on the formation of the first discriminatory function is made only by the above cultivars.

Table 4. Standardized coefficients for canonical variables
Tabela 4. Współczynniki standaryzowane dla zmiennych kanonicznych

Variable – Zmienna	Roots – Pierwiastki			
	1	2	3	4
Boomer	-9,4160	3.4679	-1.4113	1.1962
Cubus	-0.7501	-4.5600	1.4454	-0.0510
Nadobna	4.9335	-0.8531	-1.7498	0.3477
Rapsodia	5.5442	1.9030	1.9410	-0.5166
Eigenvalue – Wartość własna	33.45	1.86	0.1211	0.02367
Cumulated % – Skumulowany %	0.9434	0.9933	0.9959	1.0000

Tables 5a and 5b present squared Mahalanobis distance. Insignificant Mahalanobis distances between the control and the particular herbicides confirmed comparable yield of the studied cultivars in the analyzed variants of plant protection. This points to the lack of differences in the yield of the studied cultivars between the control and herbicide treatments at the studied locations. Also significant differences were found between wheat yields (regardless of the weed control method) in the studied environments. This is proven by significant Mahalanobis distances between the locations Jelcz-Laskowice and Turów.

In order to compare the effect of the particular herbicides in comparison with the control , also Ward's method of cluster analysis was applied (Figure 1). When analyzing treatment concentration, two groups of protection variants may be distinguished. One-element group is made of herbicide Panida 330 EC. The second one, much removed, is made of Axial 100 EC + Adigor 440 EC, Snajper 600 SC and the control . Results of cluster analysis indicate different response of the studied cultivars to the studied herbicides. More stable action, regardless of the soil and climate conditions, is demonstrated by herbicides Axial 100 EC + Adigor 440 EC and Snajper 600 SC, whereas Panida 330 EC contributes to increased yield diversification of the cultivars in the studied environments.

Table 5a. Squared Mahalanobis distances between herbicides at locations Jelcz-Laskowice and Turów
Tabela 5a. Kwadraty odległości Mahalanobisa pomiędzy herbicydami w miejscowościach Jelcz--Laskowice i Turów

Herbicide – Herbicyd	Location – Miejscowość							
	Jelcz-Laskowice				Turów			
	(K)	(P)	(A+A)	(S)	(K)	(P)	(A+A)	(S)
Control – Kontrola (K)	0.00	14.4	21.0	13.3	0.0	1.57	2.0	1.6
Panida 330 EC (P)	14.4	0.0	36.5	12.3	1.5	0.00	0.9	5.3
Axial 100 EC + Adigor 440 EC (A+A)	21.0	36.5	0.0	7.3	2.0	0.90	0.0	3.8
Snajper 600 SC (S)	13.3	12.3	7.3	0.0	1.6	5.33	3.8	0.0

Table 5b. Squared Mahalanobis distances between environments Jelcz-Laskowice (L) and Turów (T) depending on the herbicide
Tabela 5b. Kwadraty odległości Mahalanobisa pomiędzy środowiskami Jelcz-Laskowice (L) i Turów (T) w zależności od herbicydu

Location – Miejscowość / Herbicide – Herbicyd	Turów (K)	Turów (P)	Turów (A + A)	Turów (S)
Jelcz-Laskowice / Control – Kontrola (K)	85.1*	70.1*	77.6*	103.2*
Jelcz-Laskowice/ Panida 330 EC (P)	110.3*	99.2*	106.6*	124.6*
Jelcz-Laskowice/ Axial 100 EC + Adigor 440 EC (A+A)	189.1*	164.3*	175.3*	216.0*
Jelcz-Laskowice /Snajper 660 SC (S)	158.8*	139.4*	148.5*	180.1*

* significance – istotność P = 0.05

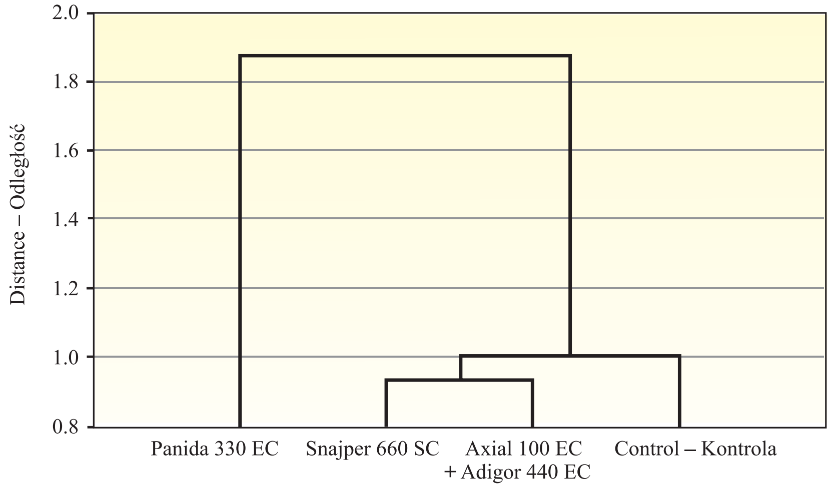

Fig. 1. Cluster analysis for winter wheat yields in different herbicide variants
Rys. 1. Analizy skupień dla plonów pszenicy ozimej w zróżnicowanych wariantach herbicydowych

DISCUSSION

Genotype-environment interaction is a phenomenon that consists of diversified yield of a given cultivar in different environmental conditions. This means that a given cultivar in one type of environment of a given climate region may give high and stable yield, whereas in a different type of environment of that region gives much lower and less stable yield in the long term. Analysis of the genotype-environment interaction makes it possible to group cultivars in regard to yield stability in a given cultivation region. Cultivars that give stable yield demonstrate poor dependency on changeable environmental conditions and, on the contrary, cultivars with higher yield changeability undergo strong environmental influence [Oleksiak and Mańkowski 2007]. In practice, cultivars with high and stable yield in diversified environmental conditions are preferred. The conducted research made it possible to distinguish cultivars with high yield changeability in the studied environment and under the effect of the applied herbicide, namely Boomer and Nadobna. It was also possible to indicate the cultivar of high yield stability in the analyzed conditions, namely Cubus. According to the descriptive characteristics of the breeder's agent [http://www.kws-zboza.pl], this is a cultivar that adapts well to poor soils and is resistant to abiotic stress, which conditions the obtainment of stable yield throughout the years and in diversified environments.

Taking into account yield stability of a given wheat cultivar in different environmental conditions and with diversified herbicide protection, also cultivar response to diversified weather and soil conditions ought to be taken into account, as well as its response to the applied herbicide in given conditions. Herbicides are characterized by different effect on the crop, which results at the same time from the susceptibility of a given cultivar to the active substance of the applied herbicide and from the weather and soil conditions in a given region. Herbicide Panida 330 EC used in the present experiment contains pendimethalin, a component known for its phytotoxic effect on the crop [Lemerle *et al.* 1985, Smith 2004]. Applied before wheat emergence may lead to a delay, inequality, and limitation of the number of emerging plants, in particular in sensitive cultivars and in the conditions of too shallow sowing. The final effect of the above action is grain yield loss. Negative response of winter wheat to the means application, which demonstrates itself with lower yield, is one of the causes of changeable yield of the grown cultivar throughout the years and in different environments.

Winter wheat susceptibility to a given herbicide is not always the same, which is conditioned by inborn cultivar susceptibility to the means and variable weather course during growth. It is a well-known fact that weather and soil conditions during herbicide application modify significantly their effect both in relation to weeds, as well as the crop, through the effect on the uptake, course, and distribution in the plant [Ramsey *et al.* 2002]. On the other hand, weather course throughout the entire growth period affects the condition of the crop, and therefore its susceptibility to different types of stress, including herbicide stress. There have been cases of freezing of winter wheat that was susceptible to the applied herbicide and with low resistance to frost as a result of interaction of this product activity and heavy frost [Kieloch and Rola 2010]. In addition to the weather conditions, also soil properties have a significant effect on herbicide selectivity, in particular in the case of pre-emergence treatments. The amount of herbicide available to plants, and therefore its phytotoxic effect on the cultivated plants, depends on the soil properties, namely pH, organic matter content, and the size of absorbing complex [Fuscaldo *et al.* 1999, Szmigielski *et al.* 2009].

CONCLUSIONS

1. Studied variants of plant protection against weeds did not diversify the yield size of winter wheat cultivars. Cultivar Rapsodia was characterized by significantly higher yield, whereas Nadobna gave lower yield, in particular on chernozem.
2. Discriminant analysis demonstrated that cultivar Cubus was characterized by higher yield stability in comparison with the other cultivars. This indicates small yield diversification of this cultivar both on podsolic soil and chernozem.
3. Herbicide Panida 330 EC contributed to higher yield changeability of the studied cultivars. The chemical may cause grain yield reduction in some winter wheat cultivars in unfavourable environmental conditions.

ACKNOWLEDGMENTS

The study was carried out within task 2.6 in the long-term programme by the Institute of Soil Science and Plant Cultivation – State Research Institute.

REFERENCES

Caliński, T., Chudzik, H. (1980). Grupowanie populacji na podstawie wyników wielozmiennej analizy wariancji. Algorytmy biometryczne i statystyczne, 9, 139-167.

Fuscaldo, F., Bedmar, F., Monterubbianesi, G. (1999). Persistence of atrazine, metribuzin and simazine herbicides in two soils. Pesq. Agropec. Bras., 34(11), 2037-2044.

http://www.kws-zboza.pl.

Kaiser, H.F. (1960). The application of electronic computers to factor analysis. Educ. Psychol. Meas., 20, 141-151.

Kieloch, R., Rola, H. (2010). Sensitivity of winter wheat cultivars to selected herbicides. Journal of Plant Protection Research, 50(1), 35-40.

Kong, L., Si, J., Feng, B., Li, S., Wang, F., Sayre, K. (2009). Differential responses of three types of winter wheat (*Triticum aestivum* L.) to autumn- and spring-applied mesosulfuron-methyl. Crop Prot., 28, 387-392.

Krzyśko, M. (1990). Analiza dyskryminacyjna. WNT Warszawa.

Lemerle, D., Leys, A.R., Hinkley, R.B., Fisher, J.A. (1985). Tolerances of wheat cultivars to pre-emergence herbicides. Australian Journal of Experimental Agriculture, 25, 922-926.

Morrison, D.F. (1976). Multivariate Statistical Methods. 2nd ed, Mc Graw – Hill New York.

Oleksiak, T. Mańkowski, D.R. (2007). Stabilność plonowania i zdolność adaptacyjna odmian jęczmienia jarego do warunków Polski. Biul. IHAR, 246, 45-54.

Orzech, K., Marks, M., Dragańska, E., Stępień, A. (2009). Plonowanie pszenicy ozimej w zależności od warunków pogodowych i różnych sposobów uprawy gleby średniej. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura, 64(4), 122-129.

Ramsey, R.J.L., Stephenson, G.R, Hall, J.C. (2002). Effect of relative humidity on the uptake, translocation and efficacy of glufosinate ammonium in wild oat (*Avena fatua*). Pest. Biochem. Physiol., 73(1), 1-8.

Rymuza, K., Marciniuk-Kluska, A., Bombik, A. (2012). Plonowanie zbóż ozimych w zależności od warunków termiczno-opadowych na polach produkcyjnych Rolniczej Stacji Doświadczalnej w Zawadach. Woda-Środowisko-Obszary Wiejskie, t. 12, z. 2(38), 207-220.

Singh, S.P., Pandey, P., Kumar, M., Singh, S., Pandey, N.S., Srivastva, D. (2013). Growth and biochemical responses of wheat (*Triticum aestivum* L.) to different herbicides. Afr. J. Agric. Res., 8(14), 1265-1269.

Smith, M.A.K. (2004). Pendimethalin phytotoxicity and seedlings weed control in Indian spinach (*Basella alba* L.). Crop Prot., 23, 201-204.

Soltani, N., Shropshire, Ch., Sikkema, P.H. (2011). Response of spring barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.) and wheat (*Triticum aestivum* L.) to mesotrione. Crop Prot., 30, 849-853.

Szmigielski, A.M., Schoenau, J.J., Johnson, E.N., Holm, F.A., Sapsford, K.L., Liu, J. (2009). Development of a laboratory bioassay and effect of soil properties on sulfentrazone phytotoxicity in soil. Weed Technol., 23(3), 486-491.

Ward, J.H. (1963). Hierarchical grouping to optimize an objective function. J. Am. Statist. Assoc., 58(301), 236-244.

ZMIENNOŚĆ PLONOWANIA ODMIAN PSZENICY OZIMEJ W ZRÓŻNICOWANYCH SIEDLISKACH I WARIANTACH HERBICYDOWYCH

Streszczenie. Poziom plonowania jest wypadkową właściwości genetycznych uprawianej odmiany, warunków siedliskowych i stosowanej agrotechniki, w tym ochrony herbicydowej. W praktyce rolniczej preferowane są odmiany o szerokiej adaptacji do zmiennych warunków siedliska oraz tolerancyjne w stosunku do wielu substancji aktywnych herbicydów, co zapewnia uzyskanie stabilnych plonów. Celem badań była ocena wpływu różnych herbicydów na zmienność plonowania odmian pszenicy ozimej uprawianej w zróżnicowanych warunkach siedliskowych na terenie Dolnego Śląska. W latach 2010-2013 wykonano badania polowe nad zmiennością plonowania czterech odmian pszenicy ozimej (Boomer, Cubus, Nadobna, Rapsodia) w zależności od herbicydu i warunków siedliskowych. Badane siedliska były zlokalizowane w dwóch miejscowościach, leżących w okolicach Wrocławia, o zróżnicowanych warunkach glebowych (gleba płowa i czarna ziemia). Do badań wykorzystano trzy herbicydy o różnych mechanizmach działania: Panida 330 EC (pendimetalina), Snajper 600 SC (diflufenikan + izoproturon), Axial 100 EC (pinoksaden) łącznie z adiuwantem Adigor 440 EC. Do oceny zmienności plonowania odmian pszenicy w poszczególnych siedliskach zastosowano wielozmienną analizę wariancji oraz analizę dyskryminacyjną. W celu pogrupowania herbicydów o podobnym efekcie działania zastosowano analizę skupień Warda. Odmiana Rapsodia odznaczała się znacząco wyższym plonowaniem, natomiast Nadobna dawała niższe plony zwłaszcza na czarnej ziemi. Badane warianty ochrony roślin przed chwastami nie zróżnicowały wysokości plonowania odmian pszenicy ozimej. Odmiana Cubus charakteryzowała się większą stabilnością plonowania w porównaniu z pozostałymi odmianami. Herbicyd Panida 330 EC przyczynił się do większej zmienności plonowania badanych odmian. Preparat ten może spowodować redukcję plonu ziarna niektórych odmian pszenicy ozimej w niesprzyjających warunkach siedliskowych.

Słowa kluczowe: interakcja genotypowo-środowiskowa, ochrona herbicydowa, odmiana, pszenica ozima, stabilność plonowania, typ gleby

Accepted for print – Zaakceptowano do druku: 17.04.2015

For citation – Do cytowania:

Kieloch, R., Weber, R., Doroszewski, A., Purchała, L. (2015). Yield changeability of winter wheat cultivars in diversified environments and herbicide variants. Acta Sci. Pol. Agricultura, 14(3), 73-83.