Acta Agrophysica, 2008, 11(1), 23-32

MACROELEMENT CONTENT IN WINTER WHEAT GRAIN AS AFFECTED BY CULTIVATION AND NITROGEN APPLICATION METHODS

Irena Brzozowska

Department of Farming Systems, University of Warmia and Mazury
pl. Łódzki 3, 10-718 Olsztyn
e-mail: brzozi@uwm.edu.pl

A b s t r a c t. The objective of the research was to determine the effect of various cultivation methods and nitrogen fertilization on the content of macroelements (N, P, K, Mg, Ca) in grain of winter wheat. A field experiment with cultivation of winter wheat var. Rysa was carried out in the years 2003-2004 at the Olsztyn University of Warmia and Mazury (UMW), in the Experimental Station in Tomaszkowo. The experiment was conducted with the method of split-plot randomised blocks, in 4 replications, on heavy brown soil ranked in the good wheat complex. The first experimental factor were methods of plant cultivation: 1. Control plot – without cultivation, 2. Harrowing at the tillering stage; 3. Harrowing at the tillering stage (2 – fold); 4. Protection with Aminopielik D 450 SL herbicide; 5. Harrowing (1-fold) + protection with Aminopielik D 450 SL herbicide. The second experimental factor were variants of top dressing nitrogen fertilization (135 kg N ha^{-1}): a) control plot – without nitrogen; b) fertilization with: 70 kg N ha^{-1} after re-vegetation – ammonium nitrate, 65 kg N ha^{-1} at the full stage of shooting – pelleted carbamide; c) 70 kg N ha^{-1} after re-vegetation – ammonium nitrate, 25 kg N ha^{-1} at the beginning of shooting stage and 40 kg N ha^{-1} at the end of the shooting stage – pelleted carbamide; d) as in plot "c", yet with foliar application of the second dose of nitrogen (25 kg N ha^{-1}) with carbamide concentration of 18.1% (8.33% N). The content of macroelements in grain of winter wheat was significantly differentiated between the particular experimental years, except for nitrogen. Significant changes were also observed in contents of phosphorus and magnesium as affected by the cultivation methods applied. Variants of nitrogen fertilization exerted a significant effect only on the concentrations of nitrogen and potassium.

Keywords: winter wheat, macro-nutrients, herbicide, nitrogen, foliar feeding

INTRODUCTION

The primary source of minerals for monogastric animals is plant fodders, and therefore their content in cereal grain is highly important. Macroelements play structural functions, constitute an integral part of enzymes, play the role of regulators of enzymatic processes. Both a deficit and an excess of those elements causes disturbances in the metabolism of plant organisms, and – through their mediation – also in those of animals (Szynal and Sykut 1992). The level of chemical components in grain may be subject to certain variations (Pawłowska and Dietrch-Szóstak 1995). Their content in grain is determined by species- and variety-related features, and also by soil and weather conditions during vegetation and by agricultural measures applied, including plant protection against weed infestation and nitrogen fertilisation (Czuba and Mazur 1988). According to the literature on the subject, the effect of herbicides on the mineral composition of cereal grain is not wholly explicit. One can encounter information supporting the view that such agents cause changes in the content of mineral components (Nowicka 1993, Jurkowska *et al.* 1992). Results obtained by other authors, however, suggest that herbicide preparations, applied at recommended doses and times, in most cases do not cause significant changes in the level of mineral elements in grain (Brzozowska 2003, Brzozowski i Brzozowska 2001, Makarska 1997, Ostapczuk *et al.* 1993). Podolska *et al.* (2004) point out that neglect in providing herbicide protection for sown grain leads to deterioration of qualitative features of wheat grain. In turn, Jurkowska *et al*. (1992) demonstrated that the effect of nitrogen on the mineral composition of grain depends on a variety of factors, e.g. the dose and type of nitrogen fertiliser, growth stage of the plants, etc. Taking the above into consideration, a study was undertaken with the objective of determination of the effect of various methods of cultivation and nitrogen fertilisation on the content of macroelements (N, P, K, Mg, Ca) in grain of winter wheat.

MATERIAL AND METHODS

In the years 2003-2006, at the UWM Experimental Station in Tomaszkowo near Olsztyn, a field experiment with cultivation of winter wheat var. Rysa was carried out, in which the studied factors were various methods of cultivation and nitrogen fertilisation. The experiment was set up with the method of split-plot randomised blocks, in 4 replications, on heavy brown soil ranked in the good wheat complex. The first experimental factor were methods of plant cultivation: 1. Control plot – without cultivation, 2. Harrowing at the tillering stage; 3. Harrowing at the tillering stage (2-fold); 4. Protection with Aminopielik D 450 SL herbicide; 5. Harrowing (1-fold) + protection with Aminopielik D 450 SL herbicide. The second experimental factor were variants of top dressing nitrogen fertilization (135 kg N ha^{-1}): a) control plot – without nitrogen; b) fertilization with: 70 kg N ha^{-1} after restart of vegetation – ammonium nitrate, 65 kg N ha^{-1}, at the full stage of shooting – pelleted carbamide; c) 70 kg N ha^{-1} after restart of vegetation – ammonium nitrate, 25 kg N ha^{-1}, at the beginning of shooting stage and 40 kg N ha^{-1} at the end of the shooting stage – pelleted carbamide; d) as in plot "c", but with foliar application of the second dose of nitrogen (25 kg N ha^{-1}) with carbamide concentration of 18.1% (8.33% N).

Moreover the wheat received pre-sowing fertilisation with nitrogen at the dose of 35 kg ha^{-1} and with phosphorus (P_2O_5 – 80 kg ha^{-1}) and potassium (K_2O – 120 kg ha^{-1}). In the case of the foliar fertilisation (plot D), 300 dm^3 of the working liquid was applied per 1 ha.

The area of a single plot was 16 m^2 (8 m x 2 m). The Aminopielik D 450 SL herbicide was applied at the dose of 3 dm^3 ha^{-1} (Plant protection recommendations 2001). Top dressing was performed by means of a knapsack spraying machine at recommended weather conditions, before evening, applying 300 dm^3 of the working liquid per 1 ha.

Chemical analyses of the grain (in 2004 and 2005) for their macro-element content (N, P, K, Mg, Ca) were performed at the Agricultural Chemistry Station in Olsztyn, as follows: nitrogen – with the potentiometric method, phosphorus – with the vanadium-molybdenum method, magnesium – with the method of absorption atom spectrometry, potassium and calcium – with the method of flame photometry.

RESULTS AND DISCUSSION

The mineral composition of wheat grain var. Rysa was strongly affected by the weather conditions of the analysed seasons covered by the study (Tab. 1).

Table 1. Air temperatures and rainfall in the vegetation period of winter wheat in 2004-2005 according to Meteorological Station in Tomaszkowo

Month	Air temperature (^oC)			Rainfalls (mm)		
	Average of many years	Deviation from normal values (^oC)		Average	Percentage of normal value	
	1961-2000	2004	2005	1961-2000	2004	2005
April	6.9	–0.5	0.6	36.1	128.8	30.2
May	12.7	–0.3	–1.1	51.9	152.8	64.9
June	15.9	–0.8	–2.0	79.3	140.7	60.0
July	17.7	–0.8	2.0	73.8	103.1	126.8
August	17.2	2.6	–0.9	67.1	147.7	49.3
Average or sum	14.1	0.0	–0.3	308.2	133.9	71.0

In 2004, during the period of spring-summer vegetation (April-August), at moderate temperatures there was over 30% more rainfalls that in the multi-year period, but the rainfalls were favourably distributed in time, which was conducive to the crop growth and yielding. In the second year of the study, in turn, there amount of rainfalls was about 30% lower. In the experiment under analysis, the content of macroelements in winter wheat grain was significantly differentiated between the years of the study, with the exception of nitrogen.

Its level was on average from 17.3 g kg^{-1} in the first year to 17.9 g kg^{-1} of dry mass of grain in the second, i.e. below the values given by Czuba and Mazur (1988), concerning average content of the element of in wheat grain originating from various regions of Poland (Tab. 2-6).

Table. 2. Nitrogen (N) content in winter wheat grain depending on applied method of plant cultivation and nitrogen application method (g kg^{-1} d.m.)

Specification	Year of research		Mean
	2004	2005	
Method of plant cultivation (a)			
Without cultivation (Control object)	17.9	16.5	17.2
Harrowing	17.5	17.4	17.5
Harrowing x 2	17.6	17.6	17.6
Herbicide	18.5	17.7	18.1
Harrowing + herbicide	18.2	17.5	17.9
Mean	17.9	17.3	17.6
$LSD_{(0.05)}$	n.s.	n.s.	n.s.
Nitrogen application method (b) (kg ha^{-1})			
Without nitrogen	16.6	13.8	15.2
70 + 65	18.2	18.2	18.2
70 + 25 + 40	17.8	17.7	17.8
70 + 25* + 40	19.0	19.5	19.3
Średnio – Mean	17.9	17.3	17.6
$LSD_{(0..05)}$	0.6	1.2	1.1
$LSD_{(0.05)}$ a x b	n.s.	n.s.	n.s.

*/foliar application $LSD_{(0.05)}$ for years – n.s. – Other interactions – not significant.

The content of macroelements, with the exception of potassium, was higher in 2004 which was a year when high crop yields were produced. The drop observed in the content of macroelements of grain from 2005 can be attributed to the exceptionally unfavourable weather conditions during wheat vegetation. The greatest differences between the years of study were recorded in the case of calcium. Grain from he first year of the study had a calcium content that was more than double (average of 0.64 g kg^{-1} d.m.) compared to that in the second year (average of 0.29 g kg^{-1} d.m.). In the case of nitrogen. phosphorus and magnesium the differences between the years amounted to 10%. In turn, the concentration of potassium in wheat grain in the second years of the study was higher by 9.6% and its average level was 3.81 g kg^{-1} d.m.

Table. 3. Phosphorus (P) content in winter wheat grain depending on the plant cultivation method applied and nitrogen application method (g kg^{-1} d.m.)

Specification	Year of research		Mean
	2004	2005	
Method of plant cultivation (a)			
Without cultivation (Control object)	4.03	3.51	3.77
Harrowing	3.72	3.44	3.58
Harrowing x 2	4.13	3.82	3.98
Herbicide	4.38	3.86	4.12
Harrowing + herbicide	4.15	3.82	3.99
Mean	4.08	3.69	3.89
$LSD_{(0.05)}$	n.i.-n.s.	0.16	0.26
Nitrogen application method (b) (kg ha^{-1})			
Without nitrogen	3.98	3.74	3.86
70 + 65	4.12	3.60	3.86
70 + 25 + 40	3.98	3.68	3.83
70 + 25* + 40	4.24	3.73	3.99
Mean	4.08	3.69	3.88
$LSD_{(0.05)}$	n.s.	n.s.	n.s.
$LSD_{(0.05)}$ a x b	n.s.	n.s.	n.s.

*/ foliar application. $LSD_{(0.05)}$ for years – 0.23 – Other interactions – n.s. – not significant.

The methods of plant cultivation and nitrogen fertilisation did not cause any clear-cut, repeatable in the years and significant changes in the content of the analysed macroelements in wheat grain. Taking an average for the years of the study, the method of wheat cultivation had only a significant differentiating effect on the content of phosphorus and magnesium. The highest content of magnesium was recorded after the application of the herbicide alone (4.12 g kg^{-1} d.m.), but the differences were significant only with relation to wheat grain obtained from the object with no cultivation (3.77 g kg^{-1} d.m.) and that with single harrowing (3.58 g kg^{-1} d.m.).

Table 4. Potassium (K) content in winter wheat grain depending on the plant cultivation method applied and nitrogen application method (g kg^{-1} d.m.)

Specification	Year of research		Mean
	2004	2005	
Method of plant cultivation (a)			
Without cultivation (Control object)	3.70	4.11	3.91
Harrowing	3.98	4.07	4.03
Harrowing x 2	3.83	3.90	3.87
Herbicide	3.78	4.21	4.00
Harrowing + herbicide	3.78	4.55	4.17
Mean	3.81	4.17	3.99
$LSD_{(0.05)}$	n.s.	n.s.	n.s.
Nitrogen application method (b) (kg ha^{-1})			
Without nitrogen	3.68	4.30	3.99
70 + 65	3.64	3.98	3.81
70 + 25 + 40	4.12	4.26	4.19
70 + 25* + 40	3.80	4.12	3.96
Mean	3.81	4.17	3.99
$LSD_{(0.05)}$	0.30	n.s.	0.23
$LSD_{(0.05)}$ a x b	n.s.	n.s.	n.s.

*/ foliar application $LSD_{(0.05)}$ for years – 0.31 – Other interactions – n.s. – not significant.

In turn, the highest concentration of magnesium was ensured by the application of the integrated method of plant cultivation, i.e. harrowing plus herbicide, and of herbicide alone (at 1.30 g kg^{-1} s.m.), but the differences were significant only in comparison to the wheat from the plot with single harrowing (1.19 g kg^{-1} d.m.).

Numerous authors point out the lack of a noticeable clear-cut effect of the studied cultivation measures on the chemical composition of cereal grain (Makarska 1997, Nowicka 1993, Pawłowska and Dietrych-Szóstak 1995). In a study by Makarska *et al.* (2001), irrespective of cultivation measures applied (differentiated fertilisation and chemical plant protection). concentration of mineral components in hard wheat grain was dependent on the individual properties of the genotype. Szynal and Sykut (1992) indicate that the effect of herbicides on the content of mineral components in cereal grain may be varied. However, the authors emphasize that the observed changes are rather related to the interaction of numerous variable external factors, and also to the varied response of particular varieties to the application of the same preparations. Makarska (1997) and Nowicka (1993) suggest that inhibiting effects of herbicides, causing decreasing trends in terms of the content of mineral elements, may become evident under unfavourable atmospheric conditions, and the value of the changes is related to the genetic sensitivity of a given variety to a given preparation.

Table 5. Magnesium (Mg) content in winter wheat grain depending on the plant cultivation method applied and nitrogen application method (g kg^{-1} d.m.)

Specification	Year of research		Mean
	2004	2005	
Method of plant cultivation (a)			
Without cultivation (Control object)	1.35	1.17	1.26
Harrowing	1.23	1.14	1.19
Harrowing x 2	1.25	1.24	1.25
Herbicide	1.30	1.29	1.30
Harrowing + herbicide	1.38	1.21	1.30
Mean	1.30	1.21	1.26
$LSD_{(0.05)}$	0.10	n.s.	0.07
Nitrogen application method (b) ($kg \cdot ha^{-1}$)			
Without nitrogen	1.34	1.20	1.27
70 + 65	1.28	1.17	1.23
70 + 25 + 40	1.26	1.22	1.24
70 + 25* + 40	1.32	1.23	1.28
Mean	1.30	1.21	1.25
$LSD_{(0.05)}$	n.s.	n.s.	n.s.
$LSD_{(0.05)}$ a x b	n.s.	n.s.	n.s.

*/ foliar application $LSD_{(0.05)}$ for years – 0.07 – Other interactions – n.s. – not significant.

In the experiment under analysis, the method of nitrogen fertilisation had a significant effect only on the content of nitrogen and potassium. Wheat fertilised with nitrogen, irrespective of the method of its application, accumulated significantly more nitrogen (17.8-19.3 g kg^{-1} d.m.) than wheat without such fertilisation (15.3 g kg^{-1} d.m.). The highest content of the element was recorded in grain of wheat fertilised in three parts, including a single foliar application (19.3 g kg^{-1} dm.) – significant differences. The highest level of potassium (4.19 g kg^{-1} d.m.) was observed in grain after the application of nitrogen fertilisers in the form of top dressing, in 3 parts in pelleted form. and the differences were significant in comparison to the other methods of application.

Kruczek and Wójtowicz (1998) demonstrated that nitrogen fertilisation caused an increase in nitrogen content in wheat grain. but did not differentiate the content of phosphorus, potassium, magnesium and calcium. Likewise, in a study by Borkowska (2004), varied nitrogen fertilisation had no effect on the content of magnesium and potassium in grain of winter wheat, but the level of phosphorus increased under the effect of increased fertilisation. In turn, in a study by Chwil (2000), the content of magnesium in wheat grain increased with increasing intensity of NPK fertilisation. Kryńska *et al.* (1997), on the other hand. demonstrate that the concentration of mineral elements in cereal grain depends more on the level of nitrogen dosage than on the method of its application.

Table 6. Calcium (Ca) content in winter wheat grain depending on the plant cultivation method applied and nitrogen application method (g kg^{-1} d.m.)

Specification	Year of research		Mean
	2004	2005	
Method of plant cultivation (a)			
Without cultivation (Control object)	0.63	0.29	0.46
Harrowing	0.58	0.29	0.44
Harrowing x 2	0.63	0.29	0.46
Herbicide	0.65	0.29	0.47
Harrowing + herbicide	0.70	0.28	0.49
Mean	0.64	0.29	0.46
$LSD_{(0.05)}$	n.s.	n.s.	n.s.
Nitrogen application method (b) ($kg\cdot ha^{-1}$)			
Without nitrogen	0.64	0.29	0.47
70 + 65	0.70	0.29	0.50
70 + 25 + 40	0.58	0.29	0.44
70 + 25* + 40	0.62	0.29	0.46
Mean	0.64	0.29	0.46
$LSD_{(0.05)}$	n.s.	n.s.	n.s.
$LSD_{(0.05)}$ a x b	n.s.	n.s.	n.s.

*/ foliar application $LSD_{(0.05)}$ for years – 0.08. Other interactions – n.s. – not significant.

Numerous authors point out the significant effect of habitat conditions. including also meteorological conditions, on the chemical composition of cereal grain (Gromova and Polaćek 1995, Jurkowska *et al.* 1992, Makarska 1997, Pawłowska and Dietrych-Szóstak 1995, Rutkowska 2004, Pisulewska 1995, Pisulewska *et al.* 1998). In the literature one cal also find information according to which the course of weather conditions during the vegetation period has only a slight effect on the accumulation of mineral elements in wheat grain (Kruczek and Wójtowicz 1998). Likewise, in a study by Kryńska *et al.* (1997), variable weather conditions in the years of the study had a notable effect on the yield of winter triticale, while their effect on the content of macroelements (N, P, K, Mg, Ca) in the grain was negligible.

CONCLUSIONS

1. The content of the studied macroelements in winter wheat grain varied significantly between the years of the study, with the exception of nitrogen.

2. Among the macroelements under analysis, only the content of magnesium and phosphorus varied with relation to the methods of plant cultivation. The highest content of magnesium was recorded in grain of wheat cultivated with the mechanical-chemical method and the chemical method, and in the case of phosphorus – only with the chemical method.

3. Only the content of nitrogen and potassium changed under the effect of various methods of nitrogen application. The highest content of the element was found in grain of winter wheat fertilised three times, including a single foliar application. and in the case of potassium – after top dressing application of nitrogen in three parts, in pelleted form.

REFERENCES

Borkowska H., 2004. Changes in the concentration of some elements in wheat grain depending on the level of nitrogen fertilization. J. Elementol., 9(3),223-229.

Brzozowska I., 2003. Studies on fertilization and weed control in the cultivation of winter triticale. Wyd. UWM. Rozprawy i monografie, 82.

Brzozowski J., Brzozowska I., 2001. Effect of protective and integrated protective-fertilization treatments on the content of macronutrients in winter wheat grain. Zesz. Probl. Post. Nauk Roln., 478, 113-120.

Chwil S., 2000. Influence of mineral fertilization intensity on winter wheat yield and magnesium content in soil and plant. Biul. Magnezol., 5(4), 278-283.

Czuba R., Mazur T., 1988. Effect of fertilisation on quality of crops (in Polish). PWN, Warszawa.

Gromova Z., Polaćek M., 1995. Odbery zivin u triticale. Rostlinna vyroba, 41(2), 71-75.

Jurkowska H., Rogóż A., Wojciechowicz T., 1992. Content of mineral components in plants with relation to soil moisture. Part I. Macroelements (in Polish). Acta Agraria et Silvestria. Series Agraria, 30, 29-35.

Kruczek G., Wójtowicz J., 1998. Influence of nitrogen fertilization on the yielding and chemical composition of winter grain. Zesz. Nauk. AR w Krakowie, 330, 119-126.

Kryńska B., Majda J., Kud K., 1997. Effect of level and method of nitrogen treatment on the crop of winter cultivars of triticale and contents of macro-elements in grain. Cz. II. Contents of macro-elements in winter triticale grain. Bibl. Fragm. Agron., 3, 353-358.

Makarska E., 1997. Winter triticale grain quality under conditions of application of selected herbicides (in Polish). Wyd. AR w Lublinie. Rozp. hab., 205.

Makarska E., Kowalczyk A., Rachoń L., 2001. Content of mineral nutrients in grain of selected lines of hard wheat (*Triticum durum* Desf.) under different nitrogen fertilization and chemical control treatments. Biul. Magnezol., 6(1), 28-35.
Nowicka B., 1993. The effect of herbicides on yields and crop quality of winter wheat cultivars. IUNG Puławy. Praca doktorska, R(302).
Ostapczuk E., Rola H., Sykut A., Nowicka B., 1997. The effect of herbicides applied at different terms on protein content and amino acides composition in the winter wheat grain of the Arda and Juma varieties. Pestycydy, (1-2), 59-65.
Pawłowska J., Dietrych-Szóstak D., 1995. Effects of some herbicides on yield and quality winter triticale grain. Mat. XXXV Sesji Nauk. IOR. Poznań, Cz. 2, 291-293.
Pisulewska E., 1995. The effect of increasing nitrogen fertilization levels on the yield, protein content and amino acid composition of winter triticale grain. Fragm. Agron., 3(47), 87-95.
Pisulewska E., Zając T., Oleksy A., 1998. Mineral composition of grain of winter triticale cultivars as affected by increasing nitrogen fertilization. Biul. IHAR, 205/206, 179-188.
Podolska G., Stypuła G., Stankowski S., 2004. Yield and grain of winter wheat depending on different plant protection intensity. Annales UMCS. Sec. E, 59(1), 269-276.
Podolska G., Sułek A., 2002. Yielding and technological value of winter wheat grain depending on plant protection methods against diseases and weeds. Pam. Puł., 130 (2), 597-605.
Rutkowska A., 2004. Studies on winter wheat fertilization with nitrogen. Nawozy i nawożenie, 4.
Szynal J., Sykut A., 1992. Effect of selected herbicides on protein content and amino acids composition in winter wheat grain. Bromat. Chem. Toksykol., XXV, 3, 243-249.

ZAWARTOŚĆ MAKROELEMENTÓW W ZIARNIE PSZENICY OZIMEJ W ZALEŻNOŚCI OD SPOSOBU PIELĘGNACJI I NAWOŻENIA AZOTEM

Irena Brzozowska

Katedra Systemów Rolniczych, Uniwersytet Warmińsko-Mazurski, pl. Łódzki 3, 10-718 Olsztyn
e-mail: brzozi@uwm.edu.pl

Streszczenie. Doświadczenie polowe z uprawą pszenicy ozimej odmiany Rysa prowadzono w latach 2003-2004 w Zakładzie Dydaktyczno-Doświadczalnym w Tomaszkowie, należącym do UWM w Olsztynie. Eksperyment realizowano metodą podbloków losowanych, w 4 powtórzeniach, na glebie brunatnej właściwej, ciężkiej, zaliczonej do kompleksu pszennego dobrego. Celem badań było określenie wpływu różnych sposobów pielęgnacji roślin i sposobu nawożenia azotem na zawartość makroelementów w ziarnie pszenicy ozimej (N. P. K. Mg. Ca). Czynnik pierwszy doświadczenia stanowiły sposoby pielęgnacji roślin: 1. Obiekt kontrolny – bez pielęgnacji, 2. Bronowanie w fazie krzewienia roślin, 3. Bronowanie w fazie krzewienia (2-krotnie), 4. Aminopielik D 450 SL, 5. Bronowanie + Aminopielik D 450 SL. Drugim czynnikiem był sposób pogłównego nawożenia azotem (135 kg $N \cdot ha^{-1}$): a) obiekt kontrolny – bez azotu; b) nawożenie: 70 kg $N \cdot ha^{-1}$ po wznowieniu wegetacji – saletra amonowa, 65 kg $N \cdot ha^{-1}$ w fazie strzelania w źdźbło – mocznik granulowany; c) 70 kg $N \cdot ha^{-1}$ po wznowieniu wegetacji – saletra amonowa, 25 kg$N \cdot ha^{-1}$ w fazie strzelania w źdźbło oraz 40 kg $N \cdot ha^{-1}$ w końcu fazy strzelania w źdźbło – mocznik granulowany; d) jak na obiekcie "c", ale drugą część azotu (25 kg $N \cdot ha^{-1}$) stosowano dolistnie o stężeniu mocznika 18,1% (8,33% N). Z wyjątkiem azotu, zawartość pozostałych makroelementów w ziarnie pszenicy ozimej była istotnie zróżnicowana między latami badań. Stwierdzono także istotne zmiany zawartości fosforu i magnezu, w zależności od stosowanych metod pielęgnacji pszenicy. Sposób nawożenia azotem wywierał istotny wpływ jedynie na ilość azotu i potasu.

Słowa kluczowe: pszenica ozima, makroelementy, bronowanie, herbicyd, azot