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# EVALUATION OF QUALITATIVE FEATURES OF MIKON CULTIVAR WINTER WHEAT GRAIN AND FLOUR DEPENDING ON SELECTED AGRONOMIC FACTORS

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## ABSTRACT

A field experiment was carried out at the Minikowo Agricultural Experiment Station the vicinity of Bydgoszcz and aimed at defining the effect of the sowing date and nitrogen fertilisation on yielding and selected technological parameters of ‘Mikon’ winter wheat grain and flour. Two sowing dates were applied (factor I): optimal in a given year and 2-week delayed date and 4 nitrogen fertilisation levels (factor II): 0, 80, 120 and 160 kg N·ha$^{-1}$. The sowing date delayed by two weeks, as compared with the optimal date, significantly decreased the grain yield by 6.6% and increased the content of wet gluten and the value of sedimentation ratio. The dose of 120 kg N·ha$^{-1}$ was most favourable for ‘Mikon’ winter wheat yielding. A further increase in N fertilisation used to show a tendency for decreased wheat yielding. The qualitative indicators researched showed a growing tendency throughout the range of the nitrogen doses applied. However the nitrogen fertilisation level most favourable for the most important flour technological parameters (content of wet gluten, sedimentation ratio and bread volume) was 120 kg·ha$^{-1}$.

**Key words:** winter wheat, sowing date, nitrogen fertilisation, grain yield, technological parameters

## INTRODUCTION

The experiments conducted so far show clearly that winter wheat yielding and quality are a derivative of numerous factors, including nitrogen fertilisation as being of special importance. It shows a favourable effect not only on the increase in grain yield but also the increase in its content of protein and wet gluten [2,13,14,16,17]. However marking only the percentage content of total protein and gluten in wheat grain does not mean the same as the evaluation of the technological value. The opinion that a high content of both components does not always correspond to a high baking value of flour is confirmed by the results reported by Achremowicz et al. [2]. What is essential is not only the content of these components but in particular low- and high-molecular gliadins and gluteine sub-units which form it, related with baking value [11]. Besides there are reports [1,4] in which the effect of nitrogen fertilisation on the value of technological parameters of wheat did not run in one direction. The discrepancies between the results obtained so far call for further research in this field.

Nitrogen application should be considered together with other factors which condition its effect to include the sowing date [23]. The literature includes little coverage on the effect of the sowing date on the qualitative features of wheat grain and flour. Furthermore the opinions of various authors on the effect of the sowing date, e.g. on the percentage of total protein in cereals are not compliant. Mazurek and Podolska [21] claim that a late sowing date increases the percentage of total protein in winter wheat grain. However the reports by Wilczyńska-Kostrzewa [27] show that the content of protein in wheat grain does not depend on the sowing date.

The working hypothesis assumes that the sowing date and N fertilisation are one of the most important agronomic treatments which can determine winter wheat yielding and technological properties of grain and flour. The aim of the present research was to determine the effect of optimal and late sowing date and a varied N and their interaction on yielding and technological value of grain and 'Mikon' winter wheat grain and flour.

## MATERIAL AND METHODS

The field experiment was carried out over 1995-1998 at the Minikowo Agricultural Experiment Station on typical lessive soil, classified according to the international FAO-UNESCO classification as Albic Luvisols. The soil representing very good rye complex showed a neutral reaction and the content of phosphorus, potassium and magnesium was, respectively, 77-102 mg $P \cdot kg^{-1}$ of soil (content ranging from high to very high), 128-221 mg $K \cdot kg^{-1}$ (content ranging from high to very high) and 31-61 $mg \cdot Mg \cdot kg^{-1}$ (content ranging from medium to high) [18]. The experiment was set up with randomised split-plot method in four replications. The experimental plots to be sown with and fertilised were 25 $m^2$ each, while harvest was made from the area of 15 $m^2$.

The research covered 'Mikon' winter wheat sown on the following days (factor I):
$1^{st}$ – optimal sowing date (25.09.1995, 27.09.1996, 19.09.1997),
$2^{nd}$ – late sowing date (09.10.1995, 11.10.1996, 06.10.1997).

Nitrogen fertilisation (factor II) was applied in a form of 34% ammonium nitrate for three fertilisation levels + control without nitrogen ($N_0$):

- 80 kg $N \cdot ha^{-1}$ ($N_{80}$) – applied once at the beginning of spring vegetation period – in phase 23 following the Zadoks scale,
- 120 kg $N \cdot ha^{-1}$ ($N_{120}$) was divided 2/3 at the beginning of spring vegetation period (phase 23 following the Zadoks scale) and 1/3 over full shooting stage – phase 34 compliant with the Zadoks scale,
- 160 kg $N \cdot ha^{-1}$ ($N_{160}$) was divided into 1/2 at the beginning of spring vegetation period (phase 23 compliant with the Zadoks scale), 1/4 at full shooting stage (phase 34 compliant with the Zadoks scale) and 1/4 at the beginning of earing – at phases 50-51 compliant with the Zadoks scale.

The same level of fertilisation with phosphorus and potassium was used, namely, 26 kg $P \cdot ha^{-1}$ and 100 kg $K \cdot ha^{-1}$, respectively. The winter wheat forecrop was oat harvested for green matter. Wheat was sown following grain dressing with Baytan Universal 17.5 at the amount of 200 $g \cdot 100\ kg^{-1}$ of grain. Over the experiment, following the beginning of the spring vegetation period, a chemical weed control treatment was made using the following preparations: Granstar (20 $g \cdot ha^{-1}$) in 1996 and Dicuran Forte (1.5 $kg \cdot ha^{-1}$) over 1997 and 1998. Plants were harvested over full maturity stage.

In the experiment grain yield was determined as well as the following baking value indicators:

- in ground grain – the content of total protein – $\%N \cdot 5.70$ (following Kjeldahl, PN-75A-04018) and falling number (according to Hagberg, PN-ISO-3093),
- in flour – the content of gluten and gluten weakening (PN-A-74-043), sedimentation ratio (the Zeleny test, PN-ISO-5529) and bread volume obtained with 100 g of flour (PN-A-74108).

The results obtained were verified statistically with variance analysis, while boundary differences were evaluated with the Tukey test at significance level $\alpha = 0.05$. To define the relationships and dependences between nitrogen fertilisation and the results obtained of the winter wheat quality features researched, the results obtained were linear-correlation and linear regression analysed (separately for sowing dates $1^{st}$ and $2^{nd}$). Linear regression equations are presented in a graphic form only for the correlation for which the value of determination coefficient exceeded 70%.

## RESULTS

Mean air temperature over the vegetation period over the experimental years was 7.2°C and remained at the level of multi-year mean. Over the research years, that is 1995/96, 1996/97 and 1997/98 the total precipitation from sowing to harvest was higher, respectively by 19%, 11% and 23% as compared with the multi-year mean (Table 1).

**Table 1. Weather conditions at the Minikowo Agricultural Experiment Station over wheat growth and development**

| Research year | Sowing date | Vegetation period | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | From sowing to harvest | | | From beginning of spring vegetation to harvest | | | From earing to harvest | | |
| | | days | °C | mm | days | °C | mm | days | °C | mm |
| 1995/96 | 1st | 329 | 6.0 | 476.7 | 123 | 15.6 | 318.1 | 73 | 16.4 | 239.1 |
| | 2nd | 315 | 5.6 | 456.9 | | | | | | |
| 1996/97 | 1st | 318 | 7.3 | 445.0 | 143 | 13.1 | 321.3 | 68 | 18.1 | 189.0 |
| | 2nd | 304 | 7.1 | 429.1 | | | | | | |
| 1997/98 | 1st | 335 | 8.0 | 492.2 | 145 | 14.8 | 296.7 | 85 | 16.9 | 214.7 |
| | 2nd | 318 | 7.8 | 470.9 | | | | | | |
| Mean for 1985-95 | | September – August | 7.4 | 401.1 | April – August | 14.4 | 223.2 | June – August | 17.4 | 153.6 |

1st – optimal
2nd – late

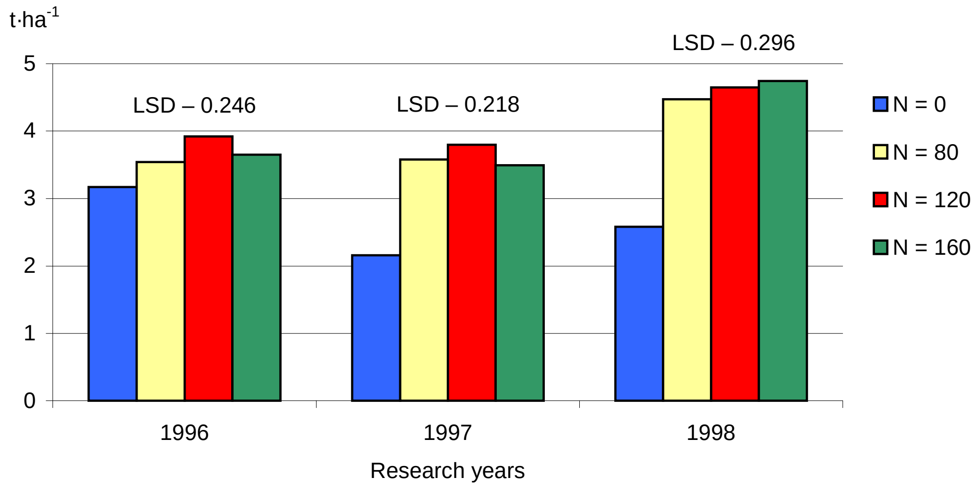
There was observed a significant effect of the sowing date on winter wheat grain yielding (Table 2). Irrespective of the cultivation years and nitrogen fertilisation level, the sowing date delayed by two weeks resulted in, as compared with the optimal sowing date, a significant decrease in grain yield by 6.6%. The application of 80 kg N·ha$^{-1}$ significantly (by 46%) increased the grain yield as compared with the control; further increases in N fertilisation did not affect the mean wheat yield, however over 1996 and 1997 a significant increase in yielding was also recorded following the application of the dose of 120 kg N·ha$^{-1}$. Increasing the N dose to the level of 160 kg·ha$^{-1}$ resulted in a significant, except for 1998, decrease in wheat grain yield as compared with the dose of 120 kg N·ha$^{-1}$ (Fig. 1). There was noted no significant effect of the interaction between the sowing date and nitrogen fertilisation on the wheat grain yielding.

**Table 2. Effect of the sowing date and nitrogen fertilisation on 'Mikon' winter wheat grain yielding over 1995-1998, t·ha$^{-1}$**

| Sowing date (I) | N fertilisation (II), kg N·ha$^{-1}$ | | | | Mean |
|---|---|---|---|---|---|
| | 0 | 80 | 120 | 160 | |
| 1st – optimal | 2.79 | 3.94 | 4.27 | 4.11 | 3.77 |
| 2nd – late | 2.49 | 3.79 | 3.98 | 3.81 | 3.52 |
| Mean | 2.64 | 3.86 | 4.12 | 3.96 | 3.64 |
| $LSD_{0.05}$ for factors | II – 0.691 | | | | I – 0.103 |
| for interaction I x II | ns | | | | |
| II x I | ns | | | | |

ns – non-significant differences

**Fig. 1. Winter wheat grain yield (1996-98) depending on the nitrogen fertilisation level, kg·ha$^{-1}$**




A late sowing date significantly affected the content of wet gluten and sedimentation ratio, and N fertilisation – on most of the technological grain and flour parameters researched (Table 3). Over successive years a two-week delay in the sowing date resulted in a significant increase in the content of protein by an average of 3 g·kg$^{-1}$ (1996), 7 g·kg$^{-1}$ (1997) and 9 g·kg$^{-1}$ (1998) as compared with the contents obtained for the optimal sowing date (Fig. 2). The content of total protein was also determined by the nitrogen fertilisation. On average for cultivation years, along with an increase in nitrogen doses a significant increase in the protein content, respectively by 9 g·kg$^{-1}$, 22 g·kg$^{-1}$ and 31 g·kg$^{-1}$ was recorded, as compared with the control. The late winter wheat sowing significantly increased the content of wet gluten by 2.3%, as compared with the optimal date. The different doses of nitrogen applied ranging from 0 to 160 kg·ha$^{-1}$ also increased the percentage of wet gluten in grain. On average for cultivation years, there was observed its significant increase following the application of 120 kg N·ha$^{-1}$; as compared with $N_{80}$ and $N_0$ objects, its content was higher by respective 5.5% and 8%. Based on the results obtained it was also calculated that along with an increase in the content of protein in grain, e.g. by 10 g·kg$^{-1}$, the content of gluten can increase by 4.33% (sowing date 1st, Fig. 3) and 4.29% (sowing date 2nd, Fig. 4), while the falling number can increase by 129 s (sowing date 2nd, Fig. 4).

**Table 3. Effect of the 'Mikon' winter wheat sowing date and nitrogen fertilisation on technological parameters over 1995-1998$^{-1}$**

| Technological parameters | Sowing date (I) | N fertilisation (II), kg N·ha$^{-1}$ | | | | Mean | $LSD_{0.05}$ for: | |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 80 | 120 | 160 | | I | II |
| Protein content, % | 1st | 88 | 96 | 113 | 121 | 104 | ns | 5.5 |
| | 2nd | 97 | 105 | 115 | 125 | 111 | | |
| Mean | | 92 | 101 | 114 | 123 | 107 | | |
| Gluten content, % | 1st | 20.7 | 23.1 | 28.8 | 32.8 | 26.4 | 1.93 | 3.74 |
| | 2nd | 23.3 | 25.9 | 31.1 | 34.4 | 28.7 | | |
| Mean | | 22.0 | 24.5 | 30.0 | 33.6 | 27.5 | | |
| Gluten weakening, mm | 1st | 3 | 4 | 4 | 5 | 4 | ns | 0.9 |
| | 2nd | 3 | 4 | 5 | 5 | 4 | | |
| Mean | | 3 | 4 | 5 | 5 | 4 | | |
| Sedimentation ratio, ml | 1st | 36.5 | 39.5 | 49.0 | 53.5 | 44.6 | 2.79 | 5.39 |
| | 2nd | 45.0 | 46.8 | 53.7 | 57.3 | 50.7 | | |
| Mean | | 40.8 | 43.2 | 51.3 | 55.4 | 47.7 | | |
| Falling number, s | 1st | 485 | 394 | 415 | 440 | 408 | ns | 21.0 |
| | 2nd | 411 | 417 | 426 | 449 | 426 | | |
| Mean | | 398 | 406 | 421 | 445 | 417 | | |
| Bread volume, cm$^3$ | 1st | 523 | 534 | 562 | 568 | 547 | ns | 21.8 |
| | 2nd | 530 | 545 | 561 | 566 | 551 | | |
| Mean | | 527 | 540 | 562 | 567 | 549 | | |

1st – optimal, 2nd – late, ns – non-significant differences

**Fig. 2. Total protein content in 'Mikon' winter wheat grain depending on the sowing date**

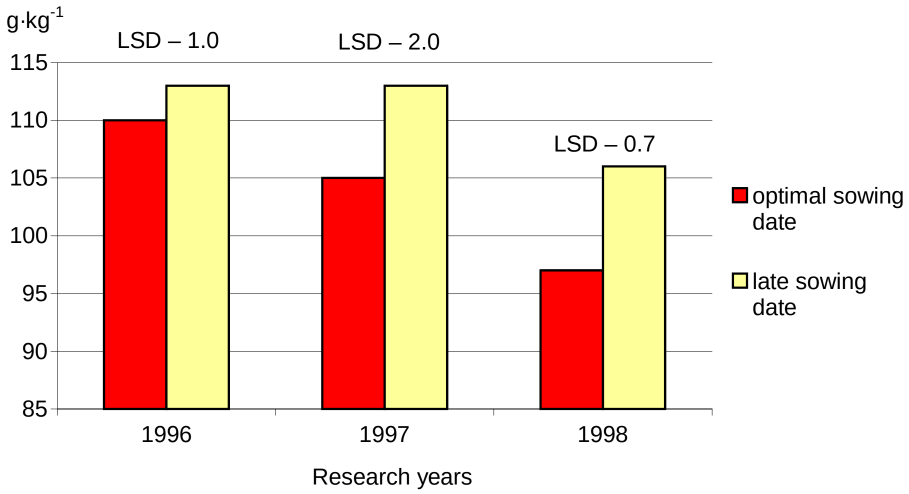
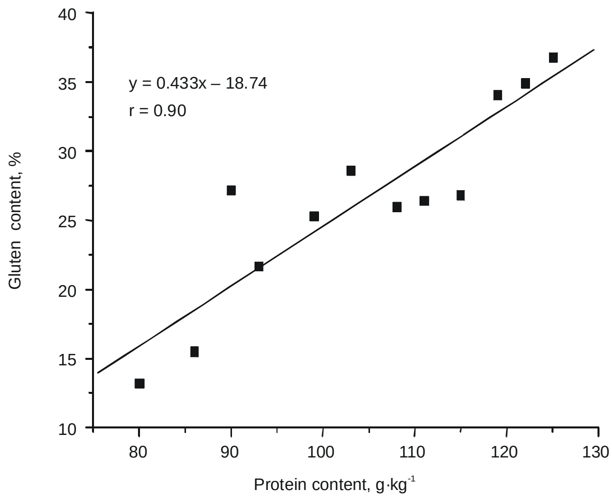
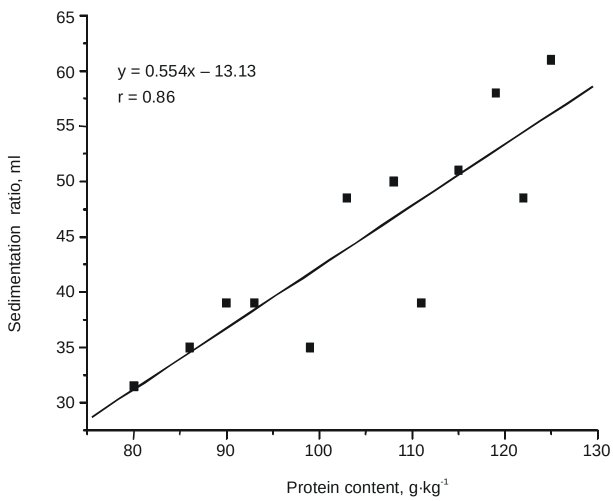
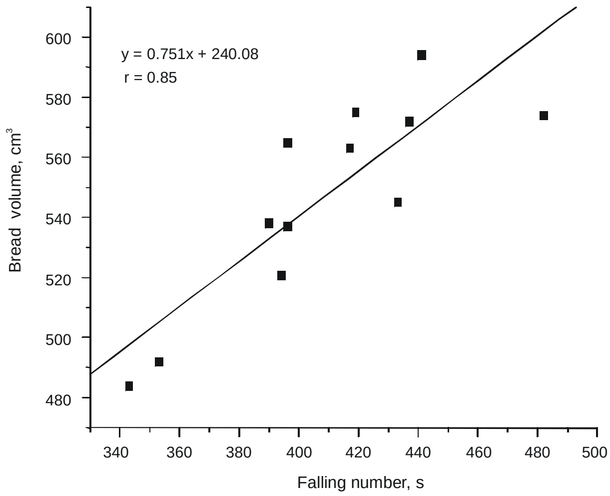
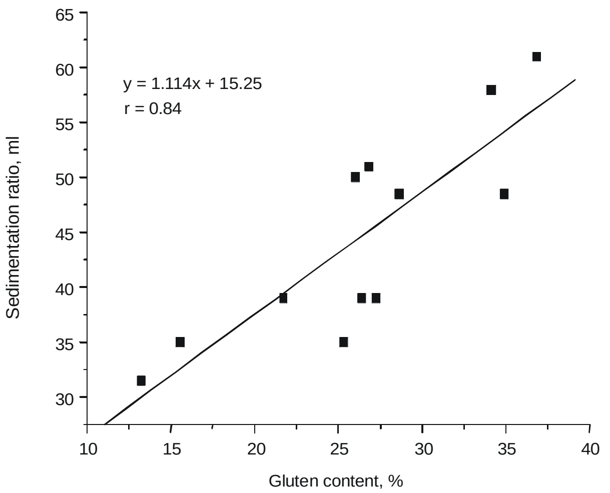


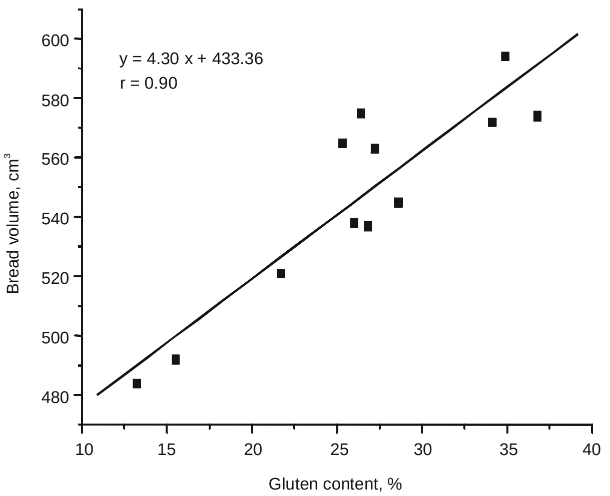

**Fig. 3. Relationships between technological parameters of 'Mikon' winter wheat (sowing date I)**




y = 0.751x + 240.08
r = 0.85
Bread volume, cm3
Falling number, s
600
580
560
540
520
500
480
340
360
380
400
420
440
460
480
500


y = 1.114x + 15.25
r = 0.84
Sedimentation ratio, ml
Gluten content, %
65
60
55
50
45
40
35
30
10
15
20
25
30
35
40


y = 4.30 x + 433.36
r = 0.90
Bread volume, cm3
Gluten content, %
600
580
560
540
520
500
480
10
15
20
25
30
35
40

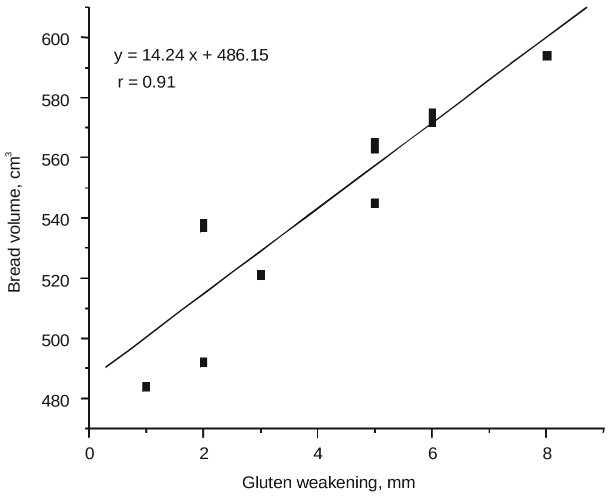
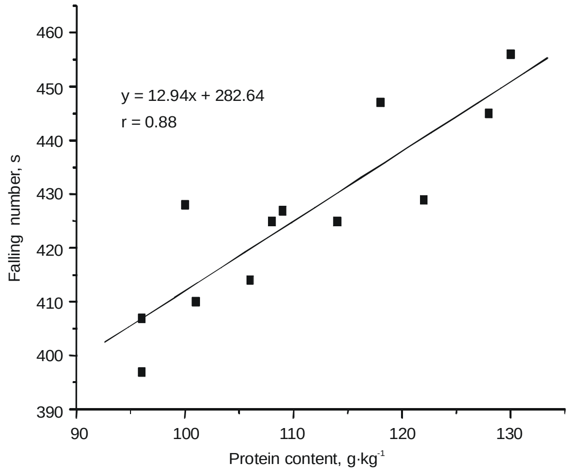
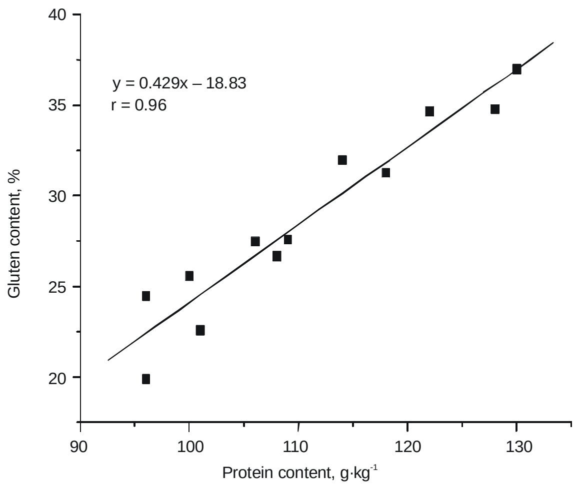
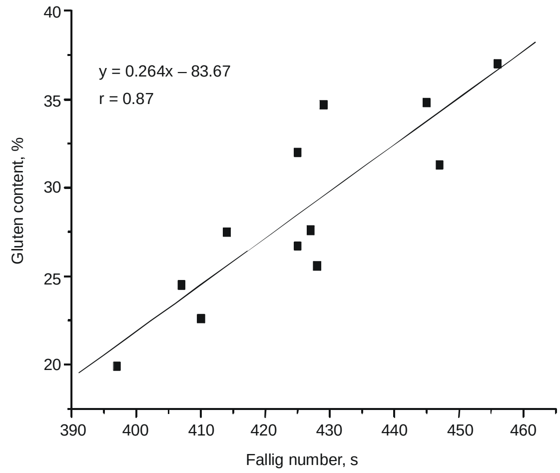



**Fig. 4. Relationships between technological parameters of 'Mikon' winter wheat (sowing date II)**






Determining the protein and wet gluten contents in winter wheat grain is not sufficient to evaluate the baking value of flour. The content of gluten is not the only important indicator but also its quality which is evaluated by gluten weakening. Based on the linear correlation analysis, significant relationships were noted between the content of wet gluten and its weakening, for both sowing dates (r = 0.81 and 0.73) (Table 4). For both sowing dates gluten showed a similar weakening. Irrespective of the cultivation years and the sowing date, the application of 120 kg of N·ha$^{-1}$ significantly increased gluten weakening by 1 and 2 mm, as compared with the values of that feature obtained in $N_{80}$ and $N_0$. A further increase in nitrogen fertilisation to 160 kg·ha$^{-1}$ did not affect gluten weakening.

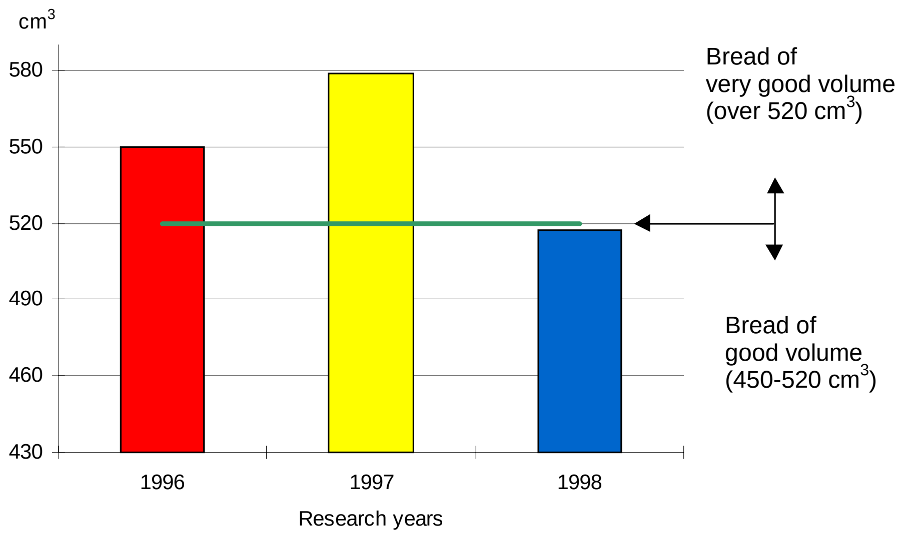
**Table 4. Significant coefficient values of linear correlation between the 'Mikon' winter wheat features researched and the sowing date**

| Parameters | Optimal (1$^{st}$) sowing date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| (1) N fertilisation | – | | | | | | | |
| (2) Grain yield | – | – | | | | | | |
| (3) Protein content | 0.68 | – | – | | | | | |
| (4) Falling number | – | – | 0.61 | – | | | | |
| (5) Gluten content | – | – | 0.90 | 0.77 | – | | | |
| (6) Gluten weakening | – | – | 0.64 | 0.76 | 0.81 | – | | |
| (7) Sedimentation ratio | – | – | 0.86 | – | 0.84 | – | – | |
| (8) Bread volume | – | – | 0.78 | 0.85 | 0.90 | 0.91 | – | |
| | Late (2$^{nd}$) sowing date | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| (1) N fertilisation | – | | | | | | | |
| (2) Grain yield | – | – | | | | | | |
| (3) Protein content | 0.71 | – | – | | | | | |
| (4) Falling number | 0.73 | – | 0.88 | – | | | | |
| (5) Gluten content | – | – | 0.96 | 0.87 | – | | | |
| (6) Gluten weakening | – | – | 0.59 | – | 0.73 | – | | |
| (7) Sedimentation ratio | – | – | 0.75 | – | 0.74 | – | – | |
| (8) Bread volume | – | – | 0.62 | 0.63 | 0.70 | 0.82 | – | – |

The results obtained, irrespective of the cultivation years and the nitrogen fertilisation level, show a significant effect of the sowing date on the sedimentation ratio determined for the flour for the cultivar researched. The value of the sedimentation test was significantly higher for the late sowing date by 13.7% as compared with the value obtained for the optimal sowing date. The present different nitrogen fertiliser doses, irrespective of the cultivation years and the sowing date, increased the sedimentation test results. However a significant effect on the increase in the sedimentation ratio value was observed following the application of nitrogen fertiliser for 120 kg·ha$^{-1}$ as compared with the control and the object where 80 kg N·ha$^{-1}$ was applied, by respective 25.7% and 18.8%. The sedimentation ratio value for flour was closely correlated with the contents of protein and gluten in grain. Determination coefficients for these dependences were, respectively, 74% and 71% (sowing date I) and 56% and 55% (sowing date 2$^{nd}$). One can, therefore, calculate that an increase in the content of total protein by e.g. 10 g·kg$^{-1}$ and of wet gluten by e.g. 5% will be followed by an increase in the sedimentation test value for sowing date I by respective 5.54 ml and 5.57 ml.

Mean for years, the falling number, following Hagberg, of 'Mikon' winter wheat was 417 s. The results obtained showed that a two-week delayed sowing date did not affect the technological feature researched. Due to the application of N dose of 80 kg·ha$^{-1}$, on average for the total research period, the falling number, following Hagberg, did not differ significantly, as compared with its value obtained for the control. Only did the increase in the nitrogen fertilisation up to 120 kg·ha$^{-1}$ significantly increase the value of the falling number, but only as compared with the control. Further increases in nitrogen fertiliser doses up to 160 kg·ha$^{-1}$ significantly increased the said value, as compared with the other nitrogen fertilisation levels, namely $N_0$, $N_{80}$ and $N_{120}$, respectively by 11%, 9.6% and 5.7%. The linear correlation analysis determined the dependences between the value of the falling number and the other qualitative grain features (Table 4). The falling number was positively correlated with the content of total protein (sowing date 1st r = 0.61; sowing date 2nd r = 0.88), with the content of wet gluten (r = 0.77 and r = 0.87), with bread volume (r = 0.85 and r = 0.63) for 1st and 2nd sowing date respectively, and with gluten weakening, however only for the optimal sowing date (r = 0.76).

**Fig. 5. Average bread volume (cm$^3$) in subsequent experimental years**




The bread volume from the trial baking is the final, direct quality indicator which shows a baking value of wheat flour. Irrespective of the experimental factors, the value of the feature researched was, in respective research years, 550 cm$^3$, 579 cm$^3$ and 517 cm$^3$ (Fig. 5). A two-week delay in the sowing date did not result in significant differences in the bread volume, although a higher volume was recorded for sowing date 2nd. The bread volume showed a growth trend throughout the nitrogen dose range researched. However a significant volume increase was recorded following the application of 120 kg N·ha$^{-1}$; as compared with the control and $N_{80}$ object; the bread volume was higher by respective 6.6% and 4.1% and positively correlated with protein content, the falling number, gluten content and weakening (Table 4). Determination coefficients for these relationships were, respectively, 61%, 72%, 81%, 83% (sowing date 1st) and 38%, 40%, 49%, 67% (sowing date 2nd). One can therefore calculate that for the optimal sowing date, along with an increase in e.g. the falling number by 10 s, the content of gluten by 5% and its weakening by 1 mm, the bread volume will increase by respective 7.51 cm$^3$; 21.50 cm$^3$ and 14.24 cm$^3$. However there was recorded no significant effect of the interaction between the sowing date and nitrogen fertilisation on the bread volume and on the other baking value indicators researched.

## DISCUSSION

The sowing date is one of the main agronomic factors which determine winter wheat yielding, which is due to photoperiodic reaction of plants [23]. The research conducted so far show that the reaction of respective wheat cultivars on late sowing date differs clearly. It was observed that for some cultivars even a slight delay in the sowing date significantly decreases the grain yield [10], while for other cultivars such a tendency was recorded only with very late sowing dates [23]. In the present research the two-week delayed sowing date significantly, by almost 7%, decreased the grain yield, which is similar to research reported by Jończyk [10] carried out on good wheat complex soil.

The wheat grain yield depends also on mineral fertilisation, especially nitrogen fertilisation, which is confirmed in numerous literary reports, while the recommended fertiliser doses differ considerably from 80 kg N·ha$^{-1}$ [17,20] to 120 kg N·ha$^{-1}$ [13], and even 160 kg N·ha$^{-1}$ [29]. In the present research the application of 160 kg N·ha$^{-1}$ on very good rye complex soil resulted in, as compared with the most favourable dose of 120 kg N·ha$^{-1}$, a decrease in grain yield.

The reports by Mazurek and Podolska [21] show that a late sowing date increases the total content of protein in cereal grain, which complies with the present results. A significant increase in the total protein content in grain was also due to nitrogen fertilisation for all of the dose range. The relationship is confirmed by the calculated significant positive coefficients of linear correlation both for the optimal (r = 0.67) and late sowing date (r = 0.71). All that complies with the reports by other authors who observed a positive significant effect of increasing nitrogen doses on the content of total protein in wheat grain [5,13,14,15,28,29]. Cygankiewicz [8] and Subda et al. [26] noted a significant correlation between the content of total protein in wheat grain and sedimentation ratio, bread volume, amylolytic activity and gluten weakening. In the present research the calculated linear correlation coefficients confirmed these relationships both for the optimal and late sowing dates.

Sowing wheat at late date significantly increased the content of wet gluten and, similarly as in the present research, its content increased along with increasing doses of nitrogen fertiliser [2,15,17,22,24,25]. Additionally the content of wet gluten depended on the content of total protein in grain. Depending on the sowing date, the linear correlation coefficient for that relationship was significant for both sowing dates (r = 0.90 and r = 0.96); slightly lower values of correlation coefficient between the features discussed were reported by Achremowicz et al. [2] and Cygankiewicz [6,7] (r = 0.87; r = 0.71).

Klupczyński and Ralcewicz [13] and Podolska and Stankowski [24] report on increasing nitrogen fertilisation affecting the unfavourable increase in gluten weakening. In the present research an unfavourable effect on the value of this feature was observed up to 120 kg N·ha$^{-1}$. Further increases in nitrogen fertilisation up to 160 kg·ha$^{-1}$ did not result in significant differences in gluten weakening. It shall be stressed that for the whole nitrogen dose range, gluten weakening fell within the range (0-6 mm) suitable for baking flour [9].

According to Mazurek [19], the sedimentation ratio marked for wheat flour did not show greater differences depending on the sowing date, while in the present research a two-week delayed sowing date, as compared with the optimal sowing date, significantly increased the value of sedimentation test. Also similarly as reported by other authors [13,17,24], nitrogen fertilisation applied to e.g. 'Mikon' plants showed a favourable effect on the sedimentation ratio enhancement. In the spring wheat research reported by Mazurek [19] only the fertilisation with 80 kg N·ha$^{-1}$, as compared with the control, increased the sedimentation ratio value, while the application of higher nitrogen doses did not affect that feature. The value of sedimentation ratio for flour obtained for both sowing dates was closely correlated with the content of protein (r = 0.86 and r = 0.75) and wet gluten (r = 0.84 and r = 0.74). The positive yet slightly lower values of correlation coefficient between the content of total protein and the sedimentation ratio were reported by Cygankiewicz [6] and Subda et al. [26]. Furthermore Cygankiewicz [7] unlike in his earlier reports of 1995 proved no relationship between the sedimentation test results and the content of total protein, which confirms the opinion by Achremowicz et al. [2] and Bichońskiego [3] that the content of total protein cannot serve as a basis to determine the quality of baking flour.

Flour which is most suitable for bread baking is wheat flour of the falling number of 170-250 s [9]. In the present experiment the falling number by Hagberg (417 s) shows a low activity of alpha-amylases. The value of this feature does not disqualify the grain researched as suitable for baking, which is the case for high activity of alpha-amylases, showing the occurrence of sprouting. In the reports by Klupczyński et al. [15], the application of 120 kg N·ha$^{-1}$ significantly increased the falling number, as compared with the control and the object treated with 80 kg N·ha$^{-1}$. In the present experiment a significant increase in the value of the falling number following the application of 120 kg·ha$^{-1}$ was noted only as compared with the control.

Achremowicz et al. [1] observed no significant effect of nitrogen fertilisation on the bread volume obtained from winter wheat flour and a favourable reaction of spring cultivars. Similarly as in the present research, the tendencies to increase bread volume due to increasing doses of nitrogen fertiliser (0 to 160 kg·ha$^{-1}$) were reported for winter wheat by Klupczyński and Ralcewicz [13], Knapowski et al. [17] and Wróbel and Szempliński [29]. According to Jakubczyk and Habeer [9], the bread obtained in the present research showed a very good and good bread volume. However, while considering new proposals of wheat cultivars quality classification criteria developed by Klockiewicz-Kamińska and Brzeziński [12], the bread volume recorded in the present research qualified 'Mikon' as bread cultivar only over 1996 and 1997.

The bread volume obtained for both sowing dates was positively correlated with the content of protein and gluten (r = 0.78 and r = 0.90 and r = 0.62 and r = 0.70). Lower but also significantly positive relationships between the bread volume and the content of protein (r = 0.24) and gluten (r = 0.36) were showed by Subda et al. [26], while Cygankiewicz [6] noted a negative correlation for the interaction of these features. The effect recorded in the same experiments by Cygankiewicz [6] and Subdy et al. [26] of sedimentation ratio on the bread volume was not confirmed in the present research.

## CONCLUSIONS

1. A two-week delayed 'Mikon' winter wheat sowing date, as compared with the optimal date, significantly lowered the grain yield and significantly increased the content of wet gluten and sedimentation ratio.
2. Following the application of the dose of 80 kg $N \cdot ha^{-1}$ there was recorded a significant increase in grain yield for the cultivar researched, as compared with the control, while higher nitrogen doses did not show a significant effect on the winter wheat grain yield.
3. The nitrogen fertilisation applied significantly increased the content of total protein in grain.
4. Nitrogen fertilisation throughout the dose range increased the values of the technological indicators. A significant increase in the values of most important technological parameters (content of wet gluten, sedimentation ratio, bread volume) was recorded due to the application of 120 kg $N \cdot ha^{-1}$.
5. For both sowing dates significant correlation was recorded between:

- content of total protein in grain and the other technological features researched,
- falling number and the content of wet gluten and bread volume,
- content of wet gluten and gluten weakening, sedimentation ratio and bread volume,
- gluten weakening and bread volume.

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