Effect of sowing date on winter wheat yields in Poland

Wpływ terminu siewu na plonowanie pszenicy ozimej w Polsce

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Abstract

The aim of this study was to evaluate the timeliness of winter wheat sowing on results obtained in practical production. The research material comprises results of farm surveys conducted in years 1986-2003 and 2008-2013. Yields obtained by sowing earlier than the date adopted as the optimum did not cause reduction in yields and in many cases were higher than those obtained by sowing in the optimal dates. Delayed sowings were a risk factor reducing yields significantly. After taking into account differences in technology the average yields, on fields sown after optimum sowing date were significantly lower in both analyzed periods, respectively 4,5% and 2,5%. The relatively high yields were obtained from some very late sown fields. It proves that use of appropriate agricultural technology and good forecrops allows to limit the decrease in yield due to late time of sowing.

Keyword: sowing date, winter wheat, yield

Streszczenie

Celem pracy jest ocena terminowości siewów pszenicy ozimej oraz wykorzystania tego czynnika agrotechnicznego w praktyce. Materiał badawczy stanowiły wyniki, prowadzonych w latach 1986-2003 i 2008-2013, badań ankietowych gospodarstw rolnych. Plony uzyskane w wyniku siewów w terminach wcześniejszych niż przyjęte za optymalne nie powodowały zmniejszenia plonów a wielu przypadkach były wyższe niż uzyskiwane przy siewach w terminach przyjmowanych za optymalne. Siew opóźniony stanowił istotny czynnik ryzyka zmniejszenia plonów. Na polach obsiewanych po optymalnym terminie agrotechnicznym średnie plony, po uwzględnieniu różnic agrotechnicznych, były istotnie niższe w obydwu analizowanych okresach, odpowiednio o 4,5% i 2,5%. Relatywnie wysokie plony uzyskiwane po bardzo opóźnionych siewach dowodzą, że opóźnienie nie przekreśla możliwości uzyskania wysokich plonów. Odpowiednia agrotechnika i dobre przedplony umożliwiają zniwelowanie niekorzystnych następstw opóźnień.

Słowa kluczowe: plon, pszenica ozima, termin siewu

Streszczenie rozszerzone

Celem pracy jest ocena terminowości siewów pszenicy ozimej w praktyce oraz wpływu tego elementu agrotechniki na osiągane plony. Materiał badawczy stanowiły wyniki, prowadzonych w latach 1986-2003 i 2008-2013, badań ankietowych gospodarstw rolnych. Ankietowano gospodarstwa towarowe, dostarczające IERiGŻ informacji do Sieci Danych Rachunkowych z Gospodarstw Rolnych (FADN).

Analizowane pola uprawne podzielono na podstawie zaleceń agrotechnicznych uprawy (Podolska, 2005) na pola, na których wysiewano pszenicę przed optymalnym terminem siewu (grupa Tw); na pola, na których wysiewano pszenicę w terminie optymalnym (grupa To) oraz na pola, na których siew wystąpił po terminie optymalnym (grupa Tp).

Przeprowadzona analiza wariancji plonów w zależności od terminu siewu wykazała istotność różnic. Liczebność dla poszczególnych poziomów obserwacji były różne, dlatego do porównania średnich wykorzystano procedurę Tukeya-Kramera (Mądry i in.2010).

Dotrzymanie zalecanych terminów siewu stanowi poważny problem w całym kraju. Największe trudności z zachowaniem optymalnych terminów siewu występowały w północno wschodniej Polsce gdzie ponad 80% areału upraw pszenicy ozimej obsiewano po zalecanym terminie agrotechnicznym, niewiele lepiej było w Polsce środkowo wschodniej. Jedynie w rejonach III i V, czyli w Wielkopolsce i na Śląsku opóźnienia siewu dotyczyły mniej niż 30% obsianych pól (Rysunek 1).

Plony uzyskiwane po siewie wcześniejszym nie ustępowały plonom po siewach w terminie optymalnym a w wieloleciu 1986-2003 były istotnie wyższe niż uzyskiwane przy siewach w terminach przyjmowanych za optymalne. Podobne wyniki uzyskali w trzyletnim doświadczeniu mikropoletkowym Śniady i Sobkowicz (1999) - pszenica ozima przy siewie w terminie wcześniejszym niż zalecany dała istotny wzrost plonu. Przykłady wyższego plonowania pszenicy niektórych odmian, przewyższające uzyskane z zasiewów w terminie optymalnym podają Weber i Podolska (2008). Z kolei w badaniach Kusia i Jończyk (1997) nie stwierdzono istotnego, różnicującego plony, wpływu wcześniejszych siewów a badania Dmowskiego (1993) i Dubisa (2006) wykazały, że wcześniejsze siewy powodowały spadki plonów.

Siew opóźniony stanowił istotny czynnik ryzyka zmniejszenia plonów, który może wystąpić mniej bądź bardziej wyraźnie w zależności od układu warunków pogodowych w okresie wegetacji. Bez względu na jakość gleb i poziom nawożenia opóźnienie siewów powodowało istotne spadki plonów (Tabela 3). Wczesne i terminowe siewy stanowią istotny element agrotechniki zwiększający prawdopodobieństwo uzyskania zwyżki plonów.

Wyniki bardzo zbliżone do uzyskanych na podstawie analizy rzeczywistych plonów uzyskano analizując plony relatywne poprawione, czyli wyliczone po ujednoliceniu głównych czynników agrotechnicznych które w istotny sposób wpływały na wielkość uzyskiwanych plonów, (jakość gleby, nawożenie azotowe i intensywność ochrony chemicznej przed chorobami grzybowymi). Na polach obsiewanych po optymalnym terminie agrotechnicznym średnie plony, po uwzględnieniu różnic agrotechnicznych, były niższe w obydwu analizowanych okresach, odpowiednio o 4,5% i 2,5%. (Tabela 4).

Relatywnie wysokie plony uzyskiwano po bardzo opóźnionych siewach (Tabela 5). Wynikać to może z różnic w stosowanej agrotechnice i wpływu przedplonu. Bardzo opóźnione siewy spowodowane są często względami organizacyjnymi wynikającymi ze struktury przedplonów. Późno schodzące z pola buraki czy kukurydza na nasiona, stanowiące dla pszenicy bardzo dobry przedplon, rekompensujący straty spowodowane późniejszymi siewam, w tej grupie plantacji był wysoki bo wynosił 43,2%, Dla porównania udział tych przedplonów na polach obsiewanych w terminach optymalnych i opóźnionych wynosił odpowiednio 6.6% and 17.2%. Lepsze niż średnie dla pszenicy były też ochrona chemiczna i co jest uzasadnione przy opóźnionych siewach, zwiększona ilość wysiewu (Tabela 6). Uzyskane wyniki mogą być sygnałem, że w następstwie zmieniających się warunków klimatycznych Polski, postępu hodowlanego a także zmieniającego się doboru stosowanych odmian należy ponownie przeanalizować i skorygować zalecenia uprawowe dotyczące terminów siewu dla pszenicy ozimej, a być może również i innych zbóż ozimych.

Introduction

Although the available agricultural land resources have been shrinking gradually, the area under wheat has increased from 1.5 to nearly 2 mln hectares for the last 30 years. Winter wheat, giving better yield in climatic conditions of Poland, accounts for over 80% of the total wheat cultivation area. The larger crop area results naturally in several problems: the shortage of good locations, cultivation on poorer soils and delayed sowing, resulting from harvest date of forecrops and the requirements of pre-sowing soil preparation.

The sowing date is one of the more important factors that determine yield of winter wheat. Research conducted for winter wheat on sowing dates (Green et al. 1985) has shown a trend towards increased yield as sowing is advanced. On the basis of field microplot experiment the reduction in grain yield by two-week delay in sowing is 15%, while sowing delayed by four weeks results in a reduction in yield by about 30% (Podolska, Wyzińska 2011). Higher yields after earlier sowing time were also obtained in experiments conducted by Milford et al. (1993).

The question of the impact of sowing time on wheat yield has been taken up many times in exact experimental conditions, which resulted in optimal sowing time recommendations varying for different climatic regions (Podolska, Kaczyński 1995, Grabiński 2005), and review papers (Grabiński et al. 2007). Not much research assessing the influence of sowing time has been based on data coming directly from production (Harasim, Matyka 2009, Oleksiak, Mańkowski 2007). Despite the awareness of the benefits of timely sowing and the hazard resulting from delay, sowing often takes place long after the optimal time.

It can be assumed that the breeding progress, changes of climate and used agricultural techniques make it necessary to modify the recommendation regarding the timeliness of sowing.

The goal of this paper is to assess the timeliness of winter wheat sowing and the application of those cultivation technology factors, which impact on yields in practice, as well as to attempt to verify recommendations with production results obtained directly from farms.

Material and methods

Material

Results of farm survey data collected across years 1986-2003 and 2008-2013 are the research material. In years 2004-2007 studies were suspended due to lack of funds. Every year 30 farms from all voivodeships were surveyed. Number of fields in the regions were not equal because of different size and farm structure in individual parts of the country. Data from a total of 11548 fields with a minimum area of 1 ha of a total area of 41860 hectares from all provinces were collected and analyzed. The surveys were conducted in representative group of commercial farms that provided information to Institute of Agricultural and Food Economics (IERiGŻ) for the Farm Accountancy Data Network (FADN).

Study area and method

The effect of different sowing dates of wheat (Triticum aestivum L.) on yield of grain was studied. Optimal sowing dates of wheat in Poland by Podolska (2005) are shown in Table 1.

Table 1 Recommended sowing time in regions

Sowing time	Region of north-eastern and eastern	Central region and the south-east	Region of north-western and western	Lower Silesia
Very early - Tve	Before 5 September	Before 10 September	Before 10 September	Before 15 September
Early - Te	From 5 to 14 September	From 10 to 19 September	From 10 to 19 September	From 15 to 24 September
Optimal - To	From 15 to 25 September	From 20 to 30 September	From 20 September to 5 October	From 25 September to 10 October
Late - Tl	from 26 September to 5 October	from 31 September to 10 October	from 6 to 15 October	from 11 to 20 October
Very late - Tvl	After 5 October	After 10 October	After 15 October	After 20 October

The analyzed fields were divided into three groups depending on time of sowing: the fields sown before the optimal sowing time (Te group), fields sown in optimal time (To group) and fields sown after the optimal time (Tl group).

For each level the number of observations was different, hence the Tukey-Kramer procedure (Mądry et al., 2010) was applied to compare means.

For the years 2008 - 2013 yields obtained from the fields where the delay or acceleration of the sowing time exceed 10 days in comparison to the optimal sowing period were analyzed: Tve – very early sowing time and Tvl – very late sowing time (Table 1).

Analyzed data were collected directly from farms where cultivation technology is very differentiated. For individual fields there were significant differences in fertilization, soil quality and level of chemical protection, ie. factors differentiating yields significantly. The impact of these factors on yields is shown in Table 2.To make the data more comparable and to exclude variation resulting from differences in growing conditions the adjusted yield values were calculated. The recalculation of real yields into adjusted yields was conducted according to the methodology proposed by Oleksiak et al. (2004). Multiple regression function was used to estimate the impact of factors affecting wheat yield, and then adjusted yields were calculated for mean levels of the main factors, such as soil quality, nitrogen fertilization and the intensity of chemical protection against fungal diseases.

Table 2 Multiple regression analysis between yield and main yielding factors

A. Year 2008

		Analysis of variance			
Source	DF	Sum of squares	Mean square	F value	Pr > F
Model	3	61635	20545	45,49	<,0001
Error	330	149046	451,65		
Total	333	210681			
Variable	DF	Parameter estimation	Standard error	t value	Pr > |t|
Intercept	1	46,62	5,689	8,20	<,0001
Soil quality	1	0,42	0,070	5,60	<,0001
Mineral fertilization N	1	0,13	0,036	3,59	<,0004
Fungicides	1	9,01	1,792	5,03	<,0001
R^2	0,293				
Adjusted R^2	0,286				

B. Year 2009

		Analysis of variance			
Source	DF	Sum of squares	Mean square	F value	Pr > F
Model	3	79907	26636	66,35	<,0001
Error	390	156558	401,43		
Total	393	236465			
Variable	DF	Parameter estimation	Standard error	t value	Pr > |t|
Intercept	1	54,46	4,934	11,04	<,0001
Soil quality	1	0,34	0,064	5,30	<,0001
Mineral fertilization N	1	0,08	0,026	3,28	<,0001
Fungicides	1	10,45	1,254	8,33	<,0001
R^2	0,338				
Adjusted R^2	0,333				

C. Year 2010

		Analysis of variance			
Source	DF	Sum of squares	Mean square	F value	Pr > F
Model	3	135942	45314	67,79	<,0001
Error	638	426462	668,44		
Total	641	562403			

Variable	DF	Parameter estimation	Standard error	t value	Pr > |t|
Intercept	1	39,61	5,106	7,76	<,0001
Soil quality	1	0,36	0,063	5,73	<,0001
Mineral fertilization N	1	0,26	0,032	8,15	<,0001
Fungicides	1	4,72	1,369	3,45	<,0006
R^2	0,242				
Adjusted R^2	0,238				

D. Year 2011

		Analysis of variance			
Source	DF	Sum of squares	Mean square	F value	Pr > F
Model	3	104300	34767	71,27	<,0001
Error	719	350745	487,82		
Total	722	455045			
Variable	DF	Parameter estimation	Standard error	t value	Pr > |t|
Intercept	1	47,83	4,187	11,42	<,0001
Soil quality	1	0,40	0,052	7,72	<,0001
Mineral fertilization N	1	0,13	0,022	5,94	<,0001
Fungicides	1	6,65	0,995	6,68	<,0001
R^2	0,229				
Adjusted R^2	0,226				

E. Year 2012

		Analysis of variance			
Source	DF	Sum of squares	Mean square	F value	Pr > F
Model	3	94792	31597	46,72	<,0001
Error	451	305014	676,31		
Total	454	399806			
Variable	DF	Parameter estimation	Standard error	t value	Pr > |t|
Intercept	1	42,13	5,713	7,37	<,0001
Soil quality	1	0,41	0,076	5,42	<,0001
Mineral fertilization N	1	0,14	0,034	3,985	<,0001
Fungicides	1	9,47	1,596	5,94	<,0001
R^2	0,237				
Adjusted R^2	0,232				

F. Year 2013

		Analysis of variance			
Source	DF	Sum of squares	Mean square	F value	Pr > F
Model	3	103829	34609	88,39	<,0001
Error	640	250598	391,56		
Total	643	354426			
Variable	DF	Parameter estimation	Standard error	t value	Pr > |t|
Intercept	1	49,24	3,729	13,20	<,0001
Soil quality	1	0,26	0,050	5,21	<,0001
Mineral fertilization N	1	0,20	0,0205	9,81	<,0001
Fungicides	1	5,48	1,0463	5,23	<,0001
R^2	0,293				
Adjusted R^2	0,290				

Determination coefficients of adjusted models have a value between 22,6% and 33,3% in subsequent years. It means that this part of variability could be explained by those factors. The relatively low value of the R^2 determination coefficient is caused by the specific character of the data collected in surveys, directly from the farms, and thus affected by significant error. The obtained results are, however, satisfactory since comparable results were obtained in other analyses of this type (Oleksiak et al., 2004; Laudański et al., 2007, Oleksiak and Mańkowski 2007).

The division into groups according to the quality of habitat was based on the evaluation of soil quality expressed in valorization points (100 points scale) of the agricultural production area (Witek, 1981).

Statistica package version 10 was used for statistical analysis (StatSoft 2006).

Results

Timeliness of sowing

It is a significant problem throughout the country to keep the recommended time of sowing. (Figure1). The largest difficulties to keep the optimal date of sowing were observed in north-eastern Poland, where more than 80% of winter wheat cultivation area was sown after the recommended sowing time, and the results in central-eastern Poland were not much better. Only in regions III and V, that is Wielkopolska and in south-western Poland sowing was delayed on less than 30% of sown fields (Figure 1).

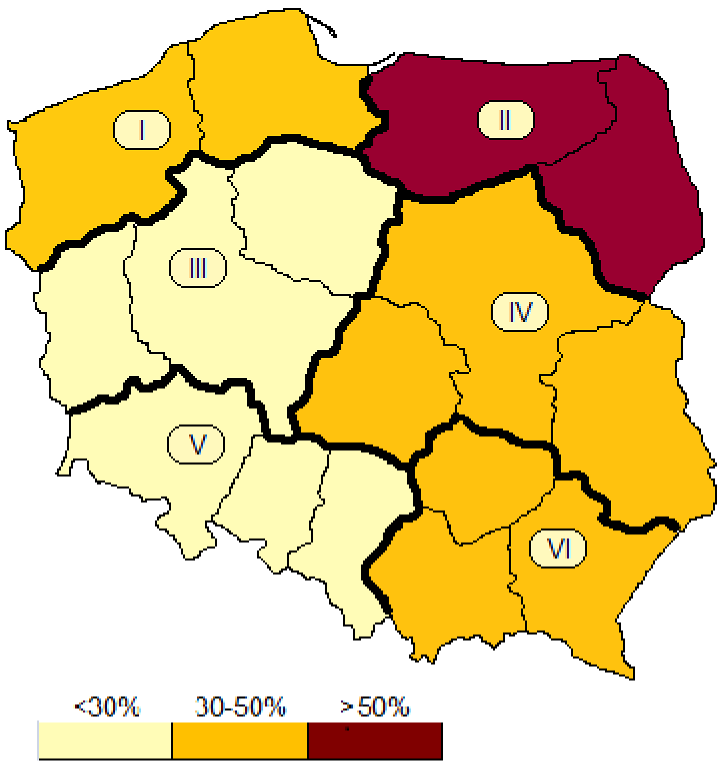

Figure 1. Share of winter wheat plantation sown after recommended cultivation technology date – average of the survey data from years 2008-2013.

Research conducted in 2008-2013 showed that an average of 47.4% of winter wheat fields were sown in optimal time of sowing for given region, 34,6% after the recommended optimal sowing dates (of which 9,7% of the plantation with over 14 days of delay), and 18,0% earlier than recommended. In recent years we can observe improved timeliness of sowing. The share of fields sown during recommended agricultural term remains the same but more and more fields are sown in early terms and share of plantation sown late decreases. Despite the improvement the share of plantation sown after the date agricultural technology is still close to 30%.

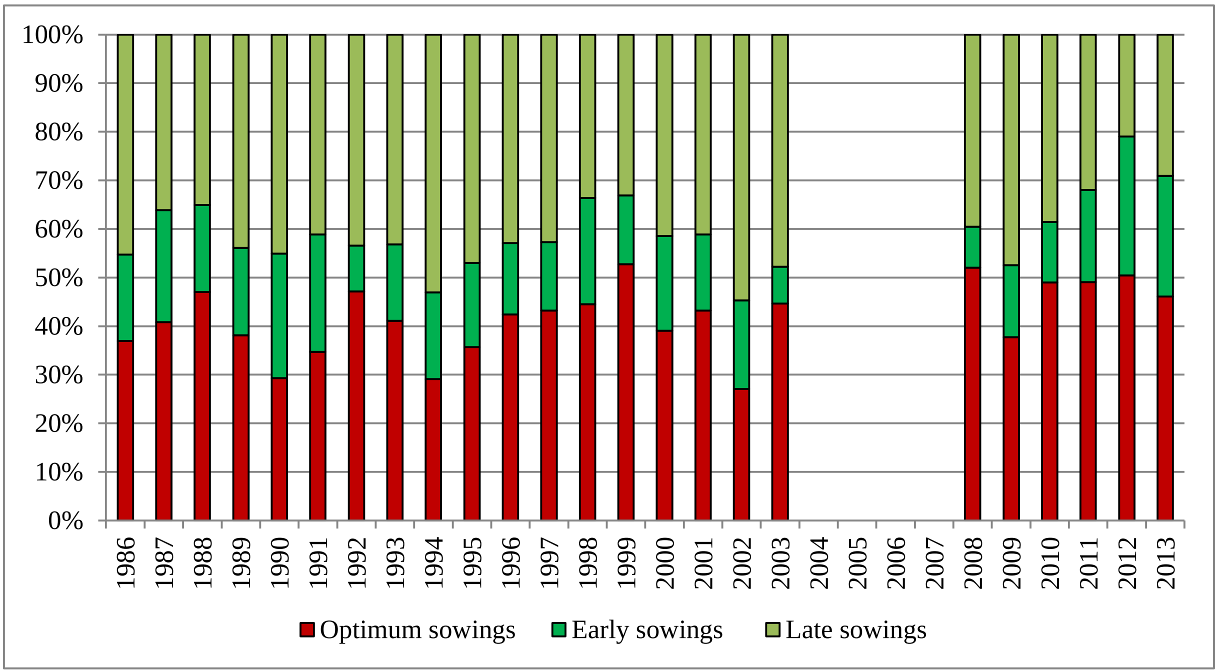

Figure 2. Timeliness of sowing of winter wheat in surveys.

Dependence of yield on sowing date - real yields

The dependency of wheat yield on the timeliness of sowing was analyzed for each year and multi-year periods. The answer to the question how it corresponds to the size of obtained crop is not unambiguous. Yields from fields sown earlier than in term considered to be the optimal usually were higher. For any of the analyzed years there was no significant reduction in yield as a result of accelerated sowing time. When we analyzed the data from the multi-year period the differences were significant. The long term average yields after early sowing were the highest for both analyzed periods but only within years 1986-2003 the yields were higher significantly. The results can be generalized by statement: the earlier sowing the greater probability of yield increase. However, the reported differences were not large. The effects of early or late sowing time for particular years are not always statistically significant and even can be completely reverse in various years. This is due to practically unpredictable influence of the complex of independent weather or environment factors in a given year. Within 24 analyzed years, the average yield of the delayed sowing was significantly higher than yield obtained after the optimum time of sowing

Table 3 Yielding depending on sowing date – real yields [dt·ha^{-1}]

Years	Sowing time			Homogeneous groups by Tukey test *		
	Early	Optimal	Late	Early	Optimal	Late
1986	39,5	40,6	39,9			
1987	44,6	40,6	37,9	A	B	B
1988	43,1	39,3	37,1	A	AB	AB
1989	44,8	44,5	41,3	A	A	B
1990	43,7	43,0	41,4			
1991	44,1	41,2	38,9	A	AB	B
1992	34,3	37,1	36,6			
1993	42,0	41,5	37,3	AB	A	B
1994	38,9	36,3	37,2			
1995	42,8	43,8	40,4	AB	A	B
1996	43,1	39,8	36,0	A	A	B
1997	38,7	35,1	32,3	A	A	B
1998	42,0	41,9	37,4	A	A	B
1999	41,8	38,2	36,2	A	B	B
2000	45,1	42,3	40,6	A	AB	B
2001	46,1	42,5	39,6	A	B	C
2002	42,1	44,1	43,1			
2003	38,5	40,8	42,3			
1986-2003	42,4	40,6	38,7	A	B	C
2008	61,1	57,0	53,0	A	AB	B
2009	54,0	52,8	53,9			
2010	52,2	51,1	50,7			
2011	52,1	52,6	51,6			
2012	50,8	52,3	49,8			
2013	56,6	52,6	55,5	A	B	A
2008-2013	54,3	52,8	52,3	A	AB	B

*- Homogeneous groups marked only for years where there was a significant variance

Table 4 Dependency of the wheat yield to sowing date– relative adjusted yields [%]

Years	Sowing time			Homogeneous groups by Tukey test*		
	Early	Optimal	Late	Early	Optimal	Late
1986	97,4	101,3	100,7			
1987	106,3	101,1	97,2			
1988	100,0	101,5	94,1			
1989	99,8	99,0	92,0	A	A	B
1990	104,5	100,0	97,9			
1991	110,9	107,0	99,9	A	A	B
1992	93,2	104,1	102,7			
1993	102,0	104,5	97,7			
1994	107,3	102,5	102,6			
1995	106,2	102,0	94,1	A	A	B
1996	108,9	99,4	93,6	A	B	C
1997	106,7	98,7	94,2	A	A B	B
1998	104,6	107,8	95,9	A	A	B
1999	115,0	101,8	95,9	A	B	C
2000	111,5	100,8	97,2	A	B	B
2001	107,8	101,9	96,9	A	A	B
2002	96,1	97,8	95,9			
2003	91,8	96,3	99,7			
1986-2003	104,7	101,4	96,9	A	B	C
2008	103,8	98,5	93,5	A	A B	B
2009	101,2	97,1	98,4			
2010	104,2	100,8	97,0			
2011	99,3	100,6	98,0	A	A B	B
2012	94,0	102,4	95,0	B	A	B
2013	101,1	97,6	97,6			
2008-2013	100,2	99,7	97,2	A	A	B

*- Homogeneous groups marked only for years where there was a significant variance

only in one year (2013). It should be noted that in that year the vegetation conditions were extremely favorable for delayed sowing. High, for this time of year, air and soil temperature in November, extended vegetation time and created favorable conditions for growth and development of winter wheat. Late sown crops in the final stage of the autumn growth were well grown and before the period of winter rest properly hardened. In all the other years, yields obtained after sowing within optimal or early terms were higher than yields after late sowing. For farm surveys conducted in years 1986-2003 the average yield from the fields where sowings were delayed was 4.7% lower of the average yield from the fields where the sowing took place during the optimal time and 8,7% lower in compare to fields sown in early date. In farm surveys conducted in the period 2008-2013 the figures were 0,9% and 3,7% respectively (Table 3).

Dependence of yield on sowing date – adjusted yields

Very close results were obtained in the analysis of the adjusted relative yield, i.e. calculated using regression coefficients, for uniform conditions of yield differentiating cultivation technology factors (soil quality, nitrogen fertilization and intensity of chemical protection against fungal diseases). Yields obtained after optimal sowing dates were significantly lower than obtained after sowing in optimal or earlier terms (Table 4).

Very early and very late sowing time

A more detailed analysis of the dependency of the yield on the time of sowing, including very early and very late sowing, was conducted for many-years periods. The results of yielding after very late sowing (delayed by over 10 days from the optimal time) were surprising. Wheat sown with a delay of over 10 days out-yielded the one sown with a delay up to 10 days. While there were no significant differences between the yields of early and very early sowing, the differences between yields of late and very late sowing were significant (Table 5).

Only in the case of yields adjusted for the period 1986-2003, no significant differences were observed for mean yield of late or very late sowing term. This cannot be explained by the differences in soil quality or fertilization. Additional analyses conducted separately for yields obtained in similar soil conditions– separately for poor soils (up to 56 valorization points), medium soils (from 57 to 70 valorization points) and good soils (from 71 to 100 valorization points), gave very close results. The same was observed for analyses conducted separately for yields obtained at a comparable level of fertilization. Regardless of soil quality and the level of fertilization, the delay of sowing resulted in significant yield reduction, while the yields of winter wheat sown very late were significantly higher than those ones of late sowing. The late harvested sugar beets and maize for grain are a good forecrop for wheat and have a large share of the group of plantations. The value of forecrop compensates losses caused by late sowing.

Discussion

It can, therefore, be concluded that delayed sowing is an important risk factor that can reduce yield, and which can be more or less significantly depending on the weather conditions and cultivation technonology level during vegetation period. Early and timely sowing is an important element of agricultural technology that increases the probability of obtaining higher yield. It is visible in the analysis of results for many years periods. The results presented in this paper are a similar to Grabiński's results (2005), which show that there is no determined date of sowing that cannot be delayed, because there is a series of examples of good production effects when sowing was delayed by 3 – 4 weeks or more. Similar results were obtained in conditions of organic farm by Rasmussen (2004) where normal sowing time resulted statistically significant higher yields only in one of the three experiments.

In the papers dealing with the influence of the timeliness of sowing on the yield, the effect of early sowing are analyzed not as often as the the sowing delay effect. Similar results were obtained in a 3 year-long microfield experiment by Śniady and Sobkowicz (1999). In the case of winter wheat earlier sowing resulted a significant growth of yield in comparison to recommended sowing data. The examples of higher yields of some wheat varieties, which exceeded one obtained from wheat sown in optimal time are provided by Weber and Podolska (2008).

On the other hand researches by Kuś and Jończyk (1997) did not show any differentiating influence of earlier sowing, while Dmowski (1993) and Dubis (2006) showed that earlier sowing resulted in greater plant infection and lower yield.

The obtained results remain partly in opposition to documented opinions about losses caused by late sowing. Kuś et al. (1991) claim that two weeks delay in winter wheat sowing caused the reduction of yield in comparison to the optimal sowing by an average of 9%. The effect of late sowing was proven to be different for different soil conditions. Yield decrease was twice bigger for poorer soils (Kuś and Jończyk, 1997). Jończyk (1998) claims that a two week delay of sowing resulted in 7 -13% decrease of yield, which cannot be compensated by increased nitrogen fertilization or higher seeding. Podolska (1997), Harasim and Matyka (2009) also point to the unfavorable impact of delayed sowing.

The positive effects of acceleration sowing dates of wheat are recognized and used in the UK for a long time. The proportion of wheat crops sown before 1st October has increased from less than 20% in the 1980s to nearly 40% since the late 1990s. A move to earlier sowing has contributed positively to yield. An analysis of trials data over several sites and seasons compared yields of wheat varieties when sown in early-mid September, or from late October onwards, against the traditional late September / early October. An average 1.4% yield advantage to 'early' sowing and 3.7% yield penalty to 'late' sowing were found. It is estimated that the trend towards earlier sowing could account for a national yield improvement of 0.003 t/ha per year since 1980. (Knight et al. 2012)

Results concerning very late sowings can be explained by the joint effect of agronomic factors. Starting from higher share of certified seed and, what is reasonable in the case of late sowing, a larger seeding rate (Noworolnik 2006, Podolska 2004), and applying more intensive protection against fungal diseases (Table 6). But the most important explanation of the high yields can be completely different forecrops structure in compare to fields sown in earlier terms. The structure of forecrops, often caused by organizational issues, can explain the high yields of very late sown winter wheat. Late harvested sugar beets and maize for grain are very good forecrops for wheat and their share among forecrops of very late sown (Tvl) wheat was 43.2%. For comparison, shares of those forecrops for fields sown in the terms optimal (To) and late (Tl) were respectively 6.6% and 17.2%. The forecrop

Table 5 Yielding depending on sowing time – relative yields and homogeneous groups by Tukey test [%].

	Yields depending on sowing time					Homogeneous groups				
Years	Very early	Early	Optimal	Late	Very late	Very early	Early	Optimal	Late	Very late
Real yields										
1986-2003	107,3	105,3	101,6	95,2	99,3	A B	A	B	C	B
2008-2013	97,3	102,8	99,7	97,6	102,6	A B	A	A B	B	A B
Adjusted yields										
1986-2003	105,3	104,7	101,4	96,8	97,2	A B	A	B	C	C
2008-2013	98,4	100,4	99,7	96,3	99,3	A B	A	A	B	A B

value could compensate losses caused by late term of sowing. For example, in the analyzed group of farms, average increases of yields due to positions in crop rotation after maize and sugar beets, in compare to winter wheat, was 4.7% and in compare to spring barley 3.0%. And there is another possible but not analyzed factor which are new cultivars, better adapted to late sowing date. The earlier researches show that the reaction of respective at cultivars on late sowing date differs clearly (Jończyk 1998, Podolska1997).

An additional, detailed analysis of improved, modern cultivars used for sowing as well as their application in practice in different conditions is necessary. The relatively high yields obtained at very late sowing terms show that delayed sowing does not necessarily mean loss of yield. In some habitats application of correct agricultural technology makes possible reduction of negative consequences of delay sowing.

Table 6 Comparison of some agrotechnical on the fields sown in optimal, late and very late terms - an average 2008-2013.

Factors	Units	Early	Optimal	Late	Very late
Soil quality	points 100^o	65,9	65,1	65,7	64,9
Share of certfied seed	%	46,0	46,1	51,8	53,4
Sowing rate	kg per ha	217	215	216	221
Fungicides	number of treatment	1,56	1,45	1,45	1,66
Herbicides	number of treatment	1,44	1,41	1,40	1,32
Share of maize and sugar beet as forecrop	%	7,6	6,6	17,2	43,2

Conclusion

Despite an awareness of the importance of timely sowing, less than a half of winter wheat plantation are being sown in a time considered to be optimal. The analysis showed a significant decrease of yield as a result of delayed sowing. The delayed sowing date is an important risk factor that can reduce yield and whose occurrence and value depend on weather conditions during the vegetation period.

The research has confirmed an earlier state of the knowledge on the significance of the timeliness of sowing. Yields from the late sown fields were significantly lower than from the fields where the sowing took place during the recommended time. It was also confirmed by comparing adjusted yields, unaffected by the applied agricultural technology. High yields obtained from the crops sown very late prove that correct and complete agricultural technology can compensates the decrease of yield due to late time of sowing.

Yields after early sowing usually were higher than the yields from fields sown in time defined as optimal. It could be assume that the gradual climatic changes in Poland, progress of breeding, the new released improved varieties, and changes in production technology may require reanalyzing the sowing time recommendations for winter wheat, and possibly for other winter crops.

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