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RATING LONG-TERM USE OF SIMPLIFICATIONS IN TILLAGE AND PREVIOUS CROP ON BIOMETRIC FEATURES, PHYSIOLOGICAL AND YIELD OF WINTER WHEAT CULTIVAR 'Kobra Plus'

OCENA WIELOLETNIEGO STOSOWANIA UPROSZCZEŃ W UPRAWIE ROLI ORAZ PRZEDPLONU NA CECHY BIOMETRYCZNE, FIZJOLOGICZNE I PLONOWANIE PSZENICY OZIMEJ ODMIANY 'Kobra Plus'

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Streszczenie. Badania przeprowadzono w latach 2006–2008 w doświadczeniu statycznym, założonym w 1993 roku, w Rolniczej Stacji Doświadczalnej Lipnik (k. Stargardu Szczecińskiego). Stacja jest położona w centralnej części Niziny Szczecińskiej (φ 53⁰21`N, λ 14⁰58`E, Hs 30 m n.p.m.). Badania polowe przeprowadzono na pszenicy ozimej uprawianej w zmianowaniu czteropolowym (burak cukrowy – pszenica ozima – bobik – pszenica ozima + międzyplon gorczyca biała). Badano wpływ stosowania uproszczeń w uprawie roli, polegających na eliminacji orki na rzecz uprawy bezpłużnej i siewu bezpośredniego, w odniesieniu do uprawy tradycyjnej, pod rośliny uprawiane w zmianowaniu. Badanym czynnikiem były systemy uprawy roli stosowane pod pszenicę ozimą po różnych przedplonach (bobik, burak cukrowy). Systemy uprawy istotnie kształtowały długość źdźbła i wskaźnik powierzchni asymilacyjnej liści (LAI). Pszenica ozima uprawiana na stanowisku po bobiku osiągała istotnie większe wartości krzewistości ogólnej i produkcyjnej, długości źdźbła i kłosa oraz wskaźnika zazielenienia liści (SPAD). Nie stwierdzono wpływu czynników doświadczalnych oraz ich współdziałania na plon ziarna pszenicy ozimej. Niezależnie od testowanych czynników doświadczenia pszenica ozima plonowała na poziomie 5 t · ha^{-1}. Nieznaczne tendencje do większego plonowania odnotowano w systemie tradycyjnym płużnym.

Key words: tillage systems, forecrop, winter wheat, biometric and physiological yield components.
Słowa kluczowe: systemy uprawy roli, przedplon, pszenica ozima, biometryczne i fizjologiczne komponenty plonu.

INTRODUCTION

Most of the field experiments, both worldwide and in Poland, upon the response of crops to reduction in the intensity of cultivation, were carried out using cereal plants, because their production profitability has an impact on the economy (Krzymuski 1998; Stolarski 2004). Although tillage simplifications reduce the energy inputs (Kostucic et al. 2001; Olson and

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Senjem 2002; Baker et al. 2007; Derpsch and Friedrich 2009) and associated costs, however, this may cause a decrease in yield (Dzienia et al. 2001; Lepiarczyk et al. 2006; Sekutowski 2007; Rieger et al. 2008). One of the main causes reducing the yield of cereals, by simplified tillage systems is to reduce the number of ears per 1 m^2 (Małecka et al. 2012).

According to other authors, this effect should be combined with the occurrence of adverse weather course, because under favorable conditions, these reductions are small or do not exist (Anken et al. 2004; Golik et al. 2005).

There are studies that found an increase in the yield of winter wheat in the application of simplified tillage systems (Blecharczyk et al. 2006; De Vita et al. 2007).

In addition, the soil cultivated by the simplified scheme indicates a greater mass of plant residues than in the cultivated soil using plow.

Left in the soil, plant residues increase the stability of the agricultural ecosystems by the renewal of soil and maintain the positive balance of organic matter and its biological activity (Pałys et al. 2004).

Selection of an appropriate cultivation system is closely linked to the field crop production of a farm and soil conditions (Olson and Senjem 2002).

Location of Poland, and especially its north-west area, at the interface between maritime and continental climate, significantly determines the formation of pluvio-thermal conditions. Very frequent periods of rainfall shortage in spring and summer months are particularly dangerous. This situation, coupled with the predominant area of light soils, means that crops have unfavorable conditions for growth and development, the symptoms of which can be reduced dynamics of aboveground parts and roots growth, as well as deterioration in the yield structure components determining the size and quality of crops.

Use in these conditions minimized cultivation, reduces water and wind erosion, stimulates soil biodiversity, increases the content of organic matter and macro-and micronutrients (Dzienia et al. 2001; Weber 2002; Rokosz and Podsiadło 2015).

The aim of the study was to determine the response of winter wheat of Kobra Plus cv., by means of assessing the dynamics of canopy growth and yielding on a long-term use of simplifications in the pre-sowing tillage, depending on the forecrop applied.

MATERIAL AND METHODS

The study was conducted in a static experiment founded in 1993 in the Agricultural Experimental Station Lipnik (near Stargard Szczeciński). Localization of the station in the central part of Szczecin Lowland (φ 53^{0}21`N, $\lambda$ 14$^0$58`E, Hs 30 m.a.s.l.) makes the measurement results are representative for the whole region, and even for western part of West Pomerania (Koźmiński and Michalska 2000). The field tests were carried out using winter wheat grown in four-field crop rotation (sugar beet – winter wheat – faba beans – winter wheat + white mustard intercrop). The experiment was founded on light soil of good rye complex and IVb bonitation class. The soil was developed from light loamy sand (*plg*), with weak loamy sand underneath (*psg*), and light silt in some spots (*gl*). In typological terms, this soil is counted to brown soils. Thickness of the humus layer is 14–25 cm, humus content amounts to 1.3–1.5%. Content of alluvial parts 11–13%, pH_{KCL} 6.0, average content of K – 105 mg · kg^{-1} soil, P – 79 mg · kg^{-1} soil. The soil in terms of categories of agronomic soil is light typical for the region of Western Pomerania.

Bi-factorial field experiment was established in the perpendicular bands pattern of randomized sub-blocks in four replicates. The studied factor consisted of tillage systems used for winter wheat cultivation after different forecrops (faba beans, sugar beet). Surface of the plot for harvest was 30 m^2.

The first-order factor (tillage system): A – plowing tillage – classic tillage used for winter crops, B – no-plowing tillage – cultivator + string roller, C – direct sowing – sowing machine for direct sowing.

The second-order factor (forecrop): 1 – faba bean (self-completing 'Martin' cv.), 2 – sugar beet ('Kutnowska' cv.).

The winter wheat of 'Kobra Plus' cv. was sown in the experiment within the period recommended by agrotechnical procedures for Western Pomerania. For objects with conventional (A) and plowless tillage (B), wheat was sown using row cereal seeder. In contrast, on objects with direct sowing, a special seeder (for direct sowing) was applied. The frost-resistance of a variety is estimated for 4° (in 9° scale). It is resistant to lodging, sprouting, and shedding. It exhibits resistance to wheat stem rust and brown rust, and is also resistant to the take-all diseases.

Plant density [pcs · m^{-2}] – in autumn after emergence after, the framing by 2 times in each plot, with 0.5 m^2, tota number of blades and, with ears – at full ripeness phase by means of square-frame method, twice from 0.5 m^2 area, before winter wheat harvest – determination of the stalk length [cm] and spike length [cm] – for 30 random plants in each plot. Moreover, the coefficient LAI, chlorophyll content in the leaves in the shooting phase. The yield of winter wheat achieved from 30 m^2 area recalculated onto t · ha^{-1}. In all the years of research applied before sowing wheat, fertilization with nitrogen, phosphorus and potassium, respectively, in quantities of 24, 80, and 120 kg · ha^{-1}. In the spring after the start of vegetation used only nitrogen fertilization, dividing them into two doses. Plant protection treatments were applied in accordance with the recommendations of agricultural technology used in the cultivation of winter wheat.

The study results were statistically processes using variance analysis for multi-year experiments, and difference significance at the level of α – 0.05, was evaluated applying Tukey's test in FR-ANALWAR 4.3. software based on Microsoft Excel (Rudnicki 2011).

Table 1 shows the average monthly temperatures and their deviation (in ° C) from the multi-year average of 1961 to 2000 and the classification of the thermal months Lorenc (2000) based on a standard deviation. Precipitation is characterized by the scale developed by Kaczorowska (1962), taking into account the percentage of rainfall in a given month in relation to the value of multi-year.

Among the analyzed period of years, where the average monthly air temperature considerably exceeded the standard began in June 2006 and lasted until mid – 2007 hottest and at the same time extremely dry was July 2006., The temperature of the month was nearly 6°C higher than the average, at very low rainfall (10 mm). Deficiencies rainfall persisted since the autumn of 2005, which further worsened the conditions of the growing season, rainfall in 2006 accounted for less than 80% of normal, so this year was recognized as dry. In 2007, the air temperature was much higher than average, except for the autumn months (IX–XI), but rain in most parts of the year were high, and the months from May to August, even extremely wet. The year 2008 was warmer than normal, and while annual rainfall was close to the average, their distribution was uneven, the worst moisture conditions prevailed in May and June.

Table 1. Average monthly air temperature and precipitation in 2005–2008, together with a deviation from the norm (1961–2000) at the agrometeorological station in Lipnik

Tabela 1. Średnia miesięczna temperatura powietrza i sumy opadów atmosferycznych w latach 2005–2008, wraz z odchyleniem od normy (1961–2000) w stacji agrometeorologicznej w Lipniku

	Year/Deviation from the norm Rok/Odchylenie od normy	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I–XII
Temperature – Temperatura	2005			–	–	–	–	–	–	15.6	10.2	4.2	1.2	
	deviation odchylenie [ºC]									2.3 bc	1.4 c	0.4 n	0.8 n	
	2006	–5.5	–0.6	0.3	8.4	13.7	18.2	23.5	17.7	17.1	11.7	7.2	5.8	9.8
	deviation odchylenie [ºC]	–4.4 ch	–0.3 n	–2.5 ch	1.0 lc	1.0 lc	2.2 bc	5.9 ec	0.5 n	3.8 ac	2.9 ac	3.4 bc	5.4 ac	1.6 bc
	2007	4.9	1.5	6.7	9.9	14.9	18.3	18.4	18.6	13.3	7.7	3.4	2.0	10.4
	deviation odchylenie [ºC]	6.0 bc	1.8 lc	3.9 bc	2.5 bc	2.2 bc	2.3 bc	0.8 lc	1.4 c	0.0 n	–1.1 lch	–0.4 n	1.6 lc	2.2 ac
	2008	2.5	4.3	4.1	8.0	14.3	17.9	19.4	18.7	13.1	9.1	5.3	2.0	9.9
	deviation odchylenie [ºC]	3.6 c	4.6 c	1.3 lc	0.6 n	1.6 lc	1.9 bc	1.8 c	1.5 c	–0.2 n	0.3 n	1.5 lc	1.6 lc	1.7 bc
	1961–2000	**–1.1**	**–0.3**	**2.8**	**7.4**	**12.7**	**16.0**	**17.6**	**17.2**	**13.3**	**8.8**	**3.8**	**0.4**	**8.2**
Ranfall – Opady	2005	–	–	–	–	–	–	–	–	26	20	19	72	
	the percentage norm procent normy [%]									55 s	51 s	46 bs	176 sw	
	2006	12	32	33	22	43	23	7	104	38	25	61	27	427
	the percentage norm procent normy [%]	34 bs	123 n	97 n	58 s	83 n	37 bs	10 ss	192 sw	81 n	64 s	149 w	66 s	79 s
	2007	76	42	54	4	105	109	109	103	47	14	55	34	752
	the percentage norm procent normy [%]	217 sw	161 bw	159 bw	11 ss	202 sw	176 sw	163 bw	191 sw	100 n	36 bs	134 w	83 n	140 bw
	2008	59	23	46	109	10	30	35	49	47	68	36	40	552
	the percentage norm procent normy [%]	168 bw	88 n	135 w	287 sw	19 ss	48 bs	52 s	91 n	100 n	174 bw	88 n	97 n	103 n
	1961–2000	**35**	**26**	**34**	**38**	**52**	**62**	**67**	**54**	**47**	**39**	**41**	**41**	**536**

Thermal classification months – Termiczna klasyfikacja miesięcy: ec – extremely warm – ekstremalnie ciepły, ac – anomalously warm – anomalnie ciepły, bc – very warm – bardzo ciepły, c – warm – ciepły, lc – slightly warm – lekko ciepły, n – normal – normalny, lch – slightly cool – lekko chłodny , ch – cool – chłodny.

Drop classification months – Opadowa klasyfikacja miesięcy: ss – extremely dry – skrajnie suchy, bs – very dry – bardzo suchy, s – dry – suchy, n – normal – normalny, w – wet – wilgotny, bw – very wet – bardzo wilgotny, sw – extreme wet – skrajnie wilgotny.

RESULTS AND DISCUSSION

Based on studies conducted in 2006–2008, the impact of tillage systems and forecrop on biometric properties of winter wheat was statistically demonstrated (Table 2).

Table 2. The significance of main effects and interactions to impact system (S) tillage and previous crop (P) on the properties of the selected biometric and physiological characteristics of winter wheat variety 'Kobra Plus' 2006–2008 (L)
Tabela 2. Istotność efektów głównych oraz interakcji dla wpływu systemu (S) uprawy oraz przedplonu (P) na właściwości biometryczne oraz wybrane cechy fizjologiczne pszenicy ozimej odmiany 'Kobra Plus' w latach 2006–2008 (L)

Years – Lata	Types of variation Rodzaje zmienności	Characteristic – Cecha							
		yield plon [$t \cdot ha^{-1}$]	number of plants obsada roślin [m^{-2}]	total number of blades liczba źdźbeł ogółem [m^{-2}]	the number of blades, with ears liczba źdźbeł z kłosami [m^{-2}]	steam length długość źdźbła [cm]	ear length długość kłosa [cm]	LAI	SPAD
2006	S	*	–	*	–	*	–	–	–
	P	–	–	–	*	*	–	–	*
	S · P	–	*	–	–	–	*	–	*
2007	S	–	–	–	–	–	*	*	–
	P	*	–	–	–	–	–	–	*
	S · P	–	–	*	–	–	*	–	–
2008	S	–	*	–	–	–	*	–	–
	P	–	–	–	*	–	*	–	–
	S · P	–	–	–	–	–	–	–	–
2006 –2008	S	–	–	–	–	*	–	*	–
	L · S	–	–	–	–	*	*	–	–
	P	–	–	–	*	*	*	–	*
	L · P	–	–	–	–	–	–	–	–
	S · P	–	–	*	*	–	–	–	–
	L · S · P	–	–	–	–	*	*	–	–

* a significant effect – efekt istotny, „–" – not significant effect – efekt nieistotny.

A study conducted in 1996–1998 in ZDD Brody showed that winter wheat grain yield applying conventional tillage was higher by 0.72 $t \cdot ha^{-1}$ as compared to the yield obtained due to the direct sowing. The difference in favor of the traditional cultivation was underlined in 1996 and 1997, while in the last year of the study there was no difference in the level of yields between tillage systems. Wheat grown in direct sowing was characterized by a smaller spike density (Blecharczyk et al 1999).

Jędruszczak and Antoszek (2004) claimed that the highest grain yields were obtained from plowing cultivation, and any deviation from this system was accompanied by a reduction in grain yield. Replacement of the pre-sowing plowing with disking or cultivating resulted in the decrease of yield by 9% and 12%, and the use of direct sowing resulted in a 17% yield reduction.

The number of spikes is determined by the productive tillering, which largely depends on the environmental conditions (Mittler 2000).

Among the biometric features in our study, cultivation systems differentiated only the length of stalks, which was the largest in the traditional tillage (84.3 cm) and the smallest in direct sowing (80.80 cm). The leaf assimilation index – LAI varied in a similar manner (Table 3 and 4).

Table 3.The influence of (S) tillage system and previous crop (P) on the properties of biometric winter wheat varieties 'Kobra Plus'
Tabela 3. Wpływ systemu (S) uprawy oraz przedplonu (P) na właściwości biometryczne pszenicy ozimej odmiany 'Kobra Plus'

Characteristic Cecha	Years Lata	Tillage system System uprawy			Previous crop Przedplon		Mean Średnia	LSD0.05 for NIR0.05dla	
		A	B	C	1	2		S	P
Number of plants Obsada roślin [m⁻²]	2006	500	490	485	595	494	513	ns.	ns.
	2007	480	470	490	490	470	480	ns.	ns.
	2008	490	480	500	500	480	490	ns.	ns.
	2006–2008	490	480	495	495	480	488	ns.	ns.
Total number of steam Liczba źdźbeł ogółem [m⁻²]	2006	640	560	580	660	530	594	ns.	ns.
	2007	450	480	480	475	470	471	ns.	70.549
	2008	650	570	560	655	525	592	ns.	32.663
	2006–2008	570	550	570	560	520	550	ns.	33.525
The number of steam with ears Liczba źdźbeł z kłosami [m⁻²]	2006	632	557	557	646	518	582	ns.	80.697
	2007	426	470	471	456	456	456	ns.	ns.
	2008	632	557	557	646	518	582	ns.	75.541
	2006–2008	564	528	528	583	497	540	ns.	37.664
Steam length Długość źdźbła [cm]	2006	91.5	89.21	87.10	92.69	85.86	89.28	2.958	2.178
	2007	77.5	78.22	75.91	76.82	77.51	77.17	ns.	ns.
	2008	84	80.66	79.35	80.95	81.64	81.30	ns.	ns.
	2006–2008	84.30	82.70	80.80	83.50	81.70	82.60	2.280	1.525
Ear length Długość kłosa [cm]	2006	7.40	7.57	7.22	7.77	7.02	7.39	ns.	ns.
	2007	8.38	7.79	7.94	8.00	8.08	8.04	0.276	ns.
	2008	7.22	7.25	7.84	7.70	7.17	7.43	0.403	0.295
	2006–2008	7.66	7.53	7.66	7.82	7.42	7.62	ns.	0.183

A – ploughing – płużny, B – ploughless – bezpłużny, C – direct sowing – siew bezpośredni, 1 – faba bean – bobik, 2 – sugar beet – burak cukrowy, ns. – not significant – nieistotne.

In the case of the forecrop, diversity concerned: total number of steam and, with ears, length of stalks and spikes, as well as the ratio of leaf greenness – SPAD (Table 3, 4). All these features had higher values in the position after faba bean. The interaction of both experimental factors differentiated only total number of steam and, with ears. In our study, there was no the effect of experimental factors and their interaction on grain yield of winter wheat.

Table 4. The influence of (S) tillage system and previous crop (P) on the properties of the selected biometric and physiological characteristics of winter wheat cultivar 'Kobra Plus'
Tabela 4. Wpływ systemu (S) uprawy oraz przedplonu (P) na właściwości biometryczne oraz wybrane cechy fizjologiczne pszenicy ozimej odmiany 'Kobra Plus'

Characteristic Cecha	Years Lata	Tillage system System uprawy			Previous crop Przedplon		Mean Średnia	$LSD_{0.05}$ for $NIR_{0,05}$dla	
		A	B	C	1	2		S	P
Grain field Plon ziarna [t · ha^{-1}]	2006	4.64	4.43	4.11	4.35	4.43	4.39	0.336	ns.
	2007	6.45	6.44	5.98	6.08	6.50	6.29	ns.	ns.
	2008	3.94	4.39	4.63	4.32	4.32	4.32	ns.	ns.
	2006–2008	5.00	5.09	4.91	4.92	5.08	5.00	ns.	ns.
LAI	2006	2.78	3.05	2.58	2.83	2.78	2.80	ns.	ns.
	2007	3.50	3.24	2.91	3.11	3.33	3.22	0.495	ns.
	2008	3.95	3,35	3.45	3.61	3.56	3.58	ns.	ns.
	2006–2008	3.40	3.20	3.00	3.20	3.20	3.20	0.355	ns.
SPAD	2006	47.92	48.31	47.98	51.36	44.77	48.07	ns.	1.264
	2007	48.60	48.98	48.28	47.75	49.49	48.62	ns.	1.140
	2008	41.36	38.24	40.36	40.85	39.12	39.99	ns.	ns.
	2006–2008	46.00	45.20	45.50	46.60	44.50	45.60	ns.	1.115

Explanations as in Table 3 – Objaśnienia jak w tab. 3.

In the literature, opinions about impact on the biometric and physiological features of these experimental factors are very diverse. Significant effects of the tillage systems in relation to the length of the stalk, were pointed out by Dzienia and Wereszczaka (1999). Instead, like in own study, these authors along with Orzech et al. (2002), Weber and Hryńczuk (2004), as well as Kuś (1999) reported that cultivation systems have no significant influence on the length of spike and grain yield. The latter author also points to the presence of the trend of lower yielding in conventional tillage. Our findings do not confirm such result. On the contrary, the tendency to lower yields was observed in the direct sowing. Among authors confirming the significant effect on biometrics and plant yielding, following should be listed: Kuś (1999) as well as Orzech et al. (2002) – plant density, Dzienia and Dojss (1999), Weber and Hryńczuk (2004) – productive tillering, Włodek et al. (1999) – plowless tillage can cause lower plant density and in years with rainfall deficiency, also lower grain yields.

A number of authors indicate higher yielding of cereal crops in the traditional and simplified tillage systems, while the lowest in direct sowing (Dzienia and Dojss 1999; Dzienia and Wereszczaka 1999; Orzech et al. 2002).

Study of Biskupski et al. (2009) confirmed that, regardless of experimental factors examined, the leaf assimilation index (LAI), average angle of leaf inclination (MTA), and yield of selected spring wheat varieties, were affected exclusively by weather conditions.

CONCLUSIONS

1. Tillage system significantly shaped the length of stalks and leaf assimilation index (LAI). Winter wheat grown in the position after faba bean had significantly higher values of total number of steam and, with ears, the length of stalk and spike, as well as the ratio of leaf greenness (SPAD). In our study, there was no the effect of experimental factors and their interaction on grain yield of winter wheat.
2. In the first year of study (12 year of experience) reported uneven growth and development of winter wheat depending on the agents tested experience. In subsequent years experience ontogenesis of winter wheat he was as balanced, with a slight tendency in favor of the classical plow cultivation.
3. Regardless of the experimental factors tested, winter wheat yielded at the level of 5 t · h^{-1}. Slight tendencies to a higher yielding was recorded at the traditional plowing system.

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Abstract. The study was conducted in the years 2006–2008, in a static experiment founded in 1993 in the Agricultural Experimental Station Lipnik (near Stargard Szczeciński). The station is located in the central part of the Szczecin Lowland (φ 53^{0}21`N, λ 14$^0$58`E, Hs 30 m.a.s.l.). Field tests were carried out using winter wheat grown in four-field crop rotation (sugar beet – winter wheat – faba beans – winter wheat + white mustard intercrop). The effect of simplified tillage involving the elimination of plowing for the plowless tillage and direct sowing was examined, as compared to conventional tillage under crops grown in rotation. Studied factor consisted of the farming systems used for winter wheat after different forecrops (faba beans, sugar beet). The tillage systems significantly shaped the length of the stalk and leaf assimilation index (LAI). Winter wheat grown in the field after faba bean had significantly higher values of total number of steam and, with ears, the length of stalk and spike, as well as the ratio of leaf greenness (SPAD). In our study, there was no the effect of experimental factors and their interaction on grain yield of winter wheat. Regardless of tested experimental factors, winter wheat yielded at the level of 5 $t \cdot ha^{-1}$. A slight tendency to higher yields was recorded for the traditional plowing system.