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Winter Wheat (*Triticum aestivum* L.) Overwintering Under Different Sowing Densities

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Abstract

Wheat overwintering ability affects the final number of plants that are able to continue their growth and development when necessary conditions are established. This research was conducted to study the overwintering ability of winter wheat cultivars (NS 40S, Prima and Nova Bosanka) under different sowing densities during 2013/14 and 2014/15 in agroecological conditions of Banja Luka. Standard agronomic practices for winter wheat were performed. Wheat cultivars were sown manually, under sowing densities with different seed arrangements: 384, 424, 451, 504, 544, 584, 588, and 604 seeds m^{-2}. Counting of wheat plants in both examined years was carried out in the second decade of February. Statistical analysis was performed using factorial analysis of variance 2×8×3, while significant differences between treatments were tested by LSD test. The average overwintering plants percentage for all three examined wheat cultivars was 50.06%. Sowing density of 588 seeds m^{-2} stands out as the density with a tendency of the highest percentage of overwintering plants in both years.

Key words: winter hardiness, sowing density, wheat

Introduction

Wheat (*Triticum aestivum* L.) as the main bread cereal is sown at around 40 000 hectares, or 7% of total arable land of the Republic of Srpska. During the winter period, wheat plant is exposed to the winter stresses, as well as to the influence of low temperatures, the more in absence of snow cover. Nevertheless, differential performances of cultivars regarding tiller formation and survival as well as the crop environment, should be taken into account for achieving proper seed densities (Valerio et al., 2013). Overwintering ability of wheat plants depends on various factors, not only on their ability to tolerate low temperatures, but it is a combination of response to winter stresses that includes weather, soil properties and applied cultivation practices affecting the plant's potential to survive (Fowler & Gusta, 1978). According to Poltarev et al. (1992) influences of all factors are not equally important; therefore prevalent factor which has an impact on winter kill is low soil and air temperature. Winter kill of wheat was caused by low temperatures in 35% cases, by alternate freezing and thawing in 26% cases, and by ice encasement in 22% cases in years when significant winter damage occurred. Also, Barlow et al. (2015) said that the impact of low temperatures during winter is the occurrence of frost ($t < 0$ °C) which affects crop production and represents a significant risk which needs to be managed to maintain profitable production.

Low temperature tolerance in cereals is dependent upon a highly integrated system of structural, regulatory, and developmental genes (Fowler et al., 2001). Frost during vegetative growth affects seedling survival (Fuller et al., 2007) and causes leaf damage resulting in the scorched appearance of leaves (Shroyer et al., 1995). While there is a distinct impact on crop yield with seedling death, other frost damage during the vegetative stages has a small potential impact on yield as the growing point of wheat is located in the soil typically protecting it from damage (Shroyer et al., 1995; Porter & Gawith, 1999). In addition to temperature, the duration of freezing temperatures is important in determining the damage that occurs (Al-Issawi et al., 2012).

Finally, the effect of low temperatures on wheat development is in interaction with pedo-climatic conditions such as soil type, soil moisture and soil fertility, but also with the plant density and level of the plant development. According to Prášilová & Prášilov (2001) the average WHS degrees (winter hardiness scale) classified wheat cultivars from different countries of Europe: 2.8 for cultivars from Italy, 4.7 for Austria, 5.7 for Czech Republic, 5.7 for Poland, 5.8 for Denmark, 5.9 for Sweden and 7.0 for Finland.

The effect of geographical origin of cultivars on the degree of winter hardiness is evident as the average hardiness increases from south to north. It is also possible to deduce that a certain degree of winter hardiness is typical for certain areas. According to Chipilski & Uhr (2014) the main purpose of any breeding program is the creation of cultivars combining high productive potential and good quality under different environmental conditions. However, Braun & Sãulescu (2002) concluded that little progress has been made in breeding for increased tolerance to low temperature compared to old landraces such as Minhardi, and the lack of sufficient winter hardiness remains a problem mainly in areas with very severe winters, such as the Great Plains of North America, the Russian Federation and Ukraine. For the majority of winter wheat breeding procedures, the main breeding objective is to maintain rather than increase the winter hardiness level present in commercial cultivars. The aim of this study was to examine the ability of winter wheat cultivars for overwintering under different sowing densities in existing agroecological conditions in Banja Luka region.

Material and Methods

Experiment was conducted at eight different sowing densities in an open field during 2013/14 and 2014/15. The overwintering ability of plants were studied for three winter wheat cultivars: NS 40S, Prima and Nova Bosanka. Research was conducted in agroecological conditions of Banja Luka (44°46’ N; 17°11’ E). Wheat cultivars were sown under sowing densities: 384 seeds m^{-2} (arrangement of seeds in the honeycomb), 424 seeds m^{-2} (classical arrangement of seeds in rows), 451 seeds m^{-2} (classical arrangement of seeds in rows), 504 seeds m^{-2} (classical arrangement of seeds in rows), 544 seeds m^{-2} (classical arrangement of seeds in rows), 584 seeds m^{-2} (classical arrangement of seeds in rows), 588 seeds m^{-2} (arrangement of seeds in the honeycomb) and 604 seeds m^{-2} (classical arrangement of seeds in rows). The soil where the experiments were conducted belongs to the degraded eutric cambisol.

Standard agronomic practices for winter wheat were performed. Sowing was carried out manually where wheat seeds were sown on 4 ± 1 cm depth (Fig. 1 and Fig. 2). The experimental unit size was 1 m^2, with four replications, and there was a total of 96 experimental plots.

Sowing was carried out from 6th to 8th November in 2013 and from 3rd to 5th November in 2014. Wheat was harvested on the 14th of July in the first experimental year, while in the second experimental year on the 10th of July. Counting of wheat plants in both examined years was carried out in the second decade of February.

Fig. 1. and Fig. 2. Manually sowing of winter wheat using pattern with a determined sowing density
Ручна сјетва озиме пшенице коришћењем шаблона са одређеном густином сјетве

Overwintering plants percentage (%) was calculated as the ratio of the number of overwintering plants and the number of sown seeds (determined sowing density) in each experimental unit.

Tab. 1. The average monthly air temperatures and total monthly precipitation for the region of Banja Luka in period 2013-2015
Просјечне мјесечне температуре и укупне мјесечне количине падавина на подручју Бање Луке за период 2013-2015

		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2013	°C	2.8	2.3	6.1	13.4	16.6	20.4	23.0	23.5	16.7	13.1	7.4	2.5
	mm	93.7	115.8	88.5	62.9	119.6	54.3	27.4	36.3	69.7	67.6	156.0	0.6
2014	°C	5.6	6.5	9.6	13.1	15.8	20.3	21.7	20.6	16.4	13.5	8.9	4.0
	mm	52.0	73.5	90.6	214.0	217.8	97.0	139.3	276.3	284.0	117.3	41.8	82.6
2015	°C	3.4	2.4	7.3	11.8	17.4	20.9	25.2	24.0	18.3	11.5	7.1	3.5
	mm	111.2	91.1	79.0	54.1	117.6	60.5	20.5	22.8	75.0	142.7	85.7	8.1

According to Table 1. the average temperature for the period November–February was 5.5 °C in 2013/14 and 4.7 °C in 2014/15, therefore the examined period November–February in 2013/14 was warmer by 0.8 °C compared to the same period in 2014/15. The average temperature from November to February in 1981-2000 period was 2.3 °C, which is significantly lower than these examined periods.

Statistical analysis was performed using factorial analysis of variance 2×8×3 [factorial design: year (2) × sowing density(8) × cultivar (3)], while significant differences between treatments were tested by Fisher's least significant difference test (LSD). Analysis of interaction effects was graphically determined.

Results and Discussion

The two-year results of the study on the overwintering ability of three winter wheat cultivars originating from the region of the Western Balkans, under different sowing densities, are shown in Table 2.

Tab. 2. The percentage of overwintering plants (%) for wheat cultivars NS 40S, Prima and Nova Bosanka under diferent sowing densities for 2013/14 and 2014/15
Проценат презимљавања биљака (%) за сорте пшенице NS 40S, прима и нова босанка у условима различите густине сјетве у 2013/14 и 2014/15

Number of seeds m^{-2} *Број сјеменки / m^2*	Cultivar *Сорта* / Year *Година*	NS 40S	Prima	Nova Bosanka	$\overline{X} \pm s_x$ for sowing densities *(за густине сјетве)*
384	*2014*	50.00 ± 5.55	48.44 ± 3.81	47.53 ± 3.10	47.39 ± 1.89
	2015	44.47 ± 4.37	53.65 ± 4.99	40.23 ± 9.55	
424	*2014*	57.08 ± 2.92	58.90 ± 2.83	52.54 ± 2.07	52.24 ± 2.07
	2015	47.64 ± 3.50	51.24 ± 5.31	46.05 ± 4.96	
451	*2014*	53.82 ± 3.42	65.08 ± 4.27	50.22 ± 2.99	49.59 ± 4.43
	2015	40.91 ± 4.47	53.33 ± 2.42	34.09 ± 5.42	
504	*2014*	55.80 ± 1.71	67.06 ± 3.35	48.07 ± 2.65	50.63 ± 3.76
	2015	44.30 ± 2.62	43.95 ± 4.39	44.59 ± 6.85	
544	*2014*	59.83 ± 6.16	68.57 ± 4.22	55.06 ± 9.60	51.40 ± 4.77
	2015	43.61 ± 5.81	43.29 ± 0.77	38.05 ± 2.71	
584	*2014*	53.72 ± 1.30	59.89 ± 3.02	48.97 ± 1.37	44.25 ± 4.77
	2015	33.60 ± 3.69	38.48 ± 2.10	30.82 ± 3.00	
588	*2014*	64.67 ± 2.06	64.50 ± 3.23	61.18 ± 6.18	54.87 ± 3.97
	2015	43.54 ± 6.76	50.17 ± 1.61	45.15 ± 3.21	
604	*2014*	60.18 ± 4.76	64.53 ± 5.27	56.83 ± 0.69	50.15 ± 4.82
	2015	38.91 ± 6.53	43.50 ± 10.25	36.92 ± 7.43	
$\overline{X} \pm s_x$ for cultivars *(за сорте)*		49.51 ± 2.19	54.66 ± 2.41	46.02 ± 2.24	

$F_{blocking} = 0.531^{ns}$; $F_{cultivar} = 13.655^{**}$; $F_{sowing\ density} = 2.754^{**}$; $F_{year} = 110.009^{**}$;
$F_{cultivar \times sowing\ density} = 0.377^{ns}$; $F_{cultivar \times year} = 0.193^{ns}$; $F_{sowing\ density \times year} = 2.813^{**}$;
$F_{cultivar \times sowing\ density \times year} = 0.590^{ns}$. ns ($P > 0.05$), * ($P \leq 0.05$), ** ($P \leq 0.01$)

Wheat sowing in this experiment was carried out during the first decade of November in both experimental years, which belongs to the fourth sowing period (1st to 10th of November) in our agroecological conditions.

Nevertheless, according to Fowler (1982) general recommendation for optimum time of wheat sowing, regarding plant preparation for overwintering, should be 4 to 6 weeks before the winter onset. In this study, regardless of delayed sowing, wheat plants still had enough time to prepare for the overwintering.

Factorial analysis of variance 2×8×3 showed that all main effects were very significant. However, interaction between sowing density and year was very significant ($P \leq 0.01$), according to Table 2.

Observed regardless of the different sowing densities and years, cultivar Prima had the highest average overwintering plants percentage (54.66%), and LSD test showed that this was very significantly higher in comparison with cultivars NS 40S (49.51%) and Nova Bosanka (46.02%). Also, cultivar NS 40S had significantly higher overwintering plants percentage in comparison with cultivar Nova Bosanka (Tab. 3).

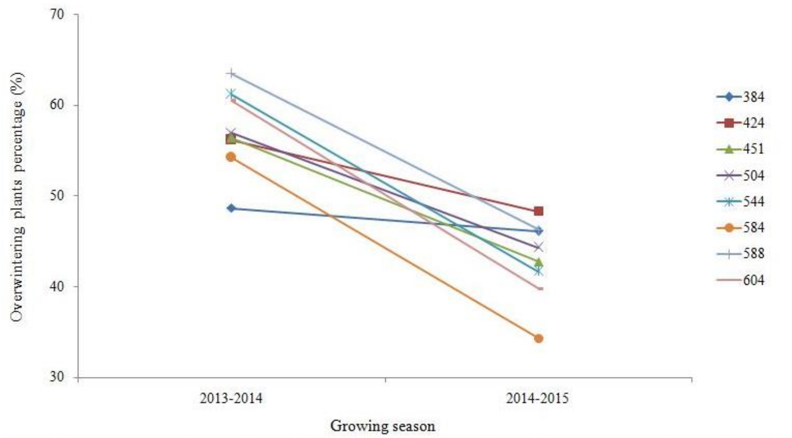
Tab. 3. Multiple comparison LSD - test for significant main effect of cultivar
LSD тест вишеструких упоређења за значајност главног фактора сорте

Cultivar *Сорта*		average overwintering plants (%) *просјечан број презимљених биљака*
Prima		54.66
NS 40S		49.51
Nova Bosanka		46.02
LSD test ($F_{cultivar}$)	0.05	3.29
	0.01	4.34

However, the average overwintering plants percentage for three examined wheat cultivars was 50.06%. This is in accordance with the research of Prášilová & Prášilov (2001) who found that wheat cultivars originating from the Western Balkan countries had a relatively small average percentage of the overwintering plants of only 39.80%.

Graph. 1. shows a significant interaction effect between sowing density and year. Analysis of interaction indicated different tendencies of average overwintering plants percentage. All tested sowing densities showed decrease in average overwintering plants percentage in 2014/15, possibly caused by the average temperature from November to February in 2014/15, which were for 0.8 °C lower than in the same period in 2013/14.

Average monthly temperatures in the reported period in both experimental years were above 0 °C, and according to Jame et al. (1999) it is well known that the wheat development can already begin at a temperature from 0 to 5 °C.



Graph. 1. Effect of different sowing densities and years on average overwintering plants percentage
Утицај различитих густина сјетве и година на просјечни проценат презимљених биљака

However, there were different tendencies considering wheat overwintering ability at tested years. Sowing densities of 384 and 424 seeds m^{-2} showed a tendency of overwintering stability. Sowing density of 384 seeds m^{-2} (arrangement of seeds in the honeycomb) showed the smallest variation of the average overwintering plants percentage in the observed periods (from 48.65% to 46.12%), but it is the only examined density with overwintering below 50.00% in both periods. Sowing density of 424 seeds m^{-2} had slightly different tendency, with overwintering plants percentage from 56.17% to 48.31%. Contrary to abovementioned tendency, sowing densities of 451, 504, 544, 584, 588 and 604 seeds m^{-2} showed noticeable decrease in average percentage of overwintering plants in 2014/15. The most evident decline was detected for sowing density of 584 seeds m^{-2} with overwintering ranging from 54.20% in 2013/14 to 34.30% in 2014/15 (Graph. 1). Generally, wheat plants behavior during the overwintering in this experiment can be explained by the fact that plant overwintering is strongly influenced by climatic conditions.

Differences in overwintering plants percentage, considering different sowing densities and years in interaction, were analyzed by LSD-test (Tab. 4).

Tab. 4. Multiple comparison LSD-test for significant interaction effect sowing density×year
LSD тест вишеструких упоређења за значајан интеракцијски ефекат густина сјетве×година

Sowing density×year *густина сјетве×година*	interaction mean (%) *интеракцијска средина*	Sowing density×year *густина сјетве×година*	interaction mean (%) *интеракцијска средина*
588 × 2013/14	63.45	424 × 2014/15	48.31
544 × 2013/14	61.15	588 × 2014/15	46.29
604 × 2013/14	60.51	384 × 2014/15	46.12
504 × 2013/14	56.98	504 × 2014/15	44.28
451 × 2013/14	56.37	451 × 2014/15	42.78
424 × 2013/14	56.17	544 × 2014/15	41.65
584 × 2013/14	54.20	604 × 2014/15	39.78
384 × 2013/14	48.65	584 × 2014/15	34.30
LSD – test	0.05 7.60		
($F_{sowing\ density×year}$)	0.01 10.03		

The highest average overwintering plants percentage, regardless of the cultivars, was achieved at sowing density of 588 seeds m^{-2} in 2013/14 (63.45%). However, this was not significantly higher in comparison with average percentage of overwintering plants achieved at sowing densities of 544, 604, 504, 451 and 424 in 2003/14, but was significantly higher in comparison with sowing density of 584 seeds m^{-2} in 2013/14 and very significantly higher in comparison with sowing density of 384 seeds m^{-2} in 2013/14.

In the 2014/15 experimental year, overwintering values had different gradation, considering sowing density, which caused interaction effects. The highest average overwintering plants percentage in 2014/15, regardless of the cultivars, was achieved at sowing density of 424 seeds m^{-2} (48.31%), which was not significantly higher in comparison with sowing densities of 588, 384, 504, 451 and 544 seeds m^{-2}, but was significantly higher in comparison with sowing density of 604 seeds m^{-2}, and very significantly higher in comparison with sowing 584 seeds m^{-2}.

The difference between sowing density of 384 seeds m^{-2} in 2013/14 and 2014/15 (0.34%) was not significant ($\bar{X}_1 - \bar{X}_2$ < LSD$_{0.05}$) which signifies a relatively small variation in overwintering values and overwintering stability. The difference between sowing density of 424 seeds m^{-2} in 2013/14 and 2014/15 (7.86%) was significant (LSD$_{0.05}$ < $\bar{X}_1 - \bar{X}_2$ < LSD$_{0.01}$). The difference between remaining sowing densities throughout growing seasons was however very significant ($\bar{X}_1 - \bar{X}_2$ > LSD$_{0.01}$) (Table 4).

Conclusion

The response of different wheat cultivars was different in the studied 2013/14 and 2014/15 experimental years and under different sowing densities, which caused an interaction effect. Observed regardless of the different sowing density and year, cultivar Prima had the highest average overwintering plants percentage (54.66%). The average overwintering plant percentage for all three examined wheat cultivars was 50.06%. Taking into consideration interaction between sowing densities and years, the observed sowing densities could not be considered regardless of the years. All tested sowing densities showed decline in average overwintering plants percentage in the experimental 2014/15, which can be explained by the relatively lower average temperatures during the period November–February in this season. Sowing density of 588 seeds m^{-2} stands out as the density with a tendency of the highest overwintering plants percentage in both years, while the sowing density of 384 seeds m^{-2} only had the average overwintering plants percentage below 50% in both years but showed evident stability. However, both sowing densities (384 and 588 seeds m^{-2}) had the honeycomb arrangement of seeds.

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Презимљавање озиме пшенице (*Triticum aestivum* L.) у условима различите густине сјетве

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Сажетак

Способност пшенице за презимљавање утиче на коначни број биљака које су способне да наставе раст и развој када се за то остваре потребни услови. Експеримент је извршен с циљем истраживања способности презимљавања озимих сорти пшенице (NS 40S, прима и нова босанка) у условима различите густине сјетве током 2013/14 и 2014/15 у агроеколошким условима Бање Луке. Примијењена је стандардна агротехника за производњу озиме пшенице. Сорте пшенице су засијане ручно у условима различите густине сјетве, с различитим распоредом зрна: 384, 424, 451, 504, 544, 584, 588 и 604 зрна по m^2. Бројање биљака пшенице у обје експерименталне године је извршено у другој декади фебруара. Статистичка обрада података је извршена коришћењем факторијалне анализе варијансе 2×8×3, док је значајност разлика између третмана тестирана LSD тестом. Просјечни проценат презимљених биљака за све три испитиване сорте пшенице био је 50,06%. Густина сјетве од 588 зрна по m^2 била је густина с тенденцијом највећег процента презимљених биљака у обје године.

Кључне ријечи: отпорност према зими, густина сјетве, пшеница

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