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EFFECT OF DIFFERENT SOWING DATE, PLANTING DENSITY ON YIELD AND MAIN AGRONOMIC TRAITS IN WINTER WHEAT VARIETY BAINONG 207

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Nowadays, the field is changed from «three parts planting, seven parts management» to «seven parts planting, three parts management», which requires good varieties with high adaptability and simplified and practical farming techniques to support modern agriculture.In our studies, we used the Bainong 207 winter wheat variety as the experimental material and had four sowing dates and four sowing density options for each sowing date. The influence of sowing dates and sowing density on yield, yield components and main agrotechnical features has been studied. According to the results of research, it was found that the influence of sowing dates and density on yield and the main components of yield differed significantly, with the influence of sowing time was greater than the influence of density. Yield, spike number and grain number per spike were highest in A2, and weight of thousands of grains - in A3; B2 and B3 had the highest yields, spike number and the grain number per spike increased and then decreased with increasing density, and the thousand grain weight gradually decreased. The setting percentage was higher at a certain date and density; there is no clear tendency of bulk weight with sowing date delay and increase density. The plant height gradually decreased with the sowing date delay , and increase with density. Spike length was a relatively stable feature with no significant changes with sowing dates and density. According to the results of research, the most appropriate terms of sowing of winter wheat of Bainong 207 variety have been established. Correlation analysis showed that high yields can be achieved by combining three yield factors with corresponding sowing dates and sowing densities.

Key words: *correlation analysis, winter wheat; sowing date; planting density; yield, variety, yield components, main agronomic traits, Bainong 207.*

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Inroduction. Wheat is one of the most important food crops in the world, and China is a populous country that needs to increase its grain production to meet the demand of its population. Good and efficient cultivation techniques are necessary for high and stable yields, among which, sowing date and density is one of the important cultivation techniques for wheat, because different sowing dates and planting densities determine different ecological conditions and make the whole growth process of wheat show variability (Hai ,2002; Hao et al.,2011; Lin,1996;Wu et al., 2004). A suitable sowing period can ensure maximum use of pre-winter light, heat and other resources to cultivate strong seedlings [5] (Hu , 1986); a reasonable population density is the basis for high yield, and different sowing densities cause corresponding changes in the synthesis and operation and accumulation of photosynthetic products, which in turn affect the yield and quality of wheat (Cao , 2011; Yang et al.,2010; Li et al.,2016). A great deal of research has been done on this subject, and the determination of sowing and density varies according to variety and region(Kong et al., 2004; Hu et al., 2008; Liu et al.,2017; Zhang et al., 2014; Chen et al.; 2014;Jiang et al.,2014). It was shown that the effects of different sowing dates and densities on grain yield and its component factors reached the significant level, and the effect of density on yield component factors was greater than that of sowing date. Some researchers have shown that the high yield potential of this variety can be fully utilized with appropriate planting density, moderate sowing and appropriate late sowing (Liu et al., 2009). Both sowing date and density had significant effects on grain yield, and the effect of sowing date was greater than that of density. The grain number per spike and thousand grain weight decreased and the spike number per unit area grew with the increase of sowing density. This indicates that high yield can be achieved by sowing the optimal date and density (Li et al., 2010).The effect of sowing date on the grain number per spike and thousand grain weight was small, and the effect on the spike number per unit area and yield was large; density had a great effect on both yield and its components; it had a important effect on both yield and spike number per unit area between sowing date and density interaction (Su et al., 2015; Yang et al.,2015). Bainong 207 is an excellent variety selected by Henan Institute of Science and Technology. It needs corresponding high-yielding supporting cultivation techniques to further exploit the yield potential of the variety on the base of optimal sowing date and crop density to achieve stable and high yield of winter wheat.

Materials and methods. The experimental material – variety of Bainong 207 was provided by the Wheat Genetic Improvement Research Center of Henan Institute of Science and Technology.

Experiment design. The experiment was conducted in 2019–2020 in the experimental field of Hui Xian. The research field was flat, with good irrigation and drainage conditions and uniform fertility. Four sowing dates were set for this variety: October 1st(A1), October 8th (A2), October 15th (A3) and October 22d (A4), respectively; four densities for basic seedlings were 300×10^4 plant·hm^{-2} (B1), 375×10^4 plant·hm^{-2}(B2), 450×10^4plant·hm^{-2} (B3) and 525×10^4 plant·hm^{-2}(B4). There were 3 repetitions for each variant the row length of the plot was 4m, the width was 1.5 m, and the field management was common.

Measurement items and methods. After the emergence, select a representative 1-meter double-row sample for each plot to investigate population tiller number before winter and the highest population tiller number after winter; counting the spike number, grain number per spike, plant height and spike length at maturity phase. After winter maturing it was harvested according to the plot, threshing, drying, recording the yield separately, and measuring the thousand-grain weight (g).

Using volumetric HGT1000 to determine the volumetric weight (volume weight is the weight of the grain in the unit volume, the unit is g/l).

$$\text{Seed} - \text{setting rate} = \frac{\textit{Single spike summary real number}}{\textit{Total flowering per spike}} \times 100\%$$

For data analysis were used such program as Microsoft Excel and SPASS statistical software.

Results. *Effect of sowing date and density on yield and yield components of Bainong 207.*The effects of sowing date and density on yield and yield components reached significant levels (Table 1). The results of multiple comparisons showed that the average yield was A2>A3>A4>A1, and it increased by 10.25%, 3.8%, and 3.16%, respectively, compared with A1. The spike number and grain number per spike was more in A2 and A3 than in A1 and A4, indicating that both early sowing (A1) and late sowing (A4) were unfavorable for the growth of spike number and grain number per spike. Thousand grain weight decreased with delayed sowing, indicating that late sowing delayed the growth and development process and shortened the filling period, resulting in insufficient grain filling. From the effect of planting density on yield and yield components, the order of yield among different densities was B2>B3>B1>B4, in which B2 increased yield by 2.48% and 4.47% compared with B1 and B4, respectively, and the difference between B2 and B3 was not significant. With increasing density, the spike number and grain number per spike increased and then decreased, and the thousand grain weight gradually decreased, indicating that planting density was too high (B1) or too low (B4), which was not conducive to high yield. Only under the proper sowing date and planting density, high yield could be obtained.

Effect on the yield and yield components of Bainong 207 between sowing date and density interaction. The significance of the difference between sowing date and density interactions on yield and yield components is shown in Table 2, indicating that there were large differences between various densities at the same sowing date or between different sowing dates at the same density. Under A1 sowing date, the yield decreased with the increase of planting density, with B1 yielding the highest (10281.52 Kg·hm^{-2}). The spike number of B2 was the highest, followed by B3; the grain number per spike exhibited a trend of decreasing and then increasing with the growth of density, with B4 spike number, grain number per spike being the highest. The thousand grain weight of B2 was the highest, and the above results indicated that the coordination of yield components was affected by either too high or too low density under the same sowing date. Under A2 sowing, B3 had the highest yield (11,891.74 Kg·hm^{-2}), which was 6.86%, 4.02% and 9.02% higher than B1, B2 and B4, respectively. In A3 and A4 sowing, B2 had the highest yield and spike number. The yields were 10743.84 Kg·hm^{-2} and 10895.5 Kg·hm^{-2}, respectively. With increasing density, the grain number per spike gradually increased and the thousand grain weight gradually decreased under A3 sowing, and both the grain number per spike and thousand grain weight decreased under A4 sowing. Data of Table 2 also shows that A2B2 yield is the highest, A1B4 yield is the lowest, the spike number, the grain number per spike, thousand grain weight are the lowest in A4B4. The combined results show that the best sowing date is A2, the suitable density range is B2~B3, and the best planting density is B2.

Effect of sowing date and density on agronomic traits of Bainong 207. The differences of agronomic traits between different sowing periods and densities of Bainong 207 were significant as shown in Table 3. Setting percentage was highest in A3 at sowing date, and reached significant differences with A1, A2 and A4, but they were not large with A1, A2 and A4. Plant weight in creased gradually with sowing date, and was highest in A4 (781.25g·L^{-1}), and reached significant differences with other variants. Plant height decreased gradually with sowing date, indicating that it could be adjusted by sowing date. Spike length was the highest at A1, followed by A3, which did not differ significantly from each other, but reached significant differences with A2 and A4. With increasing density, seed-setting rate gradually decreased: they were the highest with B1 and B2, B3 but it was not significantly different for B4; plant weight was the highest under A1, followed by A4. Plant height and spike length did not differ significantly among different densities: plant height gradually increasing with density increasing, and spike length was the longest under A2, followed by A3, indicating that density should not be too large or too small.

Agronomic traits of Bainong 207 depend and in of sowing date and planting density. Seed-setting rate, plant weight, plant height and spike length were significantly difference between sowing date and density interaction (Fig. 1). Under A1, A3 and A4 sowing dates, the seed-setting rate decreased gradually with increasing density; under A2 sowing date, the setting percentage increased and then decreased. With the same density, the seed-setting rate was higher in A2 and A3 with delayed sowing date, among which A3B1 was the highest. The order of plant weight between different sowing dates was A4>A2>A1>A3, and the plant weight between different densities was B1>B4>B2>B3; A4B3 had the highest volume weight (783.67 g-L-1), followed by A4B1 and A4B4, indicating that late sowing and high density had a greater effect on plant weight. Under the same density, plant height gradually decreased with delayed sowing and under the same sowing date,

Table 1

Result of grain yield and its components depending sowing dates and planting densities

Variant		Grain yield (Kg·hm^{-2})	Spikes (10^4·hm^{-2})	Grain number per spike	Thousand-grain weight(g)
Sowing date	A1	10141.69c ±144	567.21bc ±27.04	43.48b ±1.89	42.07b ±0.59
	A2	11300.12a ±426	580.38a ±22.11	43.62b ±2.68	43.99a ±1.61
	A3	10542.45b ±174	576.55ab ± 29.08	44.52a ±1.31	41.83b ±1.41
	A4	10472.82b ±299.8	556.78c ±30.08	42.05c ±1.62	39.53c ±2.04
Density	B1	10545.45b ±333.6	560.16c ±21.08	42.83c ±1.59	43.13a ±1.92
	B2	10813.73a ±463.1	587.09a ±25.49	43.44b ±2.58	42.42b ±2.22
	B3	10767.58a ±709.8	572.43b ±29.18	44.43a ±1.63	41.56c ±1.15
	B4	10330.33c ±338.9	561.25c ±29.58	42.97bc ±2.25	40.31d ±2.2

Note: Values followed by different small and capital letters are significantly different at 0.05 levels. The same below.

Table 2

Grain yield and its components of Bainong 207 at different sowing dates and planting densities

Variant	Grain yield (Kg·hm^{-2})	Spikes (10^4·hm^{-2})	Grain number per spike	Thousand-grain weight(g)
A1×B1	10281.52ghij ±31.3	550.34def ±3.03	43.87e ±0.76	42.13cdef ±0.25
A1×B2	10201.73hij ±146.7	606.67a±2.32	40.73hi ±0.81	42.87cde ±0.42
A1×B3	10087.54ij ±73.4	571.37cde ±8.67	43.87e ±0.83	41.7defg ±0.26
A1×B4	9995.96j ±123.3	540.46f ±8.27	45.47bcd ±0.31	41.57efg ±0.31
A2×B1	11075.71bc±55.1	582.73abc ±4.81	40.52hi ±0.84	46.07a±0.57
A2×B2	11413.84b±107.9	548.94ef ±2.24	45.57abc ±0.35	44.63b±0.61
A2×B3	11891.74a±90	597.12ab ±6.62	46.6a±0.2	43.07c±0.35
A2×B4	10819.19cde ±90.8	592.73abc ±5.68	41.8fg ±0.4	42.2cdef ±0.44
A3×B1	10431.96fghi ±152.6	535.3f ±6.17	42.8f ±0.4	42.93cd ±0.76
A3×B2	10743.84cdef ±131.2	601.06ab ±9.43	46.13ab ±0.5	42.93cd ±0.65
A3×B3	10601.29defg ±67.6	588.03abc ±3.81	44.67cde ±0.7	40.8g ±0.85
A3×B4	10392.71fghi ±59.6	581.82bc ±4.17	44.47de ±0.31	40.63g ±0.51
A4×B1	10392.62fghi±65.1	572.28cd±10.41	44.13e ±0.51	41.37fg ±0.35
A4×B2	10895.5cd ±99.8	591.67abc ±4.82	41.33gh±0.41	39.27h ±0.32
A4×B3	10489.72efgh±77.9	533.19f±9.46	42.6f ±0.87	40.67g ±0.93
A4×B4	10113.44hij ±47.8	530f ±6.36	40.13i±0.83	36.83i ±0.40

plant height decreased and then increased with increasing density, but under A4 sowing date, plant height gradually increased with increasing density. A1B4 plant height was the highest (86.85 cm) and A1B1 plant height was the lowest (76.67 cm), indicating that plant height could be improved by adjusting sowing date and density. Spike length was the highest in A1B4, followed by A1B2, they did not differ significantly. With delayed sowing, spike length did not differ considerably among densities, indicating that sowing date had a little effect on spike length.

Correlation analysis of the yield and main agronomic traits. The correlation coefficients of yield traits for each variants were calculated as shown in Table 4. The index traits were positively correlated with yield, seed-setting rate were (r = 0.092), plant weight (r=0.079), spike number (r=0.37), grain number per spike (r=0.292), and thousand grain weight(r=0.464). The correlation coefficients of seed-setting rate, plant weight and yield were not significantly different, and the correlation coefficients of spike number and thousand grain weight were highly large. The correlation coefficients between plant height (r=0.18), spike length (r=0.572) and yield were negatively correlated, with no significant difference in plant height and a highly significant difference in spike length.

The correlations among the other agronomic traits were as follows: plant weight, spike number and thousand grain weight were negatively correlated. Seed-setting rate, plant height, spike number, grain number per spike and thousand grain weight were positively correlated, but not significantly for grain number per spike. The traits that were positively correlated were seed-setting rate, plant height, spike length, spike number, seed-setting rate, spike length at a significant level, the other two were not significantly different. But there was a highly significant negative correlation between plant weight and the grain number per spike. Seed-setting rate, plant height and spike length were positively but not significantly correlated with the spike number, while volume weight was highly significantly and negatively correlated with the spike number. Plant height, setting percentage and spike length were positively correlated, plant height was significantly and positively correlated with spike length, and volume weight was highly significantly and negatively correlated with spike length. Seed-setting rate, plant weight and plant height were negatively correlated, and plant weight was significantly different. The seed-setting rate was significantly and negatively correlated with the plant weight. The analyses showed that the plant weight was

Table 3

Agronomic traits of winter wheat depending on sowing dates and planting densities

Variant		Seed-setting rate (%)	Plant weight ($g \cdot L^{-1}$)	Plant height (cm)	Spike length (cm)
Sowing date	A1	83.71b ±0.011	772.83c ±3.04	85.44a ±1.42	10.16a ±0.47
	A2	85.32b ±0.03	776.08b ±2.5	81.7b ±4.61	9.21c ±0.47
	A3	88.70a ±0.02	765.08d ±2.84	81.64b ±2.11	10.08a ±0.41
	A4	83.36b ±0.02	781.25a ±3.11	77.78c ±2	9.5b ±0.54
Density	B1	85.81a ±0.037	774.75a ±6.59	80.88a ±4.03	9.72a ±0.28
	B2	84.99a ±0.038	773.17ab ±6.51	80.86a ±3.78	9.77a ±0.18
	B3	85.09a ±0.025	772.67b ±8.12	82.17a ±3.48	9.79a ±0.16
	B4	85.19a ±0.02	774.67a ±5.3	82.64a ±4.28	9.68a ±0.28

Table 4

Correlation analysis of the yield and main agronomic traits

Correlation Coefficient	Seed-setting percentage (%)	Plant weight (g)	Plant height (cm)	Spike length (cm)	Spikes ($10^4 plant \cdot hm^{-2}$)	Grain number per spike	Thousand-grain weight (g)	Grain yield (Kg hm^{-2})
Setting percentage (%)	1	-0.462**	-0.014	0.271	0.06	0.302*	0.24	0.092
Plant weight (g)		1	-0.310*	-0.547**	-0.334*	-0.373**	-0.185	0.079
Plant height (cm)			1	0.294*	0.071	0.146	0.238	-0.18
Spike length (cm)				1	0.021	0.312*	-0.05	-0.572**
Spikes ($10^4 plant \cdot hm^{-2}$)					1	0.064	0.259	0.370**
Grain number per spike						1	0.229	0.292*
Thousand-grain Weight (g)							1	0.464**
Grain yield ($Kg \cdot hm^{-2}$)		* p<0.05	** p<0.01					1

*Note: * and ** indicate correlations significant at the 0.05 and 0.01 levels, respectively.*

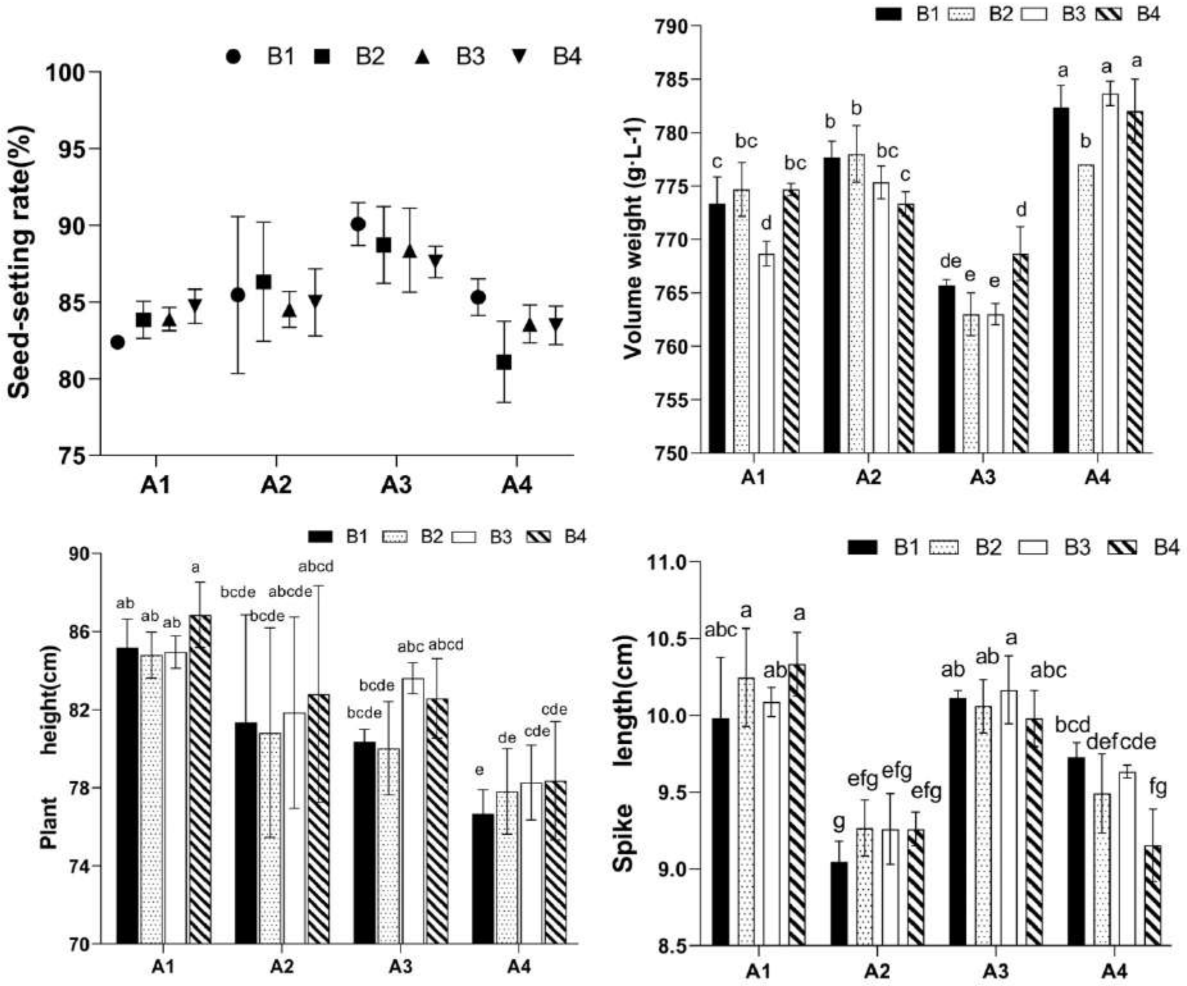

Fig. 1. Influence of sowing date and planting density on agronomic traits

negatively correlated with plant height, spike length, spike number, grain number per spike and thousand grain weight.

Discussion. Sowing date and density are two important factors affecting yield, the results of which are controlled by variety, cultivation techniques, environmental and management conditions (Liu et al., 2014; Zhang et al., 2009; Guo et al., 2004; Yang et al., 2007). The results of this study showed that yield, spike number, and grain number per spike were higher at sowing dates A2, A3, and densities B2 and B3, and the thousand grain weight decreased gradually with delayed sowing dates and increasing densities. It can be seen that the appropriate sowing date for Bainong 207 is October 8~15, and the appropriate density is 375~450 ×10^4 plant·hm^{-2}. The interaction effect of sowing date and density A2B3 has the highest yield of 11,891.74 Kg·hm^{-2}, followed by A2B2, indicating that the best sowing date is October 8, and the best density is 450 ×10^4 plant·hm^{-2}. The spike number and grain number per spike increased and then decreased with increasing density at the same sowing date, and the thousand grain weight gradually decreased. In conclusion, both early and late sowing dates are not good for high yield, which is consistent with the results of previous studies (Xi et al.,2012;Han et al., 2011; Wang et al.,2009; Yan et al., 2008;Guo et al., 2009; Qu et al., 2013).The effect of sowing date and density on agronomic traits showed that the effect of sowing date was greater than that of density. The differences between sowing dates were significant in seed-setting rate, plant weight, plant height and spike length, but no significant differences were found in density on setting percentage, plant height and spike length. Setting percentage A3 was the highest, followed by A2, which gradually decreased with increasing density; the volume weight fluctuated more with delayed sowing, and changed less with increasing density, which might be related to the climatic conditions during the filling period. Plant height gradually decreased with delayed sowing, so plant height could be adjusted by changing sowing period, This is consistent with the findings of other scholar (Wang et al., 2007); and the trend of plant height changed less with increasing density, which might be the result of growth competition within the population. Spike length varied with different sowing periods. The difference between the maximum and minimum values is only 0.95 cm, and the difference between the maximum and minimum values is only 0.11 cm, which shows that the spike length is relatively stable trait and does not change significantly with sowing date and sowing density, which is consistent with the result other scholar study (He et al., 2018).

The results of correlation analysis showed that the spike number, the grain number per spike and thousand grain weight were positively correlated with yield, the plant height and the spike length were negatively correlated with yield, and the seed-setting rate and the plant weight were not significantly correlated with yield. The results showed that the three components of yield can be harmonized and high yield can be achieved with proper sowing at the optimal date and the proper density.

Conclusions. This experiment is only a preliminary study to compare the sowing date and density of Bainong 207. There are many factors affecting yield: variety, geographical environment, temperature, light and climatic conditions, so further research of field management measures, pest and weed control is needed to facilitate the formation of good variety and method of cultivation technology to provide guarantee for high quality and yield of wheat.

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Вплив різних строків і густоти посіву на урожайність та основні агрономічні ознаки озимої пшениці сорту Bainong 207

Нині є актуальні вимоги щодо сортів із підвищеною адаптованістю та спрощеною і практичною агротехнікою для підтримки сучасного сільського господарства. У наших дослідженнях ми використовували сорт озимої пшениці Bainong 207 як експериментальний матеріал і мали чотири строки посіву та чотири варіанти густоти посіву для кожного терміну. Було досліджено вплив строків та густоти посіву на врожайність, компоненти врожайності та основні агрономічні ознаки. За результатами досліджень було встановлено, що вплив строків і густоти посіву на врожайність та основні компоненти врожайності суттєво відрізнялися, причому вплив строку посіву виявився сильнішим, ніж вплив густоти. Урожайність, кількість колосків та кількість зерна на колосі були найвищими у А2, а маса тисячі зерен – у А3; найбільшу врожайність мали В2 та В3. Кількість колосків та кількість зерна на колосі зростали, а потім зменшувалися зі збільшенням густоти, а маса тисячі зерен поступово зменшувалася. При цьому не спостерігалося тенденції до збільшення маси рослин з урахуванням строків та густоти посіву. Висота рослин пшениці поступово зменшувалася зі строком посіву та збільшувалася з густотою посіву. Довжина колоса була відносно стабільною ознакою без істотних змін із терміном та густотою посіву. За результатами досліджень встановлено найбільш придатні сроки посіву для сорту озимої пшениці Bainong 207. Кореляційний аналіз показав, що високий урожай можливо досягнути шляхом поєднання трьох факторів врожайності при відповідних строках та густоті посіву.

Ключові слова: *кореляційний аналіз, озима пшениця, строки посіву, густота посіву, урожайність, сорт, компоненти врожайності, основні агрономічні ознаки, Bainong 207.*