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Morphological Changes of Above-Ground Internodes of Spring Barley Plants Depending on the Seeding Rate and Foliar Top Dressing

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AIM

To determine the complex influence of the seeding rates and foliar top dressing on modification changes of above-ground internodes of spring barley plants. ***Methods****. Field, measuring, analysis, generalization, statistical.* ***Results****. Morphological changes of above-ground internodes under the complex influence of the seeding rate and foliar top dressing were established and analyzed. The length of the three lower internodes increased with an increase in the seeding rate, and the two upper ones decreased. Among the types of foliar top dressing, the elongation of the upper internodes, compared to the control, was provided only by the type in which the crops were treated in the tillering and stem formation phase. With an increase in the seeding rate, the dry mass of a centimeter segments of all internodes and their diameter decreased. The seeding rate had a greater impact on the variability of vertical resistance indicators of spring barley plants. Thus, the range of divergence in the plant resistance index against lodging under its influence was 18.0 %, and under the influence of foliar top dressing it did not exceed 2.0 %.* ***Conclusions****. Change of the density of plants and carrying out foliar top dressing with a biostimulator-antistressant allow you to control the parameters of above-ground internodes of spring barley. The seeding rate from 350 to 450 pieces/m^2 ensures the formation of crops with a sufficiently high resistance to lodging. If the seeding rate increases over 450 pieces/m^2 there is a decrease of indicators in the resistance of spring barley plants to lodging, which is associated with the elongation of other internode at samultanious reducing its diameter due to greater competition between plants. The experiment established a high efficiency of two foliar top dressing of crops with a biostimulator-antistressant – Vuksal Aminoplast to increase the vertical resistance indicators of spring barley plants, primarily by increasing the diameter of the lower internodes.*

Keywords: *internodes, spring barley, seeding rate, lodging, foliar top dressing.*

INTRODUCTION

Spring barley is a strategic grain crop in the world. Its sown area is about 60 million hectares and according to this indicator it takes sixth place in the world. Ukraine's share in global barley production is about 8 %. More of it is sown only in Russia (15 %). Large areas alloted for this crop indicate its high genetic potential of productivity and economic competitiveness [1].

In terms of barley grain cropping capacity of 2.5 t/ha, Ukraine is significantly inferior to the EU countries, where this indicator is 5-6 t/ha [2]. The low level of barley grain cropping capacity in Ukraine indicates the need for further improvement of the technology of growing this crop.

One of the reasons for the decrease in barley cropping capacity is its lodging. Therefore, when developing the technology for growing this crop, special attention should be paid to the factors responsible for the resistance of plants to lodging.

For the adaptation of higher plants to existence in the above-ground environment, development of special tissues and anatomical structures that ensure the strength of plant organs and their resistance to mechanical loads is important. As with other cereals, the stem strength in barley is determined by its chemical composition [3], anatomical structure and growing conditions [4].

Morphological changes that occur in plants during growth and development determine the architectonics of plants, resistance to lodging, and cropping capacity. Protective reactions of plants can only be carried out at the expense of the reserves of the plants themselves. Changes of the

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internodes length, their diameter, the mass of centimeter segments, the ratio of the size of the above-ground and basal parts ensures plants adaptation to growing conditions [5-7].

The realization of the genetic potential of crops yield is ensured by the resistance of plants to lodging. It is believed that the lodging of crops is caused by the structure peculiarities of the plants themselves, physical and technological factors, and the affection of crops by diseases [8].

The resistance of plants to lodging is determined by the parametric structure of the stems: their height and diameter, the ratio of these indicators, and the wall thickness [6, 9]. It is clear that a long and thick stem can be more resistant to lodging than a short but thin one.

Crops lodging causes a violation of energy exchange, intensification of plant affection by diseases, deterioration of grain quality, increased grain losses during yield harvesting and complications of its harvesting [4, 10, 11-13]. One of the reasons for the loss of vertical resistance by plants is the reutilization of cellular substances that give resistance to the walls of straw. However, the quantitative and qualitative ratio of the main components of the stem building material is crucial in ensuring plant resistance to lodging [14].

Grain crops react strongly to the seed seeding rates and form the highest grain cropping capacity at a certain its indicator, which depends on a complex of other factors, in particular on the weather conditions of vegetation, crops nutrition system, sowing methods, etc. An increase in the seeding rate away from the optimal one is one of the main reasons for a decrease in the resistance of crops plants to lodging [15, 16].

The reason for lodging is morphological changes of stem internodes, namely, their elongation with a simultaneous decrease in the diameter and mass of centimeter segments [17]. Lodging-resistant varieties have stronger lower internodes, a larger diameter, and a shorter length [6]. In this context, N.A. Maievska [18] notes great theoretical and practical importance of studying the nature of morphological changes of stem internodes, since this makes it possible to effectively select plants and varieties with the necessary traits.

Researcher M.S.Nekhoroshykh [19] notes a lower variability in the “dimensions” of internodes of the main stems of grain crops compared to the side stems. He also notes a different rate of stems development of different ranks, which is due to their formation time. In his opinion, one of the factors of accelerated stems development of late formation period is the lengthening of daylight hours and increased in solar activity.

Analysis of research materials indicates insufficient studying of dependencies of parameters variation of stem internodes. In the literature, there is enough information about the relationship between individual productivity indicators or cropping capacity elements and some morphological stem parameters [20]. There are few publications on the relationship between individual indicators of the morpho-anatomical stem structure of grain spike crops [16, 21].

However, a comprehensive assessment of morphological changes of prefloral internodes of spring barley plants depending on the seed seeding rate, foliar top dressing and weather conditions of the growing season was not carried out. At the same time, this issue is very important, since the studying of the formation regularities of prefloral zone internodes parameters of spring barley plants is important for solving the problem of crops lodging of this crop, which among spike crops is most susceptible to lodging and, in this respect, has a much narrower range of optimal plant stand parameters.

MATERIALS AND METHODS

The study was conducted in 2016-2020 on the basis of the Educational Research and Production Center “Experimental Field” of V.V. Dokuchaiev Kharkiv National Agrarian University according to the generally accepted methodology [22]. For research, we have chosen spring barley of Monomakh variety, which is included in the State Register of varieties and is allowed to be grown in all agroclimatic zones of Ukraine.

Two-factor field experiment was carried out on the method of organized repetitions. In experiments, five variants of the seeding rate (factor *A*) were compared: 350 pieces/ m^2; 400; 450; 500 and 550

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pieces/ m^2 and four options for foliar top dressing of crops with a stimulant-antistressant with a high content of phytohormones – Vuksal Aminoplant (Factor *B*): 1 – control (water treatment); 2 – top dressing during tillering (microfase 22-23); 3 – top dressing during stem formation (microfase 33-34); 4 – double top dressing in the marked phases.

Vuksal Aminoplant – biostimulator-antistressant of plant origin obtained by a special extracting technology, which allows you to preserve all the properties of biologically active substances. It contains the entire amino group of *L*-amino acids of plant origin and other biologically active substances (auxin, GABA, vitamins, etc.). This preparation activates the protective plants system to the effects of adverse environmental factors (drought, high or low temperature), increases lignin content in the walls of straw strengthening them, improves root system development, quickly and effectively removes the plant from the state of stress caused by pesticides.

A single dose of preparation application in studies was set at the rate of 1.5 l/ha and the working fluid consumption rate of 250 l/ha. The area of the sown plot is 25 m^2, accounting – 20 m^2, laboratory – 5.0 m^2. The number of repetitions is four times.

The length, diameter, and air-dry mass of centimeter segments of above-ground internodes of spring barley were determined by measurements, calculations, drying, and weighing according to generally accepted methods [23, 24].

The soil of the experimental plot is typical deep heavy loam chernozem on a carbonate loess. Humus content in the arable layer is 4.4–4.7 %, movable phosphorus (according to Chyrykov) – 13.8 mg, potassium – 10.3 mg per 100 g of soil.

The climate of the research area is temperate continental. Disproportion between high soil fertility and the warm growing season, on the one hand, and moisture deficit and manifestations of drought, on the other, is clearly expressed. The main factor limiting grain cropping capacity is the amount of precipitation.

Taking into account the importance of vegetation weather conditions for the growth and development of spring barley plants, we will give a brief description of them.

In 2016, the amount of precipitation during the growing season of barley plants was 230 mm, which is 20% more than the climatic norm. At the same time, the decadal distribution of precipitation was very uneven. For example, in the first and third decades of July, only 5 and 6 mm of precipitation fell, while in the second decade – 95 mm. Temperature indicators in all months of the growing season significantly exceeded the long-term average indicators, and in the third decade of June and the second decade of July they were extremely high.

In 2017, according to the temperature regime, weather conditions of the growing season of spring barley plants were close to the climatic norm. At the beginning of plant development, there was a noticeable moisture deficit, which affected the plants growth processes. In May, there was enough precipitation. A certain deficit of precipitation was observed in June and July.

Weather conditions in 2018 were the least favorable for the growth and development of barley crops. In summer, almost twice less precipitation fell compared to long-term indicators. There wasn't almost any precipitation in April, while the air temperature in April-July significantly exceeded the long-term average indicators. The sum of effective temperatures during the growing season was 2396 °C, which is almost 25% more than the indicator of climatic norm.

In 2019, there was also a significant moisture deficit at temperature indicators at the level of the climatic norm. During plants vegetation, precipitation fell twice less than the long-term average indicators. Most of them was in the first half of the growing season of spring barley crops.

The growing season of 2020 was characterized by temperatures at the level of the climatic norm and a sufficient amount of precipitation in the first half of the plants vegetation and high temperatures and deficit of precipitation in the second. Fall of the temperature in the third decade of May (the average temperature was 3.2 °C less than the indicator of climatic norm), along with a sufficient amount of precipitation, delayed the growth and development of spring barley. At the same time, such conditions

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ensured the formation of a larger number of generative metamers. In the third decade of June and the first decade of July there was a heat (the temperature on some days exceeded 35.0 °C), which, along with the absence of precipitation, accelerated the growth processes of barley plants.

Thus, weather conditions in the years of research in terms of temperature regime, amount and distribution of precipitation significantly differed from the long-term average indicators. However, taking into account the global warming tendency, it can be noted that they were typical for the research area. In general, the weather conditions of the growing season of 2016 and 2020 to a greater extent corresponded to the biological requirements of spring barley.

RESULTS AND DISCUSSION

In the studies it has been established significant morphological changes of above-ground internodes under the influence of the studying factors. On average for years, the length of the lower internode, depending on the seeding rate, varied in the range from 2.8 to 4.8 cm; the second – from 8.9 to 12.0 cm; the third – from 15.1 to 17.1 cm; the fourth – from 22.6 to 24.7 cm; the fifth – from 29.6 to 32.1 cm (Table 1).

1. Length of above-ground internodes of spring barley depending on the seeding rate and foliar top dressing, cm (average for 2016-2020)

Seeding rate, seeds/m^2 (factor *A*)	Types of top dressing (factor *B*)	Internode				
		1-st	2-nd	3-rd	4-th	5-th
350	Control (I)	2,7/I	8,9/I	14,8/I	24,1/I	31,7/I
400		2,9/II	9,3/II	15,0/I	23,9/I	31,3/I
450		3,4/III	9,7/III	15,5/II	23,7/I	30,7/II
500		4,1/IV	10,5/IV	16,2/II	23,2/II	30,1/III
550		5,0/V	11,9/V	16,9/III	22,1/III	29,3/III
350	Vuksal Aminoplant (tillering) (II)	2,5/I	9,0/I	15,1/I	24,7/I	31,9/I
400		3,1/II	9,3/I	15,4/I	24,4/II	31,6/II
450		3,5/III	9,8/II	15,7/I	24,2/II	30,9/II
500		4,0/IV	10,5/III	16,4/II	23,5/II	30,4/II
550		4,7/V	12,1/IV	17,1/II	22,7/III	29,5/III
350	Vuksal Aminoplant (stem formation) (III)	3,1/I	8,8/I	15,0/I	24,7/I	32,1/I
400		3,2/I	9,1/I	15,0/I	24,6/I	31,9/I
450		3,6/II	9,6/II	15,4/I	24,1/I	31,2/II
500		4,0/III	10,3/III	16,2/II	23,8/II	30,4/II
550		4,8/IV	11,7/IV	17,0/III	22,4/III	29,7/III
350	Vuksal Aminoplant (tillering) (IV)	2,8/I	9,0/I	15,3/I	25,1/I	32,7/I
400		3,0/II	9,2/I	15,6/I	24,8/I	32,2/I
450		3,3/III	9,8/II	16,0/I	24,4/I	31,4/II
500		3,9/IV	10,6/III	16,6/II	24,0/II	30,8/II
550		4,8/V	12,1/IV	17,4/III	23,1/III	29,7/III
Average by factor *A*	350	2,8/I	8,9/I	15,1/I	24,7/I	32,1/I
	400	3,1/II	9,2/II	15,3/I	24,4/I	31,8/I
	450	3,5/III	9,7/III	15,7/II	24,1/I	31,1/II
	500	4,0/IV	10,5/IV	16,4/III	23,6/II	30,4/II
	550	4,8/V	12,0/V	17,1/IV	22,6/III	29,6/III
Average by factor *B*	I	3,6/I	10,1/I	15,7/I	23,4/I	30,6/I
	II	3,6/I	10,1/I	15,9/I	23,9/I	30,9/I
	III	3,7/I	9,9/I	15,7/I	23,9/I	31,1/I

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	IV	3,6/I	10,1/I	16,2/II	24,3/II	31,4/II

Note: the numerator shows the indicators of internodes length, and the denominator shows their distribution over homogeneous groups according to statistical analysis using the Duncan's rank criterion.

Length indicators of the first and second internodes of spring barley stem belon-ged to five statistically different rank groups, length indicators of the third internode – to four groups and length indicators of the fourth and fifth – to three groups.

Seeding rates had different effects on the length of the prefloral internodes of the stem. The length of the three lower internodes increased with an increase in the seeding rate, while the two upper ones, on the contrary, decreased. This regularity was expressed in all types of foliar top dressing.

In general, an increase in the seeding rate, at the expense of the elongation of the three lower internodes, led to the "stretching" of spring barley plants. In particular, according to the seeding rates of 350, 400, 450, 500 and 550 pieces/m^2 their length on average was 83.5 cm; 83.7; 84.0; 84.9 and 86.0 cm, respectively.

In the experiment, a significant influence of the studying types of foliar top dressing on the length of the upper internodes was noted. The length of the two lower internodes did not change under the influence of the studying types of crops foliar top dressing. Among the types of foliar top dressing, the change of the length of the upper internodes compared to the control (their elongation) was provided only by the type in which the crops were treated twice – during the tillering and stem formation.

Regression analysis has proved the close dependence of internodes length on the seeding rate and the dry mass of their centimeter segment. The multiple correlation coefficient between the length of the second internode, the seeding rate and the dry mass of the centimeter segment of the internode was 0.974.

According to the calculated regression equation, an increase in the seeding rate by 100 pieces/m^2 will theoretically provide an increase in the length of the first and second internodes by 1.4 and 1.0 cm, respectively. The correlation coefficient between the length of the second internode and the seeding rate was 0.991. The length of the second internode and the mass of its centimeter segment had a close reverse relationship – r = -0.987. The length of the upper internode had a close reverse relationship with the seeding rate (r = -0.976) and a direct relationship with the dry mass of the centimeter segment of the internode (r = 0.951).

The dry mass of a centimeter segment of internodes was determined in all above-ground internodes of barley plants. Larger changes of this indicator were observed in the second and third internodes. The dry mass of the centimeter segment of the first internode under the influence of the seeding rate varied in the range from 13.5 to 17.0 mg (divergence 26 %), the second – from 10.3 to 12.2 mg (divergence 18 %), the third – from 6.9 to 9.6 mg (divergence 39 %), the fourth – from 6.5 to 7.4 mg (divergence 14 %), the fifth – from 3.9 to 4.4 mg (divergence – 13 %) (Table 2).

The influence of the seeding rate was least expressed on the change of the dry mass indicators of the centimeter segment of the upper internode. According to statistical analysis using the Duncan's rank criterion, two statistically different rank groups of indicators were identified. The first group included indicators of dry mass of centimeter segments of the lower three internodes, the second group – two upper internodes.

A reliable effect of the interaction of the cultivation technology studying elements on changes of the dry matter mass indicators of centimeter segments has not been established. At the same time, there is a tendency to increase discrepancies in the indicators of centimeter internodes segments due to the influence of the seeding rate on the variants with application of two foliar top dressing of crops with a biostimulator-antistressant – Vuksal Aminoplant. To a greater extent, this tendency was observed in change of the indicators of centimeter segments of plants' two upper internodes.

2. Dry matter mass of a centimeter segment of above-ground internodes of spring barley, depending on the seeding rate and foliar top dressing, mg

(average for 2016–2020)

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Seeding rate, seeds/m^2 (factor *A*)	Types of foliar top dressing (factor *B*)	Internode				
		1-st	2-nd	3-rd	4-th	5-th
350	Control (I)	16,5/I	12,0/I	9,4/I	7,2/I	4,2/I
400		16,7/I	12,0/I	9,3/I	7,2/I	4,3/I
450		16,3/I	11,3/II	8,7/II	6,9/I	4,0/I
500		15,0/II	11,1/II	7,8/III	6,5/II	3,8/II
550		13,1/III	9,7/III	6,6/IV	6,2/II	3,8/II
350	Vuksal Aminoplant (tillering) (II)	17,2/I	12,2/I	9,5/I	7,0/I	4,5/I
400		16,9/I	12,4/I	9,1/I	7,1/I	4,3/I
450		17,0/I	11,8/I	8,8/II	7,0/I	4,2/I
500		15,7/II	11,3/II	8,0/III	6,7/I	4,0/II
550		13,9/III	10,2/III	6,8/IV	6,4/II	3,7/II
350	Vuksal Aminoplant (stem formation) (III)	16,8/I	12,5/I	9,7/I	7,5/I	4,4/I
400		16,8/I	12,7/I	9,5/I	7,4/I	4,4/I
450		16,3/II	12,4/I	9,1/II	7,2/I	4,3/I
500		15,2/III	11,8/II	8,4/III	7,0/II	4,3/I
550		13,4/IV	10,8/III	7,1/IV	6,7/II	4,0/II
350	Vuksal (tillering) (IV)	17,6/I	12,2/I	9,8/I	7,7/I	4,6/I
400		17,1/I	11,7/I	9,6/I	7,6/I	4,5/I
450		16,7/II	11,6/II	9,0/II	7,4/I	4,3/II
500		15,5/III	11,4/II	8,3/III	7,1/II	4,3/II
550		13,7/IV	10,6/III	7,0/IV	6,5/III	4,1/II
Average by factor *A*	350	17,0/I	12,2/I	9,6/I	7,4/I	4,4/I
	400	16,9/I	12,2/I	9,4/I	7,3/I	4,4/I
	450	16,6/II	11,8/II	8,9/II	7,1/II	4,2/I
	500	15,4/III	11,4/III	8,1/III	6,8/II	4,1/II
	550	13,5/IV	10,3/IV	6,9/IV	6,5/III	3,9/II
Average by factor *B*	I	15,5/I	11,2/I	8,4/I	6,8/I	4,0/I
	II	16,1/II	11,6/II	8,4/I	6,8/I	4,1/I
	III	15,7/I	12,0/III	8,8/II	7,2/II	4,3/II
	IV	16,1/II	11,5/II	8,7/II	7,3/II	4,4/II

Note: the numerator shows the dry matter mass indicators of centimeter segments of internodes, and the denominator shows their belonging to rank groups according to statistical analysis using the Duncan's rank criterion.

The studying types of foliar top dressing also had a significant effect on the change of the dry mass of the centimeter segment of prefloral internodes. Their influence to a greater extent was expressed on the variability of dry mass indicators of centimeter segments of the second internode. In particular, the divergence between the dry matter mass indicators of the centimeter segments of the first, second, third, fourth and fifth internodes, depending on the foliar top dressing of crops, was 0.6 mg, 0.8, 0.4, 0.5 and 0.4 mg, respectively.

Regression analysis has proved a high dependence of the change of the dry mass of the centimeter segment of the internode on the seeding rate and the internode length. The multiple correlation coefficient between the dry mass of the centimeter segment of the second internode, its length and the seeding rate was 0.958.

An increase in the seeding rate led to a decrease in the diameter of all internodes of spring barley plants. The diameter of the lower internodes under the influence of the seeding rate underwent greater changes than the upper ones. Thus, with an increase in the seeding rate from 350 to 550 seeds/m^2, the diameter of the lower, second, third, fourth and upper internodes decreased by 0.49 mm (15,4 %); 0,48 (14,8 %); 0,52 (18,5 %); 0,27 (10,8 %) and 0.21 mm (9.2 %), respectively (Table 3).

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Diameter indicators of the three lower internodes under the influence of the studying seeding rates belonged to four statistically different rank groups. There was no significant difference between the diameter indicators of the three lower internodes on the variants of the seeding rates of 350 and 400 pieces/m^2, according to other seeding rates, the indicators were divided into different statistical groups.

Diameter indicators of the two upper internodes were divided into three statistically different rank groups. In particular, the diameter indicators of the fourth internode at the seeding rates of 350, 400 and 450 pieces/m^2 varied within the smallest essential difference and belonged to the same rank group, and the diameter of the upper internode did not change significantly with an increase in the seeding rate from 350 to 400 pieces/m^2 (first rank group), and from 450 to 500 pieces/m^2 (second rank group).

Foliar top dressing significantly affected the change of the diameter of the third and fourth internodes of spring barley plants. Their effect on increasing the diameter of the first, second and fifth internodes has not been statistically proven, but it has been noted a tendency to increase the diameter of these internodes after foliar top dressing applying.

Diameter of the second and upper internodes had a close reverse relationship with the seeding rate, – r = -0.866 and r = -0.913, respectively. A close direct relationship was established between the length of the upper internode and its diameter – r = 0.778.

The calculated resistance indices of spring barley plants to lodging indicate the possibility of influencing the indicators of plants vertical resistance by changing the density of plant standing and foliar top dressing applying.

Seeding rates had a greater influence on the variability of vertical resistance indicators of spring barley plants. The range of divergence in the plant resistance index to lodging under the influence of the seeding rate was 18.0 %, and under the influence of foliar top dressing – 2.0 %.

3. Dameter of above-ground internodes of spring barley depending on the seeding rate and foliar top dressing, mm (average for 2016-2020)

Seeding rate, seeds/m^2 (factor *A*)	Types of foliar top dressing (factor *B*)	Internode				
		1-st	2-nd	3-rd	4-th	5-th
350	Control (I)	3,63/I	3,66/I	3,20/I	2,74/I	2,45/I
400		3,55/I	3,60/I	3,17/I	2,70/I	2,42/I
450		3,43/II	3,46/II	3,03/II	2,63/I	2,37/I
500		3,30/II	3,37/II	2,90/III	2,54/II	2,31/II
550		3,17/III	3,20/III	2,74/IV	2,41/III	2,25/III
350	Vuksal Aminoplant (tillering) (II)	3,72/I	3,75/I	3,33/I	2,75/I	2,51/I
400		3,61/I	3,66/I	3,25/I	2,75/I	2,45/I
450		3,48/II	3,53/II	3,11/II	2,69/I	2,41/II
500		3,35/III	3,39/III	2,96/III	2,63/II	2,33/II
550		3,19/III	3,22/IV	2,77/IV	2,52/III	2,26/III
350	Vuksal Aminoplant (stem formation) (III)	3,68/I	3,77/I	3,33/I	2,80/I	2,49/I
400		3,60/I	3,71/I	3,30/I	2,77/I	2,47/I
450		3,45/II	3,64/I	3,22/I	2,72/I	2,40/I
500		3,33/II	3,47/II	3,07/II	2,66/II	2,36/II
550		3,21/III	3,27/III	2,87/III	2,55/III	2,30/II
350	Vuksal Aminoplant (tillering) (IV)	3,70/I	3,71/I	3,36/I	2,77/I	2,51/I
400		3,65/I	3,67/I	3,28/I	2,74/I	2,48/I
450		3,52/II	3,61/I	3,17/II	2,74/I	2,45/I
500		3,37/II	3,44/II	3,09/III	2,69/I	2,43/I

550		3,19/III	3,25/III	2,84/IV	2,50/II	2,29/II
Average by factor *A*	350	3,68/I	3,72/I	3,33/I	2,77/I	2,49/I
	400	3,60/I	3,66/I	3,25/I	2,74/I	2,46/I
	450	3,47/II	3,56/II	3,13/II	2,70/I	2,41/II
	500	3,34/III	3,42/III	3,01/III	2,63/II	2,36/II
	550	3,19/IV	3,24/IV	2,81/IV	2,50/III	2,28/III
Average by factor *B*	I	3,42/I	3,46/I	3,02/I	2,60/I	2,36/I
	II	3,47/I	3,51/I	3,08/I	2,67/I	2,39/I
	III	3,45/I	3,57/I	3,16/II	2,70/II	2,40/I
	IV	3,49/I	3,54/I	3,15/II	2,69/II	2,43/I

Note: the numerator shows the indicators of internodes diameter, and the denominator shows their belonging to homogeneous groups according to statistical analysis using the Duncan's rank criterion.

In general, we can note a slight change of the lodging resistance index in the range of the seeding rate from 350 to 450 pieces/ m^2. The decrease in this indicator within the indicated range of the seeding rate on average for the studying types of foliar top dressing did not exceed 4.0 %. Therefore, from the point of view of plant resistance to lodging, this gives reason to recommend these seeding rates for sowing spring barley.

4. Resistance indices of spring barley plants to lodging depending on the influence of the seeding rate and foliar top dressing (average for 2016-2020)

Types of foliar top dressing	Seeding rates, pieces/m^2				
	350	400	450	500	550
I*	225	229	240	250	266
II	222	229	238	250	267
III	222	226	230	244	262
IV	229	231	235	249	268

Note: foliar top dressing types: I –Control; II – foliar top dressing with Vuksal Aminoplant in the tillering phase (microphase 22-23); III – foliar top dressing with Vuksal Aminoplant in the stem formation phase (Microphase 33-34); IV– double foliar top dressing in the marked phases.

CONCLUSIONS

Change of plants density and foliar top dressing applying with biostimulants-antistressants make it possible to control the formation of morphological parameters of above-ground internodes of spring barley plants.

The seeding rate in the range from 350 to 450 pieces/ m^2 ensures the formation of crops with a sufficiently high resistance to their lodging. Reduction of vertical resistance indicators of spring barley plants to lodging with an increase in the seeding rate of more than 450 pieces/ m^2 is associated with an elongation and decrease in the diameter of the second above-ground internode, which is "responsible" for the plants vertical resistance.

It was established positive effect of two foliar top dressings of spring barley crops with a biostimulator-antistressant – Vuksal Aminoplant on improving the indicators of plants vertical resistance, primarily by increasing the diameter of the lower internodes. Also, foliar top dressings contributed to the formation of longer upper internodes with a larger diameter, which is an additional reserve for increasing plant cropping capacity, since larger internodes contain more building material for forming and grain formation.

REFERENCES

1. Demydov O.A., Ghudzenko V.M., Kochmarsjkyj V.S. (2018) *Elementy tekhnologhiji vyroshhuvannja nasinnja sortiv jachmenju jarogho myronivsjkoji selekciji u Lisostepu Ukrajiny* [Elements of technology for growing seeds of spring barley varieties of myronivska selection in the Forest-Steppe of Ukraine]. Methodological recommendations

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2. Dubovyk O.O. (2012) Osoblyvosti formuvannja produktyvnosti steblostoju suchasnykh sortiv jachmenju jarogho zalezhno vid norm vysivu [Formation peculiarities of plant stand productivity of spring barley modern varieties depending on the seeding rates]. *Breeding and Seed production*, vol.101, pp. 272–278.

3. Lyaskovskiy M.I. (1991) Poleganie zlakov i puti ego predotvrashcheniya [Lodging of cereals and ways to prevent it]. *Plant physiology and biochemistry*, vol.23/4, pp. 315–328.

4. Gawda H., Trebacz H. (1988) Determining of the influence of agrotechnical conditions on elasticity of cereal stalk material from ultrasonic measurements. *Physical properties of aqricultural materials and products*, pp. 133–138.

5. Kovrigina L.N., Zaushintsena A.V. (2010) Istochniki ustoychivosti yarovogo yachmenya k poleganiyu [Sources of spring barley resistance to lodging]. *Bulletin of Krasnoyarsk State Agrarian University, no.1, pp.57-62.*

6. Yusov V.S., Yevdokimov M.G. (2013) Itogi izucheniya genofonda yarovoy pshenitsy na ustoychivost k poleganiyu po programme kasib [Study results of spring wheat gene pool for lodging resistance under the KASIB program]. *Bulletin of Altai State University*, no.3, pp.5-8

7. Yusov V.S., Yevdokimov M.G. (2009) Formirovanie dliny i diametra pervogo i vtorogo nadzemnogo mezhdouzliya u sortov tverdoy pshenitsy v usloviyakh Zapadnoy Sibir [Formation of the length and diameter of the first and second above-ground internodes in durum wheat varieties under conditions of Western Siberia]. *Paper of Russian Academy of Agricultural Sciences*, no.5, pp.7-9

8. Demydov O.A., Vasyljkivsjkyj S.P., Ghudzenko V.M. (2016) Rivenj vyjavu ta zv'jazok urozhajnosti, vysoty roslyn i stijkosti do vyljaghannja jachmenju ozymogho u Lisostepu [The level of expression and relationship of cropping capacity, plant height and lodging resistance of winter barley in the Forest-Steppe]. *Bulletin of Agricultural Science*, no. 10, pp.30-34.

9. Eryan Konga, Dongcheng Liua, Xiaoli Guoc (2013) Anatomical and chemical characteristics associated with lodging resistance in wheat. *The Crop Journal*, vol. 1, issue 1, pp. 43–49.

10. Kukulenko S.Gh., Ghazinsjka T.V., Kozak S.V. (2013) Dobri sorty – zaporuka urozhaju [Good varieties are the key to the yield]. *Seed production*, no.8, pp.11-18.

11. Berry P., Sterling M., Mooney S. (2006) Development of a model of lodging for barley. *Agronomy Crop Science*, no. 192, pp. 151–158.

12. Eduardo C. (2006) Effect of induced lodging on grain yield and quality of brewing barley. *Crop Breed. Appl. Biot*, no. 6, pp. 215–221.

13. Chen W.Y., Liu Z.M., Dengl G.B. (2014) Genetic relationship between lodging and lodging components in barley (Hordeum vulgare) based on unconditional and conditional quantitative trait locus analyses. *Genetics and Molecular Research*, no. 13(1), pp. 1909–1925.

14. Iyamabo, O., Hayes, P. (1994) Effects of selection and opportunities for recombination in doubled – haploid populations of barley (hordeum vulgare L.). *Plant Breeding*, 114 pp.

15. Ismagilov, R. (2010) Intervarietal variations in the content of water-soluble pentosans in winter rye grains. *International Symposium on Rye Breeding & Genetics*. Minsk 29 June – 02 July 2010. Zhodino, pp. 93–94.

16. Lazarevich S.V. (1999) *Evolyutsiya anatomicheskogo stroeniya steblya pshenitsy* [Evolution of the anatomical structure of the wheat stalk] (Monograph), Minsk: Khata.

17. Rasulov B.R. (2018) Vliyanie normy vyseva semyan na formirovanie produktivnoy solo-miny myagkoy pshenitsy na fone mineralnykh udobreniy [Influence of the seeding rate on the formation of productive straw of soft wheat on the background of mineral fertilizers]. *Bulletin of Krasnoyarsk State Agrarian University*, no. 1, pp.12-17.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 4, 2021, Pages. 10526 - 10535
Received 05 March 2021; Accepted 01 April 2021.

18. Maevskaya N.A. (2013) Izmenchivost razmerov steblya u yachmenya dvuryadnogo [Variability of stem size in two-row barley]. *Bulletin of Kemerovo State University*, no. 4(56), pp. 18-21.

19. Nekhoroshikh M.S., Ismagilov R.R. (2016) Morfometricheskie pokazateli pobegov ozimoy rzhi raznogo poryadka obrazovaniya [Morphometric indicators of winter rye shoots of different formation order]. *Perm Agrarian Journal*, no. 1(13), pp.16-21

20. Kovrigina L.N., Stepanyuk G.Ya. (2013) Sopryazhennost elementov produktivnosti s priznakami struktury steblya u sortov i gibridov yachmenya [Conjugation of productivity elements with features of the stem structure in barley varieties and hybrids]. *Bulletin of Kemerovo State University*, no. 1, pp. 31-34.

21. Tsilke R.A. (2005) *Geneticheskie osnovy selektsii myagkoy yarovoy pshenitsy na produktivnost v Zapadnoy Sibiri* [Genetic basis of soft spring wheat breeding for productivity in Western Siberia] (scientific publication). Novosibirsk.

22. Dospekhov B.A. (1985) *Metodika polevogo opyta (s osnovami statisticheskoy obrabotki rezultatov issledovaniy)* [Field experiment methodology (with the basics of statistical processing of research results)]. Moscow: Agropromizdat

23. Bild K.L. (1989) Analiz rosta rasteniy [Analysis of plant growth]. Fotosintez i bioproduktivnost. Metodi opredeleniya [Photosynthesis and bioproductivity. Methods of determination]. Moscow: Agropromizdat, pp.53-61.

24. Ghrycajenko Z.M., Ghrycajenko A.O., Karpenko V.P. (2003) *Metody bologhichnykh ta aghrokhimichnykh doslidzhenj roslyn i gruntiv* [Methods of biological and agrochemical research of plants and soils]. Kyiv: “Nichlava”, pp. 17-18.