УДК 633.1:632.165-026.564

MANAGEMENT OF RESISTANCE OF CEREALS CROPS PLANTS TO THE LODGING

Kalenska S.M., doctor of agricultural sciences, full professor, corresponding member of National academy of agricultural sciences of Ukraine, National university of life and environmental sciences (NULES),svitlana.kalenska@gmail.com
Tokar B.Y., PhD student at NULES, estb@ukr.net
Tasheva Y.V., PhD student at NULES, j.tasheva@agroconsulting.at

Species' particularities of the cereals crops on resistance to lodging depending on abiotic factors are presented. Results about formation of plants' resistance to lodging in case of growth retardants usage and cultivation on different fertilization schemes are shown. It is theoretically justified and proposed practical ways of avoiding of cereals crops plants lodging, and decreasing of the negative effect of retardants on crop performance, with introducing of new varieties, balanced usage of fertilizers, growth retardants, scientifically based norms of sowing densities with taking into account of biological particularities of the varieties.

Wheat, rye, barley, triticale, variety, growth retardants, lodging, fertilizers, plants' height, length of internodes, stem diameter, yield.

Modern technologies of crops growing are based on the clear identification of the stages of individual growth and development of plants and clear explication of growing technology elements of the crop to them, which is consistent with the control system of forming plant productivity according to genetically determined particularities during influence of biotic and abiotic factors [1, 2].

In practice of the modern agricultural production the increase of plant resistance to stressful environmental conditions is carried out in several ways. In the complex set of measures, there are three basic ones: geographical, breeding and genetic and agrotechnical [1, 2, 3].

Creation and use of high-yielding varieties is one of the most efficient and cost-effective ways of increasing production.

For the same conditions of soil fertility, energy and resources inputs, a new variety forms 30-60% more production than old one. Intensification of plant sciences have set an important task for the reeders – to create semi-short stem varieties of cereal crops that have high potential productivity and resistant to disease, pests and lodging [4, 5, 6].

The role of plant growth regulators increases due to the widespread use of adaptive technologies of crop cultivation, in which all blocks of growing technology should be related to each other, including chemical regulation of plant growth and development. In case of high doses of mineral fertilizers input, especially nitrogen, and increased humidity levels there is a risk of plants' lodging, which causes:

Increasing of infectionsof the crops, reduction or end of the synthesis of organic matter, enzyme-mycosis depletion, drainage of grains, etc. Preventing and reducing of the negative effect of lodging requires the use of retardants.

Cereals cropsreact positively on increasing doses of mineral fertilizers, it is confirmed by studies of many domestic and foreign scientists. However, increasing the rate of fertilizer causes, due to several factors, reduced plant resistance to lodging and reduced yield [5,6].

In this regard, research on yield formation characteristics, technological grain quality depending on fertilizers, growth regulators, pesticides; establishing of effective regulatory combinations of their application are extremely important in the context of different types of crops.

The aim of our research are:

• setting of specific features of cereal crops for resistance to lodging, depending on biotic and abiotic factors;

• study of the formation mechanism of plant resistance to lodging;

• theoretical study and practical ways to prevent lodging and reducing its negative impact on the formation of yield and grain quality;

• optimization of the technologies of crops growing, that give realizationof the biological potential of varieties at a high level, through the introduction of new varieties, balanced use of fertilizers, retardants, scientific basing of the sowing rates, considering the biological characteristics of varieties.

CONDITIONS AND METHOD OF RESEARCH. In 2011-2014 in the stationary experiment at the Department of Plant sciences of NULES of Ukraine "Agronomic Research Station" (villagePshenychne, Vasylkiv district, Kyiv region) on the typical blacksoil containing less humus substance (….)

twomultifactorfield experiments were established for studying of theparticularities of the formation of (producibility) of varieties of cereal crops.

Experiment 1. Efficacy of the plant growth retardants for growing of spring barley varieties at various backgrounds of mineral nutrition and complex influence of the studied factors on the growth, development, yield and quality of grain of spring malting barley varieties.

The problems were solved by means of field trial (Table. 1) and laboratory experiments. The size of accounting plot 36 sq. m, elementary plot – 66 sq. m, 4-repetition experiment with systematic placement of the plots.

Table 1 .Scheme of the trial

Variety Factor A	Retardant Factor B	Fertilizers, kg/ha Factor C
Vodogray (check variety) Gladys Kangoo Komandor Concerto	No retardant protection (check) Chlormequat chloride 750(chlormequat chloride)	No fertilizers (check) $N_{60}P_{60}K_{80}$ $N_{90}P_{90}K_{120}$

Svyatogor	Terpal (mepiquat chloride + ethephon)	

Experiment 2. The yield and quality of winter wheat in case of optimization of cultivation technology. Three-factors experiment: factor A - variety: Poliska 90, Lybid, Kapo, Josef, Midas, Balaton; factor B - sowing rate: 3,4 and 5,0 mln. germinatingseeds per 1 ha; factor C - norm of nitrogen and its distribution during the phases of development of culture: N120; N150, N180. General background - P2O5 90 kg/ha; K2O 90 kg/ha. Order of variants in the trial – according to the split plots method: blocks of the first order - varieties of winter wheat; second order –sowing rates; third order – variants of the norms of nitrogen. 4 repetitions in the trial, accounting area – 25 sq. m.

Experiment 3. Particularities of formation of triticale crop resistance to lodging (1988-2000). Multifactor experiment was established according to the program of Institute of Farming of NAASof Ukraine on the dark gray (podzolic) soils. The scheme of the experiment is shown in Table.

RESEARCH RESULTS

According to the results of experiments carried out in 2012-2014 it was established, that the yield level of the spring barleywas defined by all studied factors – "fertilization level", "protection by retardants", "variety", "weather conditions". However, the share of these factors in forming of the yield was significantly different.

All studied varieties almost equally positively reacted to the use of crops retardants during all years of the study. During protection of the field by retardantsthe intensity oflodging and resistance to lodging was determined in greater extent by weather conditions and norms of fertilizing, than by varieties.

The lodgingwas not noticedduring the cultivation of spring barley varieties without fertilizers. By using of N60P60K80 and N90P90K120 resistance to lodging (in 9-point scale) decreased to 7-8 and 6-7 points respectively, if the plots were not treated by retardants. During application of the plots by chlormequat

chloride the lodging was present only in case of fertilization of N90P90K120 - resistance to lodging increased to 7-8, and in case of application of terpal - up 8-9 points.

Field methods for evaluating resistance to lodging cereals have some drawbacks - they are largely subjective, not sufficiently reliable. Only in case of comprehensive consideration of elements of resistance to lodging and their interactionit is possible to get a better understanding of the mechanical condition of spring barleystraw. Our studies about patterns of change of internodes diameter (including 3rd internode) give grounds to assume, that during the use of studied retardantsthe diameter of thethird internode ofstudied barley varieties tended to increase for all variants of fertilization during the years of the study.

During use ofchlormequat chloride 750 diameter of the third internode increased by 0.5-0.8 mm (15,6-37,2%), and during the application of terpal diameter increased by 0.6-1.0 mm or 19,0-41,7% depending on the fertilization, varieties and weather conditions of the years of thestudy. Yield of spring barley varied the most in case of different rates of fertilizers – the share of factor "fertilizer rate" in the average during the years of research was 63.5%. Share of the factor "retardant protection" was 18.2%, as crop treatment by retardants contributed to increase of plant resistance to lodging, that caused as a direct effect of retardants and indirect - through biochemical changes in the plant caused by redistribution of transformation of nutrients to the generative organs by suppression of apical growth. The contribution factor "variety" in the formation of the average yield in the years studies was 8.3%, indicating significant successes in breeding of barley varieties, which in recent decades has aimed at breedingof short plants, but the general problem of quite low resistance to spring barley to lodging remains valid especially in case of growing barley in high fertilization inputs and badweather conditions. The weather conditions in 2012 and 2013 were very favorable for the formation of a high performance of the crop and lodging phenomenon was not found for almost all varieties. However, under conditions of excessive moisture in some periods of 2013/2014 growing year - heavy rains that

were on 17th and 30th June (50.0 and 57.0 mm, which together amounted to 167.2% of the monthly norm) accompanied by strong wind, there was significant lodging especially in high level of fertilization. The lodging resulted in a significant reduction of yield in case of the growing without the use of retardants. Share of factor D «weather conditions» on average for three years was 10.0%.

2. Yield of barley varieties depending on fertilization and protection by retardants, t/ha, average in 2012-2014.

Retardant	Fertilizers dose, kg/ha	Сорт					
		Vodogray	Gladys	Kangoo	Komandor	Concerto	Svyatogor
Check	No fertilizers	3,24	3,25	2,96	3,21	3,45	3,23
	$N_{60}P_{60}K_{80}$	4,68	4,71	4,14	4,32	4,61	5,08
	$N_{90}P_{90}K_{120}$	4,31	4,41	4,04	4,22	4,47	4,63
Chlormequat-chloride	No fertilizers	3,28	3,23	3,08	3,25	3,39	3,26
	$N_{60}P_{60}K_{80}$	5,10	5,31	5,26	5,10	5,55	5,27
	$N_{90}P_{90}K_{120}$	5,45	5,69	5,67	5,84	5,98	5,71
Terpal	No fertilizers	3,35	3,33	3,23	3,36	3,52	3,34
	$N_{60}P_{60}K_{80}$	5,30	5,82	5,43	5,50	5,59	5,34
	$N_{90}P_{90}K_{120}$	5,82	6,29	5,97	6,04	6,17	6,09

During winter wheat cultivation (experiment 2) in 2011- 2014 under conditions different procedural norms combinations of nitrogen fertilizer and sowing rates we have established that all investigated varieties of plants are

characterized by relatively high resistance to lodging. Lodging of crops was observed only in conditions of excessive moisture. May and June 2013/2014 was marked by enough of moisture, and in some periods –by excessive moisture that caused severe crop lodging of almost all varieties. Lodging was observed during growing of winter wheat with on nitrogen nutrition backgrounds -150 kg/ha and 180 kg/ha and on increased sowing rates – 5 and 4 millionsgerminated seeds/ha. The case of plants lodging of varieties Capo, Josef, Poliska 90, Lybid Midas for sowing rate of 5 mln.germinated seeds per hectare was 80 - 100%,and only variety Balaton – about 70%. For sowing rate of 4 mln. germinated seeds/hathe lodging of tall varieties Capo,Poliska 90, Joseph was 70%, and varieties Midas and Balaton - 70 and 30% respectively.

Study of triticale resistance to lodging (experiment 3) showed that the efficiency of the retardantsis influenced by genotypic specificity of the varieties.

Genetic particularity ofshort varieties such as Amfidyploid60 is resistance to lodging, and only in extreme weather conditions that are comparable to mechanical influence on crops, there is lodging of crops this variety.

In tall varieties of triticale,which have rye morphological type Amfidyploid 3/5, as variety which is less resistant to lodging, in all the years of research lodging was observed, the extent of which depended on the weather conditions as well as elements of agrotechnology.

The research conducted by us on the effectivenessof retardants with different active matterduring use in crops cultivation technologies have established their mechanism of action from the standpoint of anatomical, morphological structure of stem, physiological changes in plants and plant resistance to lodging.

Researchwere conducted with various retardants,which for the active substance can be attributed to two groups: group 1 –retardants based onchlorcholinchloride (CCC, tur,chlormequat); group 2 – with drugs active substance etephon (kampozan).

A series of experiments with triticale varietiesduring use of retardantsof both groups revealed that the growth regulators with active substance

chlorcholinchloryde are highly effective in case of the applications prior to the intensive stem elongation - before the release of the tube (Table 3). At the same time,the retardantswith the active matter etephon have been effective for a longer growing season crops - to phase VII of organogenesis.

Use of the retardant at a later terms had negative impact on the formation of ear, causing the appearance of deformed "white" ears, which will no longer form the grains.

Microscopic studies of slices oftriticale internodes showed that during treatment of plants by retardants there are not only stem morphological changes, but also significant changes in its characteristics – the ratio of mechanical and vascular tissues. Retardants, influencing the change of the process of cell differentiation, promote thickening of the walls of the stem. Thickening of the walls of the stem was due to intensive proliferation of parenchyma layer and partial thickness increase of sclerenchyma ring. Significant impact on increasing of sclerenchyma ring of the stem of the short-stem triticale variety Amfidyploid 60 in the lower internodes did all of the retardants and their combinations. Thickening for 38,3-45,3 micron of sclerenchyma layer of the 1st internode was observed during application of kampozan, mix of CCC and kampozan and 3-times application of CCC and kampozan. Application of retardants in several times helped uniform increasing of sclerenchyma layer in all the internodes,which contributes to a significant strengthening of the entire length of the stem.

The significant increase of stem (sclerification) of Amfidyploid 3/5 was observed during applications of all combinations, excluding mixtures of CCC + kampozan (3+2 l/ha– 5^{th} organogenesis stage), although by increasing the parenchyma layer of the stem wall thickening was noted on all interstices. Physiological effect of retardants reflected more on proliferation of parenchyma layer thickness (2^{nd}internode),for Amfidyploid 60 it increased to 60% during application of kampozan (4l/ha – VIorganogenesis stage); to 44.5% - mixture CCC + kampozan (3+2 l/ha – Vorganogenesis stage); to 47% with three times retardant treatment. For Amfidyployidu 3/5 the increase of parenchyma layer of 2^{nd}

internode by the same variants increased respectively by 62.8%, 57% and 39.7%. As a result of the increase sclerenchyma and parenchyma layers the wall was thickening – fulfilment of the straw increased. The area of fulfilled straw of plants of Amfidyploid 60 (I and II internodes)in check plants was 3.6 and 2.9% higher than in plants of Amfidyploid 3/5. The most significant changes were observed for application by kampozan and a mixture of retardants that are applied as in one stage and as well in several stages –up to 3.

Note that for the use of mixtures of CCC and kampozan (3+2 l/ha - V organogenesis stage) we found the significant difference regarding the effectiveness on different varieties. While in Amfidyploid 60 fulfilmentof the stem increased by 10.4% (I internode); 7.4% (II internode); 8.9% (III internode), in variety Amfidyploid 3/5 these figures were much lower - 2.0; 1.9; 5.6%, respectively.

Increasing of the number of vascular bundlesas a result of retardants action occurred as in both the parenchyma and in sclerenchyma, except variants, where only CCC was applied. Some differenceswere found in forms of vascular bundles – talltriticale variety plants Amfidyploid 3/5 were more elongated compared with Amfidyploid 60. Retardants partly determined the changeof shape of bundles, changing it to a more rounded shape. Elongation ratio changed from 1.3 (control version) for the variety Amfidyploid 60 to 1.0 in case of 2 times applicationof CCC (3 l/ha – V organogenesis stage; 2 l/ha – VI organogenesis stage) and kampozan (2 l/ha on VII organogenesis stage), and from 1.4 to 1.1 in case of application by kampozan in dose of 4 l/ha on V organogenesis stage for the variety Amfidyploid 3/5.Retardants have uneven influence on the size of mechanical tissues layers of cereals, the number of vascular bundles and their shape. The biggest shortening effect on stem, on complex of morphological and anatomical parameters, was during of application on both short and long stem triticale varieties of the active matter etephon- kampozan in dose of 4 l/ha on Vorganogenesis stage.

CONCLUSIONS

Limiting factor in cereal crops growinginintensive farming conditions is the lodging of crops. The use of retardants is compulsory for growing of tall varieties of wheat and triticale and all barley varieties. In conditions of the increased moisture in a year, the protection by retardantis needed on all cereal crops varieties.

The degree of inhibition of stem growth depends on the variety, concentration and chemical nature of the retardant, time of application on plants. The biggest shortening effect was obtained by application on spring barley and tall triticale varieties of retardants with active matter etephon or mixture of active matters (kampozan, terpal), and short varieties of triticale – retardants with active matter CCC or mixture of retardants (CCC + etephon). During the application of plants by retardants there is an increase in 13,0-72,0% ofmechanical tissue of stem, number of vascular bundles and changing their shape.

Retardants help to improve the productivity of crops as by reducing elongation, as well as due to structural changes of plants - increasing productivity of tillering, the number of grains and grain weight from the ear.

List of references

1. Kalenska S.M. Intensive growth regulators in crops cultivation technologies / Plant growth regulators in plant, Kyiv, UDNDPTI "Agroresurs", 1998.- P. 65 - 69.

2. Kefely V.I., Prusakova L.D. Chemical regulators plants / M., 1985.-63.

3. Radtseva G.E., Radtsev V.S.Phisiologic action aspects of chemical growth regulators on plants // M .: Nauka, 1982.- 148 p.

4. Sheveluha V.S.Plants growth and its regulation / K M .: Kolos, 1992. - 594 p.

5. Anatomical and chemical characteristics associated with lodging resistance in wheat / Eryan Konga, Dongcheng Liua, Xiaoli Guoc, Wenlong Yanga, Jiazhu Suna, Xin Lia, Kehui Zhanb, Dangqun Cuib, Jinxing Lind, Aimin Zhanga // The Crop Journal.- V . 1, Issue 1.- 2013.- P. 43-49

6. G.J. Dunn, K.G. Briggs Variationinstemanatomyamongbarley cultivars differinginlodgingresistance // Canadian J. Botanice .- № 67.-1989.- R. 1838-1843

7. Kalenskaya S.M. Optimization of nitrogen nutrition of triticale and retardant protection during its growing in intensive conditions, in northern Lesostep in the USSR / Thesis. Thesis ... candidate. s.-'s. Science. USHA, Kiev, 1991 .- 24 p.

8. Kokubo A., Kuraishi S., Sakurai N. Stem strength of barley // Plant Physiology. - №91.- 1989.- R. 876-882

9. Kalenska S.M. Growth regulators in technology of growing triticale / Coll. Science. Institute of Agriculture UAAS works. - Vyp.1.- 1997. - p.42 - 44.

10. Genetic relationship between lodging and lodging components in barley (Hordeumvulgare) based on unconditional and conditional quantitative trait locus analyses / WY Chen, Z.M. Liu, G.B. Deng1, Z.F. Pan1, J.J. Liang, X.Q. Zeng, N.M. Tashi, H. Long and M.Q. Yu // Genetics and Molecular Research. - № 13 (1). - 2014. - R.1909-1925

11. Kandemir N. Search for high yielding, lodging resistant barley cultivars with satisfactory straw yields for a fertile production area of Turkey // Pakistan J. Biological Science. - №7.- 2004.- P. 971-976.

12. Berry PM, Sterling M and Mooney SJ. Development of a model of lodging for barley // Agronomy Crop Science.- № 192.- 2006.-P.151-158

13. Eduardo C. Effect of induced lodging on grain yield and quality of brewing barley. Crop Breed. Appl. Biot. - № 6.- 2006.- R. 215-221

14. Blinovskyy I.K., Kalashnikov D.V., Kokurin A.V. Development of synergical mixtures of retardants on base of studies of mechanism of their action. // Regulators of plants growth.- N .: Agropromizdat, 1990.- S.36-45.

15. Deeva V.P. Retardants - regulators of growth of plants. - Minsk: Science and technology. - 1980. - 175 p.