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Grain Production of the Winter Barley Under Growingin the Conditions of the Climatic Changes

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Abstract: In conditions of deficient and unstable moistening studying of growing and development winter barley plants in period of autumn vegetation and at the time of formation stability of winter plants under adverse weather conditions of winter has obtained important meaning as it had influence on yield. Aim of the researches was studying influence agro-technical ways of growing on winter barley production in conditions of northern Steepe of Ukraine. According to the results of three-year field researches (2016-2019 years) it was cleared up influence of sowing date, norms of seed sowing on plant production of barley after a precursor – sunflower. It is established on average during the years of researches, morphological-biological indexes of winter barley plants differed substantially depending on hydro-technical conditions in autumn period of vegetation. Barley plants with early date of sowing (September, 20) formed more vegetative mass since 17,8 till 18,7g depending on norms of seed sowing, number of sprouts 3,2 – 3,7 pieces and a nodal roots 2,4 – 3,1 pieces. Displacement sowing date for each 10 days from early to later ones led to lessening all indexes. In dependence on state of a plant during cessation of autumn vegetation and weather conditions in winter period (2016-2019 years), survival rate of plants varied within 93 – 98%. Sowing on September, 30 and October, 10 provided the highest level of survival rate and was – 96 – 98%. In phase of whole ripeness of seeds after sowing on September, 30 winter barley plants formed bigger production while after early (September, 20) and late (October, 20) date of sowing average yield by years depending on seed sowing reduced to 1,5 and 2,3 t/ha accordingly.

Keywords: Winter Barley, Sowing Dates, Norms of Seed Sowing, Survival Rate, Elements of Structure, Yielding

1. Introduction

The substantial climatic changes during last ten years can be considered as a real shock for the society not only in Ukraine but in the world as a whole. The typical climatic peculiarity of the Steepe Zone of Ukraine is its drought due to the insufficient of the rainfall, their irregular allocation throughout vegetation that very often get complicated by the increased temperature regime. So, during last ten years in the winter months (December and February) month`s rainfall diminished on 10-15%, in July and August the rainfall was on 15-27% less than the norm that became the cause of the strong summer drought [1, 2].

The agrarians of the entire world are worried about the changes of the conditions for growing agricultural crops, whose sowings suffer from anomalous high temperatures and long droughts more often. So, climatic conditions of the present time induce farmers and producers of the agricultural production to search and introduce the adaptive sorts and hybrids of the field crops into the agricultural production with concurrent improvement of the technologies of growing and correction of the practice of dealing with agriculture for keeping the productivity of crops [3].

That`s why to take into account the substantial mutability of the climate and the weather conditions we were carrying out our researches with aim to find out the effective ways of the adaptation of the technological actions for growing winter barley in the Steepe Zone of Ukraine.

Barley (*Hordeum vulgare L.*) along with wheat, corn and rice is one of the most important grain crops of forage, fodder and food meaning and has considerable demand at the world market.

During last years in Steepe zone of Ukraine increase of

land under crop of winter barley is the most dynamic. It is conditioned on higher yield in comparison with its spring form and favorable weather conditions in winter period which allow spending winter plants well and use cumulative reserves of soil moisture efficiently. Growing winter barley in conditions of qualitative looking after crops allows getting high yield indexes in farms even after such not-fallow precursors as a sunflower and corn for seeds. In case destruction of crops during winter period that happens 1 time for 3-5 years in farms of Steepe zone always there is possibility to re-sowing a field with spring barley or other spring cereals. Namely danger of frost-killing for crops is a definite factor which limits extension for sown areas of this important grain crop in all regions of Ukraine [4].

At the same time in connection with progressive change of climate to warming, this fact has positive character for winter cereals on the bigger part of territory in Ukraine. There is possibility to increase gross harvest of grains at the expense of increasing sowing winter barley. During last years they occupied territory about 1 million ha [5-7]. As indicated above the retentive factor that limits extension of winter barley in Steepe zone of Ukraine is its periodical frost-killing. This crop has greatly lower frost and winter stability in comparison with wheat. Reducing soil temperature at a depth of occurrence of tillering node to -10 ─ -14°C leads as a rule to whole frost-killing of plants. Crops of early sowing dates are the most vulnerable in winter period so they often outgrow and loose stability to low temperatures very fast, especially without snow covering [8-13]. In view of this information grain-producers attend high profile not only to right choice of sort structure of winter barley; there must be connected organically high indices of yield, drought-resisting and firmness to diseases and pests, but also they pay attention to growing technology that finally determines productivity of this crop [14].

In spite of necessary attention is given to agro-technical ways of growing winter grain crops in zone of Northern Steepe in Ukraine however there isn't enough dates in modern scientific literature or they are absent absolutely; as to research results of separate elements of technology during growing winter barley after sunflower relatively a new (the most broadened) precursor for winter crops in Steepe region [15].

Practice of realization sowing winter crops after sunflower is conditioned by different reasons, especially by increase of sown areas of this crop to 6400 thousand ha that led to ousting and replacement of better precursors with growing early-ripe hybrids, appearance highly productive complex technic, extension of autumn vegetative period and presence of favorable temperature regime during winter. It often gives possibility for plants of late sowing dates to resist against difficult weather conditions. Especially it concerns to Steepe zone, so more than 70% of sown areas of sunflowers from nationwide ones are situated there, and its part in structure of crop rotation of some farms exceeds sown areas of winter wheat and other winter grain crops that in future constrains grain-producers to make sowing after this oil crop [16].

One of the most important technological elements of growing winter barley is keeping optimal sowing dates that stipulates highly for development of plants during autumn period, their winter-hardness and productivity [17]. In the time of early sowing dates especially in years with long warm autumn, winter barley can have stage of vernalization in this period and as a result its frost resistance decreases fast. To the contrary plants and of late sowing dates don`t have enough time to bushing out and gather protective substances as more as they need so as after not severe frosts they are injured a lot and can perish even in early spring period. Plants of winter barley have high winter-hardness if they formed 3-5 sprouts and have well developed root system before wintering.

It is considered optimal sowing dates of winter barley are in the second part or in the finish of sowing winter wheat with prevision of duration for its autumn vegetation within 55-60 days and cumulation about 25-30% soluble carbohydrates in tillering nodes of plants that provides successful wintering [18-20].

Also in system of agro-technical ways of growing winter barley norms of sowing seeds have important place as they define intensity of terminal processes for plants, thickness of productive plant stand and yield of crop. It is known crops with optimal thickness not only spend winter better and also ripe faster that is very important for drying regions. Liquefied and heavy seeding of winter barley leads to lowering yield. Under heavy seeding individual development of plants gets worse because of large competition, considerable part of sprouts and whole plants die off, they straighten up, harden up badly, damaged by diseases, loose more water and nutrients, become inclined to lodging, form a thin stem, a small colossus that influences on yield negatively. Baseless lessening norm of seed sowing reduces crop capacity more than with its overstatement; so far as in result of strong bushing out there is a great number of underplants which don't form grains or make a small grain and insufficient number of productive stems are formed [21, 22].

To take into account aforesaid information and with regard to that fact for today there isn't consensus of opinion among specialists as to best sowing dates and norms for seed sowing of winter barley for growing after sunflower in Steepe zone of Ukraine. The aim of accomplished researches was to define optimal parameters of these technological elements which influence on development of plants in autumn period, their survival rate in winter, forming elements of productivity and level crop capacity after such unsatisfactory and undesirable precursor from agronomical point of view.

2. Materials and Methods

Field researches by studying influence of sowing dates and sowing norms of seeds on growth and development plants of winter barley and forming its crop capacity were accomplished during 2016-2019 years on basis of the research farm "Dnipro" SE Institute of cereals NAAS of Ukraine.

Soil covering of research plots consisted of ordinary, low humus, medium loam, black earth with contents of humus in

the arable layer (by Tiurin) – 3,3- 3,5%; general nitrogen – 0, 23- 0,25; phosphorus – 0,10 – 0,12%; potassium – 2,1%.

An object of researches was sort of winter barley "Decuman wave" (*Dev`iatyi val)* which is recommended for growing in all soil-climatic zones of Ukraine and invected to State register of plant sorts which are suitable for broadening in Ukraine since 2014 year.

At the beginning of field researches a precursor was a sunflower. Preparing soil was made according to generally accepted recommended technology for winter grain colossus crops in conditions of Northern Steepe of Ukraine.

Complete mineral fertilizer with norm $N_{60}P_{60}K_{30}$ was brought before pre-sowing cultivation. Early spring additional fertilizing for plants of winter barley was accomplished with nitrogen fertilizer in form of ammonium nitrate (N – 34, 4%) with dose 30 kg/ha active matter**.** The sowing was realized by a seeding machine SH-16 with a solid drill method.

Accounting of yield for winter barley was carried out according to method of solid thrashing all area of accounted plots by a combine harvester "Sampo-500" with perfect ripeness of seeds.

Technology of growing winter barley in researches was generally accepted for Northern parts of Steepe in Ukraine besides questions were put for studying.

Researches were accomplished according to existent methods and recommendations [23, 24].

3. Results

State of winter barley plants at the time of cessation of autumn vegetation is extremely important so far as their good development in this period is a guaranty of high level for winter-hardness.

By researches it was established that intensity of growing processes in winter barley essentially depended on hydro-thermal conditions which completed in period "sowing – cessation autumn vegetation", and so before wintering mixed age plants with different thickness of plant stand essentially differed by force of vegetative mass.

So in average during years of carrying out researches the biggest mass 100 absolutely dry plants was marked for sowing winter barley on September, 20 with norm of seed sowing 4,5 ml./ha, that was 18,7 g, and after more later sowing – September, 30 and October, 10 and 20 in the same conditions it was accordingly 12,1; 5,7 and 1,8 g (table 1).

It was observed lessening overground mass of plants with rising of norms for seed sowing. For example if after sowing on September, 20 with norm of seed sowing 4,5 ml. pc./ha mass of 100 absolutely dry plants was as pointed 18.7 g, and with increase of sowing norm till 5,0; 5,5 and 6,0 ml pc./ha similar seeds, size of overground plant reduced to 18,4; 18,1 and 17,8 g. The same tendency was marked during other more late sowing dates.

During the researches the maximum height of winter barley plants before wintering was noted at the crops of early sowing date (September, 20) in dependence on sowing norms of seeds in average it was within 15,8-16,9 cm. At the same time during late sowing date (October, 20) in all variants of research it was lower nearly half in compare with plots of early sowing date.

Table 1. *Morphologic-biologic indexes of winter barley plants for time of cessation during autumn vegetation, 2016-2018 years.*

Sowing date	Norm of seed Sowing [ml. pc./ha]	Mass of 100 absolutely dry plants, [g]	Height of plants [sm]	Average number of sprouts, [pc./plant]	Average number of nodal roots [pc./plant]
20.09	4,5	18,7	15,8	3,7	3,1
	5,0	18,4	16,2	3,5	2,9
	5,5	18,1	16,4	3,3	2,7
	6,0	17,8	16,9	3,2	2,4
30.09	4,5	12,1	13,4	2,7	1,7
	5,0	11,9	13,7	2,5	1,5
	5,5	11,5	14,1	2,4	1,4
	6,0	11,3	14,4	2,2	1,3
10.10	4,5	5,7	12,6	1,0	-
	5,0	5,5	13,0	1,0	-
	5,5	5,2	13,2	1,0	-
	6,0	4,9	13,5	1,0	-
20.10	4,5	1,8	7,8	1,0	-
	5,0	1,6	8,1	1,0	-
	5,5	1,4	8,3	1,0	-
	6,0	1,1	8,5	1,0	-

Increase of sowing norms since 4,5 till 6,0 ml pieces of germinable seeds for 1 ha led to insignificant but noticeable rise of plant height for all sowing dates.

Accomplished researches showed that during displacement sowing dates to late, plants for time completion of autumn vegetation formed less number of sprouts. So in comparison with early sowing date (September, 20) number of sown plants on September, 30 reduced for 25-27%. After sowing winter barley on October, 10 and 20, as a rule, plants came into wintering in phase 1-2 leaves without making a tillering node and additional sprouts.

Before wintering winter barley plants formed the biggest number of nodal roots after sowing on September, 20 and in dependence on norm of seed sowing their number was in average since 2,4 to 3,1 pc./plant. After sowing on September, 30 number of derivative roots in comparison with preceding date of sowing reduced highly and varied in average within 1,2-1,6 pc./plant in dependence on norms of seed sowing.

Increase of norm for seed sowing since 4,5 to 6,0 ml/ha led to formation of less number of nodal roots in plants, and after sowing on October, 10 and 20 they didn't have time to form them taking into account short time of autumn vegetation.

Hydrothermal conditions of winter periods 2016-2019 years were favorable for wintering of winter barley generally. In dependence on state of its development at the time of cessation for autumn vegetation with different sowing dates, norms of seed sowing and weather conditions, number of plants which spent winter well was at the level 93-98% (table 2).

Table 2. *Survival rate of winter barley during wintering in dependence on sowing dates and norms of seed sowing, 2016-2019 years.*

Date of sowing	Norm of seed sowing, [ml pc./ha]	Number, [pc./м^2] in period				Kept, [%]	
		Cessation of autumn vegetation		Renewal of spring vegetation			
		plants	sprouts	plants	sprouts	plants	sprouts
20.09	4,5	359	1457	345	1379	96	95
	5,0	399	1520	383	1440	96	95
	5,5	435	1550	413	1453	95	94
	6,0	470	1629	445	1513	95	93
30.09	4,5	363	1055	354	1015	98	96
	5,0	401	1126	391	1056	98	96
	5,5	437	1162	427	1101	98	95
	6,0	475	1237	461	1172	97	95
10.10	4,5	338	338	328	319	97	95
	5,0	374	374	363	353	97	95
	5,5	407	407	391	382	96	94
	6,0	442	442	424	413	96	94
20.10	4,5	331	1-2 leaves	310	-	94	-
	5,0	367		343		94	
	5,5	401		372		93	
	6,0	431		398		93	

The highest survival rate of barley plants was noted during sawing on September, 30 and October, 10 and formed 96-98%. Analogical tendency was noted with number of kept sprouts after wintering – 95-96%.

Noted lowering of winter-hardness for plants according to directed early (September, 20) and late (October, 20) dates of sowing is explained that in the first case they because of very developed overground mass lost greatly more supply matters in autumn; level of their content in plant organisms defines their winter-hardness in many respects; in the second – sown plants in late dates began wintering without tillering node having only 1-2 leaves that led as a rule to their insignificant losses due to negative actions of low temperature especially without snow covering.

However it must be mentioned during carrying out of researches destruction of winter barley plants didn't exceed innate liquation of crops for winter cereals which is observed for years with ordinary i.e. comfortable winter conditions.

Sowing dates and norms of seed sowing influenced highly on forming elements of plant productivity and yield capacity of winter barley [25].

Table 3. *Elements of productivity for winter barley plants in dependence on sowing dates and norms of seed sowing, 2017-2019 years.*

Date of sowing	Norm of seed sowing, [ml. pc./ha]	Number of productive stems [pc./m^2]	Number in a colossus, [pc.]		Mass, [g]	
			colossuses	seeds	Seeds from colossus	1000 seeds
20.09	4,5	352	15,5	32,6	1,19	36,4
	5,0	378	15,3	32,0	1,16	35,8
	5,5	385	15,0	31,5	1,11	35,2
	6,0	409	14,8	30,9	1,04	34,5
30.09	4,5	401	16,7	34,1	1,33	38,9
	5,0	435	16,5	33,6	1,29	38,4
	5,5	444	16,4	33,3	1,24	37,1
	6,0	451	16,1	32,8	1,21	36,5
10.10	4,5	357	16,2	33,2	1,23	37,0
	5,0	379	16,0	32,6	1,20	36,8
	5,5	394	15,7	32,1	1,17	36,4
	6,0	408	15,3	31,9	1,10	35,1
20.10	4,5	338	14,5	28,3	0,98	34,7
	5,0	350	14,3	27,8	0,95	34,1
	5,5	381	13,9	27,3	0,92	33,5
	6,0	392	13,6	26,9	0,89	32,9

In average for years of researches at the time of complete ripeness of seeds the biggest figures for number of productive stems (401-451 pc./m) were noted in the crops of winter barley on September, 30 (table 3). Sowing process with reference to this calendar term in earlier or later dates led to whole liquation of plants during vegetation and making less thickness

of productive plant stand. The biggest average number of colossuses in a colossus formed for sowing on September, 30 and October, 10 with norm of seed sowing 4,5 ml./ha, which was accordingly 16,7 and 16,2 pieces. In proportion to growing norms of seed sowing and carrying out of sowing number of colossuses in a colossus was reducing gradually in comparatively late dates. So the least showings of this index (in average 13,6-13,9 pc.) were noted for sowing of winter barley on October, 20 with norm of seed sowing 5,5 and 6,0 ml. pc./ha, i.e. the difference in comparison with better variants was in average since 2,3 to 3,1 pc./colossus.

As is well known plants of winter barley in optimal growing conditions and moisture supply in period of efflorescence and ripening of seeds form more number of seeds and also bigger mass due to their filling. In carried out researches the biggest average number of seeds (34,1 pc.), and also their mass of colossus (1,33 g) were formed by plants, which were sown on September, 30 with norm of sowing 4,5 ml/ha germinable seeds. At the same time for sowing on October, 20 with analogical norm of sowing number of seeds in a colossus and also their mass reduced for 5,8 pc. and 0,35 g. accordingly. In the researches [26] analogical tendency was noted and delay sowing led to lessening number of seeds in colossus and their mass and also lowering of yield.

Crop capacity is the main index for realization of biological potential crop and efficiency of technological elements which are studied in researches. During carrying out of researching favorite weather conditions of early spring period allowed fast renewal and growth of vegetative mass to plants thus observed high grain productivity winter barley which was defined by sowing dates and norms of seed sowing.

So, for sowing on September, 30 with norm of seed sowing 5,0 ml. pc./ha yielding of winter barley was the biggest in the researches and had in average 5,52 t/ha led to lowering of yielding for 0,12-0,28 t/ha (table 4), while in the researches [27] increase of seed sowing on squares didn't have any influence on yielding.

Table 4. *Yielding of winter barley in dependence on sowing dates and norms of seed sowing, 2017-2019 years.*

Date of sowing (A)	Norm of seed sowing [ml. pc./ha] (B)	Yielding for years, [t/ha]			Average
		2017 y.	2018 y.	2019 y.	
20.09	4,5	4,00	3,16	5,02	4,06
	5,0	4,31	3,39	5,20	4,30
	5,5	4,17	3,33	5,10	4,20
	6,0	4,15	3,28	5,07	4,17
30.09	4,5	5,39	4,38	5,95	5,24
	5,0	5,65	4,56	6,36	5,52
	5,5	5,50	4,51	6,20	5,40
	6,0	5,41	4,45	5,99	5,28
10.10	4,5	4,21	3,47	5,16	4,28
	5,0	4,56	3,52	5,31	4,46
	5,5	4,63	3,54	5,49	4,55
	6,0	4,32	3,49	5,17	4,33
20.10	4,5	3,07	2,39	4,15	3,20
	5,0	3,11	2,41	4,29	3,27
	5,5	3,20	2,78	4,37	3,45
	6,0	3,14	2,50	4,32	3,32

LSD_{05}, t/ha, for factor A – 0,04–0,15; for factor B – 0,02–0,12; for factor AB – 0,04–0,25

According to early (September, 20) and late (October, 20) sowing dates yielding of winter barley in comparison with plots where sowing dates were on September, 30 reduced generally, in dependence on norms of seed sowing for 20-30%, namely for 0,83-1,02 and 1,36-1,78 t/ha accordingly. It is explained by those plants in conditions of early sowing were defective more in winter period and as it was mentioned their survival rate and regenerative ability after wintering were worse than at the plots of better (optimal) sowing date. Winter barley of late sowing date also was characterized by deficient ability to resist winter conditions and in result of weak development had relatively low stability to droughty conditions which were noted during spring-summer vegetation in all years of researches that at the end influenced on productive bushy of plants and yield figures. Despite of our researches [28] affirmed that yielding taken in more early sowing dates was at the optimal level and even in some cases it was higher but due to displacement of sowing terms to the side of late ones led to its lowering.

4. Conclusions

On the basis of the analysis of carried out researches it was established that in the conditions of the insufficient moistening and the irregular allocation of the rainfall the researched agro-technical methods of growing had an influence on the frost resistance, the winter-hardiness and grain productivity of the winter barley plants. The wide application these methods into production will facilitate the stabilization of the gross grain yield of the crop. The divergence from the optimal term of the sowing as to the side of early (September, 20), as to the side of late (October, 20) caused the weakening of the frost resistance and winter-hardiness of the winter barley plants, the decrease of indexes of the level yield and the quality of the grain. Analogical tendency was observed under conditions of increase of the sowing norms of seeds until 6,0 mln. pc/ha.

On base of carried out researches it can be asserted that in

conditions of Northern Steepe in Ukraine with aim of more complete realization for productive potential standard of growing winter barley after sunflower must envisage of sowing at the end of September (30.09.) with norm of seed sowing 5,0 mln. pc/ha that with direct observance of other technical claims and availability of favorable weather conditions during its vegetation can provide yielding of crop at the level 5,5 t/ha.

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