Morpho-biological traits of filmy wheat in the central region of non-chernozem zone

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Abstract: The article presents the results of field assessments and laboratory assessments of the crop structure of filmy wheat species of various origins. The results of estimating the height of the main stem and productive bushiness are presented. Analysis of the main ear, which includes the total number of spikelets, the number of developed spikelets, the length of the ear, the density of the ear, the number of grains in the ear, the average number of grains in the ear, the mass of the main ear, the mass of the ears from the plant, as well as the analysis of the plant (the mass of grain from the plant, the number of grains from the plant, weight of 1000 grains). As a result of the analysis of experimental data, a conclusion is given on the level of economically useful features of the considered variety samples.

1 Introduction

The genus wheat (Triticum L.) belongs to the bluegrass family (Poaceae Barnhart), or cereals (GraminaceaeJuss). According to the number of chromosomes in somatic cells, wheat is divided into three groups: 42, 28, and 14 chromosomes.

Spelt, or two–grain wheat (Triticumdicoccum), is an ancient semi-wild type of wheat.

According to N. Vavilov's theory, the initial area from where the spelt spread is Abyssinia. As K. Flaxberger's research has shown, the ancient Egyptian spelt is similar, at least in the structure of the spikelet and scales, to the modern Abyssinian ones and, apparently, came to Egypt from Abyssinia. From Abyssinia, it also got to Yemen (Arabia), where it differentiated into an even earlier form, and to India. Then, of the spelt known on the globe, the Balkan (Serbian forms) are the closest to the Abyssinian spelt, which are very similar and perhaps identical to our Volga spelt. The more deviant forms are the spelt of Iran. In Transcaucasia, further differentiation has developed (forms caucasicaStol., armeniacaStol., aestivalisStol., autumnalisStol. and others). Thus, a group of northeastern and Asian forms of spelt was formed. Another branch went through north Africa or southern Europe and entered Spain, where it differentiated into a special branch, a very late Spanish form of vascomicaStol., in the Basque country. Along the way, and possibly from southern Europe, the Moroccan forms described by Miege stood out. As for the Middle European forms - Swiss—German, on the

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one hand, the late ripeness and scale shape of some forms brings them closer to the Spanish, and on the other hand, the late and large-columned form of serotina is very similar in the construction of the ear and scales with a beak-shaped tooth to the form from Greece, represented in Percival's exsicta. It should be noted that the spikelets from stilt buildings in Stone Age Switzerland are very similar to modern Central European ones, but not to Abyssinian or Egyptian ones, which indicates a very ancient differentiation of these spelt already in the Stone Age. Thus, a beautiful picture is obtained of the settlement and differentiation of spelt across the globe [1-5].

Spelt (double grain, emmer) is one of the most ancient crops. It was widely cultivated in ancient Egypt for more than 4,000 years BC. However, it is no longer found there, having been replaced by other wheat crops. In ancient Babylonia, from the beginning of the 4th millennium BC, it was the main bread and has lost importance since the beginning of the period of the Iranian kings and under Greek influence. In Cilicia, Syria, and south Arabia, it was cultivated before our era and is currently preserved in extremely small quantities, for example, in Yemen.

In Central Europe, a lot of it was cultivated in the Stone Age, as evidenced by finds in pile structures in Switzerland. Currently, in Germany, it has been completely eliminated from culture in recent years and remains in small amounts in German Switzerland. In general, everywhere the spelt is displaced and replaced by other wheat.

Spelt has been known in Russia since the 5th century BC, and occupied the largest areas in the 18th century. Up to the 19th century, bread and porridge from spelt were very common dishes in the central and northern provinces of Russia, the Volga region and Siberia. There is information in fiction that Peter the Great loved spelt porridge. By the middle of the 19th century, spelt was almost forgotten in our country, it was preserved as a culture only in Bashkiria, Chuvashia and the North Caucasus. This continued until the 1990s, when nutritionists began talking about the beneficial properties of semolina.

In recent years, interest in spelt has increased due to the dietary value of its grain, which is used in the manufacture of high-quality cereal products for patients suffering from diabetes and cardiovascular diseases (Dedkova et al., 2007).

One of the most valuable properties of the crop is its unpretentiousness to growing conditions, plasticity, high drought and cold resistance in the initial period of development, in addition, it is characterized by early maturity, resistance to leaf and ear diseases.

All these qualities of spelt make it valuable as a similar material for crossing with soft and, especially, durum wheat as a genetic source of economically valuable traits.

Today, in the West, spelt is valued as a product of a "healthy diet." Interest in spelt has also resumed in our country.

The basis of the work is the analysis of 11 varietal samples of filmy wheat species. The samples differ in origin, ploidy, degree of cultivation, and a set of economically useful features.

2 Materials and methods

The paper presents the results of field assessments and laboratory assessments of the crop structure - the height of the main stem, productive bushiness. Analysis of the main ear, which includes the total number of spikelets, the number of developed spikelets, the length of the ear, the density of the ear, the number of grains in the ear, the average number of grains in the ear, the mass of the main ear, the mass of the ears from the plant, as well as the analysis of the plant (the mass of grain from the plant, the number of grains from the plant, weight of 1000 grains). As a result of the analysis of experimental data, a conclusion is given on the level of economically useful features of the considered variety samples.

The purpose of the work is to describe a collection of varietal samples of filmy wheat species of various levels of ploidy according to morphological characteristics and adaptability to the conditions of the Central region of the Non-Chernozem zone.

To fulfill the purpose of the work, the following tasks were set:

1. To make phenological observations and analyze them.
2. To assess the resistance of the studied samples to lodging, disease damage (brown rust, powdery mildew, dusty and hard smut) on a natural infectious background.
3. Analyze the structure of the crop (height, productive bushiness), the parameters of the main ear (length, number of spikelets, water content of one ear, grain weight), plant parameters (the same, only from the whole plant), ease of threshing.
4. Analyze the productivity of the tested samples relative to the standard (Gremme grade).
5. Determine the grain quality indicators (weight of 1000 grains).
6. To identify cultivars of filmy wheat species that are maximally suitable for cultivation in the conditions of the CRNZ, with high productivity indicators and a complex of economically useful features.

The experimental material consists of 11 cultivars of filmy wheat species obtained from the Institute of General Genetics (Table 1). The samples differ in ploidy, degree of cultivation, and complex of economically useful characteristics.

Table 1 - Samples of filmy spring wheat species included in the study in 2021.

Samplenumber	Typename	Thevariety	Catalognumber
1	*Triticumispahanicum*	var. ispahanicum	TRI 6177, Iran
4	*Triticumdicoccum*	var. serbicum	к-12133, Bulgaria
6	*Triticumdicoccum*	var. vasconicum	к-20410, Spain
8	*Triticumdicoccum*	var. dicoccum	к-21582, France
9	*Triticumdicoccum*	var. rufum	к-36527, Switzerland
10	*Triticumdicoccum*	var. volgense	к-40032, Yugoslavia
12	*Triticumdicoccum*	var. rufum	к-45926, Romania
13	*Triticumdicoccum*	var. miegei	к-15840, Morocco
16	*Triticumdicoccum*	var. arras	к-44154, India
20	*Triticumdicoccum*	var. volgense	к-7492, Russia
34	*Triticumdicoccum*	var. tashkenticum	Russia

Field experiments were conducted in the fields of the Field Experimental Station. Breeding crops of filmy wheat in 2021 were placed in the field of the breeding crop rotation. The predecessor is white mustard. Tillage included winter plowing in autumn, closing of moisture in spring, fertilization ("Azofoska") at a dose of 200 kg/ha (N15%P15%K15%), pre-sowing cultivation. In the active substance, it was N30P30K30. Agrotechnics – accepted for the zone.

The accounting area of the plot is 1 row (sometimes 2) with a length of 1 m. There is no repeat.

The sowing of experiments in 2021 was carried out manually on May 12. The seeding rate is 30 pcs./m running. The seeds had different germination rates.

Shoots appeared on May 21, 2021.

In the phase of the 3rd leaf – the beginning of tillering, ammonium nitrate was fertilized at a dose of 60 kg/ha. treatment of crops with the insecticide "Decis" from the Swedish fly and the herbicide "Pruner" from dicotyledonous weeds.

During the growing season, phenological observations were carried out (the dates of sowing, emergence, earing, and waxy ripeness were noted).

https://doi.org/10.1051/bioconf/202519401023

The cleaning was done manually, it consisted in pulling the plants out by the roots, it had to be done carefully, without damaging the plants themselves, if there were difficulties, then it was necessary to dig up with a shovel and shake off the earth, and then the plants were carefully pulled out. If it doesn't work out, then they dig up with a shovel and carefully shake off the earth. Then each variety was connected closely at the roots with a sheaf label with the signature "P-21 No. 1). N stands for the name of the nursery "filmy wheat", No. 1 – "sample No. 1". The harvested samples were tied together and hung in a mesh house for further analysis of the crop structure.

The meteorological conditions of the experiment are shown in the graph below (Figure 1).

Meteorological conditions in 2021 were characterized by temperatures close to the annual average and uneven precipitation.

After sowing, the weather conditions were favorable for the emergence of seedlings. The amount of precipitation was sufficient in May and June, the lack was observed in July, and therefore the plant stems turned yellow and withered early.

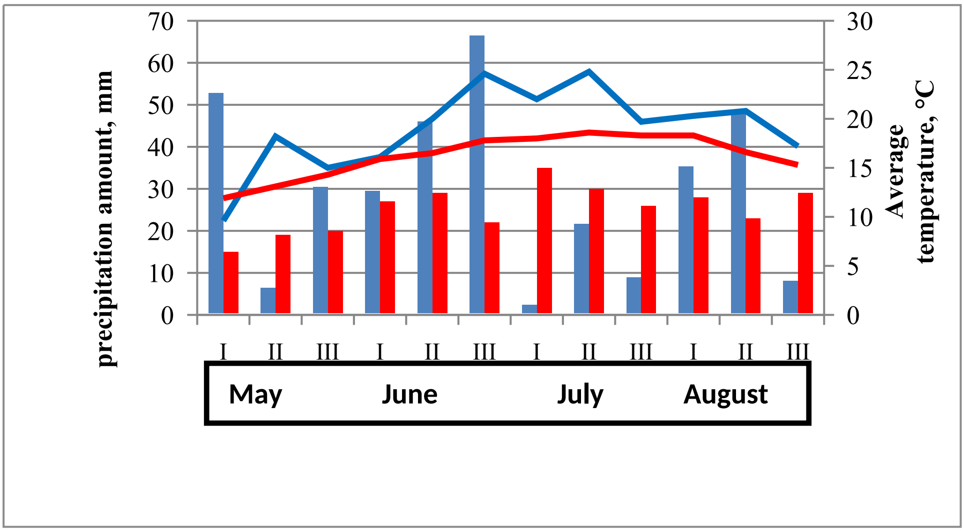

Fig. 1. Meteorological conditions in 2021

3 Results and discussions

The analysis of the main ear includes the total number of spikelets, the number of developed spikelets, the length of the ear, the density of the ear, the number of grains in the ear, the average number of grains in the ear, the mass of the main ear, the mass of the ears from the plant, as well as the analysis of the plant (the mass of the grain from the plant, the number of grains from the plant, the mass of 1000 grains).

Lodging of crops is quite common. It can take place in different phases of plant growth and development. One of the main methods of combating lodging is the breeding of non-lodging varieties. As is well known, many researchers associate the sign of unavailability to a large extent with the height of the plant, controlled by a complex system of genes and environmental factors. Estimating the height of the main stem is necessary for selecting valuable forms. The optimal value of the crop height for the Non-Chernozem zone is 70-100 cm.

Productive bushiness is the average number of normally developed stems yielding grain per plant. Productive bushiness is one of the important indicators that characterizes yield.

Table 2 shows the results of a laboratory assessment of stem height and productive bushiness.

Table 2 – Results of laboratory assessment of the height of the main stem and productive bushiness

Samplen umber	Number of plants in the sample	Height of the main stem		Productivebushiness	
		Height of the main stem, cm (0.1)	Thestandarder ror	Productivebush iness	Thestandarde rror
1	57	56,11	0,85	2,42	0,15
4	31	73,42	1,70	**4,45**	0,72
6	37	**85,72**	1,72	2,73	0,21
8	23	71,22	3,83	**3,09**	0,43
9	34	75,18	2,44	2,71	0,24
10	42	78,88	1,59	**3,10**	0,23
12	23	69,24	2,51	2,00	0,19
13	29	57,24	1,50	2,21	0,20
16	28	48,36	1,52	2,32	0,25
20	35	**84,11**	1,50	2,71	0,24
34	42	**80,79**	1,99	2,71	0,23

As can be seen from table No. 2, almost all cultivars, except 1, 13 and 16, had the optimal height of the main ear for the Non-Chernozem zone, numbers 6, 20 and 34 had the highest height, which is optimal for the Non-Chernozem zone 70-100. The standard number 34 is Gremme grade, and it also has the optimal height for the Non-Chernozem zone (80.79 cm).

According to the indicator of productive bushiness, cultivars numbered 4, 8 and 10 turned out to be the best, cultivars numbered 12, 13, 16 had the least productive bushiness. The standard at number 34 has Gremme varieties, productive bushiness is 2.71, which corresponds to the average values among cultivars.

A spike is a structural element of a complex ear. It includes wide spikelet scales; flowers are hidden inside them. The flowers have two flower scales – the outer (lower) and the inner (upper). The lower one is the backbone of wheat. On average, the number of spikelets per ear varies from 14 to 20. The total number of spikelets is an indicator that will be used to calculate the ear density.

The length of the ear is an indicator that is needed when calculating ear density.

Ear density is a complex feature. It consists of the length of the ear and the number of spikelets in the ear. In filmy wheat species, an ear with up to 24 spikelets 10 cm long is considered loose, 24-29 are medium—dense, and over 29 are dense. Ear density is quite variable and strongly depends on growing conditions. It can vary even on different stems of the same plant.

Table 3 shows the results of a laboratory assessment of the total number of spikelets of the main ear, the number of developed spikelets, the length of the spike, the density of the ear, and the standard error for each indicator.

Table 3- Results of laboratory evaluation of the number of spikelets of the main ear, the number of developed spikelets, the length of the ear shaft, and the density of the ear

№	Number of plants in the sample	Total number of spikelets of the main ear		Numberofdeveloped spikelets		Length of the ear shaft		Eardensity	
		Total number of spikelets, pcs	Thestandard error	Number of developed spikelets, pcs.	Thestandard error	Length of the ear, cm (0.1)	Thestandard error	Eardensity, pcs/10cm (1)	Thestandard error
1	57	13,74	0,12	10,40	0,23	6,64	0,09	19,31	0,21
4	31	13,55	0,25	11,48	0,32	4,77	0,19	**32,27**	6,57
6	37	**20,78**	0,56	**16,73**	0,69	**7,18**	0,23	27,86	0,63
8	23	**18,57**	0,62	**14,78**	1,00	5,87	0,24	**30,26**	0,84
9	34	17,59	0,53	**14,82**	0,77	**7,08**	0,25	23,66	0,44
10	42	14,48	0,31	11,31	0,47	5,69	0,14	23,74	0,31
12	23	**18,22**	0,54	13,61	0,72	**6,93**	0,22	25,00	0,65
13	29	14,55	0,52	11,38	0,71	4,17	0,11	**33,31**	1,67
16	28	11,75	0,35	8,86	0,63	4,51	0,18	24,32	0,79
20	35	13,97	0,36	11,23	0,44	5,37	0,14	24,20	0,42
34	42	14,14	0,22	12,57	0,36	4,75	0,09	27,95	0,55

Based on table No. 3, the following conclusions can be drawn:

1. The total number of spikelets in cultivars numbered 1, 4, 16, 20 is below the average.
2. The total number of spikelets in the cultivar number 6 is higher than the average value.
3. The remaining varietal samples have the average value of the trait.
4. Standard number 34 is the Gremme grade, which has an average value of the attribute.

Ear density is a complex feature. It consists of the length of the ear and the number of spikelets in the ear. In filmy wheat species, an ear with up to 24 spikelets 10 cm long is considered loose, 24-29 are medium—dense, and over 29 are dense. Ear density is quite variable and strongly depends on growing conditions. It can vary even on different stems of the same plant.

Table 3 shows the results of the laboratory evaluation of ear density and the standard error.

Based on table No. 3, the following conclusions can be drawn:

1. Loose ears have varietal patterns numbered 1, 9, 10.
2. Medium-dense ears have varietal patterns numbered 6, 12, 16, 20, 34.
3. Varieties numbered 4, 8, and 13 have a dense ear.

Table No. 4 shows the results of laboratory analysis of the number of grains in an ear and the standard error.

Based on table No. 4, the following conclusions can be drawn:

1. The largest number of grains in an ear of varietal samples under the numbers 6, 8, 9, 34.
2. The smallest number of grains per ear is in the variety samples numbered 1,

16.3. The remaining variety samples have an average value.

The average number of grains in a spike is an indicator showing the ratio of the number of developed spikelets to the number of grains in an ear. Table 3 shows the results of a laboratory assessment of the average number of grains in a spikelet and the standard error. Based on table No. 3, the following conclusions can be drawn:

1. The largest average number of grains in a spikelet is in varietal samples numbered 8, 12.
2. The smallest average number of grains in a spikelet is in varietal sample number 34.
3. The remaining varietal samples have an average value.

Table 4 – Earproductivity

Sample number	Number of plants in the sample	Number of grains per ear		The average number of grains per ear		Number of grains per plant	
		Number of grains per ear	Thestand arderror	Average number of grains per ear,	Thestand arderror	Number of grains per plant	Thestand arderror
1	57	13,32	0,63	0,90	0,06	15,98	1,06
4	31	18,71	0,85	0,64	0,02	69,00	10,79
6	37	28,14	1,53	0,59	0,02	61,22	5,55
8	23	21,91	2,55	1,06	0,25	50,91	10,29
9	34	20,71	1,69	0,92	0,16	47,79	6,12
10	42	18,95	0,99	0,61	0,03	51,52	4,75
12	23	18,96	1,98	1,59	0,67	30,74	3,54
13	29	14,90	1,05	0,95	0,11	25,79	2,35
16	28	13,50	1,69	0,95	0,12	23,07	3,96
20	35	18,49	1,08	0,65	0,03	46,26	5,37
34	42	25,98	1,20	0,51	0,02	62,79	5,70

The indicator that gives us an idea of the possible weight of grain from the main ear after threshing is presented in Table 5.

Table 5 – Earandgrainweight

Samplenumber	Number of plants in the sample	The mass of the main ear		The mass of ears per plant		Grainweightperplant		Weightof 1000 grains	
		Mass of the main ear, g	Thestandarderror	Weight of ears per plant, g	Thestandarderror	Grain weight per plant, g	Thestandarderror	Weightof 1000 grains, g (0.1)	Thestandarderror
1	57	0,59	0,03	1,18	0,09	0,77	0,06	54,90	6,71
4	31	0,95	0,06	3,34	0,54	2,29	0,36	32,63	0,85
6	37	1,25	0,08	2,63	0,26	1,63	0,17	25,23	0,99
8	23	1,03	0,11	2,56	0,49	1,43	0,32	28,63	2,87
9	34	1,20	0,10	2,89	0,37	1,48	0,20	28,35	1,28
10	42	0,91	0,05	2,42	0,22	1,72	0,17	31,96	1,19
12	23	1,09	0,09	1,73	0,19	0,90	0,10	29,03	0,68
13	29	0,92	0,07	1,57	0,15	1,05	0,10	39,99	0,74
16	28	0,86	0,10	1,50	0,24	0,91	0,15	47,04	11,30
20	35	0,96	0,06	2,29	0,26	1,55	0,19	35,72	4,08
34	42	1,34	0,07	3,05	0,31	2,26	0,22	34,60	0,94

Based on table No. 5, the following conclusions can be drawn:

1. The largest mass of the main ear was found in the variety samples under the numbers 6, 8, 9, 12.
2. The lowest mass of the main ear was found in the variety sample at number 1.
3. The remaining varietal samples have an average value.

Based on the weight of the ears, the following conclusion can be drawn:

1. The largest mass of ears from the plant was found in the cultivar under the number 4.
2. The smallest mass of the main ear was found in the cultivar under the numbers 1, 12, 13, 16.
3. The remaining varietal samples have an average value.

According to the indicator "grain weight per plant", the following conclusions can be drawn:

1. Variety sample number 4 has the largest mass of grains per plant.
2. Cultivars numbered 1, 2, 16 have the lowest grain weight from a plant.
3. Theremainingcultivarshaveanaveragevalue.

The mass of 1000 grains is an important agronomic feature, it is given great attention in breeding and genetic research, this indicator is determined by the grain size and the endosperm.

In the work, when determining the mass of 1000 grains in separately selected plants, a calculation method was applied, i.e. the number of grains per plant was calculated, then they were weighed and then recalculated per 1000 grains.

Based on this, the following conclusions can be drawn:

1. Varietal samples numbered 1 and 16 have the largest mass of 1,000 grains.
2. The lowest mass of 1000 grains is possessed by the varietal samples under the numbers 6, 8, 9, 12.
3. The remaining varietal samples have an average value.

4 Conclusion

Analyzing the above data on the collection of filmy wheat species: Isfahan wheat and spelt, the following preliminary conclusions can be drawn:

1. Based on the analysis of the experimental data obtained, it can be seen that the studied plant height samples were within the normal range of 70-100 cm for the Non-Chernozem zone of the Russian Federation.
2. Cultivars numbered 4,8,9 had the highest productive bushiness.
3. The total number of spikelets in the main ear of cultivars numbered 6, 8, 12 is above the average.
4. Cultivars numbered 6,9,12 have the largest length of the ear.
5. Cultivars numbered 4, 8, 13 have a dense ear.
6. Cultivars numbered have the largest number of grains in an ear. 5, 6, 8, 9, 26, 27, 28, 34, 56, 65, 67, 70, 72, 73, 75, 77.
7. The largest the average number of grains in a spike of varietal samples numbered 6,9,34.
8. The largest mass of the main ear was found in varietal samples numbered 6, 8, 9, 12, 34.
9. The largest mass of ears from the plant was found in cultivars numbered 4,9,34
10. The variety samples numbered 4,6,34 had the largest number of grains per plant.
11. Variety samples with numbers 4, 15, 27, 34, 56, 63, 67, 70, 72 they have the largest mass of grains from a plant.

Thus, the collection of filmy wheat species, namely spelt, needs to be studied in more detail and qualitative assessments of the material should be carried out.

References

1. M. Mencin, N. Markanovič, M. Mikulič Petkovšek, R. Veberič, P. Terpinc, Bioprocessed Wholegrain Spelt Flour Improves the Quality and Physicochemical Characteristics of Wheat Bread. Molecules. **28**, 3428 (2023). https://doi.org/10.3390/molecules28083428
2. H.M. Friedman, R.E. Tortolani, J. Glick, R.T. Burtis, Spelt is wheat. Allergy Proc. **15**, 217-218 (1994). https://doi.org/10.2500/108854194778702801
3. M. Liu, Q. Zhao, F. Qi, J. Stiller, S. Tang, J. Miao, J. Vrána, K. Holušová, D. Liu, J. Doležel, J.M. Manners, B. Han, C. Liu, Sequence divergence between spelt and common wheat. Theor Appl Genet. **131**, 1125-1132 (2018). https://doi.org/10.1007/s00122-018-3064-z
4. W. Akel, P. Thorwarth, V. Mirdita, E.A. Weissman, G. Liu, T. Würschum, C.F.H. Longin, Can spelt wheat be used as heterotic group for hybrid wheat breeding? Theor Appl Genet. **131**, 973-984 (2018). https://doi.org/10.1007/s00122-018-3052-3
5. The State Register of Breeding Achievements Approved for Use. Vol. 1. Plant Varieties (Moscow: FSBIU Rosinformagrotech, 2020)
6. N.N. Shagaeva, Spelt is one of the types of functional foods, in Modern Scientific Research in the Development of Public Catering and the Food Industry: Materials of the International Scientific-Practical and Scientific-Methodical Conference of Faculty and Graduate Students (Belgorod University of Cooperation, Economics and Law, 2016), pp. 93–97