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USSR

PERISHING OF WINTER CROPS

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16. Abstract (Limit: 200 words)

This report contains a summary of the many years of experimental studies on the physiological processes resulting in the loss of winter crops by rotting during the winter and early spring period. Data is analyzed concerning the growth and development of plants in the fall, winter and spring as a factor affecting the wintering ability of winter wheat and rye. Agrometeorological factors causing the rotting of winter crops and laws effecting their seasonal changes are also examined. Methods are described for long-term forecasting in various zones of the USSR.

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EXPERIMENTAL RESEARCH ON PHYSIOLOGICAL PROCESSES THAT CAUSE PERISHING OF WINTER CROPS UNDER SNOW

[Text] The perishing of winter crops under snow is an extremely complex process. It is observed when the plants remain for an extended time at a temperature close to 0°C (0, ±3°C) and when the soil, under a heavy snow cover, is without light and is frozen to a slight depth. Under these conditions the plants intensely expend supplies of nutritive substances in the leaves and tillering nodes and they become exhausted. With a shortage of oxygen and an excess of carbon dioxide in the plant tissues there is destruction of the cells, undifferentiated, anomalous growth of the vegetative cones, decomposition of pigments and a number of other phenomena that lead to damage and destruction both of individual shoots and of whole plants. Plants like these that are weakened in the winter, after the snow is gone and below-zero temperatures return in the spring, are damaged by less severe frosts than they are in the autumn and winter. They are easily susceptible to fungal diseases, the most widespread of which when the plants have been damaged under the snow are various forms of snow mold and collar rot.

Damage to plants under snow is observed primarily in the nonchernozem zone of the RSFSR--on heavy soils with poor water penetrability. But in a number of years it covers large territories, including the western regions of the USSR.

A considerable thinning of winter plantings under an abundant snow cover was observed as early as 1905 by V. V. Viner at the Shatilovskaya Experimental Station [35]. According to his data, the deeper the snow cover, the more severe the thinning.

In the winter of 1927/28 when there was mass freezing of winter crops in the southern regions, in Moscow and Ivanovskaya Oblasts, in the Belorussian SSR and in a number of northern regions of the European territory of the Soviet Union, winter plantings were severely harmed because of damage under snow. During this winter the snow fell on soil in which only the surface layer was frozen and then, under a layer of 40-50 centimeters of snow, the soil completely thawed out. The snow remained for more than 5.5 months that winter.

A considerable amount of destruction under an excessive snow cover is also observed under mountainous conditions [46].

The majority of researchers thought that the destruction of winter crops under a deep layer of snow takes place either because of a shortage of oxygen or because of suffocation with carbon dioxide gas that is discharged by the plants.

In 1930/31 I. I. Tumanov and in the winters of 1931/32 and 1932/33 he in conjunction with I. N. Borodina and T. V. Oleynikova [34] in Pushkin (Detskaya Selo) conducted a large series of experiments. On the basis of certain data concerning the content of oxygen in the dense firn snow Tumanov expressed doubts about the possibility of the plants' destruction because of a shortage of oxygen under the snow.

I. I. Tumanov formulated the problems in setting up his experiments in the following way: "First, to test the generally accepted opinion about the destruction of winter plantings under a deep snow cover from suffocation. Along with this, we explained the conditions for the destruction of winter plants under snow, established the causes of the destruction and the physiological bases of of the resistance of winter crops to the snow cover and developed methods of evaluating the resistance of winter crops to damage under snow. In addition to past analyses, we periodically checked the amount of damage and destruction of winter plantings under snow and determined changes in the frost resistance of winter crops as well as the content of carbohydrates." [34]

Thus I. I. Tumanov outlined and implemented a large program of special experiments for studying the perishing of plants under snow. The results he obtained were verified under various conditions and augmented by many physiologists and agrometeorologists and although by now a comparatively large amount of new material has been accumulated, the classical experiments of I. I. Tumanov are still of great interest.

Without discussing the methodology of gas analysis of the air adopted by I. I. Tumanov, let us note that when the oxygen content in the air above the snow is about 90.2 percent, under a snow cover of 50 centimeters three months after it has fallen the oxygen content at the surface of the soil ranged between 20.8 and 22 percent and the CO_2 content did not exceed 1.85 percent. With more precise analyses the figures obtained were O_2--21.6 percent and CO_2--0.91 percent.

In the winter of 1931/32 the experiments were conducted when the snow cover remained constant at 100 centimeters throughout the winter. The content of O_2 gradually decreased but after four months it had decreased only by 1.5 percent and was no less than 20-25 percent. The temperature under the 100-centimeter snow cover during the course of four months ranged from 0 to ± 2°C, the plants breathed intensively and they consumed oxygen. The insignificant change in the O_2 content show that even with a 1-meter layer of snow the gas exchange provided for the vital activity of the winter plants.

Thus the gas analogies showed that there was a sufficient quantity of oxygen, but the winter plants died under these conditions. Consequently it was proved with precise experiments that the destruction of winter plants at a temperature close to 0°C takes place not from suffocation as was previously supposed before the experiments of I. I. Tumanov.

In order to explain the degree to which a 50-centimeter cover of snow warms winter plants, the minimum temperature of the air under the snow was measured for three years (Figure 1).

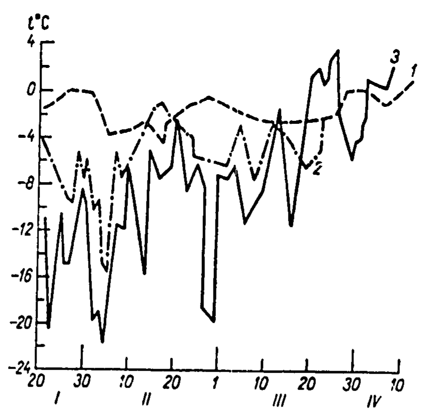

Figure 1. Change of temperature under snow cover of 50 cm (1) and 10 cm (2) and air temperature at time of observations (3) [34]

As one can see from Figure 1, in 1931/32 the air temperature under a 50-centimeter snow cover did not drop below -4.5°C while the temperature under a 10-centimeter snow cover, with severe frosts, dropped to -10 - -16°C, even though it was higher than the air temperature. The minimum air temperature in the winter of 1932/33 dropped to -20 - -21°C, but under a 10-15-centimeter snow cover it did not drop below -8 - -10°C and under a 50-centimeter snow cover it was not lower than -4°C. An increase in the layer of snow from 50 to 100 centimeters had relatively little effect on the temperature conditions for the plants that were under the snow. Under such a layer of snow it is determined more by the freezing of the soil before the snow cover was formed.

Very frequently when snow falls on thawed soil the plants spend a long time in the dark in an unfrozen condition at 0°C. According to observations of N. N. Kalitin, cited by N. N. Yakovlev [44], 20 percent of the radiation on the surface of the snow penetrates to a depth of 10 centimeters in dry snow and about 1 percent of the radiation penetrates to a depth of 50 centimeters.

K. M. Pyyklik [27], in connection with research of the phenomena of plant destruction under snow, also studied the total radiation that passed through the snow to various depths. He established that while the snow allows from 10 to 15.8 percent of the total radiation falling on the surface to pass through to a depth of 3 centimeters, half as much passes through to a depth of 8 centimeters and no more than 2.3-3.4 percent to a depth of 15 centimeters (Table 1). According to the data of P. P. Kuz'min, as N. N. Yakovlev notes [44], even in the first 5-centimeter layer of snow, from 34 to 88 percent of all the radiation penetrating the snow cover is absorbed, depending on its density and transparency.

Table 1. Total Radiation at Various Depths Under Snow Cover

Глубина от поверхности снега (2)	(1) Суммарная радиация					
	25 I		19 II		18 III	
	кал/(см²·мин) (3)	%	кал/(см²·мин) (3)	%	кал/(см²·мин) (4)	%
(5) На поверхности снега	13,0	100	38,6	100	51,5	100
(6) На глубине						
3 см	1,4	10,8	6,1	15,8	6,5	12,6
15 см	0,3	2,3	1,3	3,4	1,5	2,9

Key:
1. Total radiation
2. Depth from surface of snow
3. Cal/(cm^2 · min)
4. On surface of snow
5. At depth of:

Autumn overmoistening of the upper layers of soil in a number of regions of the USSR also affects the wintering of winter plantings under a deep snow cover--the probability of damage increases. Thus K. M. Pyyklik [27] notes that under the conditions of the Estonian SSR, in order to diagnose the destruction of winter plants under snow it is necessary to take into account the condition of the autumn moisture content of the soil.

N. N. Yakovlev [44] in 1937/38 beginning on 25 November, created an excessive snow cover to a height of 60-70 centimeters; before that the layer of snow remained at 20-25 centimeters. Under these conditions the destruction of Moskovskaya 2411 winter wheat, determined at various times from 25 November through 25 March on plots with various degrees of moisture, in February with excessive moisture was twice as great as with normal moisture content. The longer the excessive snow cover remained, the greater the destruction of the plants. When the plants remained under a deep snow cover for an extended period of time (up to 150 days) the destruction on excessively moist soil reached 57 percent and on naturally moist soil--24 percent, when in all cases the soil was frozen by the time the snow fell (down to 34-38 centimeters).

Consequently, under a snow cover of 50-100 centimeters with a temperature that does not drop below -5°C, the freezing of the plants, like suffocating from a shortage of air, was ruled out in the experiment of N. N. Yakovlev [44].

In order to explain the causes of the destruction of winter crops when they remain under snow, it was necessary to turn to a study of physiological processes that take place in winter plants. It was necessary to investigate the dynamics of the sugars in the first and second halves of the winter, to explain the respiration energy of the plants under a snow cover and to take into account the importance of the age, stages of development, bushiness, depth of tillering nodes and a number of other indicators of the physiological conditions of the plants during the autumn, winter and spring periods. It was necessary to explain the condition of rest at temperatures close to 0°C and also to investigate the growth of leaves under the snow, which was repeatedly noted by many writers, especially the growth and differentiation of the vegetative cone.

After it was established that the destruction of winter crops under an excessive snow cover is not the result of suffocation of the plants from a shortage of oxygen and that plants perish under snow with adequate gas exchange, I. I. Tumanov [34,35] began research on the resistance of plants to destruction under snow depending on their condition before the beginning of the winter and also those processes that take place in winter plants during the winter period. Here special attention was devoted to the dynamics of the carbohydrate content during the autumn, winter and early spring periods. He investigated plants that were planted at various times, plants of various ages, plants that were well tempered and plants that had not been tempered before the beginning of winter under the conditions of various snow covers.

As a result of three years of experiments it was established that the intensiveness of the expenditure of sugars under a deep snow cover is more significant at a temperature close to 0°C than at temperatures of -5, -8°C and lower, it also became clear that well tempered plants expend sugar under a deep snow cover considerably more "economically" than untempered plants do. Under these conditions the content of sugars in tempered plants decreased in the tillering nodes from 25 to 7.5 percent and in the leaves, from 17.6 to 5 percent, while in untempered plants it decreased to 2-2.5 percent. Moreover in tempered plants that have accumulated more sugars since autumn, the "critical minimum" of the content of sugars (about 2-5 percent) comes later than in untempered plants. Entering the winter with a smaller supply of sugars, poorly tempered plants begin to starve under deep snow considerably earlier than well-tempered plants do.

In a special experiment plants that were well tempered under natural conditions were compared with plants that were preliminarily kept for 10-12 days in a warm greenhouse where tempering decreased significantly. Almost all of the untempered plants died (only 6-14 percent of the plants survived) while 41-52 percent of the well tempered plants remained until spring under these conditions.

The number of surviving tempered plants fluctuated somewhat in various years but in all years there were significant differences in the resistance to damage under snow between tempered and untempered plants.

Three years of experiments confirm that the length of time the plants spend under the snow has a great influence on their damage. The longer the period a deep snow cover remains and the later the snow disappears from the plantings, the more sugars they expend and the more severely they are exhausted and thinned.

A systematic analysis of specimens of plants that have been under a constant snow cover of 50 and 90 centimeters showed that winter rye did not die off for approximately 2 months, but in the third month the destruction accelerated. With untempered winter wheat plants the destruction proceeded throughout the entire winter and a typical picture of perishing under snow was observed.

Thus even the early experiments of Tumanov confirmed observations of agrometeorologists and agronomists that perishing under snow takes place only when the plants spend an extended period of time under deep snow cover.

Experimental investigations of the links between the dynamics of sugars and the perishing of winter crops under a deep snow cover have been conducted by many writers. K. M. Pyyklik [27], for example, reports on his experiments in connection with expenditures of sugars by plants during the winter. His data are presented in table 2. From these data it is clear that a connection exists between expenditures of sugars and the temperature of the soil at the depth of the tillering nodes of the plants. The most rapid expenditure of sugar took place in the winters of 1955/56 and 1958/59 when the temperature at the depth of the tillering node was almost constantly elevated. The expenditure of sugars was much less in 1956/57 and 1957/58 and least of all in the winter of 1959/60 when the temperature was the lowest.

Table 2. Expenditure of Sugars in Winter Rye in the Winter Period

(1) Годы	(2) Интервалы преобладающих температур на глубине узла кущения (°C)	(3) Средний суточный расход сахаров зимой (мг на 1 г сухого вещества)[1]	
		(4) в листьях	(5) в узлах кущения
1955/56	0, −1	1,65	2,16
1956/57	−0,5, −2	1,10	1,53
1957/58	0, −3	1,01	1,60
1958/59	0, −1	1,66	2,58
1959/60	−2, −5	0,90	0,98

Key:

1. Years
2. Intervals of predominant temperatures at the depth of the tillering node (°C)
3. Average daily expenditure of sugars in the winter (mg per 1 g of dry substance)
4. In the leaves
5. In the tillering nodes

[1]From the beginning of wintering until the period of intensive snow melting in the spring.

Taking into account the fact that one cannot create a snow cover of the necessary depth everywhere or every year, in 1935 I. I. Tumanov [34] suggested that when evaluating various strains of winter crops for resistance to destruction under snow, experiments be conducted in dark thermostatic rooms and that the boxes of plants be covered with a layer of wet sawdust instead of snow. This way a temperature close to 0°C is easily maintained for a long period of time at the level of the plants and if necessary it can be regulated. Wet sawdust makes it possible to maintain the moisture of the air at the point close to saturation as it is in natural conditions under a deep snow cover. The results obtained in the experiments with wet sawdust corresponded to the results of field experiments under snow.

The condition of the soil during the winter--thawed or frozen--has a great influence on the expenditure of sugars. Thawed soil shows that under the snow the temperature was 0°C or a little higher all the time. The expenditure of stored substances in the plants is especially great under a deep snow cover when the soil is thawed.

In the winter of 1955/56 at the experimental basis in Kuuziku on one plot of winter rye a thawed condition of the soil was artifically created (by regulation of the snow cover) and on another--a frozen condition. The difference in the temperature of the soil on the plots was insignificant--an average of 0.5-1°C. The difference in the expenditure of sugars by the plants that spent the winter in thawed and frozen soil, both in the leaves and in the tillering nodes, reached 40 percent. Considerably more plants died in the thawed soil.

Moreover, during the course of three winters (from 1959 through 1962) other experiments were conducted in Kuuziku. In order not to allow freezing of the soil on the winter rye field, at the beginning of wintering one plot was covered with a layer of sawdust 20 centimeters thick. In the winter of 1959/1960, as a result of an exceptionally severe freeze in December, the soil even under sawdust froze slightly (3-4 centimeters), but in the second half of the winter it thawed. At the end of the snow thaw (20 April) one-fourth of the plants under the sawdust had died and in the leaves of the remaining plants there was 2-5 percent sugars and in the tillering nodes--7-9 percent.

In 1960/61 in the winter rye under sawdust even by 16 January the supply of sugars had decreased to 7 percent in the leaves and to 12 percent in the tillering nodes. A significant decline of the plants under sawdust began at the end of February. In the beginning of March in the leaves of the live plants there was 3-4 percent sugars and in the tillering nodes--7-9 percent. By the middle of April all the plants had died.

Thus in thawed soil, that is, at a temperature of 0°C and higher, the expenditure of sugars takes place 2-4 times more rapidly than in frozen soil and after winter crops have been in thawed soil for 2-3 months they begin to die--slowly at first and in the second half of March and the first half of April, in large numbers.

One of the main reasons for the intensive expenditure of sugars under a deep snow cover is the accelerated expenditure of sugars for respiration. V. A. Moiseychik [22], utilizing the data of N. V. Savinskiy, obtained at the Sobakino Agrometeorological Station, established that the expenditures in winter rye with a reduced temperature at the depth of the tillering node from 6.0 to 1.5°C increased 1.6-fold when the initial supplies of sugar were 10-18 percent. In plants with supplies of sugars of 26-28 percent in the middle of the winter the same increase in the expenditure of sugars was observed with a considerably lesser increase in the temperature at the depth of the tillering node (from 7 to 5°C).

V. A. Moiseychik [22], like other researchers later, established that a large supply of sugars in winter crops with a more developed grass stand is expended on respiration more rapidly (subsequently it became clear that this is also true of growth processes). This is one of the reasons for the great thinning when overgrown planted areas spend the winter under snow. I. I. Tumanov thinks that weakly tempered plants expend sugars considerably more rapidly at the same temperatures (2-3 times). I. M. Petunin [23] using the formula for respiration

$$C_6H_{12}O_6 + CO_2 \quad 6CO_2 + 6H_2O \qquad (1)$$

and the atomic weights of elements that comprise this formula, determined the amount of the ratio between discharged carbon dioxide and expended sugar (glucose). By dividing the weights of glucose molecules by the weight of the carbon dioxide discharged during respiration, he established that in terms of weight the sugar expended during respiration is 0.682 the weight of the discharged carbon dioxide. Taking into account the dependency of the quantity of carbon dioxide discharged during the process of respiration on the temperature, he calculated the amount of expenditure of sguars by the plant on respiration during a day (in milligrams) per 1 gram of dry substance (Table 3).

Table 3. Expenditure of Sugars by Well-Developed and Tempered Plants of Winter Crops on Respiration Under a Snow Cover During One Day, Depending on the Temperature

(1) Температура, °C	7	6	5	4	3	2	1	0	−1
(2) Расход сахаров, мг	9,86	9,07	8,30	7,56	6,91	6,31	5,74	5,23	4,73
(1) Температура, °C	−2	−3	−4	−5	−6	−7	−8	−9	−10
(2) Расход сахаров, мг	4,27	3,84	3,43	3,05	2,66	2,30	1,97	1,66	1,37

Key:
1. Temperature, °C
2. Expenditure of sugars, mg

The perishing of plants does not begin immediately upon the expenditure of supplies of sugar, but considerably later, since the plants are capable of augmenting them to a certain degree by transforming a large supply of starch into sugars. But then plant starvation takes place (expenditure of proteins and decomposition of the tissues of the plant cells) and a second phase of perishing of winter crops under snow begins. The plants begin to expend protein when they have only 2-4 percent sugars left. This takes place usually at the end of the winter and during the period of melting of the snow. The expenditure of proteins is dangerous for the life of the plants also because the heat discharged in this process creates favorable conditions for the development of microorganisms and the growth of mycelia of various fungi. The latter, growing rapidly and powerfully on the starving plants, sharply accelerate the expenditure of protein, which leads to death first of the leaves that touch the soil and then the bottoms of the shoots and subsequently also the tillering nodes of winter crops. The longer the period of starvation the more the plants are damaged from being under the snow. The results of an analysis of materials from many years of observations have made it possible for V. A. Moiseychik to come to the conclusion that all or the majority of plants die when the period of starvation is no less than 30-40 days and the melting of snow takes a long time [22].

But, as I. I. Tumanov made clear as early as 1935, the exhaustion of plants does not directly cause their death. Thus in special experiments in certain variants the leaves of winter plants were cut and removed before they were covered with snow--only one tillering node and the root system went through the winter. In this variant 85 percent of the plants survived and produced aftergrowth. In the second variant when the above-ground part was cut off at the same time but not removed and left lying on the plot, only 33 percent of the plants survived. The exhaustion of the winter plants was the same but in places where the leaves were not cut and also in places where the cut leaves remained on the plot, snow mold developed. On the plots where the leaves were removed there was no snow mold.

It is probably no accident that when there has been abundant growing of winter crops in the autumn farmers have grazed animals on areas planted in winter crops before the beginning of winter. And although the grazing of animals on winter plantings also caused damage to the plants, it was apparently less than the damage from spending the winter under the snow.

There are interesting experiments with cutting back the plants in the autumn under the conditions of three backgrounds--a natural snow cover, an excessive snow cover and without snow [44]. The plants were cut back at the end of September to a height of 10 centimeters and the mass that was cut was removed. On the background of a natural snow cover there were no essential differences in the wintering; when there was no snow the tillering nodes not covered by leaves suffered more; and under conditions of an excessive snow cover the removal of the cut mass--the nutritive environment for the development of fungi--led to a reduction of the death of plants from spending the winter under snow (Table 4).

The mass appearance of snow mold on the planted areas usually coincides with the end of winter when the plants are already weak and exhausted and when, under the influence of starvation, there is an intensive decomposition of proteins and the quantity of nitrogen compounds necessary for the development of snow mold increases. Moreover the smaller the mass of leaves, the less the fungi develop, which is clear from experiments with plants that have been cut back.

Table 4. Death of Plants that were Cut Back and Not Cut Back in the Fall (%)

(1) Место наблюдений и год опыта	(2) Снежный покров				(5) Бесснежье	
	(3) естественный		(4) избыточный			
	(6) растения					
	подрезанные (7)	неподрезанные (8)	подрезанные (7)	неподрезанные (8)	подрезанные (7)	неподрезанные (8)
(9) Кострома, 1938	18,1	17,8	24,5	42,6	66,4	40,8
(10) Овцино, 1940	24,3	24,8	30,0	36,4	72,2	64,6
(11) Пушкин, 1959	32,8	26,9	22,5	27,8	55,5	30,9

Key:

1. Place of observations and year of experiment
2. Snow cover
3. Natural
4. Excessive
5. No snow
6. Plants
7. Cut back
8. Not cut back
9. Kostroma, 1938
10. Ovtsino, 1940
11. Pushkin, 1959

Thus it has been established that starving creates the necessary preconditions and snow mold kills the plants under these conditions. Under conditions favorable for the development of mycelia of fungi (temperature under the snow--about 0°C and higher, air humidity--about 90 percent), the destruction of the plants begins within several days.

The experimental data obtained by I. I. Tumanov [34] enabled him to single out three qualitatively different phases depending on the physiological processes predominating during the course of perishing of the plants: first--carbohydrate exhaustion, second--starvation and disintegration of organic substances, and third--the death of the plants with the development of fungal diseases.

As has already been confirmed by other researchers, the first phase of perishing is characterized by hydrocarbon exhaustion of the plants. When the temperature under the snow is close to 0°C the winter plants maintain a marked respiration energy and the process of growth of the vegetative cones and root system continues almost continuously, although weakly. Each day even weak (especially with temperatures somewhat above freezing) expenditures of sugars on respiration and growth during the course of an extended period under the snow cover are accumulated and finally lead to an almost complete exhaustion of the plants.

The process of exhaustion of the plants continues for 2-3 months. The expenditure of sugars increases especially at the beginning of March, with the exception of those years when the temperature of March drops sharply and the soil freezes to a deeper level.

Expenditure of sugars in winter crops increases sharply, which was repeatedly observed by K. M. Pyyklik [27] during the period of intensive snow melting, especially at the end of this period (up to 5 milligrams and more per 1 gram of dry substance). The perishing of plants increases sharply during this period 5-6 days before the snow is gone, which frequently has a decisive significance for the plants' survival through the winter. Thus K. M. Pyyklik in 1951 compared the results of an analysis of specimens of winter rye planted at an optimum time which were taken on 12 and 20 March at the time of intensive snow melting on the fields. During these 8 days the quantity of sugars in the tillering nodes decreased from 20.1 to 13.2 percent and in the leaves--from 12.8 to 6.5 percent, which amounted to approximately 8-9 milligrams a day. In the subsequent days the content of sugars dropped to 3-4 percent.

The works of other writers also confirmed that the most active expenditure of sugars takes place under conditions of melting snow where the temperature remains stable at about 0°C and the high moisture content contributes to the rapid hydrolisis of sugars in the damaged plant tissues. The quantity of sugars in the leaves and especially in the tillering nodes before entering the winter is of great significance for the survival of winter plants under a deep snow cover.

The first experiments of I. I. Tumanov [34, 35] showed that tempered plants that accumulate a high percentage of sugars in the autumn remain longer and the second phase, starvation, begins later in them. Therefore one should discuss the factors that determine the degree of autumn tempering of plants under the conditions of the nonchernozem zone.

As we know, according to the theory of tempering developed by physiologists, a considerable increase in the content of sugars in the leaves and especially in the tillering nodes is a result of the fact that in the autumn during sunny days the processes of photosynthesis proceed relatively intensively in wheat plants and in the evening, night and morning hours when the temperature is reduced their processes of respiration and growth slow down, which leads to the accumulation of sugars. The longer the transition period from high temperatures in autumn to lower temperatures in the winter and the more optimal these temperatures are for tempering, the more intensively the process of accumulation of sugars in the tillering nodes takes place.

Table 5 gives figures from an experiment during which, after remaining at a temperature of 5°C for 14 days, the plants withstood from 2 to 5 days at temperatures of -2, -5 and -7°C. From these data it is clear that the maximum monosugars were accumulated in the variant with 14 days at a temperature of 5°C plus 2 days with -2°C and the largest number of di-sugars was accumulated in the variant with 14 days at 5°C plus 2 days at -7°C.

Table 5. Accumulation of Sugars in Various Strains of Winter Wheat (% of Dry Substance)

(8) Сорт	(1) 14 дней при 5° C							
	(2) контроль		(3) +2 дня при −2°C		(4) +5 дней при −5°C		(5) +2 дня при −7°C	
	(6) моно-сахара	(7) ди-сахара	(6) моно-сахара	(7) ди-сахара	(6) моно-сахара	(7) ди-сахара	(6) моно-сахара	(7) ди-сахара
(9) Минхарди	22,4	28,3	25,8	26,9	19,8	38,2	17,7	38,[illegible]
(10) Янетска	22,9	13,0	20,3	16,0	15,7	25,7	13,6	28,[illegible]
(11) Римпау	22,[illegible]	4,1	22,1	13,5	12,7	22,0	15,2	24,7
(12) Штубе Дикконф	12,1	3,4	20,7	4,7	11,6	18,4	17,4	15,5

Key:

1. 14 days at 5°C
2. Control
3. + 2 days at -2°C
4. + 5 days at -5°C
5. + 2 days at -7°C
6. Mono-sugar
7. Di-sugar
8. Strain
9. Minkhardi
10. Yanetska
11. Rimpan
12. Shtube Dikkopf

One of the essential factors that provide for good tempering of the plants and accumulation of sugars is optimal planting times that correspond to the best agro-meteorological conditions for the growth of the plants and the strain peculiarities of winter crops [2, 7, 13, 16, 22, 27, 25, 29].

K. M. Pyyklik [27] notes that winter crops planted at the optimal time accumulate in the tillering nodes an average of 10-15 percent more and in certain years even 20-30 percent more than plants planted at later times.

The period of autumn tempering of winter plants and the accumulation of sugars is usually observed when the average daily tempering of the air steadily decreases to 8-5°C with a large daily temperature range [22].

Observations of the dynamic accumulation of sugars in 1932/33 at the Khar'kovskaya experimental station in such strains of winter wheat as Dyurabl', Ferrugineum 1239, Gostianum 237 and Ukrainka showed that most of the sugars were in the tillering nodes; up to 30-45 percent of them were accumulated under conditions when the temperature for 13-16 hours reached 15-20°C and at night dropped to 2-3°C [7]. Summary data are also given for the Estonian SSR. Thus in the autumn of 1961 during the third ten days of September and the first five days of October there was dry sunny weather, the average daily temperature was 8-9°C, the maximum--13-17°C and the minimum!-- -1 - +3°C. By the end of this period the winter plants had accumulated about 30 percent of the sugars.

If the average daily temperature rises to above 9-10°C or there is considerable cloudiness, the accumulation of sugars is retarded and in a number of cases the quantity of already accumulated sugars, especially in the leaves, decreases considerably. With comparatively low temperatures (average daily--3-4°C), the accumulation of sugars is already slowing up even though this process continues right up to the time when the average daily temperatures are below 0. K. M. Pyyklik [27] in his work gives a description of the conditions for the tempering of winter rye and the course of accumulation of sugars for a number of years (Table 6, 7).

When analyzing days that are favorable or unfavorable for tempering, the course of them and their distribution throughout the autumn is significant. If clear sunny days predominate over overcast ones throughout the entire autumn, the process of tempering proceeds almost continually until the end of the growing period. If after the days that are favorable for tempering there appear overcast days and the temperature increases, frequently the accumulated supplies of substances are used by the plants for growth of the organs and the sugar content decreases.

It has been established that about 90 percent of the sugars in the tillering nodes in the tempered plants are localized by buriers that are difficult to penetrate. This property of tempered plants keeps the sugar firmly in undamaged cells and is possibly one of the reasons for the reduced loss of sugars under conditions where the temperature is close to 0°C, which in itself does not damage the cells, especially in the first half of the winter.

The dynamics of hydrocarbons can show the degree of the plants' readiness for wintering. But only after the temperatures begin to drop below zero can one determine the content of sugars with which the winter crops will enter the winter. When the temperatures drop below zero before the snow falls in cold winters (especially in the first half of the winter), the content of sucroses continues to increase and the more winter hardy the strain, the higher it is. During warm winters the proportion of simple forms of sugars increases, above all fructoses [31].

Many writers have engaged in the development of methods for diagnosing the condition of winter wheat in terms of the hydrocarbon content. Thus N. I. Goysa, R. V. Gatsenko and I. I. Kovtun in 1975 published the results of comprehensive research during 1967-1971. They tested strains of the Mironovskaya selection--Mironovskaya 808, Mironovskaya Yubileynaya, Lyutestsens 2488, 2917, 2877 and also Bezostaya 1 and Odesskaya 16.

Table 6. Connection Between the Conditions for Tempering Sangaste Winter Rye Planted at the Optimal Time and the Quantity of Sugars at the End of the Tempering Period

(1) Год	(2) Сумма эффективных температур от посева до прекращения вегетации (°С)	(3) Условия закаливания				(4) Количество сахаров (%)	
		(5) число дней¹		(8) в пересчете на хорошие	(9) оценка конца периода³	(10) в листьях	(11) в узлах кущения
		(6) хороших²	(7) средних				
1955	312	4	8	8	3	26	35
1956	146	4	6	7	3	22	32
1957	192	5	8	9	3	21	31
1958	252	7	11	13	4	29	45
1959	152	5	6	8	3	17	25
1960	199	0	2	1	2	12	20

Key:
1. Year
2. Total effective temperatures from planting time until end of growing period
3. Tempering conditions
4. Quantity of sugars (%)
5. Number of days[1]
6. Good[2]
7. Average
8. Expressed in terms of good ones
9. Evaluation at end of period[3]
10. In leaves
11. In tillering nodes

[1] A "good" day is expressed as 1 and an "average" day, 1/2.
[2] A good day--clear, sunny, not cloudy weather; average--slightly cloudy or with variable cloudiness
[3] Evaluation made with 5-point system: 1--very poor conditions for tempering; 5--excellent conditions.

Table 7. Connection Between the Conditions for Tempering Sangaste Winter Rye Planted at the Optimal Time and the Quantity of Sugars in the Tillering Nodes

(1) Число хороших дней для закаливания	(2) Оценка условий закаливания	(3) Количество сахаров в узлах кущения (%)
>12	(4) Хорошие	>35
8—12	(5) Средние	25—35
<8	(6) Плохие	<25

Key:
1. Number of good days for tempering
2. Evaluation of tempering conditions
3. Quantity of sugars in tillering nodes
4. Good
5. Average
6. Poor

It was established that the maximum quantity of total sugars accumulated in the autumn period in the tillering nodes of winter wheat changes little from strain to strain and amounts to 38-44 percent of the weight of the dry substance. There was no connection between the quantity of plants that live through the winter and the total sugars (R = 0.06). Thus the maximum content of sugars in the tillering nodes in the early autumn period does not serve as an indicator of the level of frost resistance of the plants.

The authors revealed a close connection between the quantity of plants that withstood the winter and the sum of sugars remaining in the tillering nodes at the end of wintering (R = 0.74). A reduction in the content of sugars is accompanied by a marked drop in the number of plants that withstood the winter. If one can understand the connection between the minimum content of sugars in the tillering nodes and the yield of grain of winter wheat (R = 0.65).

The writers think that the amount of the minimum content of sugars in the tillering nodes in the early spring can be recommended as a biological indicator for diagnosing the condition of the planted areas after wintering and, perhaps, can be utilized as a prognisticatory indicator of the harvest. In the authors' opinion, the advantage of this method of diagnosing the condition of the plants in the spring as compared to other widely known methods (sprouting the plants in core samples of soil, freezing the plants in refrigerated chamgers and so forth) is that it makes it possible to obtain in practice a simple (average for a given field) and operational idea of the relatively possible thinning after wintering and also to determine the need for replanting 1.5-2 weeks before the beginning of the spring growing period.

But what is the nature of the process of tempering and the accumulation of sugars in plants that are planted at various times or, more precisely, plants of various ages?

A study of the effects of the planting times and winter warm periods on the dynamics of the sugars was made by F. M. Kuperman in 1935 under the conditions of the Khar'kov experimental station for several years [7]. Analyses showed that when there was an overall drop in the content of sugars in the plants under the snow, after the snow was gone during an extended thawing period when the temperatures were above zero during the day (even 3-10°C) the plants are capable of carrying out photosynthesis. The content os sugars in them increases.

Many researchers have obtained similar data in the spring of years when winter plants are relieved of the snow cover early and conditions are established that are favorable for photosynthesis. In these years snow mold does not manage to develop in the plants, despite the fact that they are weak and exhausted from the lengthy expenditure of hydrocarbons under the deep snow cover, still survive and begin to grow.

K. M. Pyyklik [27] each year compared the condition of winter plants that came out from under the snow and those that were still under it. In the plants that came out from under the snow and were in the light for from 2 to 5 days there was 80 percent more sugars in the leaves and 60 percent more in the tillering nodes than in plants that were still under the snow [Table 8].

Early in the spring when there is a considerable range of day and night temperatures the plants can again be tempered and therefore withstand the return of frosts. One can judge the content of sugars in the leaves and tillering nodes in the early spring from the data in Table 9.

Even in his early works I. I. Tumanov [34] published figures on strain differences in winter crops in terms of their resistance to perishing under snow [Table 10].

N. N. Yakovlev [44] established the various resistances to perishing under snow of strains of winter crops with various origins. He noted a direct connection between the resistances of plants and the ecological-geographical conditions of their origin.

Table 8. Quality of Sugars in Winter Rye in Kuuziku in the Spring (% of Dry Substance)

Местоположение растений (1)	(2) Даты определения сахаров			
	12 III	14 III	20 III	21 III
(3) Под снегом				
(4) в листьях	11,9	—	6,5	6,2
(5) в узлах кущения	—	—	13,2	12,6
(6) На свету				
(4) в листьях	20,5	21,0	17,3	20,7
(5) в узлах кущения	—	—	16,5	16,9

Key:
1. Location of plants
2. Dates of measuring of sugars
3. Under snow
4. In leaves
5. In tillering nodes
6. In the light

Table 9. Content of Sugars in Winter Plants in the State of Stem Extension After Early Disappearance of Snow

(1) Срок сева	(2) Состояние растений ранней весной	(3) Содержание сахаров (% от сухого веса)	
		в листьях (4)	в узлах кущения (5)
(6) Оптимальный	(8) Главные побеги (трубка)	33,0	35,9
	(9) Боковые побеги (трубки нет)	31,5	
	(10) Растения, у которых не было трубкования	32,7	30,5
(7) Поздний	(11) Растения в фазе кущения (трубкования нет)	36,2	28,3

Key:
1. Planting time
2. Condition of plants in early spring
3. Content of sugars (% of dry substance)
4. In leaves
5. In tillering nodes
6. Optimal
7. Late
8. Main shoots (tubule)
9. Side shoots (no tubule)
10. Plants in which there has been no stem extension
11. Plants in the tillering stage (no stem extension)

Table 10. Description of Wintering of Plants Under Deep Snow

Число дней яровизации семян (1)	(2) Сроки сева														
	25 VIII					5 IX					25 IX				
	0	10	20	30	45	0	10	20	30	45	0	10	20	30	45
(3) Озимая пшеница															
(4) Лютесценс 0329	37	—	20	18	2	61	—	38	32	13	100	—	100	59	67
(5) Московская 02411	39	—	25	7	10	44	—	29	3	2	47	—	31	12	0
(6) Озимая рожь															
(7) Вятка	85	61	65	50	18	78	61	14	15	—	—	—	—	—	—

Key:
1. Number of days of vernalization of seeds
2. Planting times
3. Winter wheat
4. Lyutestsens 0329
5. Moskovskaya 02411
6. Winter rye
7. Vyatka

There is a lower mortality rate in plants from countries where winter crops are frequently subjected to damage under deep snow covers than in plants which rarely spend the winter under an abundant snow cover. Thus the fewest specimens died in the group obtained from Sweden is frequently combined with warm winters; strains that are resistant to damage under the snow have also been formed in the mountainous regions of Austria.

On the basis of experiments with an excessive snow cover which were conducted in the All-Union Institute of Crop Growing (City of Pushkin near Leningrad) in a year typical for damage to crops under the snow cover, N. N. Yakovlev [44] gives the information which we are printing in table 11.

From these data it is clear that the strains of wheat from regions where there are rarely conditions which lead to damage to the plants under the snow (Central Asian, Transcaucasian, Southern Steppe and Southern Forest Steppe ecological groups) are less resistant to damage under the snow than strains of wheat from the Northern Russian and Forest Steppe Volga ecological groups.

Interesting data concerning the content of sugars in winter and spring crops and their destruction after wintering in the Estonian SSR (Kuuziku Agrometeorological Station) in the winter of 1957/58 are given by K. M. Pyyklik (Table 12).

From table 12 it is clear that Sangaste and Priyekuli winter ryes accumulated approximately the same quantity of sugars in the tillering nodes, but Sangaste had 10 percent more sugars in the leaves. During the time of wintering Priyekuli expended relatively more sugars and approximately twice as much of it was destroyed. Five strains of winter wheat were tested. Puuk and Kuuziku accumulated more sugars than the others--an average of 20 percent more than the strains of the second group--Luun'ya Uluchshennaya and Gibrid 599. The results of the wintering showed that an average of 30-40 percent more plants of the second group died.

Table 11. Resistance of Strains of Winter Wheat to Perishing Under Snow (points) (Pushkin, 1965)

9-10	5-6
Lyutestsens 116	Ukrainka
Moskovskaya 2411	Odesskaya 3
Kolkhoznitsa	Stavropol'ka 328
Priyekul'skaya	Voroshilovskaya
Borovichskaya	
Kuuziku	
Luun'ya	
8-9	**4-5**
Ul'yanovka	Novokrymka 204
Sandomirka	Zemka
Lyutestsens 329	Kooperatorka
7-8	**3-4**
Lyutestsens 1060/10	Grekum 433
Eritrospermum 15	Dolis-Puri
6-7	**1-3**
Lyutestsens 17	Shark
Lesostepka 74	Surkhak
Ferrugineum 1239	Irody
Eritrospermum 917	

In addition to the strains mentioned above, Mandorf winter barley and Kauka and Diamant spring wheat were also tested. The barley contained approximately the same amount of sugar both in the leaves and in the tillering nodes as Kauka spring wheat but 60 percent of the barley plants died and all of the plants of both strains of spring wheat died.

Table 12. Content of Sugars in Winter and Spring Grain Crops and Their Death After Wintering in Kuuziku in 1957/58

Культура и сорт (1)	Срок сева (2)	Фаза развития при прекращении вегетации¹ (3)	Содержание сухого вещества в клеточном соке (%) (4)		Содержание сахаров (% от сухого вещества) (5)				[illegible] к концу перезимовки (%)	
			в начале зимы (7) (26 XI)		в начале зимы (7) (26 XI)		в конце зимы (8) (15 IV)		(11) растения	(10) листья
			узлы кущения (9)	листья (10)	узлы кущения (9)	листья (10)	узлы кущения (9)	листья (10)		
(12) Озимая рожь Сангасте	6 IX	2 побега	12,2	9,2	30,9	21,0	8,7	5,9	8	20
(13) Озимая пшеница Пуук	7 IX	2 побега	11,1	9,9	31,0	21,4	11,1	6,1	14	25
(14) Озимая рожь Приекули	6 IX	2 побега	8,4	10,1	31,2	19,4	6,3	5,3	15	40
(15) Озимая пшеница Луунья улучшенная	7 IX	3 побега	8,3	9,0	25,7	18,2	5,8	3,0	20	30
(16) Озимая пшеница Куузику	7 IX	2 побега	10,5	10,2	29,6	20,8	5,6	3,8	15	25
(17) Озимая пшеница Гибрид 599	7 IX	2 побега	7,1	8,6	23,9	20,2	5,0	3,7	20	25
(18) Яровая пшеница Каука	14 IX	3-й лист	9,6	7,5	17,4	15,8	—	—	40	60
(19) Озимый ячмень Мандорф	14 IX	2 побега	6,9	6,9	18,8	15,5	—	—	60	80
(20) Яровая пшеница Диамант	7 IX	2 побега	5,9	5,7	12,7	8,3	—	—	100	100

Key:

1. Crop and strain
2. Planting time
3. Stage of development at end of growing period[1]
4. Content of dry substance in cell sap
5. Content of sugars (% of dry substance)
6. Death by the end of wintering (%)
7. At beginning of winter
8. At end of winter
9. Tillering nodes
10. Leaves
11. Plants
12. Sangaste winter rye
13. Puuk winter wheat
14. Priyekuli winter rye
15. Luun'ya Uluchshennaya winter wheat
16. Kuuziku winter wheat
17. Gibrid 599 winter wheat
18. Kauka spring wheat
19. Manford winter barley
20. Diamant spring wheat

[1]In the tillering stage only the number of shoots is indicated.

From the results of the determination of sugars it became clear that at the time of intensive growth of the plants in the autumn they contained 3-9 percent of the sugars in the leaves and 7-12 percent in the tillering nodes. From the beginning of the period of tempering the overall quantity of sugars gradually increases both in the leaves and in the tillering nodes.

When a deep snow cover lasts for a very long time the content of hydrocarbons significantly equalizes by spring. This happens under the conditions of the northeast European part of the USSR and frequently in the western regions of the USSR. The differences in the destruction of various strains are evened out considerably (Table 13).

One of the essential reasons for the considerably smaller differences in the resistances of strains of winter crops to damage under heavy snow is that under a deep snow cover, especially when the snow begins to melt and the humidity in the plants' environment reaches 90-100 percent, fungi develop on them.

M. I. Rybakova [31] suggested an indirect method of determining the degree of winter hardiness of strains of winter wheat and rye--observing the dynamics of oligosaccharides. In addition to the plants' resistance to freezing, she also studied the reaction of strains to fall and winter thawing and the destruction of plants from remaining under a heavy snow cover. As standards for various resistances of strains to unfavorable factors of wintering she used Zhitkinskaya winter rye and Ul'yanovka winter wheat--winter-hardy strains; wheat-wheat grass hybrid 186--a medium winter hardy strain; and Motsinave winter wheat--a weakly winter hardy strain. During seven years a total of more than 50 strains and selection specimens were tested.

Table 13. Effects of Length of Winter Period on Wintering of Winter Wheat (% of surviving plants)

Сорт (2)	(1) Продолжительность зимы (дни)					
	120	140	160	180	200	230
(3) Колхозница	98,1	93,9	48,6	43,4	36,7	30,4
(4) Дюрабль	97,4	91,8	47,4	42,6	35,2	28,3
(5) Лютесценс 329	94,3	90,6	40,1	38,4	30,1	25,2
(6) Кооператорка	94,0	87,1	38,5	32,2	29,3	20,7

Key:
1. Duration of winter (days)
2. Strain
3. Kolkhoznitsa
4. Dyurabl'
5. Lyutestsens 329
6. Kooperatorka

In the tillering nodes and leaves of winter plants under the conditions of the Moscow area there are alcohol soluble hydrocarbons of oligosaccharides, sucrose, glucose and fructose. In the autumn there is usually a predominance in the winter plants of sucrose--from 30 to 50 percent (depending on the strain and autumn conditions); fructose--from 10 to 45 percent; oligosaccharides--from 10 to 30 percent (in individual periods, up to 40 percent in rye); and there was least glucose--from 10 to 20 percent (Table 14).

Table 14. Content of Sugars in Tillering Nodes of Wheat and Rye Plants (% of total sugars)

Сорт (1)	19 X				4 XI			
	(2) олиго-сахариды	(3) саха-роза	(4) глюкоза	(5) фрукто-за	(2) олиго-сахариды	(3) саха-роза	(4) глюкоза	(5) фрукто-за
(6) Вятка московская	27,6	52,6	4,8	15	28,2	30	6,6	35,1
(7) Ульяновка	17,0	50	9,3	24	17	35	9,5	38,6
(8) ППГ-186	20,6	48	14,2	17,1	9,1	34,5	18,7	37,5
(9) Кооператорка	13,2	50,2	12,1	24,2	10,3	33,5	11,3	44,7

Key:
1. Strain
2. Oligosaccharides
3. Sucrose
4. Glucose
5. Fructose
6. Vyatka Moskovskaya
7. Ul'yanovka
8. PPG-186
9. Kooperatorka

After completing the winter the most regular connection with the winter hardiness of the specimens of winter crops is found in the content of oligosaccharides. There is a less clearcut, but predictable connection between the fructose content and winter hardiness (Table 15).

Table 15. Content of Hydrocarbons in Tillering Nodes of Strains of Winter Wheat and Rye (% of Dry Substance) 14 April 1965

(1) Сорт	(2) Олиго-сахариды	(3) Сахароза	(4) Глюкоза	(5) Фруктоза
(6) Житкинская	3,00	11,66	0,04	5,72
(7) Ульяновка	2,24	9,52	1,72	5,52
(8) Мироновская 808	2,00	9,06	1,08	5,64
(9) ППГ-186	1,10	5,96	1,12	4,34
(10) Моцинаве	0,86	3,16	1,14	2,58

Key:

1. Strain
2. Oligosaccharides
3. Sucrose
4. Glucose
5. Fructose
6. Zhitinskaya
7. Ul'yanovka
8. Mironovskaya 808
9. PPG-186
10. Motsinave

M. I. Rybakova [31], on the basis of many years of analyses of the dynamics of the content of oligosaccharides in plants, recommends utilizing them as an indicator for evaluating the winter hardiness of various strains (Table 16). The change in the content of oligosaccharides and their significant expenditure is manifested especially in winter with slightly frozen soil and minimal temperatures at the level of the tillering nodes that are close to 0°C. Such were the winters of 1961/62 and 1965/66 (Table 17).

Since the most significant changes in the content of oligosaccharides both in winter rye and in winter wheat take place during warm winters, one must presume that this indicator can be utilized for characterizing the resistance of strains to damage under the snow. In a comparative evaluation of resistance to damage under the snow, the content of oligosaccharides is a considerably more reliable indicator than the content of sucrose and fructose. But when determining them it is necessary to take into account the origin of the strains and their adaptability to one type of winter or another. Thus analyses of oligosaccharides have confirmed already known information to the effect that the most frost resistant strains of steppe origin, where the snow cover usually does not last long, are far from always the most resistant to damage under snow as well.

Table 16. Content of Hydrocarbons in Tillering Nodes of Strain of Winter Wheat and Rye (% of Dry Substance) 15 April 1962

(1) Сорт	(2) Олиго-сахариды	(3) Сахароза	(4) Глюкоза	(5) Фруктоза
(6) Житкинская	2,98	13,87	1,10	8,94
(7) Ульяновка	1,12	11,06	1,10	10,76
(8) Алабасская	1,12	9,42	1,36	11,08
(9) Мироновская 808	1,06	12,9	0,10	11,56
(10) Кунцевская 45	1,06	9,88	0,04	8,20
(11) Моцинаве	0	3,16	0	1,94

Key:

1. Strain
2. Oligosaccharides
3. Sucrose
4. Glucose
5. Fructose
6. Zhitinskaya
7. Ul'yanovka
8. Alabasskaya
9. Mironovskaya 808
10. Kuntsevskaya 45
11. Motsinave

Table 17. Content of Oligosaccharides in Tillering Nodes of Strains of Winter Wheat and Rye in Various Years (% of Dry Substance)

Сорт (1)	1961/62		1962/63		1963/64		1964/65		1965/66	
	15/XI	12/IV	14/XI	19/IV	13/XI	10/IV	12/XI	14/IV	23/XI	4/IV
(2) Вятка московская	5,9	2,7	10,0	6,3	12,8	8,3	9,4	3,8	9,4	2,8
(3) Ульяновка	3,0	1,1	4,0	1,9	8,7	5,5	6,9	2,2	3,2	0,0
(4) ППГ-186	2,1	0,6	4,0	3,0	12,8	2,7	9,4	1,1	5,8	0,6
(5) Кооператорка	2,0	Следы	3,8	1,0	10,9	3,0	5,1	1,2	4,4	0,5

Key:

1. Strain
2. Vyatka Moskovskaya
3. Ul'yanovka
4. PPG-186
5. Kooperatorka
6. Traces

G. Salcheva [48] in Bulgaria studied the dynamics of free amino acids. As a result of applying the method of unidimensional chromatography on paper and visual determination of the quantity of individual amino acids, it was shown that in the process of tempering (with a reduction of the temperature in the autumn and the beginning of the winter), the quantity of free amino acids increases in the leaves and especially in the tillering nodes. There was an especially marked increase in the content of asparagine, serine, glutamic acid, alanine and proline. There was also a positive correlation between the accumulation of proline in the tillering nodes and the frost resistance of the strains of wheat.

G. Salcheva conducted experiments with reduced (45 percent), increased (85 percent) and optimal (60 percent) moisture content in the soil. The research showed that in the process of tempering with increased moisture content in the soil the quantity of free amino acids decreases in the leaves and tillering nodes. Moreover in plants grown with reduced moisture content of the soil, most of the proline is accumulated in the tillering nodes during the period of stages I and II of tempering.

With a lowering of the temperature, in winter wheat there is a shift of the enzyme reactions in the direction of a predominance of hydrolysis over synthesis. According to the research of N. N. Sisakyan, with a certain depth of the shift of enzyme reactions in the direction of hydrolysis, which he calls the "border of death," there is a decompensation of physiological processes which causes the plants to die.

L. N. Romanova [30] conducted research on the coefficients of the shift of enzyme reactions in strains of winter wheat with varying degrees of winter hardiness. The coefficients of the shift were established by dividing the indicators synthesis/hydrolysis at each date of analysis with respect to the same indicator in the September sample (Table 18).

Table 18. Coefficients of Shift of Enzyme Reactions with a Change from the Warm Autumn to the Cold Winter Period in Strains of Winter Wheat.

Сорт (1)	(2) Отношение $\frac{\text{синтез}}{\text{гидролиз}}$		(3) Коэффициент смещения	
	30 IX	30 X	30 IX	30 X
(4) Лютесценс 230	0,96	1,18	1,0	1,22
(5) Московская 2453	0,91	1,05	1,0	1,15
(6) ППГ-186	0,92	1,00	1,0	1,08
(7) Кооператорка	0,90	0,84	1,0	0,93

Key:

1. Strain
2. Ratio $\frac{\text{synthesis}}{\text{hydrolysis}}$
3. Coefficient of shift
4. Lyutestsens 230
5. Moskovskaya 2453
6. PPG-186
7. Kooperatorka

The data obtained by L. N. Romanova coincide with the results of the research of A. V. Blagoveshchenskiy. While for catalysis in winter hardy wheat he obtained Q_{10} = 1.35 and medium winter hardy wheat--Q_{10} = 1.78, in the experiments of L. N. Romanova with the winter hardy wheat Lyutestsens 230 she obtained Q_{10} = 1.59 and in the weakly winter hardy strain Kooperatorka--Q_{10} = 2.02.

The research of L. N. Romanova also agrees with the ideas of B. A. Rubin who showed that the quantity Q_{10} is not a constant, but depends both on the condition of the development of the plants and on the influence of surrounding conditions.

Along with the accumulation of sugars and amino acids and the dehydration, processes that are essential for the tempering of plants take place in stage II. They are related to the change in the hydrophily, the viscosity and the permeability of the protoplasm. With a reduction in temperature the viscosity of the protoplasm increases accompanied by a reduction in the speed of biological processes in the cells, thus contributing to their changeover to forced dormancy. The permeability of protoplasm and its adsorptive capacity also change.

As one can see from a brief survey of the work physiologists and phytopathologists conducted in the northeastern and northwestern regions of the Soviet Union, the main reason for the death of winter crops is the excessive loss of hydrocarbons, exhaustion and then starvation of the plants which leads to a decomposition of proteins when the plants remain for a long time under a deep snow cover and the temperatures are close to 0°C at the depth of the tillering node. Infection with fungal diseases is a secondary cause of the death of plants when they are damaged under the snow, since the development of fungi is possible only on plants that are already essentially weakened and physiologically ill.

In the northeastern regions of the country's European territory during years when there is a deep snow cover and deep freezing of the soil, winter plants rarely suffer from damage caused by being under the snow and in the southern steppe regions where there is almost never an excessive snow cover the winter crops most frequently die from freezing and ice crusts; but in the central belt of the country's European territory winter crops frequently subjected both to the effects of strong frosts with lengthy periods when there is no snow and to damage under the snow when the snow falls on soil that is thawed or only slightly frozen.

The majority of research on the process of tempering winter crops involves a study of the plants' resistance to freezing. Only a very small amount of work has been devoted to clarifying the correlations between tempering and resistance to perishing under the snow.

Many physiologists have been and still are engaged in research on sugars in connection with the resistance of winter crops to low temperatures. This research began with N. A. Maksimov, A. A. Rikhter and I. I. Tumanov. Certain writers are fully convinced by their data that there is a direct link between the content of sugars and the resistance of winter plants [7] while others have made a number of adjustments in connection with the strain and other peculiarities of winter crops and also agro-meteorological conditions of various geographical regions [44].

N. N. Yakovlev [44], without denying the role of tempering and accumulation of hydrocarbons in increasing the frost resistance of wheat, cites the data of a number of researchers who think that the correlation between the content of hydrocarbons before beginning the winter and the wintering of winter wheat are not always clear enough. Like many other writers, he thinks that the most significant thing for the wintering of plants is not so much the content of sugars in the autumn period as the complex of factors in the winter and early spring period.

One cannot fully agree with the conclusions of N. N. Yakovlev since, although in a number of cases no direct connection is observed between the resistance of unfavorable conditions and the content of sugars, the protective role of hydrocarbons is quite significant as is shown in the works of physiologists and selection workers who deal with the change of spring forms into winter forms [29] in the process of selection of such winter-hardy strains as Mironovskaya 808.

The development of fungal diseases plays a decisive role in the subsequent period of wintering of plants under an excessive snow cover. The period of development of fungal diseases and the damage and death of plants because of them, as was already pointed out, is the third and final phase of the perishing of winter crops under snow.

The damage to winter crops by snow mold and collar rot has been investigated in greatest detail by A. V. Pukhal'skiy [26] and S. M. Tupinevich [36-38]. Sclerotia are solid formations which are black on the outside and white or yellow on the inside. The size and shape of sclerotia are extremely varied; usually sclerotia are 1.5-10 x 1-3.5 millimeters. They are usually circular or oval in shape but one does encounter sclerotia that are long and irregular in shape. In the majority of cases sclerotia are flat and their thickness does not exceed 1-1.5 millimeters.

In certain years sclerotia are formed mostly in the axillary part of the leaf and less on the surface of the blade of the leaf, where they are located under the epidermis. In other years sclerotia are formed only on the surface of the blade of the leaf and there are none at all in the axillary part. This is explained by the conditions of the year (depth of snow cover, temperature and so forth). The number of sclerotia on one plant can be from 1 to 25 and more.

Sclerotia of fungi that form in the spring require a certain period of ripening in the light under natural conditions in order to germinate. They do not germinate in the spring of the year they are formed. Conversely, if early in the spring the young sclerotia of fungi are placed in the soil at a depth of 3-6 centimeters, within 75-80 days they are fully decomposed under the effects of saprophytic fungi, bacteria and nemotodes. Sclerotia germinate only in the autumn after the completion of ripening on the surface of the soil. In order to germinate sclerotia needs light, a high content of moisture in the air and soil and a fairly low temperature--(2-12°C). Under these conditions the germinating sclerotia form an afcomycetous fruit bearer for the fungus--apothecia with sack spores. In Leningrad on the field section of the All-Union Institute of Plant Protection the germination of sclerotia was observed during half of October in 1937 and 1938. Under natural conditions at the Falenskaya selection station the germination of sclerotia and the formation of fungal apothecia were observed at the beginning of October in 1936 and 1937 [44].

In the autumn with the alternating rainy and sunny days the mature fungal sack spores are broadcast into the air. Falling on winter plants the sack spores germinate easily and infect them. The infected plants enter the winter this way. In the spring under the snow with a low temperature above zero fungal mycolia develop on them, which at the end of their development on the infected plants form new sclerotia. Consequently, the formation of sclerotia is the final stage in the cycle of the development of the fungus.

In addition to wheat and rye, sclerotia infect many feed grasses (timothy, rye grass, sescue, wheat grass, meadow grass, cock's-foot) and grass weeds on which the fungus can maintain itself on the fields. Fungal sclerotia can be retained in the soil for 1-2 years and do not lose their capacity for germination and the formation of apothecia with sack spores.

A. B. Pukhal'skiy [26] did a large amount of work to study the resistance of strains of winter wheat to collar rot. He devoted special attention to searching for forms of winter wheat that are resistant to collar rot and characterizing various ecological groups of wheat with respect to this indicator. During three years he managed to evaluate the resistance to collar rot of more than 2,000 specimens of winter wheat from the world collection of the All-Union Scientific Research Institute of Plant Growing. During epiphytotic years sclerotia of fungi were found on all specimens of the collection included in various ecological groups, which showed their infection with Sclerotinia graminearum Elen, but the growth of the specimens differed. Certain specimens developed satisfactorily despite the infection with the fungus, formed young leaves and subsequently entered the stem extension stage, bored spikes and produced a harvest. But the majority of specimens of the collection either completely died off or only part of them survived.

A. V. Pukhal'skiy noted a fairly clear-cut grouping in terms of the degree of spring aftergrowth of wheat among specimens from various ecological group. The highest degree of winter hardiness and the best aftergrowth during the spring period characterized representatives of the Scandinavian, Western European hybrid, Altay and North American hybrid ecological group. Somewhat behind them with respect to these indicators were specimens from the northern Russian ecological group. The worst indicators (death and poor aftergrowth) were observed in specimens from the northern European, Danube, Balcan, eastern Asian, Kashir and Kashgar ecological groups. He included strains of winter wheat from the Northeastern Selection Center (now Falenskaya selection station) among the specimens that were most resistant to collar rot.

As a result of his study of the infection of winter wheats with collar rot, the author came to the conclusion that the hardiness (resistance) of specimens is determined by their capability to change over to intensive growth in the spring period, to form new roots and leaves and thus to survive the damage caused under the snow. In this respect the role of agrotechnical factors is of exceptionally great importance. In the works of S. M. Tupinevich [36, 37] he points out the significance of good agrotechnology in the fight against the destruction of winter crops by collar rot.

Snow mold, developing strongly on starving plants and accelerating the expenditure of proteins, leads to the destruction first of the leaves that touch the soil, then the bases of the shortened stalks and subsequently the tillering nodes as well. The leaves of infected plants bend down to the ground and lose their color. An accumulation of mycelia appears on them, which are white at first (hence the name "snow" mold) and then the fruit bearers cause a rose tinge. The mycelia of the fungi are spread from one leaf to another and it is as if they are glued together. The disease rapidly moves from one plant to another, covering ever larger sections of the planted area.

There are various degrees of damage to winter plants. The first degree is when the leaves are partially green, the tillering nodes are normally turgid and with a rapid disappearance of the snow in the spring and the beginning of sunny and warm weather new leaves grow. The damage to the leaves and part of the severely damaged plants die. The plant stand on the section becomes thinner. The second degree is when the leaves are partially infected with snow mold and the tillering node is not very turgid. When the temperature is about 2-3°C for a prolonged time the mycelia proliferate and the winter plants are frequently severely thinned out. The third degree is complete destruction; the leaves of the plants are dark brown in the spring, sometimes with a white or silver film on them and with sclerotia of fungi of collar rot. The bases of the plant and the tillering nodes are yellow and not turgid. A typical sign is a slight separation in places where the tillering node is attached to the root system which is usually not infected.

Another fungus that causes similar damage to winter crops, Fusarium nivale (Fr.) Ces, is no longer widespread.

Snow mold is caused by a number of other pathogenic fungi as well. Many of them are polythages which infect not only winter crops, but also many species of wild grasses. Depending on soil condition, the species and the strains of plants, winter crops are more frequently infected with collar rot in some regions and there are various forms of Fusarial wilt in other regions. Agrotechnical measures directed toward protecting planted areas from perishing under the snow reduce the harm caused by fungal diseases in the majority of cases.

RESEARCH ON THE PROCESSES OF GROWTH AND DEVELOPMENT OF PLANTS IN THE AUTUMN-WINTER-SPRING PERIOD AS FACTORS IN THE FORMATION OF WINTER-HARDY WINTER CROPS

It has long been known that increased growth of winter crops during a warm and moist autumn worsens the wintering of the planted areas. In order to protect the plants from freezing and perishing under the snow, in agricultural practice the crops have been mowed in the fall and it has been recommended that potassium top-dressing be applied in the fall which somewhat impedes the growth of parts of the plant that are above ground.

The connection between early curtailment of the growth processes in the autumn and the winter hardiness of plants has been repeatedly noted by I. M. Vasil'yev [3] and I. I. Tumanov [35]. It is known that the most winter hardy strains grow more slowly in the autumn, form short, narrow leaves and are characterized by a split bush which grows closer to the ground than those of less winter-hardy plants [7, 12].

For a long time the idea has prevailed among physiologists, crop growers and agrometeorologists that with the beginning of the winter period and the curtailment of apparent growth of winter plants, all their organs and tissues pass into a state of deep dormancy, just as they do in woody plants.

Indeed, as the research of P. A. Genkel' and T. M. Zhivukhina [7] has shown, in winter wheat there are not very prolonged, but clear processes of separation of protoplasm from the cell walls which characterize a condition of deep dormancy. But in the cells of leaves that are less tempered and especially in "overgrown" plants of less winter-hardy strains, the condition of dormancy does not last long. In the plants of less winter-hardy strains under the conditions of the Moscow area, the number of cells in which there is a separation of the protoplasm does not reach a maximum until November and in the beginning of March the plants are already completely out of the dormant condition.

During years with a long, warm autumn when the snow falls on sod soil, no changeover of winter plants to a deep dormant condition is observed. In these years, as I. I. Tumanov has already noted [35], even under a deep snow cover the etiolated leaves of winter wheat grow.

Many researchers have observed a slight growth of vegetative organs under the snow, noting that the balance of the overall expenditure of sugars frequently does not correspond to the calculated figures for the loss of sugars. Consequently, some of the sugars expended by the plants under deep snow apparently go for growth processes, although insignificant ones.

The weakening of the growth processes, as many researchers have noted, is one of the necessary conditions for the plants' changeover from a growing condition which is not resistant to unfavorable conditions of wintering to a period of dormancy and the second phase of tempering for low winter temperatures [35, 37] and this condition is also necessary for the plants' resistance to wintering under a deep snow cover.

How are the growth regulators and stimulators of growth processes first inhibited in the process of tempering the plants in the autumn period? What is the interaction and relationship among growth regulators--auxins, gibberellins, kinins and various growth stimulators and inhibitors of winter plants during the autumn, summer and early spring periods?

Many scientists attach a great deal of importance to the role of auxins in the process of tempering winter wheat. Until recently in the literature little attention was paid to the question of the dynamics and relationships of growth stimulators and inhibitors during the process of tempering winter plants [4]. In the works of V. G. Konarev (1959, 1964) it was suggested that the influence of all factors of the external environment is exercised through the functional activity of the nucleic acids.

More interesting experiments to investigate the growth processes when the plants are changing over from a growing condition to forced dormancy have been conducted in recent years by V. V. Vinogradova [5]. She investigated the frost resistance of winter wheat in connection with the intensiveness of growth and the content of endogenic stimulators and inhibitors in the autumn, winter and spring periods; she studied the influence of treatment with data-indoleacetic acid on the growth and level of native auxins and inhibitors under various temperature conditions for tempering; and she also investigated the changes in the condition of desoxyribonucleic acid in the chromatin of the cell nuclei.

The intensiveness of growth in the experiments of V. V. Vinogradova was determined by the sizes of the leaves of 60 plants and the length of the vegetative cones of 15 plants were measured under a microscope. The biological activity of the growth substances was determined through stimulation or inhibition of the growth of cuttings of the coleoptiles of winter wheat.

A comparison of the data on the intensiveness of growth of plants and the level of their frost resistance showed (Fig. 2) that the differences in the level of frost resistance of the strains investigated by the author--Ul'yanovka, Borovichskaya and Bezostaya 1--depended on the intensiveness of the growth of the plants' leaves during the autumn period. Reduced intensiveness of growth in the autumns of 1968 and 1969 contributed to the development of more highly resistant plants. V. V. Vinogradova accompanied the research on the dynamics of frost resistance of plants with measurements of the vegetative cones (Table 19).

A reduction in resistance in the experiments of V. V. Vinogradova [5] coincided with the period of growth of the vegetative cones or, as the author formulates it, with a period of "concealed growth" of the plants.

The results of the study of the dynamics of growth substances in the same experiments showed that beginning in Autumn, during the course of tempering, the stimulators in the tillering nodes of winter wheat are almost completely inactivated. Moreover, it is very interesting that Ul'yanovka, a highly frost resistant strain, is distinguished by a lower level of stimulators, high speed of their inactivation and earlier attainment of the autumn physiological maximum in the content of inhibitors (Figures 3, 4). For the weakly frost resistant strain Bezostaya 1, it was characteristic to have a slow inactivation of growth stimulators, later attainment of the autumn physiological maximum in the content of inhibitors and the prevalence of their activity over that of growth stimulators.

From the data obtained by V. V. Vinogradova [5] it is also clear that during the winter period there is a gradual reduction of the growth inhibitors and almost a complete disappearance of them from the tissues of the tillering nodes during the period that precedes visible growth.

On the basis of these and figures from literature, the author arrives at the conclusion that during the second half of the winter, even with negative temperatures, there is a change in the intensiveness of certain metabolic processes in the tillering nodes of winter wheat which lead to a loss of the tempered condition.

This is also confirmed by an analysis of the condition of the DNA in the vegetative cones. In the weakly winter hardy strain Bezostaya 1, in the differentiated tissues of the vegetative cone during freezing and especially after thawing there is a marked loss of some of the nucleic acids as a result of their degradation. Unfortunately the amount of physiological research that uncovers the mechanism of growth processes is not very great so far.

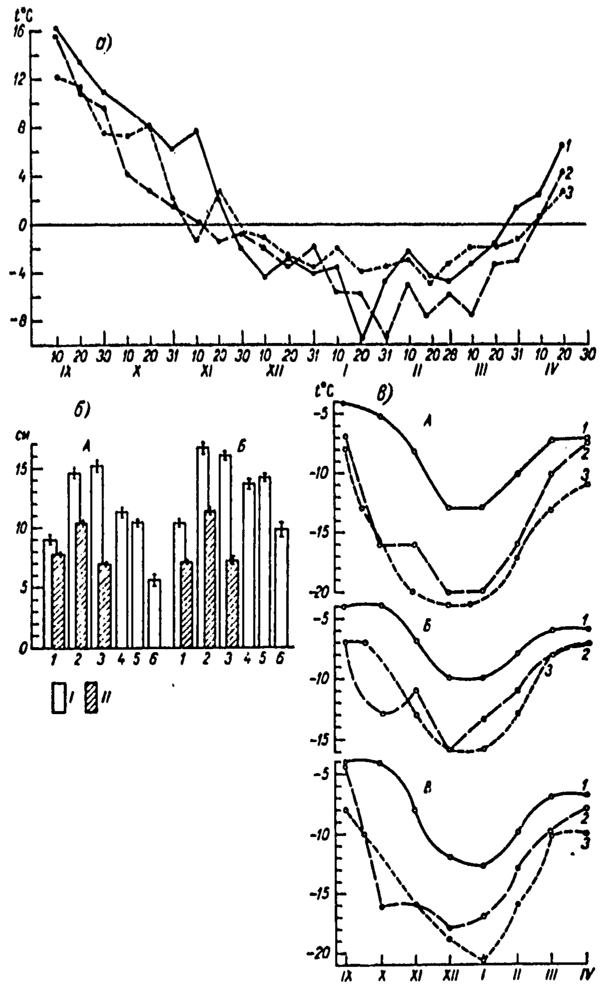

Figure 2. Frost Resistance of Winter Wheat, Depending on Temperature Conditions of the Soil and Intensiveness of the Plants' Growth in the Autumn

Key:

а. Temperature conditions of the soil at the depth of the plants' tillering nodes

б. Length of leaves (from first to sixth) at end of autumn growing periods of 1967 (I) and 1968 (II)

Key (continued):

- в. Resistance of strains of wheat in various years critical t°C (death of 50% of plants).
- A. Ul'yanovka
- Б. Bezostaya 1
- В. Borovichskaya
- 1. 1967/68
- 2. 1968/69
- 3. 1969/70

Table 19. Sizes of Vegetative Cones (mcm) of Winter Wheat in Autumn-Winter-Spring Period (1968/69)

31 X	4 XII	28 III	27 III	12 IV	15 IV	5 V
(1) Ульяновка						
236 ± 8	236 ± 12	242 ± 15	253 ± 18	284 ± 8	338 ± 14	649 ± 21
(2) Безостая 1						
260 ± 12	270 ± 13	276 ± 15	300 ± 20	312 ± 21	390 ± 17	690 ± 33

Key:

1. Ul'yanovka
2. Bezostaya 1

There is considerably more work and more observations of the growth of plants in which changes in the morphology, size and form of the vegetative cone are investigated by the microscopic method and in recent years the condition of the stages of organogenesis in the autumn, winter and spring periods has been studied.

Beginning in 1936 F. M. Kuperman reputedly noted that under the conditions of positive temperatures in the soil during the winter, especially during the thawing period, there is a certain growth of the vegetative cones, although insignificant [7]. Moreover, if the process proceeds normally, when the plants are transferred to a greenhouse the vegetative cones rapidly begin differentiation of the rudimentary spike and enter stages III-IV of organogenesis. Among the methodological aids, in 1936 F. M. Kuperman recommended diagnosing the condition of areas planted in winter crops by observing the vegetative cones by the so-called method of "bringing it to the rudimentary spike." To do this some of the plants in the pore samples for 20-25 days (from the time they are removed from the field) were placed under conditions of 24-hour light and then the rudimentary

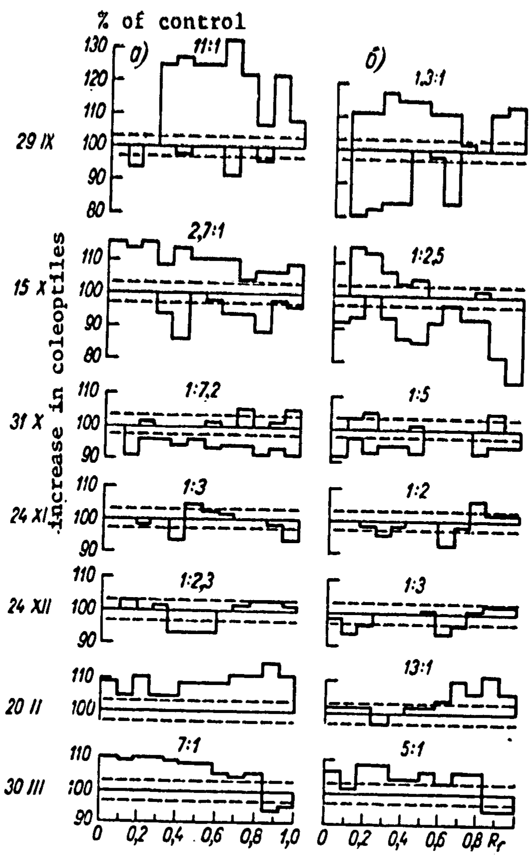

Figure 3. The Activity of Growth Substances and the Relationship Between Stimulators and Inhibitors (figures over histograms) in Tillering Nodes of Winter Wheat (1968-69)

Key:
1. % of control
2. Increase in coleoptiles

spike was analyzed. This method was later described in more detail in 1953 and 1956.

After the publication of the work which announced the main patterns of the stages of organogenesis [7] and the schemes we are presenting in figures 5 and 6, the peculiarities of organogenesis of vegetative cones during the autumn and winter periods were investigated in detail by many researchers [10, 12, 14, 18, 19, 22, 25, 45, 47].

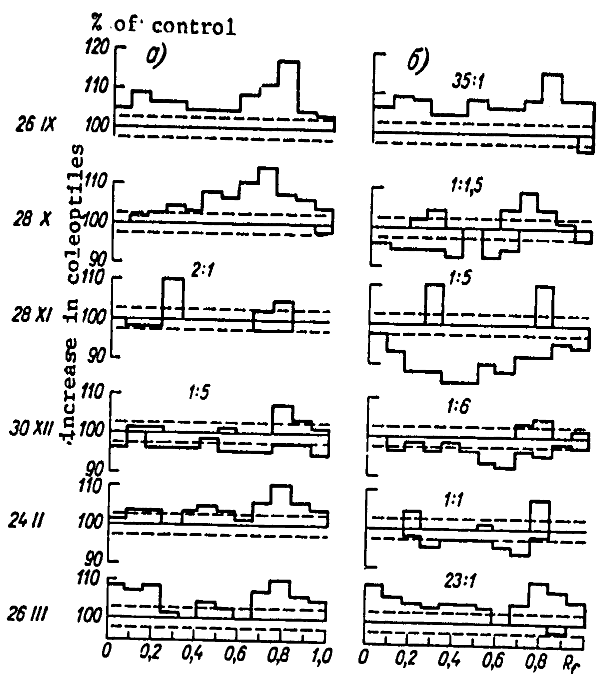

Figure 4. The Activity of Growth Substances in Extracts From Tillering Nodes of Winter Wheat in the Process of Tempering, Wintering and Renewal of Growth in the Spring (1969-70)

Key:
1. % of control
2. Increase in coleoptiles

The majority of strains of winter wheat, under the conditions of the main regions where they are cultivated, are in stage II of organogenesis before they enter the winter. As F. M. Kuperman [7, 10], V. A. Moiseychik [22] and many other authors note, at the beginning of autumn the vegetative cones in various strains are characterized by relatively similar sizes, especially if the temperature drops rapidly (below -5-8°C).

Thus at the beginning of November 1966 in Moscow Oblast in such strains at Ul'yanovka and PPG-559 the length of the vegetative cone was 0.19 mm, in the less winter hardy strains Moskovskaya 2453 and Odesskaya 16 the length amounted to 0.2 mm, and in the relatively weakly winter hardy strain Bezostaya 1 it was also 0.23 mm. From Table 20 it is clear that with various planting times and in years with various meteorological conditions, in plants of all strains (with exceptions, as will be shown subsequently, of anomalous years and extra early planting times) the vegetative cones are in stage II of organogenesis before entering the winter.

Table 20. Growth of Vegetative Cone During Winter Period in Various Types of Winter Wheat, Depending on Meteorological Conditions and Planting Times [12]

Дата посева (1)	Дата взятия пробы (2)	Мироновская 808 (3)		Куницевская 45 (4)		Ульяновка (5)	
		этап (6)	прирост (%) (7)	этап (6)	прирост (%) (7)	этап (6)	прирост (%) (7)
25 VIII 1966 г.	21 X 1966 г.	II	100	II	100	II	100
	12 IV 1967 г.	II	147	II	145	II	130
7 X 1966 г.	29 X 1966 г.	II	100	II	100	—	—
	12 IV 1967 г.	II	124	II	119	—	—
10 X 1965 г.	6 XII 1965 г.	II	100	II	100	II	100
	22 III 1966 г.	II	104	II	138	II	120
	16 IV 1966 г.	II	115	II	141	II	266

Дата посева (1)	Дата взятия пробы (2)	Фанаа (8)		Хохлана (9)	
		этап (6)	прирост (%) (7)	этап (6)	прирост (%) (7)
25 VIII 1966 г.	21 X 1966 г.	II	100	II	100
	12 IV 1967 г.	II	136	II	167
7 X 1966 г.	29 X 1966 г.	II	100	II	100
	12 IV 1967 г.	II	119	II	109
10 X 1965 г.	6 XII 1965 г.	II	100	II	100
	22 III 1966 г.	II	132	II	130
	16 IV 1966 г.	II	135	II	144

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Key:

1. Planting date
2. Date sample taken
3. Mironovskaya 808
4. Kuntsevskaya 45
5. Ul'yanovka
6. Stage
7. Increase (%)
8. Fanal
9. Kokhland

In the autumn there was very little difference in the sizes of the vegetative cones of such strains as the winter hardy Ul'yanovskaya and Mironovka 808 and the weakly winter hardy Kokhland and Fanal. Under the conditions of 1964/65 when there was an excessive snow cover in Moscow Oblast, in almost all of the strains that were tested there was an extension of the length of the vegetative cones and in February the increase in their lengths significantly exceeded the norm. But before the disappearance of the snow all strains were in stage II and rarely in stage III of organogenesis. The strain differences in terms of the differentiation in size of the vegetative cone in strains with varying winter hardiness were most easily revealed from the aftergrowth of the plants in a greenhouse during the winter or under field conditions in the early spring (Table 21).

Similar data concerning the change in the length of the vegetative cone were obtained by V. I. Ponamarev. As one can see from table 22 the intensiveness of the growth of the vegetative cone during the winter period under a snow cover depends to a significant degree on the age of the plants, the strain peculiarities and the weather conditions. Thus more intensive growth of the vegetative cone in the same stage of organogenesis was observed in "older" plants with an earlier planting time. Plants planted in September were distinguished by the slowest rates of growth of the vegetative cone under the conditions of the Moscow area. The length of the vegetative cone changed equally predictably depending on the degree of winter hardiness of the strain--the least increase in the length of the vegetative cone was observed in the most winter hardy strain, Ul'yanovka. Winter growth of the vegetative cone also changed depending on the temperature and water conditions of the autumn and winter. Thus in the dry autumn of 1966 the plants of all strains and planted at all times formed a shorter vegetative cone than in 1965.

The connection between the intensiveness of growth processes (and especially the intensiveness of growth of the vegetative cone) in the early spring and the frost resistance of the strain was excellently investigated in experiments conducted in the winter of 1966/67. The more intensive the growth of the vegetative cone under the conditions of an excessive snow cover in 1966/67, the greater the percentage of death of the plants (Table 23).

Table 21. Dynamics of Passing Through Stages of Organogenesis and Change in Length of Vegetative Cones of Various Strains of Winter Wheat Under and Excessive Snow Cover (Moscow 1964/65)

Сорт (1)	Показатель (2)	11 XI			13 II			21 IV			
		А	Б		А	Б		А		Б	
(3) Ульяновка	(7) Этап органогенеза	II	—	III	II	III	IV	—	III	IV	V
	(8) % от общего числа растений	100	—	100	100	85	15	—	100	10	90
	(9) Длина конуса нарастания, мм	0,20	—	0,29	0,20	—	0,4	—	0,32	—	1,7
(4) Мироновская 808	(7) Этап органогенеза	II	II	III	II	III	IV	II	III	IV	V
	(8) % от общего числа растений	100	23	77	100	30	70	4	25	10	90
	(9) Длина конуса нарастания, мм	0,21	—	0,21	0,21	—	0,7	—	0,29	—	2,1
(5) Кунцевская 45	(7) Этап органогенеза	II	—	III	II	III	IV	II	III	IV	V
	(8) % от общего числа растений	100	—	100	100	80	20	40	60	20	80
	(9) Длина конуса нарастания, мм	0,21	—	0,32	0,21	—	0,9	—	0,26	—	2,2
(6) Безостая 1	(7) Этап органогенеза	II	IV	V	II	IV	V	—	III	—	V
	(8) % от общего числа растений	100	20	80	100	67	33	—	100	—	100
	(9) Длина конуса нарастания, мм	0,21	—	0,92	0,21	—	1,4	—	0,31	—	2,4

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Key:
1. Strain
2. Indicator
3. Ul'yanovka
4. Mironovskaya 808
5. Kuntsevskaya 45
6. Bezostaya 1
7. Stage of organogenesis
8. % of overall growth of plants
9. Length of vegetative cone, mm

Note: A--the condition of the plants on the day the sample was taken from the field; Б--the same, after their growth for 30 days in a greenhouse.

Table 22. Change in Length of Vegetative Cones of Winter Wheat Plants of Various Ages During Winter Period

Сорт (2)	(1) Срок сева					
	16 VIII		26 VIII—29 VIII		10 IX	
	А	Б	А	Б	А	Б
1965/66 г.						
(3) Ульяновка	339	153	262	146	177	128
(4) Мироновская 808	409	165	324	157	240	137
1966/67 г.						
(3) Ульяновка	252	122	193	109	150	104
(4) Мироновская 808	314	140	252	129	189	111

Key:
1. Planting Time
2. Strain
3. Ul'yanovka
4. Mironovskaya 808

Note: A--Length of cone at beginning of spring growing period; Б--in % of Length of cone before entering winter.

The influence of growth processes on the change in winter hardiness of plants is noted in the works of A. I. Mitropolenko (1975). Table 24 gives his data concerning the frost resistance of plants of various ages under the conditions of Krasnograd (Khar'kovskaya Oblast). Table 25 shows that during the course of the winter period a change in the length of the vegetative cones of the plants was noted and the influence of the age of the plants, the strain peculiarities and weather conditions was clearly manifested here.

Plants of the Kuntsevskaya 45 and Nemchinovskaya 495 strain had a longer and more differentiated cone both at the end of the autumn growing period and at the beginning of spring aftergrowth than did plants of the Ul'yanovka strain.

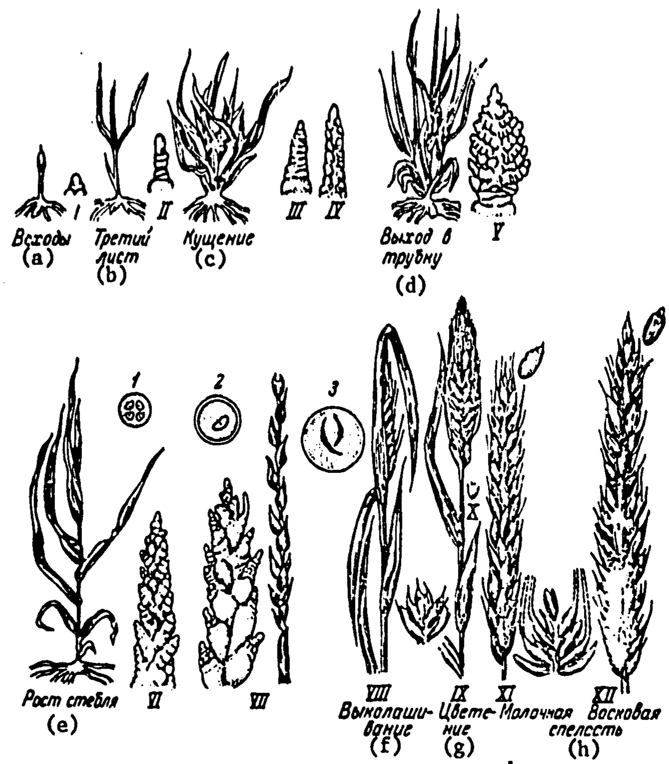

Figure 5. Phases of Development and Stages of Organogenesis of Winter Wheat

Stage I--undifferentiated vegetative cone; stage II--differentiation of rudimentary stalk into nodes and internodes (beginning of the formation of sheathes of stalk leaves); stage II--segmentation of lower part of vegetative cone and formation of rudimentary covering leaves (bracts); stage IV--beginning of formation of spike tubereles; stage V--formation of blossoms on spikes; stage VI--formation of anthers and pistils; stage VII--formation of sex cells (gametophytes), growth of length of segments of spike shank; stage VIII--formation of spikes; stage IX--blossoming, fertilization, formation of zygoes; stage X--formation of caryopsis; stage XI--milky ripeness (accumulation of nutritive substances); stage XII--waxy ripeness (transfer of nutritive substances into reserve) and ripening of seeds;

Key: 1, 2, 3 -- subsequent formation of pollen

a. Shoots
b. Third leaf
c. Tillering
d. Stem extension
e. Spike formation
f. Spike formation
g. Blossoming
h. Milky, waxy ripeness

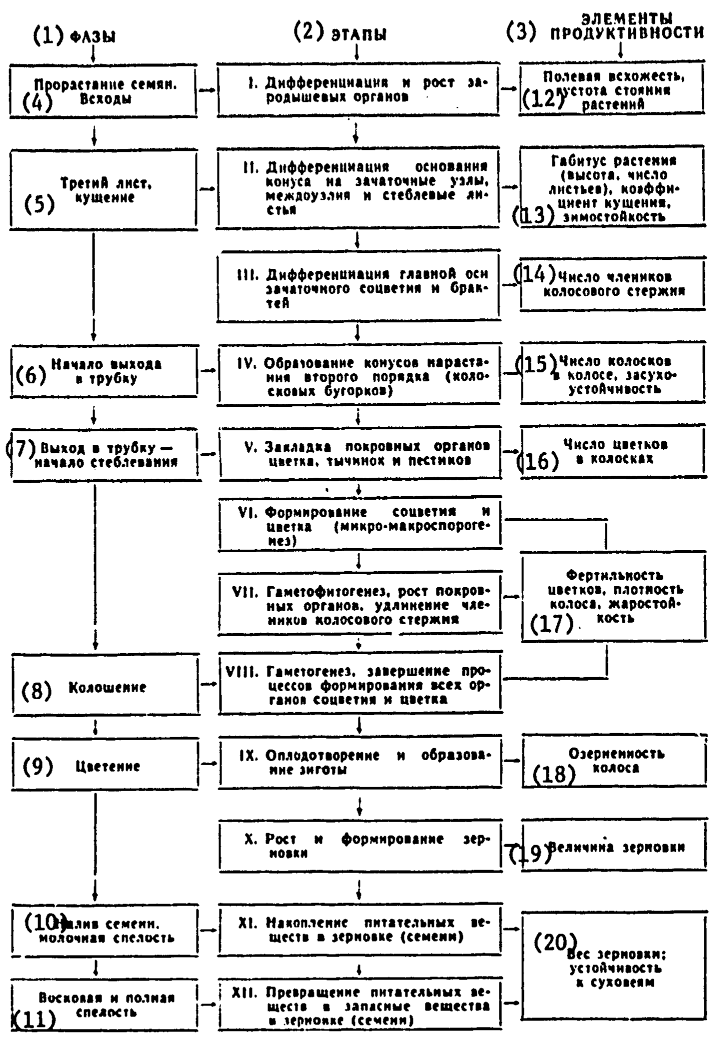

Figure 6. Formation of Productive Elements of Wheats in Various Phases of Development and Stages of Organogenesis

Key:

1. Phases
2. Stages
3. Productive elements
4. Sprouting of seeds, shoots
5. Third leaf, tillering
6. Beginning of stem extension
7. Stem extension--beginning of stem growth
8. Heading
9. Blossoming
10. Filling in of seeds, milky ripeness
11. Waxy and complete ripeness
12. Field germination, density of plant stand
13. Habitus of plants (height, number of leaves), tillering coefficient, winter-hardiness
14. Number of segments on spike shank
15. Number of spikelets in spike, drought-resistance
16. Number of blossoms in spike
17. Fertility of blossoms, density of spike, heat-resistance
18. Grain content of spike
19. Size of caryopsis
20. Weight of caryopsis; resistance to dry winds

I. Differentiation and growth of embryonic organs
II. Differentiation of cone base into rudimentary nodes, internodes and stalk leaves
III. Differentiation of main axis of rudimentary flower cluster and bracts
IV. Formation of vegetative cones of second order (spike tubereles)
V. Establishment of integumentary organs of blossom, stamens and pistils
VI. Formation of flower cluster and blossom (micro-macrosparogenesis)
VII. Gametophytogenesis, growth of integumentary organs, lengthening of segments os pike shank
VIII. Gametogenesis, completion of processes of formation of all organs of flower cluster and blossom
IX. Fertilization and zygote formation
X. Growth and caryopsis formation
XI. Accumulation of nutritive substances
XII. Transformation of nutritive substances into reserve substances in caryopsis (seeds)

When there is a long autumn and the snow falls on thawed or slightly frozen soil at a temperature close to 0°C, even at the beginning of November the vernalization processes are completed in the plants, the tempering decreases and there is a sharp decline in the resistance both to critically low temperatures and to conditions that cause perishing under the snow.

Table 23. Intensiveness of Growth of Vegetative Cones During Winter Period in Winter Wheat With Various Degrees of Winter Hardiness Under Conditions of Moscow Oblast

Сорт (1)	21 X 1965 г. (2) этап органогенеза	(3) длина конуса нарастания	12 IV 1966 г. (2) этап органогенеза	(3) длина конуса нарастания	(4) % живых растений после зимовки при бесснежье
(5) Ульяновка	II	0,20	II	0,39	40,4
(6) Мироновская 808	II	0,20	II	0,44	49,0
(7) ППГ-186	II	0,26	II	0,46	46,0
(8) Кунцевская 45	II	0,26	II	0,45	44,0
(9) Безостая 1	II	0,33	II—III	0,59	20,0
(10) Кваметас	II	0,30	II	0,57	23,0
(11) Фанал	II	0,36	II	0,59	10,0

Key:
1. Strain
2. Stage of organogenesis
3. Length of vegetative cone
4. % of live plants after wintering without snow
5. Ul'yanovka
6. Mironovskaya 808
7. PPG-186
8. Kuntsevskaya 45
9. Bezostaya 1
10. Kvametas
11. Fanal

Table 24. Frost resistance of Mironovskaya 808 Winter Wheat With Various Planting Times (February 1972)

(1) Дата посева	(2) Состояние конуса нарастания на II этапе органогенеза	(3) Без промораживания (контроль)	(4) Температура промораживания (°C) (24 ч) 16	19	21	23
			(5) сохранилось растений (%)			
17 VIII	Сильно вытянут, листовые валики (6)	81,9	55,5	30,0	0	0
23 VIII	Вытянут, листовые валики (7)	90,0	61,6	33,3	7,7	0
1 IX	Начало вытягивания и появление листовых валиков (8)	100,0	100,0	91,6	81,9	18,7
7 IX	Начало вытягивания (9)	100,0	100,0	100,0	77,7	34,5
15 IX	Состояние перехода к вытягиванию (10)	100,0	100,0	100,0	100,0	100,0

[Key on following page]

Key:
1. Planting date
2. Condition of vegetative cone in stage II of organogenesis
3. Without freezing (control)
4. Temperature of freezing (°C) (24 hours)
5. Surviving plants (%)
6. Extremely elongated leaf vallicula
7. Elongated leaf vallicula
8. Beginning of elongation and appearance of leaf vallicula
9. Beginning of elongation
10. Condition of changeover to elongation

Table 25. Change in Length of Vegetative Cones of Winter Wheat Plants of Various Ages During Winter Period (main shoot), 1964/65

Сорт (1)	(2) Сроки сева							
	15 VIII	25 VIII	5 IX	15 IX	15 VIII	25 VIII	5 IX	15 IX
	(3) длина конуса в начале весенней вегетации (мкм)				(4) в % от длины перед уходом в зиму			
(5) Кунцевская 45	338	284	212	185	127	132	119	109
(6) Немчиновская 495	328	297	224	191	138	123	112	108
(7) Ульяновка	288	260	165	169	125	122	105	101

Key:
1. Strain
2. Planting times
3. Length of cone at beginning of spring growing period (mcm)
4. In % of length before entering winter
5. Nemchinovska;a 495
7. Ul'yanovka

It has been established [7] that when vernalized seeds are planted the plants' resistance to low temperatures decreases sharply and when they are planted too early they suffer severely from freezing.

It has been explained that with early planting times the plants from vernalized seeds enter stage III of organogenesis in the autumn and strains of souther selection (Odesskaya Selection Station) complete vernalization more rapidly than do strains of Mironovskaya and Khar'kovskaya selection and therefore are more severely damaged.

I. I. Tumanov [34] also noted that the capability of tempering in vernalized plants decreased apparently because of the fact that their growth was more intensive. It was almost the rule that plants from vernalized seeds grew more rapidly and the leaves were longer; I. I. Tumanov did not check the condition of the vegetative cone.

In the winter of 1964/65 we studied the wintering of five strains of winter wheat: Ul'yanovka, Mironovskaya 264, wheat-wheat grass hybrids 186 and 559 and Bezostaya 1. Planting was done with vernalized and dry seeds at four times: early for Moscow Oblast--5 and 15 August; optimal--25 August; and late--10 September. We also planted the Vyatka strain of winter rye. The winter of 1964/65 had a lot of snow and the winter crops--not only those planted at the earliest time, 5 August, but also those planted on 15 August--were significantly damaged even by the end of February. In the spring the plants planted at all times with vernalized seeds had all died and there was intensive development of snow mold on them while 70-90 percent of the control plants, planted on 25 August and 10 September, survived the winter.

The results of this experiment convincingly prove that after the completion of vernalization processes there is a sharp reduction in the plants' resistance to damage under the snow.

With intensive growth of the vegetative cone even during 1-2 months, there is also a sharp reduction in the plants' resistance to perishing under a snow and ice cover, which is clear from the data of 1970/71 (Figure 7) [10].

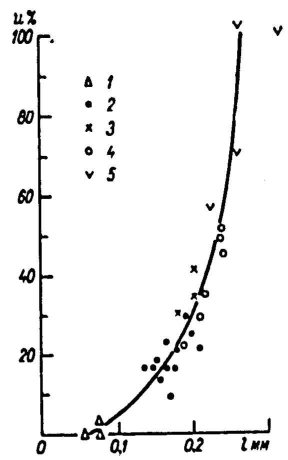

Figure 7. Dependency Between Thinning (%) of Winter Wheat of the Mironovskaya 808 Strain as a Result of Freezing and the Ice Crust and the Length (mm) of the Vegetative Cone

Thickness of ice crust: 1) mm, 2) 10-20 mm, 3) 21-40 mm, 4) 41-60 mm, 5) minimum soil temperature at depth of tillering nodes -15 - -17°C: $\lg u = 1.5277 \lg l + 0.3694 \lg m + 2.0360$.

In the winter of 1970/71 the winter hardiness of eight strains of winter wheat (Ul'yanovka, PPG-186, Mironovskaya 808, Yubileynaya 50, Bezostaya 1, Avrora, Rannyaya 12, San-Pastore, Tsezium 39 and the Vyatka strain of winter rye) was investigated on the experimental plot of Moscow State University. The planting was done at eight times, beginning extra early (from 29 July through 3 October 1970). Three conditions of the snow cover were created: 1) natural--10-20 centimeters; 2) excessive--up to 60-70 centimeters; and 3) without snow from 0 to 2 centimeters. Each day the minimum temperature at the depth of the tillering node was taken with AM-17 remote control thermometers and the depth of the snow cover and the depth of freezing of the soil were measured. In the winter the condition of the vegetative cone was determined and the plants were then grown in a greenhouse with subsequent checking of the vegetative cone. At the same time samples of wheat and rye from various regions of the USSR were investigated: in December, January, February and the first of March. Information about the condition of planted areas was processed and compared with agrometeorological conditions of the winter and the results of aftergrowth and spring investigation of the planted areas.

The winter of 1970/71 was unusual in the European part of the USSR. The snow cover in the northern belt of the territory (northern Vil'yus, Bryansk, Saratov, Ural'sk) was established very early--in the third ten days of October. The soil under it was thawed or slightly frozen. In the second ten days of November, as a result of very warm weather, the snow cover disappeared and the soil thawed everywhere except for the northeastern oblasts and the Ural area. A slight snow cover (2-5 centimeters) remained on the fields in the majority of western and central oblasts throughout the winter. The minimum temperature at the depth of the tillering node ranged from 0 to -10°C.

Even in the autumn the intensive growth of the vegetative cone in October led to a reduction in frost resistance. A comparison of the sizes of the vegetative cones of the main shoots of the plants with the agrometeorological conditions of wintering of winter crops showed that they have a great influence on the change in the sizes of the vegetative cones during the winter [18].

In the plants planted at optimal times, as one can see from figure 8, the length of the vegetative cone on 20 February had a sufficiently well expressed direct linear dependency on the minimum temperature of the soil at the depth of the tillering node t_3 and the depth of freezing of the soil H. The coefficient of the correlation between the sizes of the vegetative cones and the freezing of the soil was 0.74 ± 0.03.

Analytically the dependency between the length of the vegetative cone 1 of the main shoot of plants that had bushed normally in the autumn, the minimum temperature of the soil at the depth of the tillering node t_3 and the depth of the freezing of the soil H on 20 February, according to data from the winter of 1970/71, is expressed by the following multiple regression equations: for Vyatka winter rye

$$1 = 0.025t_3 - 0.006H + 1.377, \qquad (2)$$

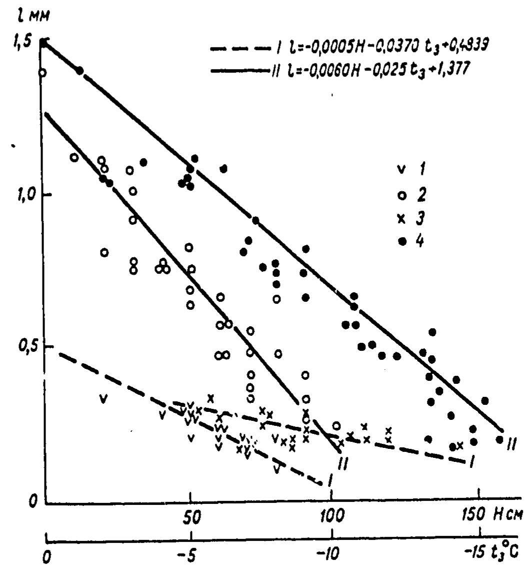

Figure 8. Dependency of Length of Vegetative Cone 1 on Minimum Soil Temperature at Depth of Tillering Node t_3 and Depth of Freezing of Soil H on 20 February

1, 3—winter wheat; 2, 4—winter rye

for winter wheat of the Mironovskaya 808 strain

$$1 = 0.0370t_3 - 0.0005H + 0.4839. \qquad (3)$$

The coefficients of the multiple correlation are 0.94 ± 0.01 and 0.91 ± 0.02, respectively; the standard deviations of the equations m are ± 0.013 and 0.028 mm. The equations are valid with minimum soil temperatures at the depth of the tillering node of 0 - -10°C and with a depth of freezing of the soil of 0 - 150 centimeters.

As one can see from the equations and curves in figure 8, the higher the minimum temperature of the soil and the lesser the depth of freezing of the soil, the longer the vegetative cone of plants that have developed normally in the autumn.

An analysis of the spring investigation of the planted areas, from which plant specimens were taken, confirmed that the intensive growth of the vegetative cone in the autumn and winter reduces the frost resistance of the plants. The thinning of winter wheat and winter rye was considerably greater in places where the sizes of the vegetative cones were significantly greater than usual.

The frost resistance of wheat, according to data from observations in the winter of 1970/71 from meteorological stations located in the central and eastern oblasts of the European part of the USSR, correlates with the lengths of the vegetative cone. The coefficient of correlation between thinning and the sizes of the cone on 20 February was 0.71 [18].

Based on data concerning the reverse dependency between the intensiveness of growth processes and the degree of hardiness of the plants, in the experiment with Mironovskaya 808 winter wheat special attention was devoted to an analysis of data concerning the length of the vegetative cone and the connection between this indicator and the degree of thinning of the plants. From Table 26 one can see that here too this dependency was clearly confirmed.

Table 26. Thinning (%) of Mironovskaya 808 Plants, Depending on Length of Vegetative Cone with Various Planting Times and Depths of Snow Cover

(1) Сроки сева	(2) Снежный покров			
	(3) естественный		(4) избыточный	
	(5) h конуса (мм)	(6) % изреженности	(5) h конуса (мм)	(6) % изреженности
29 VII	0,9	62	1,1	73
11 VIII	0,6	60	1,0	84
25 VIII	0,5	50	0,7	64
3 IX	0,4	30	0,5	45
18 IX	0,3	0	0,3	10

Key:
1. Planting times
2. Snow cover
3. Natural
4. Excessive
5. h of cone (mm)
6. % of thinning

Similar data were obtained with other strains as well. Moreover in the early ripening, less winter hardy strains (Bezostaya 1, Avrora, Rannyaya 12, San-Pastore), especially with early planting times, there was more intensive growth of the vegetative cones and, correspondingly, considerably greater destruction of the plants.

Thus the data obtained in the experiment and the results of the analysis of mass observations of the condition of winter wheat and winter rye at meteorological stations showed that the winter hardiness of winter wheats, both under the conditions of a normal and an excess snow cover, along with other physiological-biochemical processes, depends on the condition of the vegetative cone. The quantitative dependencies of the thinning of planted areas on the harmful effects of unfavorable winter conditions confirmed the great significance of growth processes during the period of the autumn and winter and the size of the vegetative cone which, in turn, is determined by the planting time and the agrometeorological conditions of the autumn-winter period.

The question arises: does increased growth of the vegetative cone when there is a prolonged, warm autumn at a time of prolonged thaws always and in all years lead to the death of the plants?

As our research showed, in these cases one should distinguish, on the one hand, types of growth of the vegetative cone and agrometeorological conditions in which processes of the growth of the vegetative cone takes place and, on the other hand, temperature conditions in the second half of the winter and in the early spring. An analysis of the vegetative cones showed that it is possible to distinguish four types of autumn-winter growth of the vegetative cones of winter crops.

The first type of growth of the vegetative cone in the autumn and winter (figure 9) is more widespread in all regions where winter crops are cultivated. In all years before the temperatures at the depth of the tillering node stabilize below -5°C, the growth of the vegetative cone in the autumn is of the first type. The longer the period of positive temperatures, the greater the size of the vegetative cone. Moreover in the majority of years the growth of the cone takes place in stage II of organogenesis and is measured initially in millimeters and then parts of a millimeter. In the second half of the winter when the temperatures at the depths of the tillering node are close to -5 - -10°C, the growth of the vegetative cone continues almost until spring, although it is insignificant and retarded. If during the winter or early spring period the plants have not been subjected to the effects of temperatures that are critical for the strain, usually in the spring when the average daily temperature rises to +3 - +5°C the vegetative cone very rapidly moves into stages III-IV of organogenesis, the rudimentary spikelets are differentiated and the plants develop normally in keeping with the agrotechnology of planted areas and the course of spring-summer meteorological conditions.

Figure 9. First Type of Growth of Vegetative Cone of Winter Wheat

Key:
- a) at beginning of autumn growing period--stage I of organogenesis;
- b) before entering winter--stage II of organogenesis;
- c) at beginning of spring growing period--plants' transition to stage III of organogenesis.

Insignificant growth of the vegetative cones according to the first types within stage II of organogenesis is a widespread phenomenon, especially in the second half of the winter. As the research of V. V. Vinogradova showed, during this period there is a sharp reduction in the content of growth inhibitors in the tillering nodes. It is almost a rule that the first type of growth is not a factor which causes thinning or death of winter crops.

The second type of growth of the vegetative cone (figure 10) is typical for the conditions of a long warm autumn. It usually takes place with very early planting times on well fertilized fallow fields, especially with strains whose growing plants quickly pass through the vernalization processes with comparatively high temperatures of the air and the soil at the depths of the tillering node. In these cases there is not only increased growth of the vegetative cone in stage II of organogenesis, but in plants in which vernalization processes are being completed, there is a transition to stage III and in individual years, to the beginning of stage IV of organogenesis. We have repeatedly observed cases like these at strain testing stations of Krasnodarskiy Kray, Rostovskaya, Odesskaya, Khersonskaya and Krymskaya Oblasts, in the Dagestan and Kabardino-Balkar ASSR's, and in individual years in Vinnitskaya, Poltavskaya and Khar'kovskaya Oblasts. The same cases of the plants' transition to stage IV of organogenesis in the autumn of 1974 under the conditions of Voronezhskaya Oblast were reported by the agrometeorologist N. G. Kolesnikov and the physiologists of the Mironov Scientific Research Institute of Selection and Seed Growing of Wheat, I. V. Moroz and N. A. Kryshevich. A transition to stages III-IV of organogenesis was observed in experiments of the laboratory of the biology of plant development in the autumn on areas planted in Bezostaya 1 and Odesskaya 51 winter wheat at early times in mass quantities.

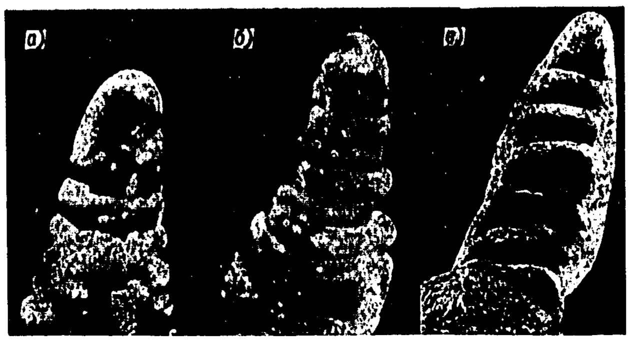

Figure 10. Second Type of Growth of Vegetative Cone of Winter Wheat

Key:
- a) at beginning of autumn growing period--stage I of organogenesis;
- b) in February under deep snow cover; at beginning of spring growing period--plants' transition to stage III of organogenesis.

If the temperatures in the winter period and the early spring do not reach critical levels and there is no freezing of winter crops, the plants that have passed through the winter in the condition of stages of III-IV form a large spike with an increased number of multiblossom spikelets in the early spring. In such years areas planted early in winter crops under the conditions of good agrotechnology realized to a considerable degree the potential productivity of the strain. The yields of winter wheat and especially of winter rye are record high.

But if after a long warm autumn before the snow falls there is a sharp reduction in the air temperature, the soil freezes rapidly and deeply and the temperature at the depth of the tillering nodes and in the zone where the vegetative cones are located (above the tillering node) drops below critical, the main shoots and even whole plants die. Plants in stages III-IV of organogenesis are usually poorly tempered and for them the critical temperatures are significantly higher (2-3°C and more) than for well tempered plants which are in stage II of organogenesis. Therefore if in the autumn plants appear whose growth takes place according to the so-called second type, the fields with these plants must be kept under constant attention, especially if minimum temperatures in the soil at the depth of the tillering node approach critical level.

The first type of growth of the vegetative cone (figure 11) is more frequently observed and mainly in the winter period in those years when the snow falls early on thawed or slightly frozen soil. The temperature remains at a level of 0 - ± 2°C under a deep snow cover for a long time. Under these conditions in the darkness of vegetative cone grows rapidly in length but does not move into stage III of organogenesis. There is a considerable elongation of the vegetative cone, a so-called undifferentiated growth of the cone in stage II of organogenesis, a kind of process of prolification of the vegetative cone. The length of these cones frequently increases 2-3-fold over normal (figure 12).

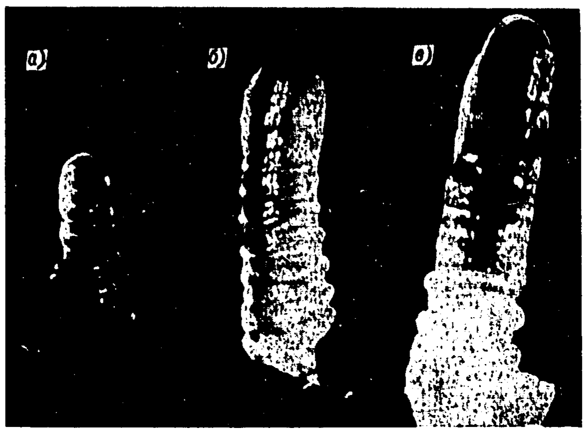

Figure 11. Third Type of Growth of Vegetative Cone of Winter Wheat

Key:

a) at beginning of winter after snow has fallen on thawed soil in stage II of organogenesis; b) in the middle of winter--under a deep snow cover in stage II of organogenesis; c) before the disappearance of the snow--at the end of winter "prolification: of undifferentiated vegetative cone.

This kind of growth of the cones is observed when the plants are perishing under the snow cover. They frequently die during the second half of the winter from starvation when there is a snow cover for an extended time, but more frequently in the spring when, being in a condition to enter stage III of organogenesis, they are first subjected to an attack of fungi that are changing from saprophytes into a parasitic form. Frequently these shoots weaken the entire plant and sharply reduce their resistance to frosts. As a result the plants die even with the return of relatively frost in the early spring.

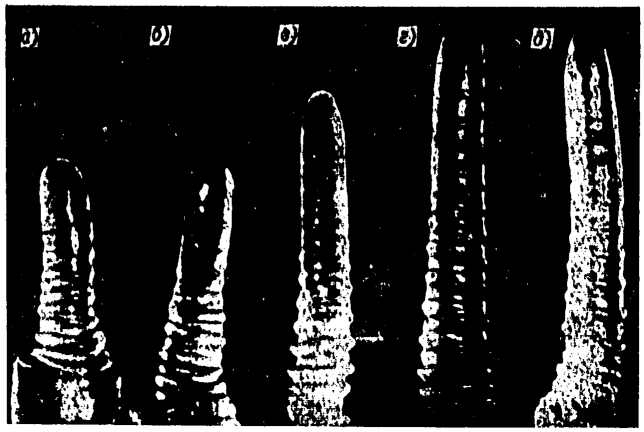

Figure 12. Third Type of Growth of Vegetative Cone of Winter Rye

Key:
a, b) at end of long autumn growing period--intense formation of leaf vallicula, stage II of organogenesis; c) in February under deep snow cover; d, e) at beginning of spring growing period--stage II of organogenesis--"prolification" of undifferentiated vegetative cone.

The undifferentiated growth of winter plants, first noted by F. M. Kuperman as early as 1951-1954 and then repeatedly observed by F. M. Kuperman, V. A. Moiseychik and M. S. Bykova [10], is one of the leading causes (in addition to hydrocarbon exhaustion and disturbance of protein exchange) of the death of winter crops under a snow cover. Perishing under a snow cover is observed especially frequently on areas planted at early times and most frequently in winter rye whose vegetative cone can grow at a lower temperature than that of winter wheat can.

We discovered the fourth type of vegetative cone (figure 13) in Mironovskaya 808 winter wheat. It is clearly distinguished from all of the aforementioned types. It is known that in the majority of strains of winter wheat which we investigated, like Kooperatorka, Bezostaya 1, Kavkaz, Ul'yanovka, Odesskaya 51, Priboy, the wheat-wheat grass hybrid 186 and others, the shoots coming out of the tillering nodes each form one vegetative cone which is subsequently formed into a spike. The points of growth of the shoots of the second order in the axils of rudimentary leaves (leaf vallicula) in the majority of strains of winter wheat die at the beginning of stage II of organogenesis and thus a shoot is formed with a stalk structure that is specific for grasses--straw. In the majority of winter crops branching takes place only in the lower nodes under the ground and in the so-called tillering zone. When there is damage (for various reason) of the vegetative cone, the shoot, deprived of a normal vegetative cone, dies in stages IV-V. In strains of Mironovskaya 808 and also certain strains obtained through hybridization with Mironovskaya 808, in the axils of the leaf vallicula when the shoots are moving into stage II of organogenesis, growth points of the second order are established. By the end of the autumn growing period they form clearly expressed vegetative cones in stage I of organogenesis, or, as F. M. Kuperman calls them, "reserve buds" (figure 13). The significant content of growth inhibitors in the vegetative cones of Mironovskaya 808 leads to a situation where growth is retarded early in the vegetative cones and frequently when the temperatures at the depth of the tillering node are -8 - -10°C it practically stops. The retarded growth of the vegetative cones is compared to Bezostaya 1, Avrora and Odesskaya 51 is also typical of Mironovskaya 808 at temperatures close to 0 or ± 2°C. This explains the comprehensive frost resistance of this strain which is resistant both to low temperatures and to an excessive snow cover.

Figure 13. Fourth Type of Growth of Vegetative Cone of Mironovskaya 808 Winter Wheat

Key:

a) vegetative cone of main shoot (stage IV) and "reserve" vegetative cone (stage I) at beginning of spring growing period; b) base of vegetative cone and "reserve" buds.

The retardation and then almost complete halting of the growth of the terminal vegetative cone leads to activation of the growth of side reserve buds which come out of a state of dormancy in the autumn and spend the winter in stage I of organogenesis. As one can see from the photograph (figure 13) taken by A. S. Yaroshevskaya with a scanning electron microscope, they are located at the bases of vegetative cones of autumn shoots. In the autumn and winter they grow extremely slowly just as they do in plants with very late planting times and at the same time, as distinct from the dormant buds of the tillering nodes, vernalization processes take place in them.

Thus vegetative cones with different degrees of frost resistance are combined on one plant and on the same shoots. During years when the vegetative cones of autumn shoots winter normally they change over early to differentiation of the rudimentary spike and form spikes with high productivity. During these years the vegetative cones of the "reserve buds" which are more than two stages behind, die without forming regrowth when the upper vegetative cone moves into stage V of organogenesis. But in years when the upper vegetative cones of autumn shoots are damaged by frosts or "prolificate" when there is an excessive snow cover for a long time, the vegetative cones of the "reserve" buds develop rapidly into productive shoots and restore the plant stand that was thinned during the winter. These shoots from these vegetative cones, like late plantings, produce a somewhat smaller yield, but because of the peculiar properties of the growth of the vegetative cones, restore the productive plant stand without replanting or under sowing and suppress spring shoots of weedy plants.

The discovery of four types of growth of vegetative cones during the autumn, winter and early spring periods made it possible to refine the essential differences in the nature of the damage and death of plants from freezing and from harmful conditions under the snow.

When plants perish under the snow, as V. A. Moiseychik notes [22], the temperature of the soil at the depth of the tillering node is high, a deep snow cover is established early and the soil is not frozen to a great depth. All these conditions contribute to the appearance of the third type of growth of the vegetative cone which is characterized by undifferentiated elongation and "prolification" in stage II of organogenesis. Perishing under the snow is a lengthy process; intense growth of the vegetative cone, like the death of winter crops, takes place if favorable conditions remain for no less than 80-100 days.

Conversely, freezing of the plants is observed when the temperature of the soil is low and when there is no snow cover or when the snow cover is shallow and the soil is frozen to a great depth. The growth of the vegetative cones is very retarded. Under these conditions the first type of growth is encountered most frequently. Damage to the cells by the low temperatures and the rupture of the tissues lead to a rapid dying off of the vegetative cones. After the average temperatures rise to 0°C the dead tissues of the vegetative cones macerate (figure 14) and the plants which are damaged by the frosts are frequently subject to attacks of fungi--snow mold, collar rot and so forth.

Figure 14. Necrosis of Vegetative Cones of Winter Wheat Damaged in Winter and Maceration of Tissues

Key:
a, b) vegetative cones of different sizes; c) top of vegetative cone (micro-photo-scanning electron microscope)

Freezing, as distinct from perishing under the snow, is most frequently a short-term phenomenon and the plants die within 1-3 days. The effects of low temperatures are especially dangerous for planted areas on which the second type of growth has already been noted in the fall (figure 15). The freezing of these plantqd areas takes place at comparatively high degrees of freezing. For such planted areas the alternation of long thaws with freezing weather is especially dangerous. This frequently takes place in the soutern steppe regions of the Ukraine and not unfrequently in the central nonchernozem regions. The death of winter plants is observed in the second half of February and the beginning of March.

In the central regions of the nonchernozem zone damage and destruction of areas planted in winter wheat are caused by a complicated complex of unfavorable weather factors (figure 16). Low temperatures in December and January when there is almost no snow or a light snow cover and be the cause of freezing of the plants. And, conversely, the early snow in October and an excessive snow cover for a long period of time and almost the same kind of snow (which is especially frequent in the northeastern regions country's European territory) can lead to perishing of the plants under the snow.

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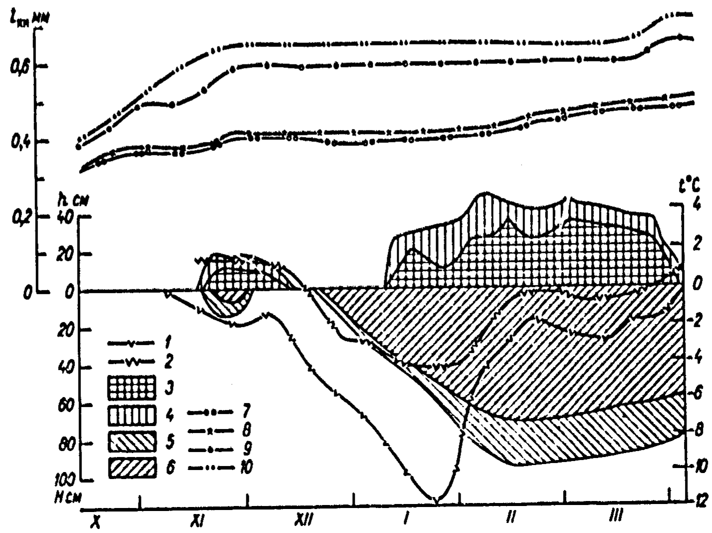

Figure 15. Growth Dynamics of Vegetative Cones of Winter Wheat Planted at Optimal Time Under Conditions of Natural Snow Cover, 1972/73, Moscow State University

Key:

Soil temperature at depth of tillering node under snow cover: 1--"natural", 2--"excessive"; depth of snow cover: 3--"natural", 4--"excessive"; depth of freezing of soil under snow cover: 5--"natural", 6--excessive".
Strains: 7--Ul'yanovka, 8--Mironovskaya 808, 9--Odesskaya 51, 10--Bezostaya 2. l_{kn}--length of cone (mm); h--depth of snow cover (cm); H--depth of freezing of soil (cm).

Under the conditions of Ryazanskaya, Kalininskaya, Novgorodskaya, Moscow and adjacent oblasts there are frequent winter thaws with precipitation in the form of rain and wet snow; when the freezing weather arrives they lead to the formation of an ice crust. In the nonchernozem zone, especially on its southern border, although it is rare there have been cases of early disappearance of the snow (at the beginning of March) with a subsequent return of short-lived but severe frosts.

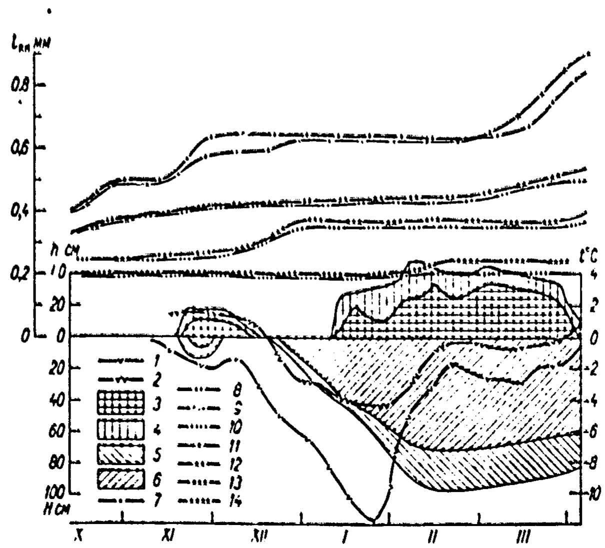

Figure 16. Growth Dynamics of Vegetative Cone of Mironovskaya 808 Winter Wheat with First-Fourth Planting Times and Various Depths of Snow Cover (Winter 1972/73). Moscow State University.

Key:

Conventional symbols l_{kn}, h and H, and also 1-6 see Figure 15. "Natural" snow cover: 7--first planting time, 10 August; 8--second planting time, 25 August; 9--third planting time, 5 September; 10--fourth planting time, 20 September. "Excessive" snow cover: 11--first planting time, 10 August; 12--second planting time, 25 August; 13--third planting time, 5 September; 14--fourth planting time, 20 September.

In individual years (such, for example, as the winters of 1973/74 and 1974/75) there is very little snow on the fields in the central chernozem oblasts and the winter crops spend the winter in temperatures of 0 ± 3°C. The shortage of warmth limits photosynthesis and the differentiation of the vegetative cone. At the same time the cones become elongated and "prolificate." Plants with these cones are infected with root fungi in the early spring.

In the central regions of the nonchernozem zone in individual periods of the wintering of plants one can observe the effects not only of individual factors, but of an entire complex of them. The diversity of factors that cause damage and death to areas planted in winter crops made it necessary in this zone to search for strains which would have a comprehensive resistance to low temperatures, close to critical, (and in which the growth of the vegetative cone is basically of the first type) and also to temperatures of about 0 ± 1°C.

In order to establish maximum winter hardiness in this zone, it is important to have strains with the first type of growth with a wide range of temperatures from 0 to -8°C. But the majority of strains previously regionalized in this zone have been characterized by the third and second types of growth. It was important to find out which were characterized by one type of growth or another and the nature of the growth dynamics of the vegetative cone under various wintering conditions.

Taking into account the diversity of the complexes of unfavorable wintering conditions, the laboratory of biology of plant development in conjunction with the USSR Hydrometeorological Center during 1970-1975 [8-10, 16-22] conducted morphophysiological research of the winter hardiness of winter crops simultaneously against various backgrounds, the major ones of which were: a) a natural snow cover whose depth usually ranged from 10 to 25 centimeters; b) an excessive snow cover with a depth of 50-60 centimeters and more; and c) so-called snowlessness or more precisely little snow, with a snow cover of no more than 1-3 centimeters. In all years the planting was done at four times; the first, early--5-10 August; the second, optimal for Moscow Oblast--20-25 August; the third, medium late--5 September; and the fourth, very late for these regions--20-25 September. Against these backgrounds they tested strains that were regionalized in the USSR and also a number of promising new strains of winter wheat: Ul'yanovka, Mironovskaya 808, Bezostaya 1, Bezostaya 2, Mironovskaya yubileynaya, Odesskaya 51, Priboy, Avrora, PPG-186 and Vyatka and Khar'kovskaya 60 winter rye [10].

In all the variants of the experiments AM-17 thermometers were used to take the minimum, maximum and periodic temperatures of the soil and the depth of the tillering nodes; frost meters installed on platforms at various depths of the snow cover were used to measure the depth of freezing of the soil and snow measuring rods were used to determine the depth and uniformity of the snow cover on the plots. The rest of the necessary meteorological data (air temperature, precipitation, number of hours of sunshine, moisture content of the soil and others) were obtained in the observatory of the geograph·· department of Moscow State University which is located 50 meters from the experimental plot of the laboratory of bioloty of plant development.

In the autumn and spring the number of plants and shoots were counted on all of the plots.

Throughout the entire autumn-winter-spring period every 10-15 days, a pneumatic drill with a spade was used to take samples of 25-50 plants from each variant of the experiment. They were subjected to a detailed morphophysiological analysis in which the condition and sizes of the vegetative cones, the tillering nodes and the leaves were taken into account. The viability of the plants was tested in a greenhouse. To do this the vessels of the plants (5-10 from each specimen) were forced to the phase of heading and blossoming. Then in the greenhouse observations of their passing through stages II-IX of organogenesis were conducted regularly.

In recent years major attention has been devoted to an analysis of growth processes of the vegetative cone under the conditions of various temperatures in the autumn-winter-spring period and to the discovery (with the help of a microscope photographic attachment on an MBS-1 binocular magnifying glass and also a scanning electron microscope of the Khitachi 11-B type with various magnitudes--from X70 to X1600) of differences in the types of damage from freezing and from perishing under the snow.

Data from observations of the dynamics of the growth of the vegetative cone were of greatest interest in research on the phenomena of winter hardiness. Regular observations were conducted for the first time with various depths of the snow cover and various minimum and maximum temperatures at the depth of the tillering nodes and various depths of freezing of the soil which were created in connection with this. In the first place, these were observations of plants of the same age, planted at the same time, on the same section and under identical soil conditions; in the second place these were one-time parallel observations of plants of various ages with intervals in planting time of 15-20 days, beginning with very early times and ending with extra late times (20 September) for conditions of the nonchernozem zone. And finally, which is also significant, we investigated for the first time not only regionalized and promising strains for the nonchernozem zone--Ul'yanovka, PPG-186, PPG-599, Mironovskaya 808, Mironovskaya yubileynaya--but also strains used as indicators of weak winter hardiness which had been regionalized in the southern oblasts of the USSR--Bezostaya 1, Bezostaya 2, Avrora and others--and also the semi-winter strains San-Pastore.

Throughout the entire autumn-winter-spring period the winter plants were subjected to detailed morphogeological analysis. The determined the coefficient of tillering, the number of shoots in various stages of organogenesis, the number of leaves on each shoot, the length and breadth of the leaves and their condition; with a point evaluation they determined the condition of the vegetative cones, their length and breadth, the number of leaf vallicula in stage II of organogenesis and the number of segments and, in cases where they had entered stage III, also the number of spike tubercles in stage IV of organogenesis.

For mass samples the accounting was done on Table 27 [9]. Throughout the winter period with unfavorable conditions, as a rule, the leaves were damaged first. The degree of damage largely determines the condition of the plants in the spring-summer period. In those cases where the leaves were not damaged (green or partially yellow-green) after the disappearance of the snow cover and the rise in the air temperature to above 0, photosynthesis begins in the plants. The development of these plants takes place normally in the spring. The condition of the leaves of these plants is evaluated by points 5 and 4.

If in the winter and spring all leaves or a large part of them are yellow and the vegetative cones are alive, a certain period of time is necessary for the appearance of new assimilating leaves after the resumption of the growing period, as a result of which the growth and development of the plants are retarded and the yield decreases somewhat. Then the condition of the leaves of winter crops is evaluated with point 3.

Plants whose leaves are brown in the winter and spring are evaluated by point 2 and dark brown--by point 1. In the majority of these cases there is also damage to the vegetative cones and tillering nodes and thinning or complete destruction of the plants.

Table 27 gives an evaluation of the condition of leaves of plants with various degrees of damage by unfavorable wintering conditions. It takes into account not only the color of the leaves, but also the number of plants in percentages with various degrees of damage to the leaves (Table 27, columns 3 and 4).

The vegetative cones have a greater resistance than the leaves do and, moreover, in the majority of years in winter crops they are located in the soil at a depth of 1-3 centimeters. The viability of the shoot, the growth and development of the insipient spike and, consequently, its productivity depend on the condition of the vegetative cone. Therefore the condition of the vegetative cone, as was noted above, determines the condition of the plants as a whole during the wintering period.

Depending on the degree of their damage in the winter, the conditions of the vegetative cones can be determined in the following way: five points--the cone is transparent, alive, turgid and slightly opalescent; three points--the cone is alive, white, turgid, dull and not opalescent; one point--the cone is dead, brown, wrinkled and macerated. The condition of the plants is evaluated taking into account the number of shoots (in percentages of the overall number in the plants that are analyzed) which have varying degrees of damage to the vegetative cone.

The indicators for evaluating the condition of the plants relate mainly to cases of damage of winter crops by low temperatures, the ice crust and drenching. When winter crops perish under the snow one takes into account

Table 27. Evaluation of the Condition of Leaves (A) and Vegetative Cones (B) of Plants in Autumn-Winter-Spring Period.

(1) Листья		Процент растений, имеющих данный балл (4)	Общий балл (5)
описание (2)	оценка (балл) (3)		
1	2	3	4
А			
Листья зеленые (6)	5	100	$\frac{5\cdot 100}{100} = \frac{500}{100} = 5{,}0$
Желто-зеленые (7)	5 4	75 25	$\frac{(5\cdot 75)+(4\cdot 25)}{100} = \frac{475}{100} = 4{,}8$
Зеленые (8) Желто-зеленые (9)	5 4	50 50	$\frac{(5\cdot 50)+(4\cdot 50)}{100} = \frac{450}{100} = 4{,}5$
	4	100	$\frac{4\cdot 100}{100} = \frac{400}{100} = 4{,}0$
Желтые (10)	4 3	50 50	$\frac{(4\cdot 50)+(3\cdot 50)}{100} = \frac{350}{100} = 3{,}5$
	3	100	$\frac{3\cdot 100}{100} = \frac{300}{100} = 3{,}0$
Бурые (11)	3 2	25 75	$\frac{(3\cdot 25)+(2\cdot 75)}{100} = \frac{225}{100} = 2{,}3$
	2	100	$\frac{2\cdot 100}{100} = \frac{200}{100} = 2{,}0$
Черно-бурые (12)	1	100	$\frac{1\cdot 100}{100} = \frac{100}{100} = 1{,}0$

(13) Конус нарастания		Процент побегов с конусами данного балла (15)	Оценка (16)
состояние конуса (14)	оценка (балл) (3)		
5	6	7	8
Б			
(17) Конус живой, тургорный, слегка опалесцирующий	5	100	$\frac{5\cdot 100}{100} = \frac{500}{100} = 5{,}0$
(18) То же	5	75	
(19) Живой, белый, тургорный, мутный, неопалесцирующий	3	25	$\frac{(5\cdot 75)+(3\cdot 25)}{100} = \frac{450}{100} = 4{,}5$

[Table 27 continued on following page]

(13) Конус нарастания		Процент побегов с конусами данного балла (15)	Оценка (16)
(14) состояние конуса	оценка (балл) (3)		
5	6	7	8
		Б	
(20) Живой, тургорный, опалесцирующий	5	50	$\frac{(5\cdot50)+(3\cdot50)}{100}=\frac{400}{100}=4,0$
(21) Живой, белый, тургорный, мутный, неопалесцирующий	3	50	
(22) Живой, тургорный, белый, мутный, неопалесцирующий	3	100	$\frac{3\cdot100}{100}=\frac{300}{100}=3,0$
(18) То же	3	75	$\frac{(3\cdot75)+(1\cdot25)}{100}=\frac{250}{100}=2,5$
(23) Мертвый, бурый, сморщенный, мацерированный	1	25	
(22) Живой, тургорный, белый, мутный, неопалесцирующий	3	50	$\frac{(3\cdot50)+(1\cdot50)}{100}=\frac{200}{100}=2,0$
(23) Мертвый, бурый, сморщенный, мацерированный	1	50	
(22) Живой, тургорный, белый, мутный, неопалесцирующий	3	25	$\frac{(3\cdot25)+(1\cdot75)}{100}=\frac{150}{100}=1,5$
(23) Мертвый, бурый, сморщенный, мацерированный	1	75	
(18) То же	1	100	$\frac{1\cdot100}{100}=\frac{100}{100}=1,0$

Key:
1. Leaves
2. Description
3. Evaluation (points)
4. Percentage of plants with given points
5. Overall points
6. Green leaves
7. Yellow-green
8. Green
9. Yellow-green
10. Yellow
11. Brown
12. Black-brown
13. Vegetative cone
14. Condition of cone
15. Percentage of shoots with cones with given points
16. Evaluation
17. Cone live, turgid, slightly opalescent
18. Cone live, turgid, slightly opalescent
19. Live, white, turgid, dull, not opalescent
20. Live, turgid, opalescent
21. Live, white, turgid, dull, not opalescent
22. Live, trugid, white, dull not opalescent
23. Dead, brown, wrinkled, macerated

the number of plants with elongated vegetative cones that have undergone "prolification." Here one determines the overall length of the vegetative cones and, separately, the length of the elongated, undifferentiated part of the vegetative cone. The vegetative cone is drawn (if possible, with a drawing device). These data are also included in the table. An account is made of each shoot on typical plants. The degree of deviations from the norm and the percentage of markedly elongated vegetative cones are also determined by points.

One can judge the way various depths of the snow cover are reflected in plants of one and the same strain planted at the same optimal time (25 August for Moscow Oblast) from data concerning the changes in the length of the vegetative cone of the Ul'yanovka strain (table 28). Thus under a natural snow cover or when there is no snow, by the end of November 1972 the vegetative cones had reached 0.40-0.46 mm and under an excessive snow cover, when the snow remained on the plots in the beginning of November, the growth of the vegetative cones continued and by the beginning of December reached 0.50-0.55 mm. Then in all variants with various snow covers the vegetative cone remained unchanged, which was typical for the first type of growth. It should be noted that in the winter of 1972/73 there were no great differences between the natural and excessive snow covers.

The effects of the planting times are very clearly traced in the same experiment. Thus with the very early planting time of 10 August and a natural snow cover, the length of the vetegative cone by 25 December had reached 0.50 mm; with planting on 25 August--0.46 mm; 5 September--0.35 mm; and with a very late planting time--0.20 mm. While there were considerable differences in the length of the vegetative cones determined by the depth of the cover and the planting times, throughout the winter period their sizes increased quite insignificantly. As one can see from the figures, the first type of growth of the vegetative cone during the winter period is typical for the Ul'yanovka strain which largely determines the great winter hardiness of this strain which has been regionalized in a number of oblasts that rarely have conditions which cause perishing of winter wheat under snow (figure 15).

There was a similar situation during this same winter of 1972/73 on areas planted in Mironovskaya 808 winter wheat. In variants with various snow covers the vegetative cones differed little and in variants with various planting times they differed quite distinctly (see figure 16).

During this same winter of 1972/73, with comparatively optimal wintering conditions for winter plants (maximum temperatures at the depth of the tillering node under a natural snow cover were mainly -2 - -5°C and only for a short period of time did they drop to -11 - 12°C), even with the first type of growth of winter crops it was still possible to discover differences in the length of the vegetative cones of winter-hardy strains which for the Moscow area are Ul'yanovka and Bezostaya 808 and relatively less winter hardy ones--Odesskaya 51 and especially Bezostaya 2 (see figure 15).

Considerably greater strain differences were noted in the winter of 1971/72 (figure 17). Even under conditions of a natural snow cover there was a continuation of insignificant, but steady growth of the vegetative cones. This took place least intensively in the highly winter hardy strain Tsezium 39 and the winter hardy strains Ul'yanovka and Mironovskaya 808, and less intensely in such strains as Mironovskaya yubileynaya, Bezostaya 2 and Odesskaya 51 and the most marked growth was noted in the Avrora strain. It is interesting that the curves representing the growth of strains with varying degrees of winter hardiness fully corresponded with their winter hardiness, which shows the existence of certain correlations between the intensiveness of growth processes and the resistance to low temperatures (the winter of 1971/72 was colder and there was less snow than in the winter of 1972/73).

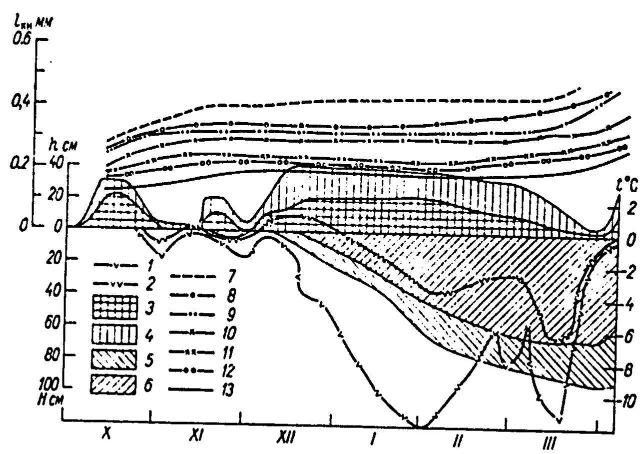

Figure 17. Growth Dynamics of Vegetative Cone of Ul'yanovka Winter Wheat and New Strains of Winter Wheat in 1971-72 With Optimal Planting Time, Under Conditions of a "Natural" Snow Cover. Moscow State University.

Conventional symbols: $1_{kn\ 1}$ h, H and 1-6, see fig. 15. 7--Avrora, 8--Odesskaya 51, 9--Bezostaya 2, 10--Mironovskaya yubileyanay, 11--Mironovskaya 808, 12--Ul'yanovka, 13--Tsezium 39

In the winter of 1970/71 the snow cover in the "excessive" variant was considerably than in the "natural" variant. The minimum temperatures at the depth of the tillering node with the excess snow cover did not drop below -2°C. During this winter there was a very clear manifestation of the third type of growth of the vegetative cones, especially in the less winter hardy strains such as San Pastore, Avrora, Rannyaya 12 and Bezostaya 2 (figure 18).

One can judge the way early planting times affect the growth of vegetative cones of weakly winter hardy strains of winter wheat from the curves of the growth of the cone in the Bezostaya 2 strain. With an early planting time, even under conditions of a natural snow cover, the growth of the vegetative cones continues until December and is renewed as early as the second half of February, long before the snow disappears from the plot (figure 19). Moreover, even under the conditions of a natural snow cover the growth of the vegetative cone was considerably greater when the planting time was early than it was with the third and fourth planting times.

The winter of 1973/74 was relatively warm and the snow cover was established early. Under these conditions, even with Mironovskaya 808 planted at an early time, there was almost continuous growth of the vegetative cone, especially in the second half of the winter (figure 20).

It was possible to trace the effects of the winter conditions of 1972/73 even more clearly in the Odesskaya 51 and Bezostaya 1 strains, which were tested as indicator strains. As one can see from figures 21 and 22, these strains which are adapted to the steppe regions are unsuitable for the central belt of the country's European territory since the relatively rapid growth of the vegetative cones in these regions and their inadequate winter hardiness lead to considerably more severe damage than Mironovskaya 808 sustained under the same experimental conditions.

The growth of the vegetative cone of Bezostaya 1 proceeded approximately in the same way as that of Odesskaya 51 throughout the entire winter (figure 23) both under the conditions of a natural snow cover and an excessive one. These data once again confirm that selecting even the most productive new and promising strains in other zones, it is necessary to examine them in detail under the conditions of various winters which are typical of the nonchernozem zone.

The high growth rate of strains like Odesskaya 51 and Bezostaya 1, which are comparatively resistant for the country's European territory, even in snow winters under the conditions of the chernozem zone can lead to "prolification" of the vegetative cones under the snow throughout the winter and to severe damage with the return of frosts in March during years with an early disappearance of the snow cover. In these cases planting times that are too early are especially inadmissable.

Table 28. Dyanimics of Development and Growth of Ul'yanovka Strain of Winter Wheat in Autumn, Winter and Spring Periods of 1972-73 With Various Planting Times and Various Variants of the Snow Cover and Temperature Conditions of the Soil at the Depth of the Tillering Node (3 cm).

Дата проведения биологического контроля (3)	(1) Естественный снежный покров 10—25 см											
	(2) сроки сева											
	10 VIII			25 VIII			5 IX			20 IX		
	(4) число побегов *n*	(5) этап	(6) длина конуса (мм)	(4) число побегов *n*	(5) этап	(6) длина конуса (мм)	(4) число побегов *n*	(5) этап	(6) длина конуса (мм)	(4) число побегов *n*	(5) этап	(6) длина конуса (мм)
1972 г.												
16 X	5	II	0,50	4	II	0,32	3	II	0,25	1	I	0,20
30 X	6	II	0,50	5	II	0,40	3	II	0,30	1	I	0,20
13 XI	6	II	0,50	5	II	0,40	3	II	0,30	1	I	0,20
27 XI	6	II	0,50	5	II	0,46	3	II	0,35	1	I	0,20
11 XII	6	II	0,50	5	II	0,46	3	II	0,35	1	I	0,20
25 XII	6	II	0,50	5	II	0,46	3	II	0,35	1	I	0,20
1973 г.												
11 I	6	II	0,50	5	II	0,46	3	II	0,35	1	I	0,20
25 I	6	II	0,50	5	II	0,46	3	II	0,35	1	I	0,20
13 II	6	II	0,50	5	II	0,46	3	II	0,35	1	I	0,20
28 II	6	II	0,50	5	II	0,46	3	II	0,35	1	I	0,20
11 III	6	II	0,60	5	II	0,46	3	II	0,35	1	I	0,20
3 IV	7	II	0,62	5	II	0,50	3	II	0,35	1	I	0,20
12 IV	7	III	0,65	5	II	0,55	3	II	0,35	1	I	0,20

[Table 28 continued on following page]

Дата проведения биологического контроля (3)	(7) Избыточный снежный покров 50—60 см; (2) сроки сева: 10 VIII			25 VIII			5 IX			20 IX			(8) Бесснежье (0—3 см): 25 VIII		
	число побегов n (4)	этап (5)	длина конуса (мм) (6)	число побегов n (4)	этап (5)	длина конуса (мм) (6)	число побегов n (4)	этап (5)	длина конуса (мм) (6)	число побегов n (4)	этап (5)	длина конуса (мм) (6)	число побегов n (4)	этап (5)	длина конуса (мм) (6)
1972 г.															
16 X	5	II	0,50	5	II	0,32	3	II	0,25	1	I	0,20	5	II	0,32
30 X	6	II	0,50	5	II	0,40	3	II	0,30	1	I	0,20	5	II	0,40
13 XI	6	II	0,50	5	II	0,45	3	II	0,30	1	I	0,20	5	II	0,40
27 XI	6	II	0,50	5	II	0,46	3	II	0,35	1	I	0,20	5	II	0,40
11 XII	6	II	0,50	5	II	0,50	3	II	0,35	1	I	0,20	5	II	0,40
25 XII	6	II	0,55	5	II	0,55	3	II	0,35	1	I	0,20	5	II	0,40
1973 г.															
11 I	6	II	0,60	5	II	0,55	3	II	0,35	1	I	0,20	5	II	0,40
25 I	6	II	0,65	5	II	0,55	3	II	0,35	1	I	0,20	5	II	0,40
13 II	6	II	0,65	5	II	0,55	3	II	0,35	1	I	0,20	5	II	0,40
28 II	6	II	0,65	5	II	0,55	3	II	0,35	1	I	0,25	5	II	0,40
11 III	6	II	0,65	5	II	0,55	3	II	0,35	1	I	0,25	5	II	0,42
3 IV	7	II—III	0,68	5	II	0,58	3	II	0,35	1	I	0,25	5	II	0,45
12 IV	7	II—III	0,70	5	II	0,60	3	II	0,46	1	I	0,30	5	II	0,45

[Key on following page]

Key:

1. Natural snow cover, 10-25 cm
2. Planting times
3. Date biological examination conducted
4. Number of shoots u
5. Stage
6. Length of cone (mm)
7. Snowlessness (0-3 cm)

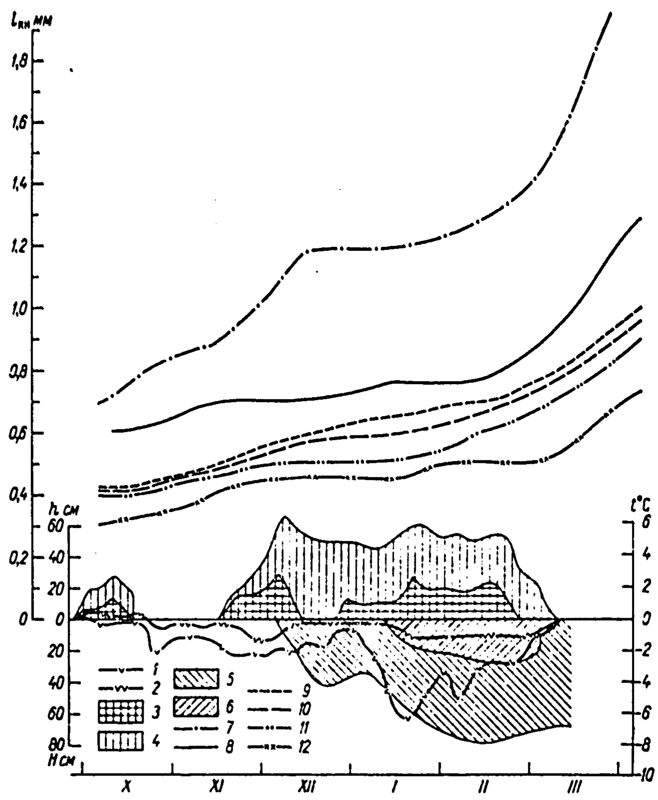

Figure 18. Growth Dynamics of Negative Cones of Winter Crops in Winter and Early Spring Periods (Winter Wheat and Rye with Various Degrees of Winter Hardiness) in 1970/71 with Optimal Planting Time Under Conditions of "Excessive" Snow Cover. Moscow State University.

[Key on following page]

Key:

Conventional symbols l_{kn}, h, tl, and 1-6, see fig. 15. 7--Vyatka, 8--San Pastore, 9--Avrora, 10--Rannyaya 12, 11--Bezostaya 2, 12--Mironovskaya yubileynaya.

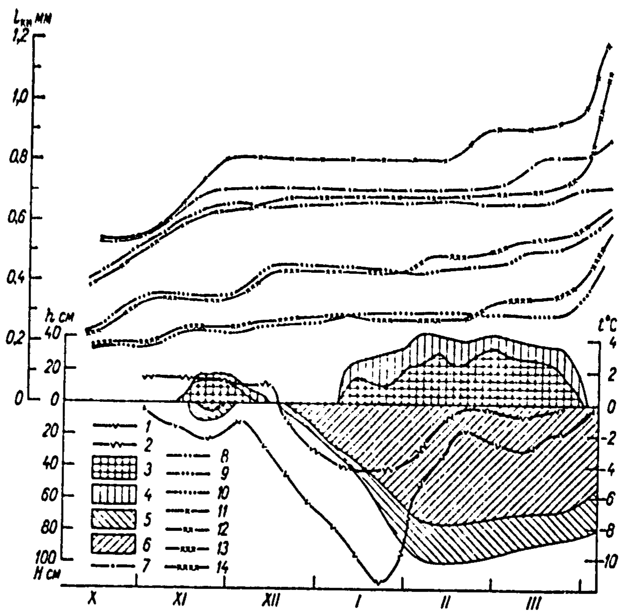

Figure 19. Growth Dynamics of Vegetative Cone of Bezostaya 2 Winter Wheat Under Conditions of Various Snow Covers With First-Fourth Planting Times (1972/73). Moscow State University

Key:

Conventional symbols l_{kn}, h, H, and 1-6, see fig. 15. "Natural" snow cover: 7--first planting time, 8--second planting time, 9--third planting time, 19--fourth planting time. "Excessive" snow cover: 11--first planting time, 12--second planting time, 13--third planting time, 14--fourth planting time.

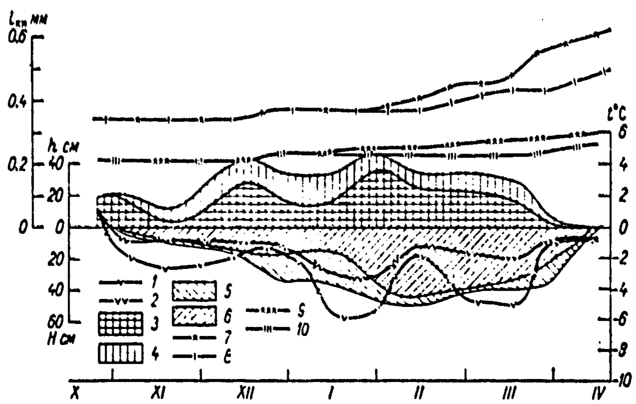

Figure 20. Growth Dynamics of Mironovskaya 808 Winter Wheat With First and Third Planting Times and "Natural" and "Excessive" Snow Covers in Winter of 1973/74.

Key:

Conventional symbols l_{kn}, h, H and 1-6, see fig. 15. First planting time: 7--"excessive" snow cover, 8--"natural" snow cover. Third planting time: 9--"excessive" snow cover, 10--"natural" snow cover.

Of especially great interest are data from a morphophysiological analysis of Mironovskaya 808 winter wheat which in the last few years has been regioanlized in the central regions of the nonchernozem zone. In plants of this strain with various planting times the vegetative cone even in stage II of organogenesis is somewhat greater than that of Ul'yanovka in the autumn and early spring, but they come out of the state of dormancy at almost the same time as Ul'yanovka does. Consequently, in terms of frost resistance (taking into account their coming out of the condition of dormancy in the spring), the Mironovskaya 808 strain comes close to the Ul'yanovka. In Mironovskaya 808 plants under conditions of an excessive snow cover (with the first planting time), even at the end of February and the beginning of March one observes a transition to stage III and even in the second ten days of April in 1974 the plants remained at stage III in their development and there was continued metamere growth of the segments that subsequently conditioned the formation of a large rudimentary spike. The transition to stage IV of organogenesis began later, after there was no return to cold weather in the spring.

Figure 21. Condition of Vegetative Cones With Inadequate Snow Cover

Key:

Vegetative cone of Bezostaya 1 strain: a) x234, б) x468; vegetative cone of Odesskaya 51 strain: b) x200, r) x400, 16 April 1973

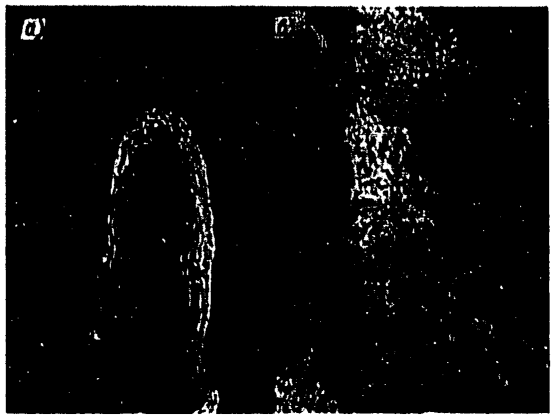

Figure 22. Effects of Planting Times on Condition of Vegetative Cones of Mironovskaya 808 Winter Wheat Under Conditions of an Excess of Snow (depth--about 60-70 cm)

Key:

a--necrosis of central part and base of cone; б--deep longitudinal ruptures and necrosis of tissues.

Thus in terms of the condition of the vegetative cone (level of development and growth rates), Mironovskaya 808 is very close to the Ul'yanovka strain. But among the strains that are included in group 1 in terms of winter hardiness, Mironovskaya 808 plants, as we know, have one peculiarity that is very important for the strain's productivity. Namely, as distinct from Ul'yanovka and other highly frost resistant strains like Lyutestsens 329 and Lyutestsens 1060, Mironovskaya 808 plants are capable not only of maintaining a live tillering node at critical temperatures when the shoots above the ground die, but also of developing new productive shoots in the spring. As was already noted, in the autumn one observes the fourth types of growth of the vegetative cone in Mironovskaya 808. It is precisely this property of the plant that makes it possible when wintering conditions are unfavorable to obtain yields that are close to average while areas planted in other strains of winter wheat during these years, because of the severe thinning of the plant stand, must be undersown with barley in the spring or replowed and replanted with late spring crops.

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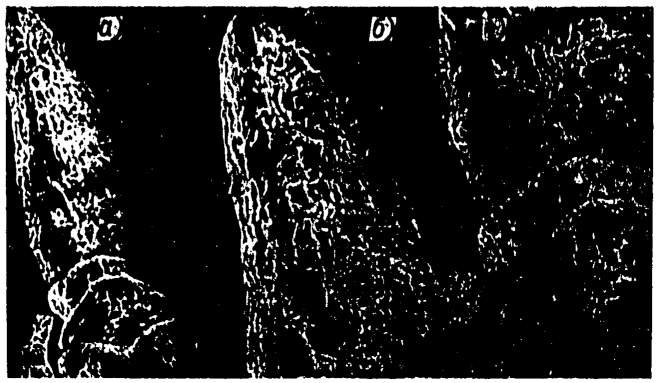

Figure 23. Types of Damage to Winter Wheat in Winter of 1972/73 (planted on 25 August). Bezostaya 1 strain.

Key:

Transverse and longitudinal fissures in vegetative cone with "natural" snow cover: a) x200, 6) x400; b) longitudinal rupture of vegetative cone in absence of snow (x400). 16 April 1973

As was already pointed out, one of the peculiarities of this strain is the formation in the autumn of shoots that are in various stages of organogenesis. Even as certain tillering shoots are developing at the same time in the autumn and providing for a uniform plant stand of productive shoots in the early spring, another group of potential shoots (third and fourth order of tillering) remain in stage I. Th ,e rudimentary shoots in the form of so-called "reserve" buds pass through the winter well. When the winter wheat plants have spent the winter well and their main shoots have rapidly moved into stages IV-V of organogenesis, because of the law of reduction the rudimentary "reserve" buds do not begin to grow and completely die off. But if because of extremely unfavorable conditions in the winter the main autumn shoots which are in stage II of organogenesis are severely damaged and are behind in their development or have completely died, then shoots from the "reserve" cones develop, which are better protected since, in the first place, in stage I they are more frost resistant than shoots in stage II and, in the second place, since they are in a dormant condition, as is the case with Ul'yanovka, vernalization processes have taken place in them during the winter, although slowly, which has enabled them to move into stages IV-V and subsequent stages of organogenesis in the early spring. Because of this they develop into normal productive shoots.

An account of the number of plants that have survived the winter in relation to the planting times shows that the main shoots of the plants which have been planted early in the majority of years, because of the completion of the first stage of development in the autumn, are more sensitive to unfavorable conditions (low temperatures and excessive snow cover). This was established in the comparatively severe winter of 1971/72. As one can see from the figures in table 29, in the early spring of 1972, under the conditions of the variant with a natural snow cover, in Mironovskaya 808 winter wheat 65 percent of the plants and 51 percent of the shoots remained (when planted on 10 August) and with an optimal planting time--98 percent of the live plants and 95 percent of the shoots; under conditions of an excessive snow cover with planting on 10 August 52 percent of the plants and 62 percent of the shoots remained alive and with planting on 25 August--77 percent of the plants and 70 percent of the shoots.

Table 29. Number of Plants and Shoots of Winter Wheat that Survived the Winter. Moscow. 1971/72 (%)

Сорт (1)	Срок сева (2)	(3) Естественный снежный покров		(4) Избыточный снежный покров	
		(5) живых (%)			
		(6) растений	(7) побегов	(6) растений	(7) побегов
(8) Мироновская 808	10 VIII	65	51	52	62
	25 VIII	98	95	77	70
	5 IX	97	97	62	58
	20 IX	100	97	100	99
(9) Мироновская юбилейная 50	10 VIII	62	58	50	62
	25 VIII	96	94	76	78
	5 IX	61	57	75	77
	20 IX	78	84	76	69
(10) Ульяновка	10 VIII	82	49	46	47
	20 VIII	96	94	65	61
	5 IX	96	96	69	68
	20 IX	100	98	76	86
(11) Безостая 1	25 VIII	83	92	46	44
	5 IX	95	96	63	71
(12) Аврора	25 VIII	81	70	48	50
	5 IX	95	95	62	69

Key:
1. Strain
2. Planting time
3. Natural snow cover
4. Excessive snow cover
5. Live (%)
6. Plants
7. Shoots
8. Mironovskaya 808
9. Mironovskaya yubileynaya 50
10. Ul'yanovka
11. Bezostaya 1
12. Avrora

In order to get a better idea of the significance of planting times and wintering conditions, one should discuss the analysis of figures concerning the reduction ("discarding") of autumn tillering shoots in various strains with various planting times. A morphophysiological analysis of the tillering shoots reveals, in the first place, strain differences in terms of this indicator and, in the second place, the effects of the planting time. All this is undoubtedly related to the question of the consequences of winter damages.

Table 30 gives figures from the autumn, spring and summer accounting for the number of tillering shoots in two strains of wheat--Mironovskaya 808 and Bezostaya 1--with various planting times. As one can see from table 30, in the first place, Mironovskaya 808 plants bush considerably more intensely in the autumn and more shoots remain until harvest than with Bezostaya 1 plants. In the second place, the significant differences in the number of autumn shoots with various planting times disappear throughout the spring and summer; the plants lose from 50 to 90 percent of the tillering shoots as early as the end of July and the most autumn shoots--both in absolute figures and in percentages--are retained when the planting time is optimal (50-60 percent). When the planting time is too early a large number of the shoots die as early as the end of May and by harvesting time only 25 percent of them remain. With a late planting time, Mironovskaya 808 plants formed no more than three shoots in the autumn and tillering does not begin in Bezostaya 1, and in the summer up to 50 percent of the plants die.

Thus in 1972/73 the plantings that were thinnest by harvest time were those on plots that had been planted very early and very late. It is interesting to note that even at the end of May, especially with early planting times, it was possible to observe a significant retardation in the development of vegetative cones at the ends of the bush: while some shoots had already passed into stages VI-VII of organogenesis, others remained in stages II-III and gradually died off.

The dying off of shoots in the spring is determined not only by the unfavorable effects of winter conditions. When evaluating both the winter hardiness of strains and the wintering conditions, one should take into account the dynamics of "discarding" of shoots: the more favorable the conditions for the development of plants in the autumn-winter period, the less "discarding" of winter shoots and the greater the productivity of the plants.

In cases where winter wheat externally seems to have survived the winter normally, in plants that have been planted at early times and have been under an excessive snow cover there is frequently deformation of the spikes even in stage V of organogenesis (figure 24). Additionally, the more snow resistant the strain, the lesser the consequences of winter damage. This is quite clear from a comparison of the rudimentary spikelets of Mironovskaya 808 and Bezostaya 1 winter wheats.

Table 30. Dynamics of Reduction of Autumn Tillering Shoots of Various Strains of Winter Wheat, Depending on Planting Times

Дата учета (1)	(2) Сроки сева							
	10 VIII		25 VIII		15 IX		25 IX	
	а	б	а	б	а	б	а	б
(3) Мироновская 808								
1972 г. 16 XI	10	100	5	100	3	100	3	100
1973 г. 21 V	10	100	5	100	3	100	2	66
26 V	4	40	3	60	2	66	2	66
20 VII	1	10	3	60	1	33	1	33

Дата учета (1)	(2) Сроки сева							
	10 VIII		25 VIII		5 IX		25 IX	
	а	б	а	б	а	б	а	б
(4) Безостая 1								
1972 г. 16 XI	6	100	4	100	2	100	1	100
1973 г. 21 V	4	67	3	75	2	100	1	100
26 V	2	33	2	50	1	50	0,5	50
20 VII	1	17	2	50	1	50	0,3	33

Key:
1. Date of report
2. Planting times
3. Mironovskaya 808
4. Bezostaya 1

Note: a--overall number of shoots before beginning of wintering, б--number of reduced shoots (%).

At the same time, plants that are planted late, which have smaller vegetative cones, are significantly behind in terms of development and the productivity of the spike in the spring. For this reason, despite the better wintering, they cannot be recommended for production. The effect of the consequences of damage under a deep snow cover in the winter depends considerably on strain resistance of the wheat (table 31). As one can see from table 31, damage to winter crops under snow in the winter of 1965/66 had a negative effect on the height of the plants, the passing through the stages of organogenesis, the coefficient of bushiness and the number of spikelets in the spikes.

Manifestations of damage to crops under the snow are observed considerably more frequently on areas planted in winter rye in the northeastern, eastern and northwestern regions of the European territory of the Soviet Union. When the snow cover falls early and remains for a long time the hydrocarbon exhaustion of the plants led to their starvation and then these plants were subject to attack by fungi when there was a high moisture content under the melting snow cover. And only in very recent years has it become clear that undifferentiated growth of the vegetative cones is one of the factors that lead to the death of shoots, primarily main shoots, to laxears, and to a considerable reduction in the productivity of the rye spike.

As one can see from table 32 and figure 25, the vegetative cone of winter rye can reach large sizes even in the autumn when the conditions are favorable for this but then under the snow with a temperature of 0 - +2°C it continues to grow even in the winter months, as was noted in the winters of 1972/73 (figure 26) and 1973/74. By spring the shoots of these plants have died off (figure 27).

As was noted in the experiments with various strains of winter wheat, in winter rye the growth of the vegetative cone took place more intensively under the conditions of an excessive snow cover and with early planting times (figure 28). Thus, for example, in the winter of 1972/73 under a natural snow cover the length of the vegetative cone of plants from the first planting time had reached 1.5 mm by 28 February and under an excessive snow cover--1.9 mm; and with a late planting time, although the length of the vegetative cones was also unusual (0.9-0.93 mm) the differences between their sizes under natural and excessive snow covers were not great.

The undifferentiated growth, elongation of the vegetative cone and its necrosis in winter rye can be illustrated with photographs (figure 29). Thus even at the end of March in stage IV of organogenesis there were clearcut differences in the condition of the vegetative cones of plants that had spent the winter under natural and excessive snow covers (figure 30). These differences were manifested even more clearly in April (figure 31) when the plants entered stage V of organogenesis. In the photographs, even with plants taken from the variant under an excessive snow cover, one can observe a loss of turgidity by the tissues of the undifferentiated top of the vegetative cone and the appearance of dark spots, which is especially clear on the upper parts of the vegetative cones in plants that have come out from under an exessive snow cover. In figure 31 a and б the tops of vegetative cones from an early planting time (10 August) in stage V of organogenesis under different snow covers (natural--a and excessive--б) are shown for comparison. In the plants that have come

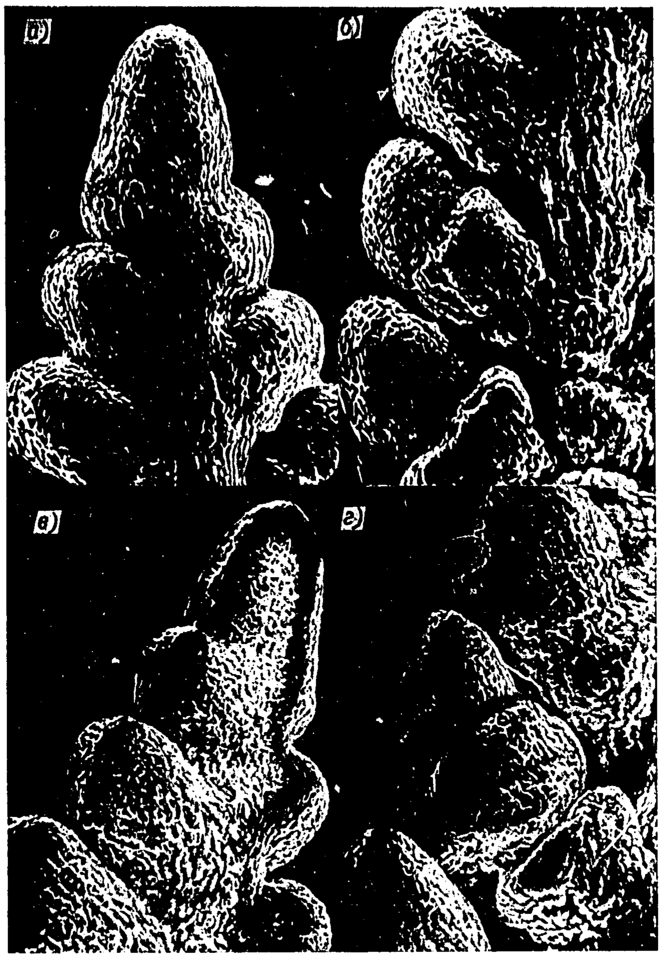

Figure 24. The Effects of an Early Planting Time (10 August) and "Excessive" Snow Cover (50-65 cm) on the Formation of Spikelets. Stage IV of Organogenesis.

[Key on following page]

Key:

Bezostaya 1 winter wheat (x333): a--the upper spikelets are behind in development, have turned dark and are beginning to die off, б--spikelets in the central part of the spike; one can see prolification of the spike and spikelet axes; Mironovskaya 808 winter wheat; b--upper spikelets are behind in development, their reduction is revealed in stage V; r--normal spikelets. 27 April 1973.

Table 31. Effects of Winter Damage Under Snow on Growth, Development and Organogenesis of Winter Wheat Plants in Moscow Area [12]

(1) Сорт	Группа по степени поврежденности (2)	Высота растений (см) (3)	Число зеленых листьев (4)	Этап органогенеза (5)	Длина колоса (мм) (6)	Число колосков в колосе (7)	Число боковых побегов (8)
(9) Мироновская 808	1	75	3,3	VIII	94	18	1,2
	2	52	3,3	VII	60	14	0,2
	3	37	2,8	VII	25	12	0,2
(10) ППГ-186	1	85	3,4	VIII	100	19	1,0
	2	56	3,4	VII	71	17	0,6
	3	40	3,4	VII	28	13	0,6
(11) Кунцевская 45	1	76	3,3	VIII	109	18,8	1,2
	2	50	3,0	VII	58	15,2	0,0
	3	49	3,0	VII	49	16,5	0,0
	4	34	3,2	VII	16	14,4	0,0
(12) Фанал	1	58	4,2	VII	54	19,9	1,1
	2	39	4,0	VII	23	17,6	0,3
	3	38	3,8	VI—VII	24	15,5	0,0
	4	25	3,3	VI—VII	8	14,2	0,0
(13) Эрос	1	66	3,5	VII	53	19,4	1,5
	2	42	3,9	VII	20	19,0	0,6
	3	43	3,5	VII	13	18,0	0,3
	4	27	3,2	VI—VII	5	13,3	0,0
(14) Хохланд	1	52	3,9	VII	47	19,9	2,1
	2	40	4,1	VII	20	17,2	1,6
	3	31	3,9	VI—VII	8	15,2	1,2
	4	25	3,2	VI—VII	5	12,8	0,0

Key:

1. Strain
2. Group in terms of degree of damage
3. Height of plants (cm)
4. Number of green leaves
5. Stage of organogenesis
6. Length of spike (mm)
7. Number of spikelets in spike
8. Number of side shoots
9. Mironovskaya 808
10. PPG-186
11. Kuntsevskaya-45
12. Fanal
13. Eros
14. Kokhland

Table 32. Dynamics of Development and Growth of Vyatka Winter Rye in Autumn, Winter and Spring Periods of 1972-1973 With Various Planting Times and Various Variants of Snow Covers

Дата проведения биологического контроля (2)	(1) Естественный снежный покров 20–25 см											
	10 VIII			25 VIII			5 IX			20 IX		
	(3) число побегов	(4) этап	(5) длина конуса (мм)	(3) число побегов	(4) этап	(5) длина конуса (мм)	(3) число побегов	(4) этап	(5) длина конуса (мм)	(3) число побегов	(4) этап	(5) длина конуса (мм)
1972 г.												
16 X	5	II	1,1	5	II	1,1	4	II	0,46	I	I	0,30
30 X	6	II	1,2	5	II	1,1	4	II	0,60	I	I	0,35
13 XI	6	II	1,2	6	II	1,2	4	II	0,80	I	II	0,35
27 XI	6	II	1,2	6	II	1,2	4	II	0,85	I	II	0,40
11 XII	6	II	1,2	6	II	1,2	4	II	0,90	I	II	0,48
25 XII	6	II	1,2	6	II	1,2	4	II	0,90	I	II	0,48
1973 г.												
11 I	6	II—III	1,2	6	II	1,2	4	II	0,90	I	II	0,48
25 I	6	II—III	1,5	6	II	1,2	4	II	0,90	I	II	0,50
13 II	6	II—III	1,5	6	II—III	1,3	4	II	0,90	I	II	0,50
28 II	6	II—III	1,5	6	II—III	1,4	4	II	0,90	I	II	0,50
21 III	5	III—IV	1,6	6	II—III	1,5	4	II	0,90	I	II	0,50
3 IV	5	IV	1,8	6	II—III	1,5	4	II	0,90	I	II	0,50
12 IV	5	IV	1,9	7	III—IV	1,6	4	II—III	1,00	I	II	0,55

[Table 32 continued ton following page]

Дата проведения биологического контроля (2)	(6) Избыточный снежный покров 50–60 см												(7) Бесснежье (2–3 см)		
	10 VIII			25 VIII			5 IX			20 IX			25 VIII		
	(3) число побегов n	(4) этап	(5) длина конуса (мм)	(3) число побегов n	(4) этап	(5) длина конуса (мм)	(3) число побегов n	(4) этап	(5) длина конуса (мм)	(3) число побегов n	(4) этап	(5) длина конуса (мм)	(3) число побегов n	(4) этап	(5) длина конуса (мм)
1972 г.															
16 X	5	II	1,1	5	II	1,1	4	II	0,46	I	I	0,30	6	II	1,1
30 X	6	II	1,2	6	II	1,1	4	II	0,60	I	I	0,30	6	II	1,1
13 XI	6	II	1,2	6	II	1,2	4	II	0,80	I	II	0,30	6	II	1,1
27 XI	6	II	1,2	6	II	1,2	4	II	0,90	I	II	0,39	6	II	1,1
11 XII	6	II	1,2	6	II	1,2	4	II	0,93	I	II	0,45	6	II	1,2
25 XII	6	II	1,2	6	II	1,2	4	II	0,93	I	II	0,55	6	II	1,2
1973 г.															
11 I	6	II–III	1,5	6	II	1,3	4	II	0,93	I	II	0,55	6	II	1,2
25 I	6	II–III	1,6	6	II	1,3	4	II	0,93	I	II	0,55	6	II	1,2
13 II	6	II–III	1,8	6	II	1,3	4	II	0,93	I	II	0,55	6	II	1,2
28 II	6	II–III	1,9	6	II–III	1,5	4	II	0,93	I	II	0,55	6	II	1,2
21 III	5	III–IV	2,0	6	II–III	1,7	4	II	1,1	I	II	0,65	6	II–III	1,3
3 IV	5	IV	2,0	6	III–IV	1,8	4	II	1,1	I	II	0,65	6	II–III	1,4
12 IV	5	IV	2,3	7	IV	1,9	4	II–III	1,2	I	III	0,65	6	III–IV	1,5

[Key on following page]

Key:
1. Natural snow cover, 20-25 cm
2. Date of biological examination
3. Number of shoots n
4. Stage
5. Length of cone (mm)
6. Excessive snow cover, 50-60 cm
7. Snowlessness (2-3 cm)

out from under a snow cover and begun to grow later, a small part of the undifferentiated top of the vegetative cone remained until that date (27 April--figure 31 6) but somewhat later (by 5 May) it dries up.

Thus, as a result of many years of experiment, it was established that under a deep snow cover, in addition to processes of respiration on which supplies of hydrocarbons accumulated in the autumn during the course of tempering are expended, in plants where the temperature is 0 ± 1°C and higher in the zone where the tillering nodes are located there are also growth processes. They are insignificant when the planting times are late and extremely marked in well bushed plants with 7-8 shoots and more. The increase in the length of the leaf blades and their etiolation do not always lead to their rapid death although in a number of years one observes that they die off prematurely, which somewhat impedes the plants' development, especially in years with a cold and dry spring. Frequently these leaves turn green in the light and for some time participate in the photosynthetic activity of winter wheat and winter rye. In the majority of years abnormally elongated, etiolized leaves 2-4 (counting from the bottom up) completely die off.

Considerably more destructive for the plants is "prolification," undifferentiated growth of the vegetative cone. Necrosis of even the uppermost part of the vegetative cone leads to a sharp reduction in the productivity of the plants and complete destruction of the vegetative cones leads to a considerable reduction in the yield. There has been repeated observations of the so-called "white spike" where some of the spike glumes are deprived of chloraphyll; in these spikes the blossoms are sterile. "White spike" can be caused by various factors--damage by concealed stalk pests, a shortage of a number of necessary trace elements, and so forth. But in the majority of cases, especially in winter rye, "white spike" is a result of winter damage, including perishing under the snow.

If one is to generalize the data obtained from physiologists concerning the processes that take place in winter plants that remain for a long time under a deep snow cover at temperatures of 0 ± 2°C, one can classify them as hydrocarbon exhaustion because of the plants' expenditures on respiration and growth processes, starvation and decomposition of protein components as well as undifferentiated growth of vegetative cones. Under conditions that are favorable for the development of fungal flora, weakened, anomalously

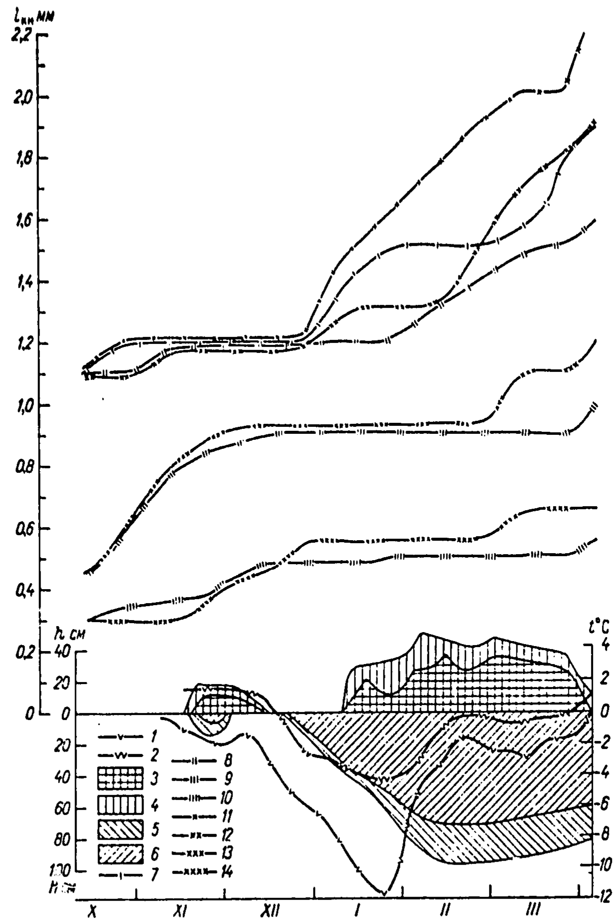

Figure 25. Growth Dynamics of Vegetative Cone of Vyatka Winter Rye With Various Planting Times Under Conditions of Snow Cover of Various Depths (1972/1973)

[Key on following page]

Key:

Temperature of soil at depth of tillering node under snow cover: 1--"natural", 2--"excessive"; depth of snow cover: 3--"natural", 4--"excessive"; depth of freezing of soil under snow cover: 5--"natural", 6--"excessive." "Natural" snow cover, planting time: 7--first, 8--second, 9--third, 10--fourth. "Excessive" snow cover, planting time: 11--first, 12--second, 13--third, 14--fourth. 1972/1973. l_{kn}--length of vegetative cone (mm), h--depth of snow cover (cm), H--depth of freezing of soil (cm).

"prolificated" organs of winter plants are infected with snow mold and collar rot which destroy the entire above-ground mass of the plants and attack and fully destroy winter crops.

MAIN AGROMETEOROLOGICAL FACTORS CAUSING PERISHING OF WINTER CROPS UNDER SNOW AND PATTERNS OF THEIR SEASONAL CHANGE

A study of the results of the research on physiological processes on perishing of winter plants under snow made it possible to come to the conclusion that the destruction of winter crops when they perish under the snow is determined mainly under the condition of the plants in the autumn, the soil temperature at the depth of the tillering node and on the surface of the soil under the snow, the depths of freezing of the soil and the length of time a deep snow cover remains on the fields.

Investigation of the temperature conditions of the soil at the depth of the tillering nodes of winter crops showed that with certain combinations of the depth of the snow cover and the depth of freezing of the soil, the temperature remains for a long period of time within the range in which perishing of the plants takes place (0 -- -5°C). From the results of observations from 1965 through 1976 at the Nemchinovka Agrometeorological Station in Moscow Oblast with slight freezing of the soil during the period of the formation of a deep snow cover (depth 30 cm and more), the minimum temperature of the soil throughout the entire subsequent period of the winter was within the range of 0 - -3°C (Table 33, 1965/66, 1967/68, 1969/70 and 1970/71).

The soil temperature at the depth of the tillering nodes of winter crops (an average depth of 3 cm) when there is no snow cover on the fields depends mainly on the air temperature and the depth of freezing of the soil [18, 22]. The daily and periodic changes in it are similar to the changes in the air temperature, but the absolute amounts are higher than the air temperature. With a slight freezing of the soil, the difference between the soil temperature at a depth of 3 cm and the air temperature is greater than when there is deep freezing of the soil.

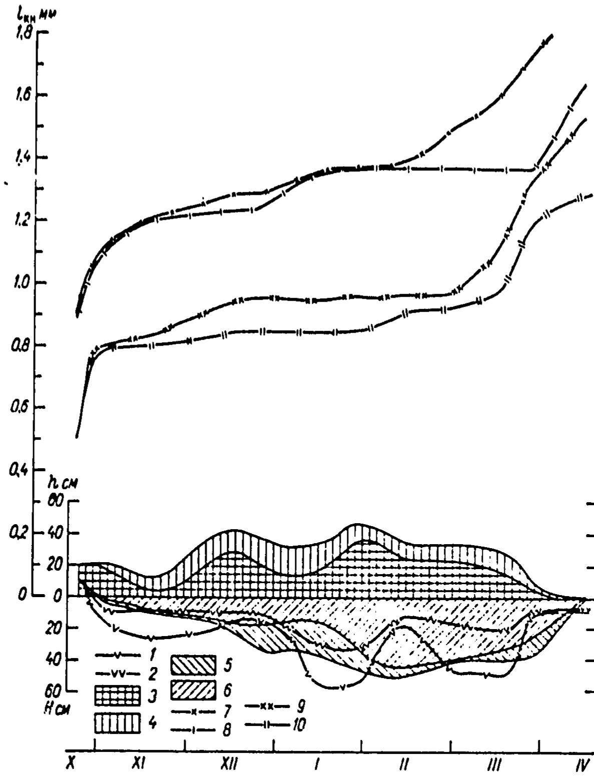

Figure 26. Growth Dynamics of Vegetative Cone of Vyatka Winter Rye of the First and Second Planting Times Under Conditions of "Natural" and "Excessive" Snow Covers.

Key:

Conventional symbols l_{kn}, h, H and 1-6, see fig. 25. First planting time, snow cover: 7--"excessive", 8--"natural"; second planting time, snow cover: 9--"excessive," 10--"natural". 1973/74

Figure 27. Perishing of Vyatka Winter Rye Under Snow in Winter of 1965/66

Key:

External appearance of plants from specimens taking from agrometeorological stations: a--Charozero (Kalininskaya Oblast), б--Igra (Udmurt ASSR), b--Cherdyn' (Permskaya Oblast)

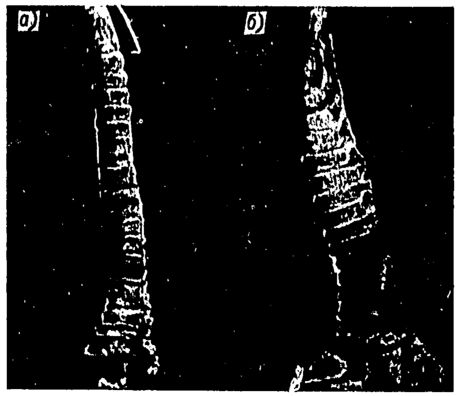

Figure 28. Condition of Vegetative Cone of Vyatka Winter Rye After Wintering on 3 April 1973. (Stage IV)

Key:

a--with "natural" snow cover (normal conditions), б--with "excessive" snow cover

When the snow cover is established on the fields of winter crops the effects of the air temperature on the soil decrease considerably since the snow has great heat insulation properties (Table 34). Its heat conductability is 10 percent of the heat conductability of the mineral part of the soil.

The heat insulating properties of the snow cover become greater as its depth and reflective capacity increase and its density decreases.

During the course of the winter the density of the snow cover increases; in January-February it amounts to an average 0.18-0.22 g/cm^3; and by the end of the winter it increases to 0.25-0.35 g/cm^3. The heat insulating role of each centimeter of the snow cover turns out to be significantly less by the end of the winter than in the first half. This is clearly confirmed by the data presented in table 34 (temperature gradient in the grass stand of winter crops). As the depth of the snow cover increases at the end of the winter and the air temperature increases, the soil temperature at the depth of the tillering node in the second half of the winter period in regions where the snow cover persists always turns out to be greater than at the beginning of the winter [5, 16, 22], as a result of which the processes of perishing of winter crops intensify during this period. But when the snow cover is packed beginning at the time it is formed on the fields, the soil temperature at the depth of the tillering node is lower than when the snow cover is natural, not only in the winter, but also in the spring during the period of thawing of the snow, which is very important for protecting the plants. The results of our field experiments for studying the role of the density of the snow cover with the wintering of winter crops at the Belogorka Agrometeorological Station are presented in Table 35.

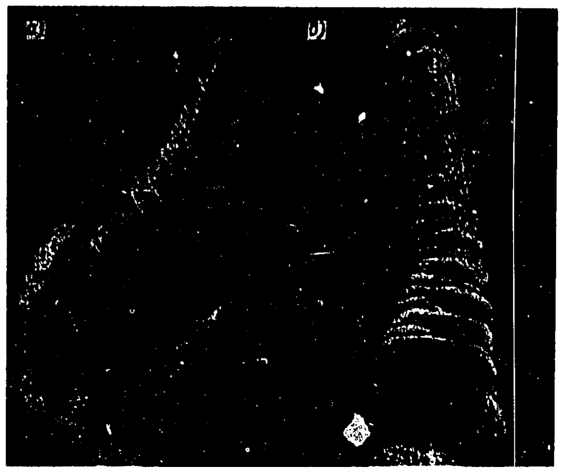

Figure 29. Condition of Vegetative Cones of Vyatka Winter Rye After W.ntering, 21 March 1973 (Beginning of Stage IV)

Key:
a--normal condition with "natural" snow cover, б--elongation of vegetative cone with "excessive" snow cover (X 140)

The soil temperature after the formation of the snow cover is almost always higher than the air temperature. Only during significant warming periods (up to thaws) with a deep snow cover and deep freezing of the soil can it turn out to be lower than the air temperature [22].

A change in the depth of the snow cover has an especially strong effect on the temperature of the soil at a depth of 3 cm when the snow cover is initially not very deep (up to 5-10 cm) but when the snow cover is as deep as 30 cm and more it does not have a great significance since the gradiant of the temperature with the depth of the snow cover decreases sharply.

2 OF 2

Figure 30. Condition of Vegetative Cone of Vyatka Winter Rye in Spring With Early Planting Time (10 August 1972) and Natural Snow Cover of 20-25 cm. 15 April 1973.

Key:

a--rudimentary spike, beginning of stage IV of organogenesis (X60),
б--top of spike is undifferentiated and all spikelets are one stage behind those of the middle part of the spike (X222)

According to the results of our research, it turned out that for each centimeter of depth of the snow cover the soil temperature at the depth of 3 cm under the snow increased in comparison to the air temperature by 0.5°C when the snow cover was 5 cm deep, 0.3°C when the snow cover was 30 cm deep and 0.2°C when the snow cover was 60 cm deep.

With an increase in the depths of the snow cover to 30 cm and more the soil temperature at the depth of 3 cm and on the surface of the soil under the snow changed very little, regardless of the fluctuations in the air temperature [17, 22].

The daily fluctuation in the temperature and the snow cover rapidly disappears. According to the data of B. P. Karol', in January 1946 near Leningrad the change in the daily fluctuation of the temperature depending on the depth of the snow cover was as follows: on the surface of the snow--30°C, at a depth of 5 cm--15.8 °C, at a depth of 10 cm--11.1°C, at a depth of 25 cm--2.1°C and at a depth of 40 cm--0.2°C.

Figure 31. Condition of the Vegetative Cone of Vyatka Winter Rye After Wintering. 27 April 1973. End of Stage IV.

Key:

Under conditions of snow cover: a--"natural" (normal condition), б--"excessive" (top of cone is not differentiated).

The results of observations at meteorological stations for four years showed that during periods of lowering of air temperatures in the winter, the soil temperature at a depth of 3 cm when the snow cover is 30 cm deep and the soil is slightly frozen decreases insignificantly, almost by the same amount as when the snow cover is 50-60 cm deep (Table 36). With deep freezing of the soil and a 30-cm snow cover there was a greater reduction in the soil temperature. When the snow cover was this deep there was almost no change at a depth of 3 cm. The maximum amount of the daily fluctuation of the soil temperature at a depth of 3 cm when the air temperature ranged from 2 to 27°C amounted to 0.8°C. In 83 percent of 190 cases the daily amount of change in the soil temperature ranged within 0.0-0.3°C. And when the snow cover was from 11 to 20 cm deep the amount of change in the soil temperature was 20-40 percent of the amount of change in the air temperature.

Table 33. Seasonal Change in Minimum Air Temperature t (°C), Depths of Snow Cover h (cm), Depth of Freezing of Soil H (cm) and Minimum Soil Temperature at Depth of Tillering Nodes of Winter Crops t_3 (°C) at Nemchinovka Agrometeorological Station From 1965/66 Through 1974/75.

Показатель (1)	XI			XII			I			II			III		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1965/66 г.															
t	−4	−22	−20	−7	−10	−9	−14	−27	−25	−31	−18	−11	−6	−18	−8
h	4	11	4	5	4	25	30	33	41	41	62	51	44	43	21
H	0	12	15	15	18	20	16	16	18	22	28	27	23	19	15
t_3	0	−5	−3	−1	−4	−2	−2	−3	−2	−2	−2	−3	−2	−2	−1
1966/67 г.															
t	−17	−4	−4	−24	−22	−18	−20	−28	−33	−32	−24	−17	−5	−12	−9
h	9	13	0	4	25	25	39	35	42	45	45	44	45	41	28
H	6	0	9	39	53	58	58	62	68	76	78	79	75	68	61
t_3	−4	−4	−1	−5	−4	−3	−2	−3	−4	−4	−3	−3	−2	−1	−1
1967/68 г.															
t	0	−2	−18	22	−24	−28	−30	−32	−30	−25	−25	−25	−19	−16	−8
h	0	1	6	20	26	28	39	48	50	47	57	67	63	65	0
H	0	0	20	20	18	25	23	31	40	37	42	44	42	40	32
t_3	0	0	−2	−2	−3	−2	−2	−2	−1	−1	−2	−1	−2	−2	−2
1968/69 г.															
t	−7	−18	−19	−28	−28	−16	−27	−32	−31	−31	−27	−18	−23	−19	−17
h	0	5	9	14	17	18	20	21	24	31	23	25	26	26	10
H	12	22	26	19	21	20	34	49	66	74	82	89	98	104	107
t_3	0	−3	−4	−3	−3	−2	−5	−6	−6	−4	−5	−5	−6	−4	−4
1969/70 г.															
t	−13	−2	−3	−8	−19	−28	−25	−37	−32	−20	−24	−20	−16	−15	−12
h	16	0	0	0	9	10	29	40	35	44	65	59	57	64	61
H	0	0	0	2	14	61	73	71	70	74	79	0	0	79	79
t_3	−3	0	0	−4	−6	−10	−10	−6	−5	−6	−5	−6	−6	−4	−4
1970/71 г.															
t	−17	−4	−9	−14	−14	−20	−20	−20	−3	−18	−24	−22	−21	−18	−11
h	18	0	5	8	10	11	16	5	11	6	18	12	10	10	0
H	0	0	15	17	15	15	27	34	34	35	43	3	93	107	109
t_3	−1	−1	−3	−2	−2	−2	−2	−4	−2	−4	−6	−4	−5	−4	−5

[Table 33 continued on following page]

Показатель (1)	XI			XII			I			II			III		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1971/72 г.															
t	−8	−14	−9	−10	−22	−24	−24	−31	−26	−26	−1	−16	−20	−20	−8
h	0	2	3	10	9	16	17	18	21	18	16	13	13	—	—
H	0	9	8	5	15	23	31	49	60	81	86	88	93	102	100
t_3	−2	−3	−2	−2	−2	−3	−4	−6	−7	−8	−5	−5	−8	−10	−3
1974/75 г.															
t	−6	−6	−8	−11	−12	−8	−19	−24	−13	−15	−26	−18	−20	−7	−7
h	2	0	0	9	9	10	13	11	21	26	40	36	23	0	0
H	0	0	11	10	12	11	16	19	20	20	21	22	21	19	0
t_3	−2	—	−2	−3	−5	−3	−4	−4	−2	−2	−4	−3	−3	−4	0

Key:

1. Indicator

The absolute soil temperature at a depth of 3 cm throughout the entire period when a snow cover of 30 cm and more fell on slightly frozen soil (less than 50 cm) remained within the range of 0 - -3°C, that is, within the range that is most favorable for the processes of perishing of plants under the snow. When a snow cover of 30 cm and more was formed after the soil was frozen to a depth of 50-60 cm, the soil temperature near the tillering nodes of winter crops is considerably lower (down to -6 - -8°C).

With very severe cooling of the soil (when it freezes down to 120-100 cm and deeper) before the establishment of a deep snow cover on the fields, the minimum temperature of the soil during the winter can be even lower than -20°C but when analyzing the materials of observations from the past 25-30 years we did not discover any cases like this in regions where plants perish under the snow. Therefore when a 30-cm snow cover is formed on deeply frozen soil the plants are in a dormant condition throughout the entire subsequent period while it remains, respiration processes are very slight, supplies of sugars are expended slowly and there is no perishing of winter crops even when the snow cover remains on the fields for a long time.

The depth of freezing of the soil in the nonchernozem zone changes from year to year within a very wide range (from 0 to 150 cm and in the northeastern regions, even more). But most frequently at the end of the winter it is less than 100 cm. A rapid increase in the depth of freezing of the soil takes place when there is no snow cover on the fields or it is not very deep and the air temperature is abnormally low (Table 37, Torzhok Meteorological Station, Saransk, 1962/63).

Table 34. Influence of Depth of Snow Cover on the Temperature in the Grass Stand of Winter Crops, on the Surface of the Soil and in the Soil at the Depth of the Tillering Nodes. Belogorka Agrometeorological Station, Leningrad Oblast.

Показатель (1)	1962/63 г.						1963/64 г. *					
	XI	XII	I	II	III	IV	XI	XII	I	II	III	IV
(2) Минимальная температура (°C)												
(3) воздуха в будке	−9,1	−24,8	−33,3	−32,6	−33,3	−22,5	−19,4	−28,7	−20,7	−28,7	−29,2	−6,7
(4) на высоте травостоя $t_т$	−8,0	−27,5	−30,0	−15,0	−13,9	−10,0	−14,3	−23,6	−16,8	−6,3	−6,5	−2,0
(5) на поверхности почвы t_0	−3,9	−3,7	−5,0	−3,9	−3,3	−2,7	−2,7	−5,0	−4,6	−1,6	−2,0	−0,4
(6) на глубине узла кущения t_3	−2,2	−2,7	−4,6	−3,3	−3,3	−2,7	−2,0	−2,0	−3,5	−1,2	−1,6	−0,4
(7) Высота снежного покрова (см)	0	5	15	20	33	31	5	5	25	37	30	12
(8) Глубина промерзания почвы (см)	13	23	60	80	100	110	15	20	28	50	63	72
(9) Высота травостоя (см)	10	10	10	10	10	10	20	20	20	20	20	20
(10) Разность температур												
$(t_т-t)$	+1,1	+2,7	+3,3	+17,6	+19,4	+12,5	+5,1	+5,1	+3,9	+22,4	+22,7	+4,7
(t_0-t)	+5,2	+21,1	+28,3	+28,7	+30,0	+19,8	+16,7	+23,7	+16,1	+27,4	+27,2	+6,3
(t_3-T)	+6,9	+22,1	+28,9	+29,0	+30,0	+19,8	+17,4	+26,7	+17,2	+27,5	+27,6	+6,3
(11) Градиент минимальной температуры в травостое (°C/см)	0,41	2,38	2,50	1,11	1,06	0,73	0,54	0,93	0,61	0,23	0,22	0,08

[Table 34 continued on following page]

Показатель (1)	1964/65 г.						За зиму		
	XI	XII	I	II	III	IV	1962/63 г.	1963/64 г.	1964/65 г.
(2) Минимальная температура (°C)									
(3) воздуха в будке	−16,2	−24,1	−24,6	−34,6	−23,3	−15,6	−33,3	−29,2	−34,6
(4) на высоте травостоя $t_т$	−15,7	−21,5	−16,5	−6,1	−4,3	−3,9	−30,0	−23,6	−21,5
(5) на поверхности почвы t_0	−9,9	−2,0	−1,8	−1,0	−0,6	0,0	−5,0	−5,0	−9,9
(6) на глубине узла кущения t_3	−9,8	−1,2	−1,4	−1,0	−0,4	0,0	−4,6	−3,5	−6,9
(7) Высота снежного покрова (см)	0	14	14	33	45	34	33	38	54
(8) Глубина промерзания почвы (см)	22	28	29	37	43	44	114	74	58
(9) Высота травостоя (см)	10	10	10	10	10	10	10	20	10
(10) Разность температур									
$(t_т - t)$	+0,5	+2,6	+8,1	+28,5	+19,0	+11,7	+3,3	+5,6	+13,1
$(t_0 - t)$	+6,3	+22,1	+22,8	+33,6	+22,7	+15,6	+28,3	+24,2	+24,7
$(t_3 - T)$	+9,4	+22,9	+23,2	+33,6	+22,9	+15,6	+28,7	+25,7	+27,7
(11) Градиент минимальной температуры в травостое (°C/см)	0,58	1,95	1,47	0,51	0,37	0,39	—	—	—

[Key on following page]

Key:

1. Indicator
2. Minimum temperature (°C)
3. Air in cabin
4. At height of grass stand t_T
5. On surface of soil t_0
6. At depth of tillering node
7. Depth of snow cover (cm)
8. Depth of freezing of soil
9. Height of grass stand
10. Difference of temperatures
11. Gradient of minimum temperature in grass stand (°C/cm)

Table 35. Influence of Density of Snow on Depth of Freezing and Minimum Temperature of Soil at Depth of Tillering Node. Belogorka Agrometeorological Station, Leningrad Oblast.

Показатель (1)	Участок (2)	1962/63 г. январь (3)	февраль (4)	март (5)	апрель (6)
(7) Высота снежного покрова на конец месяца (см)	I	23	30	30	6
	II	20	34	35	16
(8) Плотность снега на конец месяца (г/см³)	I	0,18	0,25	0,30	0,29
	II	0,34	0,34	0,36	0,39
(9) Глубина промерзания почвы на конец месяца (см)	I	75	88	98	100
	II	80	93	100	105
(10) Минимальная температура почвы на глубине 3 см за месяц (°C)	I	−5,8	−2,7	−2,7	−2,7
	II	−7,3	−6,5	−3,9	−2,7
(11) Средняя месячная температура почвы (°C)	I	−2,4	−1,9	−2,1	−1,3
	II	−4,0	−3,2	−2,5	−0,8
(12) Минимальная температура воздуха за месяц (°C)	I	−33,3	−30,8	−33,3	−22,5

Показатель (1)	Участок (2)	1963/64 г. декабрь (13)	январь (3)	февраль (4)	март (5)	апрель (6)
(7) Высота снежного покрова на конец месяца (см)	I	12	9	25	14	7
	II	12	13	29	18	12
(8) Плотность снега на конец месяца (г/см³)	I	0,22	0,25	0,22	0,28	0,28
	II	0,30	0,38	0,38	0,40	0,39
(9) Глубина промерзания почвы на конец месяца (см)	I	25	55	72	81	79
	II	57	67	86	99	97
(10) Минимальная температура почвы на глубине 3 см за месяц (°C)	I	−1,2	−1,3	−2,0	−2,4	0
	II	−7,1	−8,0	−5,0	−4,8	−0,5
(11) Средняя месячная температура почвы (°C)	I	−0,6	−1,4	−1,5	−1,6	+0,8
	II	−2,7	−2,2	−2,9	−2,8	−0,3
(12) Минимальная температура воздуха за месяц (°C)	I	−28,7	−20,7	−28,7	−29,2	−6,7

[Key on following page]

Key:
1. Indicator
2. Section
3. January
4. February
5. March
6. April
7. Depth of snow cover at end of month (cm)
8. Density of snow at end of month g/cm^3)
9. Depth of freezing of soil at end of month (cm)
10. Minimum soil temperature at depth of 3 cm during month (°C)
11. Average monthly soil temperature (°C)
12. Minimum air temperature during month (°C)
13. December

Note: I--section with natural snow cover; II--with packed snow.

Table 36. Limits of Drop in Temperature of Soil at Depth of 3 cm With Various Drops in Air Temperature, Depthos of Snow Cover and Depths of Freezing of Soil.

(2) Пределы понижения температуры воздуха (°C)	(1) Высота снежного покрова (см)						
	3		20—22	30—35		50	60
	(3) глубина промерзания почвы (см)						
	30—40	60—80	60—80	30—40	60—80	50—60	50—60
—5	—0,8	—2,0	—0,4	—0,1	—0,1	0,0	0,0
—10	—3,3	—4,5	—1,7	—0,3	—0,1	0,0	0,0
—15	—5,8	—7,2	—2,9	—0,7	—2,1	0,0	0,0
—20	—8,3	—10,0	—4,0	—1,0	—3,3	—0,2	—0,1
—25	—10,7	—12,6	—5,4	—1,2	—4,5	—0,5	—0,3
—30	—13,3	—15,3	—6,5	—1,5	—5,8	—0,7	—0,6

Key:
1. Depth of snow cover (cm)
2. Limits of drop in air temperature (°C)
3. Depth of freezing of soil (cm)

Table 37. Seasonal Change in Depth of Freezing H (cm) and Minimum Soil Temperature at Depth of Tillering Nodes t_3 (°C), Depending on Depth of Snow Cover h (cm) and Average 10-Day Air Temperature t (°C)

Станция (1)	Год (2)	Показатель (3)	(4) Ноябрь 1	2	3	(5) Декабрь 1	2	3	(6) Январь 1	2	3
(7) Торжок (Калининская область)	1962/63	H	4	25	26	18	34	47	61	91	98
		t_3	0	−2	−1	−3	−3	−4	−4	−6	−6
		h	0	0	4	0	5	5	6	12	13
		t	+1	−4	+2	−3	−8	−13	−13	−22	−15
(8) Йошкар-Ола (Марийская АССР)	1962/63	H	10	21	23	34	42	44	62	68	79
		t_3	−2	−2	−1	−6	−3	−3	−3	−6	−5
		h	0	0	0	4	14	16	30	32	34
		t	+1	−3	0	−10	−6	−13	−16	−26	−18
(9) Саранск (Мордовская АССР)	1962/63	H	0	12	0	21	33	43	63	84	105
		t_3	0	−1	−1	−8	−9	−8	−10	−14	−13
		h	0	0	0	4	3	5	14	13	18
		t	+1	−2	+1	−7	−6	−13	−15	−24	−18
(10) Тихвин (Ленинградская область)	1965/66	H	0	16	22	26	23	18	20	26	27
		t_3	0	−3	−2	−1	−1	−1	−1	−1	−1
		h	10	7	21	24	43	41	46	53	64
		t	+1	−13	−11	−1	−5	−4	−15	−20	−13
(11) Емецк (Архангельская область)	1965/66	H	0	2	4	47	44	44	45	55	65
		t_3	0	−1	−4	−2	−2	−2	−3	−4	−4
		h	5	6	9	15	29	32	43	43	45
		t	+1	−13	−16	−3	−5	−7	−28	−24	−19

[Table 37 continued on following page]

Станция (1)	Год (2)	Показатель (3)	Февраль (12) 1	2	3	Март (13) 1	2	3	Апрель (14) 1	2	3
(7) Торжок (Калининская область)	1962/63	H t_3 h t	113 −5 11 −6	120 −6 15 −15	122 −6 15 −14	128 −5 16 −6	136 −7 16 −13	139 −7 16 −12	147 −4 16 −4	150 +3 0 +4	150 — 0 +9
(8) Йошкар-Ола (Марийская АССР)	1962/63	H t_3 h t	85 −5 38 −9	92 −6 34 −17	97 −5 56 −15	99 −5 59 −13	101 −5 57 −16	102 −4 58 −15	105 −3 62 −5	105 1 13 +4	105 — 0 +7
(9) Саранск (Мордовская АССР)	1962/63	H t_3 h t	127 — 24 −9	130 −9 23 −13	142 — 25 −14	145 −9 28 −10	148 −9 40 −14	148 −9 36 −11	148 −7 32 −4	150 −1 13 +4	150 — 0 +11
(10) Тихвин (Ленинградская область)	1965/66	H t_3 h t	28 −1 75 −23	28 −1 73 −14	28 −1 72 −4	25 −1 72 −1	10 −1 78 −8	0 −1 75 −1	0 +1 0 +4	— — — —	— — — +3,5
(11) Емецк (Архангельская область)	1965/66	H t_3 h t	72 −5 48 −30	81 −6 48 −22	87 −5 50 −21	91 −3 53 −14	94 −4 59 −16	94 −3 58 −5	9 −1 20 +2	97 0 24 −6	26 0 30 −1

[Key on following page]

Key:

1. Station
2. Year
3. Indicator
4. November
5. December
6. January
7. Torzhok (Kalininskaya Oblast)
8. Yoshkar-Ola (Mari ASSR)
9. Saransk (Mordovian ASSR)
10. Tikhvin (Leningrad Oblast)
11. Yemetsk (Arkhangel'skaya Oblast)
12. February
13. March
14. April

A change in the depth of freezing of the soil, according to the data of L. A. Razumova [28], depends mainly on the total negative temperatures during the past period of the winter, on the depth of the snow cover, on the level of ground waters and on the initial depths of freezing of the soil (figure 32a and б). In regions where the ground waters are deep, when the snow cover is more than 60 cm deep even with a very low average daily air temperature (down to -20°C), the depth of freezing of the soil does not increase. Nor does it increase at all when the snow cover is 30 cm deep and the average daily air temperature is above -10°C.

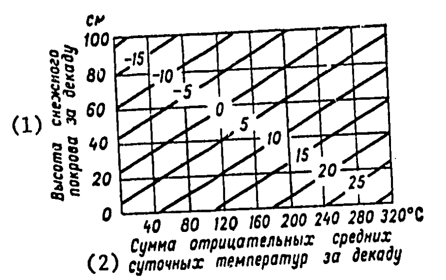

Figure 32a. Change in Depth of Freezing of Soil (cm) in 10 Days in Regions Where Ground Waters are Shallow in European Territory of USSR.

Key:

1. Depth of snow cover during 10 days
2. Total negative average daily temperatures during 10 days

Adjustments to initial freezing

Initial freezing, cm	0-16	17-48	49-79	80-110	111-140
Adjustment, cm	0	0.5	1.0	1.5	2.0

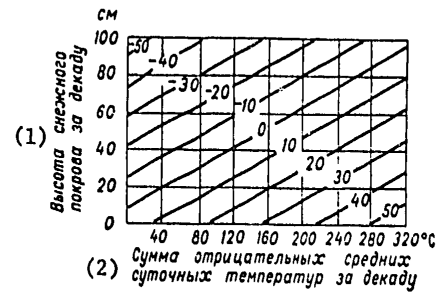

Figure 32б. Change in Depth of Freezing of Soil (cm) in 10 Days in Regions Where Ground Waters are Deep in European Territory of USSR

Key:
1. Depth of snow during 10 days
2. Total negative average daily temperatures during 10 days

Adjustments to initial freezing

Initial freezing, cm	0-2	3-9	10-16	17-23	24-30	31-37	38-44	45-51
Adjustment, cm	0	-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5

Initial freezing, cm	52-58	59-65	66-72	73-79	80-86	87-93	94-100
Adjustment, cm	-4.0	-4.5	-5.0	-5.5	-6.0	-6.5	-7.0

The results of observations of the depth of freezing of the soil have shown that after the formation on the fields of a snow cover of 30 cm and more, it increases insignificantly (figure 33). During the entire period with this depth of the snow cover, the depths of freezing of the soil in the majority of cases (80 percent) increased by no more than 20 cm and only in 7 percent of the cases, by more than 30 cm. When the depth of the snow cover was 20 cm it increased by 0-20 cm in 52 percent of the cases and by more than 30 cm in 32 percent of the cases.

If a snow cover of 30 cm and more is established when the depth of freezing is less than 30-50 cm, the depths of freezing of the soil during the rest of the winter period increased less than when the snow fell on deeply frozen soil. Even individual cases of thawing of the soil under the snow were observed.

Slight freezing of the soil (less than 50 cm) contributes to maintaining a temperature close to 0°C at the depths of the tillering node under a deep snow cover. With this depth of freezing of the soil, as M. I.

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Sumgin's research has shown [17, 32] in a zone with adequate and excess moisture, the reduction of the temperature is retarded because of the discharge of a large quantity of heat when the water freezes at the border of the freezing of the soil and layers above it.

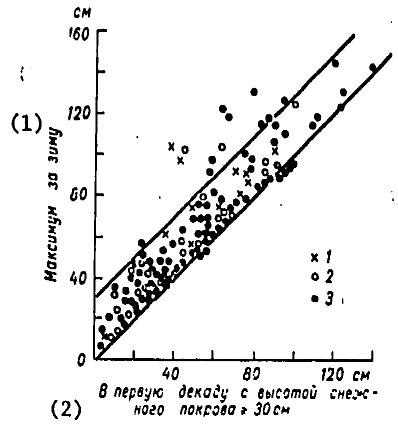

Figure 33. Connection Between Maximum Depth of Freezing of Soil (cm) During Winter and Depth of Freezing of Soil During 10 Days in Which a Snow Cover of 30 cm and More is Established on the Fields

Key:

a. Maximum for winter
b. In first 10 days with snow cover of 30 cm and more

Agrometeorological stations: 1--Sarapul, 1935-1962; 2--Gor'kiy, 1935-1962; 3--nonchernozem zone of RSFSR, 1944/45 and 1965/66.

On the basis of the patterns that have been presented concerning the connection between the depths of the snow cover, the depth of freezing and the temperature of the soil, we have taken the length of time a snow cover of 30 cm and more remains on the fields when the depth of freezing of the soil is less than 50 cm as one of the most important indicators characterizing conditions for perishing of winter crops under the snow. Under these conditions not only does the soil temperature at the depth of the tillering node remain within the limits in which perishing of plants takes place, but conditions are also created for almost complete darkness near the surface of the leaves since the transparency (light penetrability) of the snow cover is not great. The coefficient of the weakening of the penetration of solar radiation, according to N. N. Kalitin, is 0.197 for dry snow and 0.446 for wet snow. The penetration of solar radiation into dry snow is practically limited to a depth of about 30 cm and wet snow--10-15 cm. When a dry snow cover is 14 cm deep only 7-10 percent of the radiation that passes through the surface of the snow cover reaches the surface of the soil and the wintering plants under it. Research on the penetration of solar radiation into the snow cover which we conducted at the Royka Agrometeorological Station (Gor'kovskaya Oblast) confirms the conclusions reached by other authors (table 38). Therefore photosynthesis cannot take place in plants that are under a deep snow cover (30 cm and more).

Table 38. Penetration of Light (%) to Various Depths of Snow Cover, Depending on Illumination of its Surface (Royka Agrometeorological Station [22]

Время измерения (ч) (1)	Освещенность на поверхности снега (тыс. лк) (2)	(3) Глубина снежного покрова (см)				
		0	5	10	15	20
8	20,1	100	1,74	1,08	0,45	0,25
11	64,3	100	8,68	2,61	0,44	0,21
12	64,3	100	9,11	3,03	0,60	0,29
13	60,0	100	8,40	3,72	0,58	0,30

Key:
1. Time of measurement (hours)
2. Illumination on surface of snow (thousands of luces)
3. Depth of snow cover (cm)

Figure 34 shows the dependency between the thinning of winter crops and the length of time they spend under a snow cover of 30 cm and more, without taking into account the depth of freezing of the soil, from data of the Royka Agrometeorological Station for the period from 1936 through 1965. The observations were made on experimental fields of the Gor'kiy Agricultural Institute where the level of agrotechnology was sufficiently high.

As one can see from the graph, the percentage of destruction of Vyatka winter rye plants that are resistant to perishing under the snow is less than that of winter wheat, but the relationship is the same. As the number of 10-day periods with a deep snow cover on fields of winter crops increases, the thinning of the plantings increases. The large deviation of the points from the lines of connection in individual years is explained by abnormally low (1941/42) or, conversely, abnormally high (1937/38, 1942/43, 1945/46) air temperatures throughout the entire winter season, the different depths of freezing of the soil and the different conditions of the areas planted in winter crops in the autumn. When they are in very good condition (bushiness--3-4 shoots) fewer winter crops died than did winter crops in the phase of forming shoots or the third leaf or especially planted areas with aftergrowths.

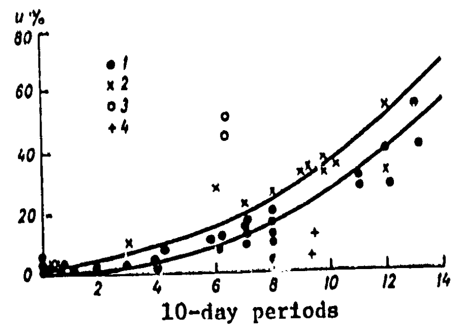

Figure 34. Dependency of Degree of Thinning u of Vyatka Winter Rye (1) and Ul'yanovka Winter Wheat (2) on Duration (in 10-Day Periods) of Snow Cover of 30 cm and More. Gor'kiy, Royka Agrometeorological Station

Key:
1, 2--1936-1964; 3--winter wheat, 1942/43, 1945/46; 4--winter rye, 1941/42, 1947/48.

The connection between the thinning of the plants and the number of 10-day periods with a snow cover of 30 cm and more is manifested somewhat better when one takes into account the depth of freezing of the soil. This dependency, according to data from observations at the Gor'kiy and Sarapul Agrometeorological Stations and a network of meteorological stations located in the nonchernozem zone of the European territory of the USSR, are presented in figure 35.

As one can see from the graph (figure 35a), the thinning of Vyatka winter rye increases with a reduction in the depth of freezing of the soil and an increase in the duration of the period with a deep snow cover of 30 cm and more. There is the least thinning (less than 10 percent) if the number of 10-day periods with this depth is less than 6 and the greatest (more than 50 percent) when the snow remains for 12 10-day periods and more. Under the same conditions the perishing of winter wheat was greater (figure 35б).

The number of plants that survive the damage under the snow depends to a considerable degree on the condition of the planted areas after the end of the growing period in the autumn. According to the results of many years of observations, this dependency was curvilinear (figure 36).
As one can see from figure 36, under the same conditions, the greatest percentage of plants survived in well developed (with an average bushiness of four stalks) planted areas. In poorly developed planted areas and areas with aftergrowth (with an average bushiness of less than 2 and more than 5 stalks), the number of plants that survived after wintering decreased significantly and this decrease was especially great with poor and very poor wintering conditions. Thus with satisfactory wintering conditions on planted areas with an average bushiness of four stalks the

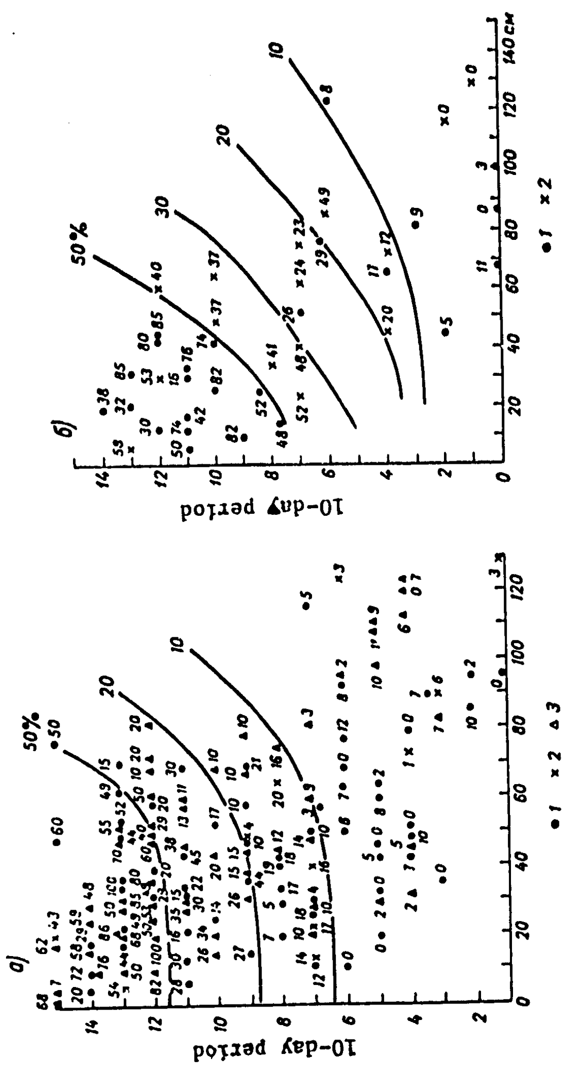

Figure 35. Thinning (%) of Winter Crops With Various Depths of Freezing of the Soil (cm) and Lengths of Time (10-day Periods) a 30-cm Snow Cover Remains

[Key on following page]

Key:
a--Vyatka winter rye (1--nonchernozem zone of RSFSR, 1950-1955, 2--Gor'kiy Agrometeorological Station, 3--nonchernozem zone of RSFSR, 1944-1946); 6--Ul'yanovka winter wheat (1--Sarapul Agrometeorological Station, 2--Gor'kiy Agrometeorological Station).

survival rate was 90-100 percent, on areas where the plants had two stalks--80 percent, and where they had one stalk--75 percent of the plants survived. There is also an increase in the percentage of perishing of plants with an average of more than four stalks in the autumn. The latter is explained not only by the reduced winter hardiness of plants with aftergrowth in the autumn (as was shown earlier), but also by the significant heat insulating properties of the grass stand when the plants have aftergrowth.

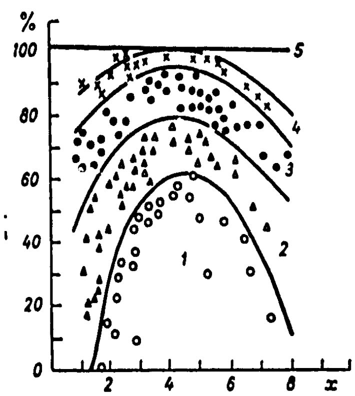

Figure 36. Dependence of Number of Surviving Vyatka winter rye plants (5) on Average Bushiness of Plants in Autumn x with Various Wintering Conditions

Key:
Wintering conditions: 1--very poor, 2--poor, 3--satisfactory, 4--good, 5--very good.

As we showed with our field experiments conducted at the Belogorka Agrometeorological Station, the freezing and minimum temperature of the soil at the depth of the tillering node and also the depth of the snow cover on a field with overgrown winter crops (planted on 13 August 1963 with interrows of 15 cm) which had a very dense plant stand (average bushiness--7.52), differed essentially from these characteristics on fields with normally developed winter crops (planting time--2 September).

Even when the overgrown planted areas were mowed down in the autumn (their height reduced from 40 to 10 cm), the difference in the maximum depth of freezing of the soil during the winter amounted to only 50 cm and the maximum depth of the snow cover--11 cm and in the minimum temperature of the soil at a depth of 3 cm--6.3°C (table 39).

Table 39. Influence of Density of Vegetative Mass of Winter Crops on the Depth of the Snow Cover, the Depth of Freezing and the Minimum Soil Temperature at the Depth of the Tillering Node.

(1) Участок	(2) Характеристика травостоя: (3) высота	(4) кустистость	(5) Ноябрь 1	Ноябрь 2	Ноябрь 3	(6) Декабрь 1	Декабрь 2	Декабрь 3	(7) Январь 1	Январь 2	Январь 3
(8) Глубина промерзания почвы (см)											
I	25	8,0		0	15	24	27	28	24	25	33
II	10	7,5		0	10	17	26	25	25	25	55
III	10	1,8		0	10	27	50	58	51	74	90
(9) Высота снежного покрова (см)											
I	25	8,0		0	6	11	24	19	14	12	20
II	10	7,5		0	5	13	20	17	10	10	15
III	10	1,8		0	5	8	10	4	1	3	5
(10) Минимальная температура почвы на глубине узла кущения (°C)											
I	25	8,0			−1,6	−2,0	−2,0	−0,8	−0,4	−2,0	−3,5
II	10	7,5		+0,4	−1,2	−1,6	−1,2	−0,8	−0,4	−2,7	−4,6
III	10	1,8	+0,2	0,0	−2,0	−2,2	−4,7	−0,4	−1,4	−10,0	−10,9

[Table 39 continued on following page]

(1) Участок	(2) Характеристика травостоя: (3) высота	(4) кустистость	(11) Февраль 1	2	3	(12) Март 1	2	3	(13) Апрель 1	2	3	(14) За зиму
(8) Глубина промерзания почвы (см)												
I	25	8,0	35	40	52	60	68	74	69	61	0	74
II	10	7,5	57	63	72	75	78	81	79	75	0	81
III	10	1,8	97	103	111	117	123	129	130	128	126[1]	130
(9) Высота снежного покрова (см)												
I	25	8,0	31	37	36	30	32	23	11	0	0	37
II	10	7,5	25	32	28	26	26	15	7	0	0	32
III	10	1,8	13	21	20	18	21	15	10	0	0	21
(10) Минимальная температура почвы на глубине узла кущения (°C)												
I	25	8,0	−0,4	−1,2	−1,2	−1,2	−1,6	−1,2	−0,4	0,0		−3,5
II	10	7,5	−1,2	−2,0	−2,0	−2,0	−2,7	−2,0	−0,4	0,0		−4,6
III	10	1,8	−2,9	−5,2	−3,1	−3,4	−4,8	−3,8	−0,8	−0,3		−10,9

[Key on following page]

Key:

1. Section
2. Description of grass stand
3. Height
4. Business
5. November
6. December
7. January
8. Depth of freezing of soil (cm)
9. Depth of snow cover (cm)
10. Minimum soil temperature at depth of tillering node (°C)
11. February
12. March
13. April
14. During entire winter

[1] Complete thawing of soil on 10 May

Note: Sections: I--planted on 13 August with interrows of 40 cm; II--planted on 13 August with interrows of 15 cm, but mowed down to a height of 10 cm; III--planted on 2 September with cross sowing

With very poor wintering conditions, by spring about 50 percent of the plants on well developed winter planted areas (with four stalks) survived and only 10 percent of those plants of winter crops with two and seven stalks survived. Thus while with satisfactory conditions the number of surviving plants decreases by 10 percent when the number of stalks decreases from four to two, with very bad wintering conditions this number decreases by 40 percent.

With good wintering conditions the degree of development of winter crops in the autumn is not reflected in the number of surviving plants by the time of renewal of growth in the spring. The number of plants in the spring, regardless of the degree of development, is equal or close to the number of them in the autumn (95-100 percent). The degree of their development is not significant for winter crops under exceptionally difficult winter conditions either since all of the plants die, regardless of their condition in the autumn. But these wintering conditions are very rare on large planted areas (80-100 percent) in the majority of regions where winter crops are cultivated (once every 20-30 years).

As was already pointed out, most frequently a reduction in the productivity of winter crops when they are damaged under the snow takes place as a result of the destruction not of the plants, but of a significant portion of the stalks of wintering plants. There is a fairly close connection ($r = 0.91 \pm 0.03$) between the number of dead stalks and plants that perish under the snow. The equation for the connection between these amounts, which was obtained from data from observations at meteorological stations of the Upper Volga Administration of the Hydrometeorological Service by G. N. Vasenina, has the form

$$y - 1.09x - 0.72. \qquad (4)$$

where y--the percentage of dead stalks and x--the percentage of dead plants. Figure 37 shows the change in the number of stalks in the spring as compared to the autumn on surviving winter rye and winter wheat plants with various wintering conditions. From this drawing it is clear that when wintering conditions are good the number of stalks in the spring on plants that have survived the winter is always greater than it was in the autumn, regardless of the degree of their development in the autumn.

With weak development of the plants in the autumn (with one or two stalks), the number of stalks on the surviving plants in the spring increases because of additional bushing under any wintering conditions. The plants that have stopped growing in the phase of shoots can produce up to 2-3 shoots and under poor wintering conditions when very few plants survive and the grass stand on the planted areas is severely thinned, the bushing in the spring of poorly developed planted areas proceeds more intensively. Since the number of surviving plants is very small in this case (see figure 36), the overall number of surviving stalks on the field turns out to be less when there are poor wintering conditions on planted areas that have developed poorly in the autumn than on well developed areas.

The connections represented in figure 37 were constructed from the results of dependencies between the bushiness of winter crops in the spring and autumn with various wintering conditions. The connection between the bushiness of winter crops in the spring and in the autumn with identical wintering conditions is linear and sufficiently close (the correlation coefficient is $r = 0.80 \div 6$). The evaluation of the degree to which the wintering conditions were unfavorable when the plants perished under the snow was determined in these connections from the amount of time the plants remained under a snow cover of 30 cm and more which was established when the soil was frozen to a depth of less than 50 cm.

The connection between the length of time the plants remain under a deep snow cover with slightly frozen soil and the number of stalks that survive the winter on planted areas that were well developed in the fall is presented in figure 38. This dependency was obtained from the results of five years of observations (from 1950/51 through 1954/55) at 33 meteorological stations and three years of special purpose observations (from 1962 through 1964) at 25 agrometeorological stations. It has also been well confirmed by data from observations of the Gor'kiy Agrometeorological Station over a large number of years: from 1923/24 through 1962/63. It was also confirmed by observations at the Sarapul, Kostroma and Belogorka Agrometeorological Stations over 20 years and also materials from observations during 1970-1975.

As one can see from figure 38, the number of stalks remaining on winter rye plants during the winter is inversely proportional to the length of time a snow cover of 30 cm and more remained on the fields. The coefficient of the correlation between these amounts is $r = 0.82 \pm 0.26$. The regression equation with limit values of from 1 to 16 10-day periods and with P from 20 to 130 percent has the form

$$P = 123.0 - 5.4x \qquad (5)$$

where P--the number of stalks surviving the winter (ratio between number of stalks per 1 square meter at time of spring and autumn examinations of planted areas expressed in percentages), x--the length of time the deep snow cover remained on the field (depth of 30 cm and more). The mean square error of the equation is $S_p \pm 12.8$ percent and the admissable error--(0.676) $\pm$ 15 percent.

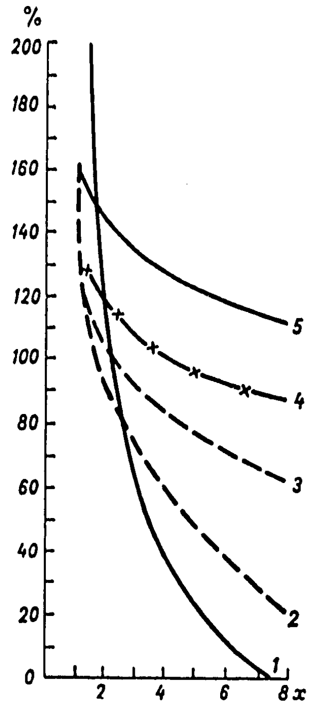

Figure 37. Change in Number of Stalks (%) on Surviving Plants in Spring, Depending on Their Bushing Coefficient in the Autumn x and the Number of 10-Day Periods With a Snow Cover of 30 cm and More and a Depth of Freezing of 50 cm and More.

Key:

Number of 10-day periods: 1) 15 and more (very poor wintering conditions), 2) 13-14 (poor), 3) 11-12 (unsatisfactory), 4) 6-10 (satisfactory), 5) 5 10-day periods and less (good).

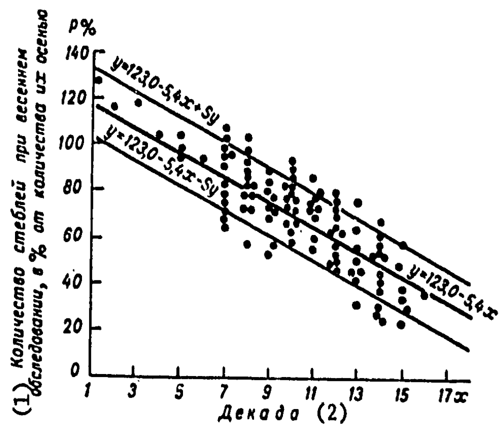

Figure 38. Dependency of the Number of Stalks on Well-Developed Winter Rye in the Spring (% of Their Number in the Autumn) on the Length of Time a Snow Cover of 30 cm and More Remained on the Fields.

Key:

1. Number of stalks at time of spring examination, in % of their number in the autumn.
2. 10-day period.

Knowing the length of time a snow cover of 30 cm or more remained on the field if it was established when the depth of freezing of the soil was 50 cm and less, this equation can be used to calculate the percentage of surviving stalks on planted areas that were well developed in the autumn with a precision of ± 15 percent and a frequency of 80 percent. An error of 20 percent or less of the stalks is ensured in 91 percent of the cases.

On the basis of this dependency, we took the following indicators of agrometeorological conditions for wintering of planted areas when there is perishing under the snow. The conditions are evaluated as good when a snow cover of 30 cm or more which was established when the depth of freezing of the soil was 50 cm or less remains for five 10-day periods; satisfactory--5-8 10-day periods; unsatisfactory--9-11 10-day periods; poor--12-14 10-day periods; and very poor--when this period lasts 15 days and more.

Using these indicators, from the connections indicated in figures 36 and 37, one can determine the quantity (percentage) of surviving plants and stalks when there is perishing under the snow of poorly developed and overgrown planted areas. For example, if the number of 10-day periods with a snow cover of 30 cm and more was 13, the conditions are evaluated as poor: with planted areas that were well developed in the fall an average of 63 percent of the plants survive; on planted areas with an average bushiness in the fall of two stalks--45 percent of the plants; and with six stalks--60 percent of the plants (figure 36). Under these conditions well developed plants retain 90 percent of the stalks (figure 37) and on planted areas with an average bushiness in the autumn of two stalks--100 percent and with six stalks--70 percent.

The expected average number of stalks in the spring per 1 square meter of good plantings in the autumn will be 90 · 63/100 = 57%; on poorly developed plantings--100 · 45/100 = 45%; and on overgrown planted areas--60 · 70/100 = 42%.

As was already noted, the perishing of winter crops on the fields under a snow cover takes place in spots--in low areas, near forest strips and bushes and in small holes. This is explained by the fact that the snow is retained here, the depth and length of time it remains are longer and the soil does not freeze to as great a depth as on the other sections of the field.

Many agrometeorologists [22, 23, 43] have engaged in research of the spatial variability of the depth of the snow cover on the fields. It was established that the less the average depth of the snow throughout the field, the greater the irregularity of the coverage of winter crops by the snow. According to data from an overall snow survey on fields with winter crops which was especially conducted under the leadership of A. A. Okushko at the Nemchinovka (Moscow Oblast) and Buzuluk (Orenburgskaya Oblast) agrometeorological stations, it turned out that when the average depth of the snow cover is great, the areas of fields covered by more than 30 cm of snow are equal even in various climatic zones (Table 40). When the snow cover is shallow its irregularity is less in the west than in the east of the USSR European territory.

The coefficient of the variation of the depth of the snow cover on fields planted in winter crops ($C = \sigma/M \cdot 100$ percent, where M--the average depth of the snow cover, σ--the average square variation of its depth) in the nonchernozem zone of the USSR European territory, in the southern part of Western Siberia and in the northern and central oblasts of Kazakhstan reaches the greatest amounts when the average value for the depth of the snow on the field is small. Thus with an average depth according to the snow survey of about 5 cm, it is equal to $\pm$ (55 ÷ 75) percent. In the nonchernozem zone (Torzhok station) with the same average depth it turned out to be $\pm$ 50 percent and in the west (Minsk station) where the snow falls at a higher air temperature and lies on the fields more uniformly, $\pm$ (30 ÷ 40) percent. With an increase in the depth of the snow cover the coefficient of variation decreases and varies within a small range in the various zones. With an average depth of 10 cm in the central Volga area it was ± 30 percent, Oboyan'--± 41 percent, Minsk--± 49 percent, Torzhok--± 40 percent and with a 15 cm snow cover it decreased in Oboyan' to ± 17 percent, Minsk--226 percent and in Torzhok--to ± 10 percent.

Table 40. Number of Measurements (%) With Various Depths of Snow Cover on Fields with Winter Crops in 1965

Станция (1)	Дата снегосъемки (2)	Общее число промеров (3)	Средняя высота снежного покрова (см) (4)	(5) Высота снежного покрова (см)								
				0	1–3	4–6	7–10	11–15	16–20	21–30	31–50	>50
(6) Немчиновка	21 I	816	34,8	0	0	0	0	0	2	27	69	2
	28 III	1136	9,8	28	6	13	12	16	12	9	4	0
(7) Бузулук	17 II	1650	33,0	0	0	0	1	3	8	28	53	7

Key:
1. Station
2. Date of snow survey
3. Overall number of measurements
4. Average depth of snow cover (cm)
5. Depth of snow cover (cm)
6. Nemchinovka
7. Buzuluk

The area of the field (percentage) with a given depth of the snow cover is determined by calculating the number of measurements with this depth during the snow survey. The depth of each measurement can be taken as an indicator of the snow cover on 1 percent of the area of the field.

In regions where a deep snow cover remains for a long time and where winter crops suffer from damage under the snow, it is important to know the area on which its depth is 30 cm and more. Therefore from the results of snow surveys on fields with winter crops from 1934/35 through 1964/65 at stations located in the upper Volga area and in the northwestern part of the country's European territory, a probability curve was obtained for measurements with a depth of the snow cover of 30 cm and more when there were various average depths according to the snow survey (figure 39). A snow cover with a depth of 30 cm and more lies on the entire area of the field only when its average depth according to the snow survey is 45 cm and when the cover is 16 cm its depth over the entire field is less than 30 cm. When the average depth from the snow survey is 30 cm, the winter crops on 40 percent of the area of the field are under a snow cover of 30 cm and more. This distribution of the snow cover throughout the fields is taken into account when determining the area of the field where there will be possible thinning of the plants and when comparing predictions of perishing of winter crops under the snow.

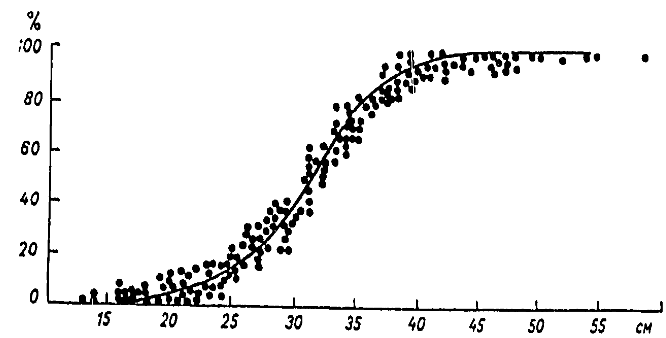

Figure 39. Change in Area of Field (%) With Depth of Snow Cover of 30 cm and More With Various Average Depths of It (cm) From Snow Survey.

The condition of winter crops in regions with a deep snow cover, however, is influenced not only by the duration of the period when the deep snow cover is on the field, but also by other factors. As was already noted, they include primarily the air temperature, the depth of freezing of the soil and the temperature of the soil at the depth of the tillering node, which constitute a comprehensive indicator of the effects of all basic agro-meteorological factors and the depths of the grass stand of the winter crops themselves.

During years with very abnormally air temperatures (1941/42, 1947/48, 1968/69 and others) during the period when the snow cover is 30 cm and more the percentage of surviving stalks turns out to be greater than in years when there are abnormally positive air temperatures (1937/38, 1943/44, 1945/46 and others). This is explained by the fact that in these years the temperature in the snow cover at the depth of the grass stand of the planted areas also remains within limits that are lower than usual.

The influence of the air temperature on the condition of the planted areas during wintering is taken into account by introducing into the results obtained from the formula P = 123.0 - 5.4x (or figure 38) the correction Δt (percentage) whose amount is determined from table 41. The value of the correction Δt is obtained empirically from the formula $\Delta t = C\sqrt{\Sigma t}$ (where C--coefficient, t--average daily air temperature) on the following basis:

Table 41. Correction Δt (%) to the Quantity of Surviving Stalks with Various Values of the Duration of the Period with a Snow Cover n of 30 cm and More and a Total Air Temperature Σt for This Period.

(2) Число декад n	(1) Σt за период n (°C)																		
	−100	−200	−300	−400	−500	−600	−700	−800	−900	−1000	−1100	−1200	−1300	−1400	−1500	−1600	−1700	−1800	−1900
1	0	3	7	12	15	19	23	28											
2	−2	0	3	8	13	17	20	25	30										
3	−4	−3	0	4	9	14	18	22	27	32									
4	−6	−6	−3	0	4	10	16	20	24	29	33								
5	−7	−8	−7	−4	0	5	10	17	21	30	30	35							
6	−8	−10	−10	−8	−4	0	5	11	18	22	26	32	36						
7	9	−11	−12	−12	−9	−5	0	6	12	19	23	28	32	37					
8	−10	−13	−14	−14	−13	−10	−5	0	6	13	20	25	29	33	39				
9		−14	−15	−16	−15	−14	−10	−6	0	6	13	21	25	30	35	40			
10			−17	−18	−18	−17	−16	−11	−6	0	6	14	22	26	31	36	41		
11				−20	−20	−19	−18	−17	−12	−6	0	7	14	22	27	32	37	42	
12					−20	−22	−20	−20	−18	−13	−6	0	7	15	22	28	33	38	44
13						−24	−23	−22	−21	−19	−13	−7	0	7	16	24	29	34	40
14							−26	−25	24	−22	−20	−14	−7	0	8	16	25	29	35
15								−28	−27	−26	−23	−21	−14	−7	0	8	16	25	31
16									−30	−29	−26	−25	−22	−15	−8	0	8	17	26

Key:

1. Σt for period n (°C)
2. Number of 10-day periods n

1) the effect of the air temperature when the crops are perishing under the snow is reflected in the plants throughout the entire period when the snow cover is 30 cm and more and therefore the value of the air temperature when calculating the correction is expressed by an integral amount--the square root of the sum of it for the entire period;

2) the corre[illegible]n, depending on the absolute value of the sum of temperatures. changes the si[illegible] since with very warm weather--a small sum of temperatures--the processes of perishing under the snow intensify and with very cold weather--a large sum--conversely, they are retarded. Therefore the correction is taken with the coefficient c whose value is calculated from the equation: $C = \sin x$ where x--the sum of temperatures during the period when the snow cover is 30 cm and more. The amount C lies within the limits from -1 to +1;

3) the sum of temperatures depends not only on the average daily air temperature, but also on the duration of the period with a snow cover of 30 cm and more. Therefore Δt is calculated and given in 41 individually for various durations of the period (from 10 to 160 days) with a snow cover of 30 cm and more.

As one can see from the figures in table 41, during warm winters (Σt = -500 - -900°C), the number of stalks of winter crops surviving after wintering turns out to be 20-30 percent less than during severe winters (Σt = -1500 - -1900°C).

The minimum temperature of the soil at the depth of the tillering nodes of winter crops is determined by a complex of agrometeorological factors [13, 22, 43]. Its value is therefore an integral indicator of agrometeorological conditions for the wintering of winter crops both with a shallow and with a deep snow cover. It was shown earlier that the condition of the vegetative cones of the plants during the winter changes depending on the temperature of the soil at the depth of the tillering node. When the soil temperature under a deep snow cover is above -5°C for a long period of time and especially when the temperature is close to 0°C, the cone grows without differentiation, as a result of which in sum of the shoots that were more developed in the autumn no spike is formed at all or else it is shortened and has a small number of spikelets and kernels. The majority of the shoots die off in the spring and the first half of the summer (table 42). A certain number of plants also die completely.

A statistical analysis of the results of many years of observations at meteorological stations of the condition of winter crops and agrometeorological conditions for their wintering have made it possible to establish quantitative dependencies between the thinning of planted areas and the crops are damaged under snow and the minimum soil temperature at the depth of the tillering node, taking into account the condition of the plants at the end of their vegetation in the autumn. The regression equation for winter rye (Vyatka, Vyatka uluchshennaya and Vyatka 2 strains) have the form:

Table 42. Change in Number of Stalks of Vyatka Strain of Winter Rye, Depending on the Duration of the Period with a Snow Cover of 30 cm or More

	Год (1)	(2) Количество дней с h > 30 см	(3) Количество стеблей на 1 м²		(6) на фазу	
			осенью (4)	весной (5)	колошение (7)	молочная спелость (8)
(9) Шуя	1964/65	5	1281/100	1267/99	1190/93	1120/87
	1965/66	7	903/100	630/70	540/60	540/60
	1967/68	12	1848/100	1127/61	392/21	392/21
(10) Сарапул	1964/65	10	1043/100	1113/106	700/67	658/63
	1967/68	14	2072/100	1470/71	392/19	388/19
	1965/66	8	665/100	642/96	476/73	413/62
(11) Лух	1967/68	12	1334/100	1526/83	588/32	5[illegible]2/29
(12) Можга	1967/68	15	1008/100	616/61	343/34	343/34
(13) Приволжск	1967/68	8	1022/100	1127/110	1050/103	1029/101
(14) Селты	1964/65	12	1080/100	1240/115	560/52	560/52
	1967/68	13	1560/100	1102/72	532/34	532/34
(15) Калуга	1965/66	5	329/100	476/145	532/162	350/108
(16) Мосальск	1965/66	4	360/100	408/113	—	312/98

[Key on following page]

Key:

1. Year
2. Number of 10-day periods with snow cover of 30 cm or more
3. Number of stalks per M^2
4. In the autumn
5. In the spring
6. In the phase
7. Tillering
8. Milky ripeness
9. Shuya
10. Sarapul
11. Lukh
12. Mozhga
13. Privolzhsk
14. Selty
15. Kaluga
16. Mosal'sk

Note: The number of stalks per 1 M^2 is given in the numerator in absolute units; in the demoninator in percentages.

$$u = 59.07 + 6.82t_3 + 0.22t_3^2 + 5.14k - 0.40k^2, \qquad (6)$$

where u--thinness of areas planted in the spring (percentage), t_3--minimum temperature of the soil at the depth of the tillering node during the period with a deep snow cover of 30 cm and more; k--average coefficient of tillering of the plants in the autumn for the entire field. The correlation ratio of the connection is n = 0.75 and an equation error of 15 percent or less is guaranteed in 94 percent of the cases. The equation is effective when t_3 is greater than -10°C and k = 1 ÷ 4. When there are more than four shoots the sine of the regression coefficient at k reverses--the thinning increases with an increase in the bushiness of the planted areas.

From the equation it is clear that when damage is caused to the plants under the snow the effects of the soil temperature on the plants is reflected, as with freezing, by a parabolic dependency, but with a reverse sine--the higher the temperature, the greater the thinning of the planted areas in the spring.

The minimum soil temperature at the depth of the tillering node is closely related to the depths of freezing of the soil. The coefficient of the correlation (r) between these elements, calculated from data from numerous measurements at meteorological stations, is equal to 0.80-0.90. Moreover, with an increase in the depth of the snow cover, the effect of the air temperature on the soil temperature decreases and the depth of freezing of the soil increases.

The dependency between the absolute minimum soil temperature at the depth of the tillering nodes of winter crops and the depth of freezing of the soil during the 10-day period of the formation of a deep snow cover (depths of 30 cm and more) on the fields, according to data of meteorological stations located in the nonchernozem zone of the USSR European territory during the winter of 1965/66 is shown in figure 40.

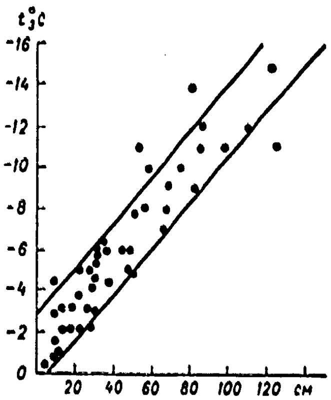

Figure 40. Dependency Between Absolute Minimum Soil Temperature During Winter at Depth of Tillering Node t_3 (°C) and Depth of Freezing of Soil (cm) During 10 Days when Snow Cover Reaches Depth of 30 cm or More.

As one can see from the drawing, with shallow freezing of the soil (less than 50cm) the absolute minimum temperature of the soil at the depth of the tillering node throughout the entire winter does not drop below -8.5°C and in the majority of the cases it was within the limits of 0 - -6°C). With this soil temperature the winter crops could not freeze. But the thinning of winter crops was very great that winter (more than 50 percent).

The seasonal course of the minimum soil temperature at the depth of the tillering node has certain patterns. An investigation of it from the data of 40 meteorological stations from 1949/50 through 1969/70 and also a number of agrometerological stations (Gor'kiy, Nemchinovka, Belogorka, Chishmy and others from 1939/40 through 1969/70) showed that the minimum soil temperatures during the first half of the winter decreases and, beginning with the second half of February, gradually increases. This pattern was also confirmed by the results of observations of a mass network of meteorological stations from 1970 through 1976.

A correlational analysis of the results of many years of observations made it possible for us to establish that the absolute minimum temperature of the soil at a depth of 3 cm during the winter in the country's European territory in 97 percent of the cases is observed before 20 February and only in 3 percent of the cases is it 2-3°C lower after this date. The coefficient of the correlation between the absolute minimum temperature of the soil at a depth of 3 cm during the winter and its value on 1 January turned out to be 0.68; on 1 February--0.73; and on 20 February--0.90.

In regions where the depth of the snow cover is greater than 30 cm the daily and seasonal course of the soil temperature at the depth of the tillering node evens out. The soil temperature during the period when the snow cover is 30 cm and more and was formed on the fields with a shallow (less than 50 cm) depth of freezing of the soil ranges within the limits of ± 3°C. Its absolute minimum during the winter is usually not dangerous for winter crops at the beginning of the winter, before the establishment of a deep snow cover on the fields. Thawing of the soil takes place before the disappearance of the snow cover in the spring and sometimes even in the winter. This intensifies the processes of perishing of the plants under the snow since the temperature in the upper layer of soil under the snow remains equal to or somewhat above 0°C for a long period.

When utilizing information about the minimum temperature of the soil at the depth of the tillering node, it is necessary to take into account its great spatial variability. The degree of this variability is determined primarily by the irregularity of the distribution of the grass stand of winter crops on the fields, the moisture, the depth of freezing of the soil and especially the depth of the snow cover.

The coefficient of the variation C_{t_3}, according to data from our observations at the Yelshanka (Orenburgskaya Oblast) and Nansen (Saratovskaya Oblast) agrometeorological stations in 1951/54, when there was no snow cover at all, amounted to 12-14 percent. When a snow cover less than 10 cm deep was established on fields with winter crops, C_{t_3} considerably increased (to 20-40 percent) but when the snow cover became deeper (to 20 cm and more) it again decreased to 12-14 percent [15, 16].

The amount of the mean square deviation σ of the minimum soil temperature, calculated from the results of its measurement at 30 points on one field, according to data of the Dobele, Minsk, Glukhov and Chishmy agrometeorological stations, depending on the depth of the snow cover and the values of t_3, ranged within the limits of 0.6-3.0°C. When the snow cover was more than 10 cm, σ_{t_3}, according to the data of V. F. Nikitina (Institute of Experimental Meteorology), amounted to 1.5°C. Such large values of σ of the minimum soil temperature at the depth of the tillering node indicate the great spatial variability of this element even on one field and the need to take into account the value of this variability when determining the expected area on which winter crops will have perished in the spring.

QUANTITATIVE EVALUATION OF AGROMETEOROLOGICAL CONDITIONS OF WINTERING AND THE CONDITION OF WINTER CROPS IN REGIONS WITH A DEEP SNOW COVER

On the basis of quantative links between the condition of winter crops in the spring and the main agrometeorological factors (the duration of the period when the snow cover on the fields is 30 cm deep and more with slightly freezing of the soil--50 cm and less--and a minimum soil temperature at a depth of 3 cm during this period t_3) we obtained a quantative evaluation of agrometeorological conditions whereby perishing of winter crops takes place under the snow (Table 43). The conditions are evaluated as very poor if a deep snow cover of 30 cm or more is established on slightly frozen soil (50 cm and less) and remains on the fields for 150 days or more with t_3 for that period being 0 - -1°C. Good conditions for the wintering of planted areas are created when these indicators are within the limits of 1-5 10-day periods and -7 - -8°C, respectively. Very good wintering conditions for winter rye and winter wheat in the nonchernozem zone's European territory exist when the snow cover does not exceed 30 cm and the minimum soil temperature at a depth of 3 cm during winter remains within the limits of -8 - -10°C [22].

Table 43. Evaluation of Agrometeorological Conditions Whereby Perishing of Winter Crops Under Snow Takes Place

Условия (1)	Число декад с $h \geq 30$ см (2)	Средняя минимальная температура почвы t_3 за период с $h \geq 30$ см (3)	(4) Средние по полю	
			(5) Изреженность посевов весной (%)	(6) Количество стеблей весной (% от их количества осенью)
(7) Очень плохие, 1 балл	≥15	0, −1	>50	≤40
(8) Плохие, 2 балла	11—14	−2, −4	30—50	40—60
(9) Удовлетворительные, 3 балла	6—10	−5, −6	10—30	60—110
(10) Хорошие, 4 балла	1—5	−7, −8	5—10	110—130
(11) Очень хорошие, 5 баллов	0	−9, −10	0—5	>130

Key:
1. Conditions
2. Number of 10-day periods with h of 30 cm or more
3. Average minimum soil temperature t_3 during period with h of 30 cm or more
4. Average for field
5. Thinning of planted areas in spring (%)
6. Number of stalks in spring (% of number in autumn)
7. Very porr, 1 point
8. Poor, 2 points
9. Satisfacotyr, 3 points
10. Good, 4 points
11. Very good, 5 points

The relation between the bushiness of winter crops in the spring and autumn with identical wintering conditions is directly linear and sufficiently close [17], the correlation coefficient being $r = 0.88 \div 0.96$.

A certain condition of areas planted in winter crops in the spring whose quantitative indicators are given in tables 43 and 44 corresponds to the point evaluation of the agrometeorological conditions for wintering. The latter have been established taking into account the effects of winter damage on the plants and the reduction in productivity of winter crops depending on their intensiveness [39, 40]. In the nonchernozem zone the dependency between the productivity of winter crops and the thinning of shoots by the beginning of spring is expressed by the coefficient correlation 0.75 ± 0.07 [6].

Table 44. Dependency Between Average Number of Shoots (Average Bushiness) in Spring (10 Days After the Renewal of Growth) y and Autumn x in Winter Crops with Various Wintering Conditions

Оценка (баллы) (1)	Условия зимовки (2)	Число декад с $h > 30$ см (3)	Уравнение (4)	Средняя квадратическая ошибка уравнения E_y (5)	Коэффициент корреляции r (6)
4	Хорошие(7)	1—5	$y = 0,99x + 1,02$ (7)	0,54	0,92
3	Удовлетворительные (8)	6—10	$y = 0,90x + 0,40$ (8)	0,35	0,96
2	Плохие(9)	11—12	$y = 0,52x + 1,02$ (9)	0,32	0,88
		13—14	$y = 0,07x + 1,66$ (10)	0,30	0,90
1	Очень плохие(10)	≥15	$y = -0,47x + 3,67$ (11)	0,21	−0,94

Key:

1. Evaluation (points)
2. Wintering conditions
3. Number of 10-day periods with h 30 cm or more
4. Equation
5. Mean square error of equation E_y
6. Coefficient of correlation r
7. Good
8. Satisfactory
9. Poor
10. Very poor

The relation between the productivity of the Vyatka and Vyatka 2 strains of winter rye and the Mironovskaya 808 and PPG-186 strains of winter wheat, on the one hand, and a number of surviving stalks in the spring as compared to the autumn, which was considered in the works [17, 22], turned out to be sufficiently close (r = 0.80 ÷ 0.86). The number of stalks on the 10th day after the renewal of spring growth characterizes not only the condition of the planted areas in the spring, but also the wintering conditions for the plants. It takes into account the degree of winter damage and possible consequences for the remaining plants in the subsequent period of their life. The number of stalks in the spring as compared to the autumn can increase under good conditions (as a result of spring bushiness), according to our data, by 30-50 percent with plants that were well developed in the autumn (3-4 shoots) and by 100-200 percent in weakly developed plants (1-2 shoots). With poor wintering conditions, especially with damage to winter crops as a result of perishing under the snow, a number of stalks in the spring on an average for the field turns out to be considerably less than it was in the autumn [22].

In severely thinned planted areas as a result of perishing of the plants under the snow during the winter the consequences are manifested to a greater degree. The reduction of the productivity of winter crops in the nonchernozem zone during warm winters with little snow is explained primarily by the death from perishing under the snow of a large quantity of stalks which were formed in the autumn and are several times more productive than stalks appear in the spring.

On the fields of the Scientific Research Institute of Agriculture of Central Regions of the Nonchernozem Zone, with a high level of agrotechnology, the productivity of PPG-186 and PPG-529 winter wheat ranged from 26 to 33 quintals per hectare when the number of live stalks in the spring amounted to 65-93 percent of the number in the autumn and from 40 to 45 quintals per hectare when in the spring the number of stalks was 139 and 154 percent of the number in the autumn.

Many years of observations at the Royka Agrometeorological Station (Gor'kiy) from 1933 through 1963 showed that the productivity of Vyatka winter rye and Ul'yanovka winter wheat, with identical bushiness in the autumn, has a directly linear relation to the quantity of stalks that survive after wintering. The coefficient of the correlation between these amounts with weak development of the plants in the autumn (in the phases of shoots and the third leaf) turned out to be 0.88 ± 0.02 and with well developed plants (3-4 shoots), 0.80 ± 0.03. This made it possible for us, with data from observations of the mass network of meteorological stations (1962-1970) to calculate on an electronic computer the dependency between the productivity of winter grain crops and the number of stalks on the 10th day after the renewal of growth in the spring. The supplies of moisture in the soil in the spring in the nonchernozem zone, as a rule, are good and therefore they have not been introduced into the equations.

Analytically, this dependency is reflected by the equations:

1) with winter rye plants of the Vyatka and Vyatka 2 strains that are weakly developed in the autumn

$$y = 0.108P - 1.3, \qquad (12)$$

where y--productivity (quintals per hectare), P--relation between quantity of stalks in the spring and quantity of them in the fall on the average for the field multiplied by 100; $r = 0.80 \pm 0.03$; n--the number of instances, exactly 55. The mean square error of the equation $E_y = \pm 1.58$ quintals per hectare; the amount of the coefficient at P--quintals per hectare;

2) with bushed plantings of winter rye

$$y = 0.063kP, \tag{13}$$

k--average coefficient of bushiness of plants in the autumn; $n = 150$, $r = 0.84 \pm 0.04$; $E_y = \pm 2.3$ quintals per hectare.

For winter wheat of the Mironovskaya 808 strain this relation is expressed by the equations:

1) for planted areas that have not bushed out in the autumn

$$y = 0.12P + 2.00; \tag{14}$$

$n = 65$, $r = 0.89 \pm 0.02$, $E_y = \pm 2.1$ quintals per hectare;

2) with planted areas that have bushed out in the autumn

$$y = 0.0866kP + 1.02; \tag{15}$$

$n = 180$, $r = 0.86 \pm 0.01$, $E_y = 22.5$ quintals per hectare.

The conventional symbols are the same. The equations are valid when k is equal to or less than 6 and P--from 30 to 200 percent.

The average number of stalks in the spring is determined by using these equations from data of autumn and spring examinations of planting areas and the equation

$$P = \frac{k_B}{k_o} \left(100 - \frac{uS_B}{100}\right), \tag{16}$$

where k_B--the coefficient of bushing of winter crops in the spring, k_o--the same in the autumn, u--the average thinning of winter crops from four repetitions (percentage) from data of a spring examination of the planted areas, S_B--the area of the field (percentage) with this amount of thinning. These amounts can also be calculated from the dependencies presented above (figures 36, 37, 38).

From the results of analagous calculations made for various values of bushiness of plants in the autumn and wintering conditions, quantitative indicators were obtained for evaluating the condition of winter crops in the spring on specific fields (table 45). Here one assumed, as was already indicated, a certain ratio between the point evaluation of the condition of the planted areas and the possible productivity of the winter crops with optimal supplies of moisture in the 1-meter layer of the soil in the spring and the modern level of agrotechnology (table 46).

Table 45. Quantitative Indicators of the Evaluation of the Conditions (Points) of Areas Planted in Winter Rye of the Vyatka Strain (I) and Winter Wheat of the Mironovskaya 808 Strain (II) in the Spring on Specific Fields

Площадь $S_в$ (%) с погибшими посевами (1)	Среднее по полю количество стеблей весной P (% от их осеннего количества) (2)	(3) Коэффициент кустистости растений осенью (число побегов)											
		1		2		3		4		5		6	
		I	II	I	II	I	II	I	II	I	II	I	II
>50	≤50	1	1	2	1	2	2	≤3	≤3	≤3	≤3	≤3	≤3
30—50	≤100	2	1	3	3	3	3	4	4	5	5	4	5
<30	≤150	2	2	3	3	4	4	5	4	5	5	4	5
0	≥100	3	3	4	3	5	4	5	5	5	5	4	4

Key:
1. Area S_B with dead plants
2. Average number of stalks on the field in the spring (% of number in autumn)
3. Coefficient of bushiness of plants in autumn (number of shoots)

Table 46. Relation Between Point Evaluation of Condition of Winter Crops in the Spring and Their Productivity (Quintals per Hectare)

Культура (1)	(2) Оценка состояния (балл)				
	1	2	3	4	5
(3) Озимая пшеница	< 8	8—12	13—25	26—32	>32
(4) Озимая рожь	< 6	6—10	11—17	18—25	>25

Key:
1. Crop
2. Evaluation of condition (points)
3. Winter wheat
4. Winter Rye

By utilizing tables 45 and 46, one can give an objective evaluation of the condition of areas planted in winter crops in specific fields in the autumn and spring. In the same way one can evaluate the condition of winter crops on specific fields when making predictions about the wintering of the planted areas.

An evaluation of the condition of winter crops in the winter when they are under a snow cover can also be given from the results of an analysis of the condition of plant samples taken from the fields at various periods of wintering by the method of biological control or by continuing their growth in soil monoliths.

An analysis of the results of continuing the growth of specimens of winter crop plants by the monolith method at meteorological stations during the past 20 years has made it possible to establish the precision of the determination by this method. The results of continuing the growth of plants after each time when specimens are taken in the winter (25 December, 25 January and 23 February) were compared with one another and with the results of a spring examination--the thinning of the planted areas after wintering. It turned out that in years with favorable wintering conditions the thinning of the planted areas according to the results obtained from continuing the growth of samples taken from the fields at various times was close to 0 and did not exceed 10-15 percent at the time of the spring examination of the winter crops.

In the nonchernozem zone during years when winter crops were damaged under the snow the average percentage of thinning of planted areas, according to the results of continuing the growth of samples taken from the fields in December and January, was also small (0-10). The thinning of these planted areas increased subsequently, especially after the disappearance of the snow cover in the spring (in April). This is clearly confirmed by data for 1965/66 in the nonchernozem zone when the death of winter crops from perishing under the snow was great during the period from 1946 through 1975 (table 47). The snow cover was established in 1965 on sod or slightly frozen soil as early as November and its depth for 10-14 10-day periods exceeded 30 cm (table 48). The minimum temperature of the soil at the depth of the tillering node remained throughout almost the entire winter between 0 and -2°C and its absolute minimum on the majority of the territory did not drop below -8°C. The plants were severely exhausted in the winter, the vegetative cones of the main shoots were very elongated (up to 1.5 mm instead of 0.30 mm according to the norm). At the end of the winter and in the period of snow thawing a considerable number of plants, especially leaves and shoots, were damaged by fungal diseases and died (table 49). Because of this, during the period from 1960 through 1975 the productivity of winter rye turned out to be the lowest in 1966.

Table 47. Average Thinning of Vyatka Winter Rye According to Results of Continuation of Growth and Spring Examination of Planted in 1965/66 (%)

Станция (1)	(2) Количество декад с высотой снежного покрова h > 30 см	(3) Глубина промерзания почвы (см) при высоте снежного покрова h > 30 см	(4) Кустистость посевов осенью	(5) Средняя изреженность (%) из четырех проб при: (6) отращивании 25 XII	25 I	23 II	15 III—10 V	(7) весеннем обследовании	Причина гибели растений (8)
(9) Макарьев	12	28	1,0	0	18	39	48	50	Выпревание (27)
(10) Солигалич	10	10	2,0	0	6	6	—	31	То же (28)
(11) Кострома	9	31	1,5	12	5	13	28	29	„
(12) Шахунья	9	67	1,5	1	0	3	4	6	„
(13) Шарья	10	50	1,5	7	12	11	41	40	Выпревание (27)
(14) Ройка	9	27	2,1	2	2	2	7	10	То же (28)
(15) Курмыш	3	125	2,0	4	5	8	9	12	Вымерзание (29)
(16) Починки	4	120	2,9	0	0	0	0	1	
(17) Арзамас	2	98	1,4	0	1	0	1	2	
(18) Лукоянов	5	82	1,9	0	0	0	0	2	
(19) Уни	13	52	1,7	0	7	17	—	29	Выпревание (27)
(20) Кумены	13	50	1,5	0	28	20	—	36	То же (28)
(21) Мураши	13	58	1,0	0	18	17	—	70	„
(22) Воткинск	12	48	1,0	0	50	66	—	75	„
(23) Сарапул	10	23	2,5	3	6	6	12	24	„
(24) Ижевск	11	30	2,5	0	1	1	—	35	„
(25) Волхов (1966/67 г.)	14	10	2,7	0	0	0	28	26	„
(26) Йошкар-Ола (1966/67 г.)	10	24	3,4	4	12	17	15	27	„

[Key on following page]

Key:

1. Station
2. Number of 10-day periods with depth of snow cover h 30 cm or less
3. Depth of freezing of soil (cm) with depth of snow cover h 30 cm or less
4. Bushiness of planted area in fall
5. Average thinning (%) of four samples with:
6. Continuation of growth
7. Spring examination
8. Cause of death of plants
9. Makar'yev
10. Soligalich
11. Kostroma
12. Shakhun'ya
13. Shar'ya
14. Royka
15. Kurmysh
16. Pchinki
17. Arzamas
18. Lukoyanov
19. Uni
20. Kumeny
21. Murashi
22. Votkinsk
23. Sarapul
24. Izhevsk
25. Volkhov (1966/67)
26. Yoshkar-Ola (1966/67)
27. Perishing under snow
28. The same
29. Freezing

The thinning of winter planted areas changed throughout the winter in a similar way during other years that were unfavorable for the wintering of plants (1957/58, 1967/68, 1968/69, 1971/72, 1973/74). In regions where the planted areas suffer from damage under the snow, the results of continuing the growth of plant specimens taken from the fields in December and January certainly do not characterize the condition of winter crops. The coefficient of the correlation r between the results of the spring examination and the continued growth of plant samples in December is equal to 0.12 and in January--0.25. The continuation of the growth of plants taken from fields on 23 February can be used for evaluating the condition of winter crops both on this date and in the spring ($r = 0.98 \pm 0.01$). But it must be taken into account that the thinning in the spring is frequently significantly greater than in February (Uni, Murashi, Sarapul, Izhevsk, 1965/66, see table 47).

Table 48. Description of Conditions for Wintering of Winter Crops in 1965/66

Область (1)	Станция (2)	Число декад с высотой снежного покрова $h \geq 30$ см (3)	(4) Максимальная высота снежного покрова (см) (5)	(4) Максимальная глубина промерзания почвы (см) (6)	(7) Минимальная за зиму температура на глубине узла кущения
(8) Архангельская	Емецк (14)	11	81	44	—6,0
(9) Вологодская	Вологда-Молочная (15)	9	77	33	—4,5
	Бабаево (16)	14	106	35	—3,0
(10) Ивановская	Шуя (17)	7	76	37	—5,0
	Юрьевец (18)	9	72	57	—7,9
	Иваново (19)	7	75	57	—1,9
(11) Костромская	Пыщуг (20)	12	83	30	—1,0
	Макарьев (21)	12	90	28	—3,0
	Галич (22)	9	108	52	—4,9
	Солигалич (23)	10	98	20	—4,5
(12) Горьковская	Ройка (24)	9	76	34	—4,1
	Ветлуга (25)	11	105	45	—4,5
	Красные Баки (26)	8	94	30	—6,0
(13) Кировская	Котельнич (27)	9	82	93	—5,9
	Даровское (28)	14	87	57	—10,0
	Нагорск (29)	13	72	66	—9,1
	Уржум (30)	12	89	81	—8,3

Key:
1. Oblast
2. Station
3. Number of 10-day periods with snow cover 30 and more cm deep
4. Maximum
5. Depth of snow cover (cm)
6. Depth of freezing of soil
7. Minimum temperature in winter at depth of tillering node
8. Arkhangel'skaya
9. Vologodskaya
10. Ivanovskaya
11. Kostromskaya
12. Gor'kovskaya
13. Kirovskaya
14. Yemetsk
15. Vologda-Molochnaya
16. Babayevo
17. Shuya
18. Yur'yevets
19. Ivanovo
20. Pyshug
21. Makar'yev
22. Galich
23. Soligalich
24. Royka
25. Vetluga
26. Krasnyye Baki
27. Kotel'nich
28. Darovskoye
29. Nagorsk
30. Urzhum

Table 49. Description of Density of Plant Stand of Winter Crops in 1965/66

Область (1)	Станция (2)	(3) Количество стеблей на 1 м²: (4) осенью	(5) весной	(6) на дату наступления фазы: (7) выход в трубку	(8) колошение	(9) молочная спелость	(10) Количество стеблей (%) в весенне-летний период по сравнению с осенью: (5) весной	(11) на дату наступления фазы: (7) выход в трубку	(8) колошение	(9) молочная спелость
(12) Архангельская	Емецк (18)	1238	1120	1120	504	532	90	90	41	44
(13) Вологодская	Вологда-Молочная (19)	924	469	581	581	462	51	63	63	50
	Бабаево (20)	973	280	280	343	343	29	29	35	35
(14) Ивановская	Шуя (21)	903	630	630	540	540	70	70	60	60
	Юрьевец (22)	1056	1224	1224	1188	1188	112	112	111	111
	Иваново (23)	889	690	690	472	497	78	78	53	56
(15) Костромская	Пыщуг (24)	875	475	357	210	329	54	75	24	38
	Макарьев (25)	434	266	266	273	245	61	61	63	57
	Галич (26)	1407	595	427	406	420	42	30	29	30
	Солигалич (27)	658	301	420	343	378	46	64	52	57
(16) Горьковская	Ройка (28)	1120	695	695	490	574	62	62	44	51
	Ветлуга (29)	917	924	903	812	805	101	99	89	88
	Красные Баки (30)	742	574	574	574	574	77	77	77	77
(17) Кировская	Котельнич (31)	245	182	252	210	210	74	102	86	86
	Даровское (32)	1071	623	644	336	375	58	60	31	35
	Нагорск (33)	798	602	567	543	543	76	71	68	68
	Уржум (34)	973	889	803	665	—	91	82	68	—

[Key on following page]

Key:
1. Oblast
2. Station
3. Number of stalks per 1 M^2
4. Autumn
5. Spring
6. On date of entering phase:
7. Stem extension
8. Heading
9. Milky ripeness
10. Number of stalks (%) in spring and summer period as compared to autumn
11. On date of entering phase:
12. Arkhangel'skaya
13. Vologodskaya
14. Ivanovskaya
15. Kostromskaya
16. Gor'kovskaya
17. Kirovskaya
18. Yemetsk
19. Vologda-Molochnaya
20. Babayevo
21. Shuya
22. Yur'yevets
23. Ivanovo
24. Pyshug
25. Makar'yev
26. Galich
27. Soligalich
28. Royka
29. Vetluga
30. Krasnyye Baki
31. Kotel'nich
32. Darovskoye
33. Nagorsk
34. Urzhum

The condition of the plantings in the winter, just as in the fall and spring, should be evaluated taking into account not only the thinning of the plants in the specimens, but also the sizes of the areas on which this has taken place [17, 18]. The latter is determined from the degree to which the fields are covered by snow of various depths. In regions that have been subjected to perishing of winter crops under the snow, one takes into account the area of the field (percentage) with a deep snow cover of 30 cm and more which was established with slight freezing of the soil (see figure 39). Table 50 gives quantative indicators of the condition of winter crops from the results of continuing the growth of specimens of plants in February and the area of thinning, taking into account the dependency of the productivity of winter crops on the condition of planted areas in the spring (from equations introduced above).

Table 50. Quantitative Indicators for Evaluating (Points) Condition of Winter Crops When Damaged Under Snow From Results of Continuation of Growth of Specimens Taken on 23 February

(1) Площадь с изреженностью (% от всего поля)	(2) Средняя изреженность посевов из четырех проб (%)				
	0	1–10	11–30	31–50	> 50
0	5	—	—	—	—
≤ 30	—	5	4	3	2
31–50	—	4	3	2	1
≥ 50	—	3	2	2	1

Key:
1. Area with thinning (% of total field)
2. Average thinning of planted areas from 4 specimens

Even with great thinning of the planted areas (31-50 percent) in February the evaluation of the condition can be good if the area with this thinning does not exceed 30 percent of the field. At the same time the condition of planted areas should be evaluated as poor if the thinning, according to the results of continuation of growth of plants, is equal to 30 percent but the area with this thinning amounts to more than 50 percent of the entire field.

In order to characterize the condition of the fields in the winter from the results of the continuation of the growth of specimens, especially for large areas (oblasts, krays, republics), it is necessary to take into account the agrometeorological conditions under which the death and damage to the planted areas took place.

In large areas (oblasts, krays, republics) the condition of winter crops in the winter can also be evaluated from the results of continuing the growth of specimens of plants taken from the fields on 23 February. The number of specimens with increased thinning (death of more than 10 percent of the plants) when the growth of specimens taken on 23 February is continued, expressed in percentages of all the specimens taken throughout the territory of the oblast, kray or republic, turned out to be sufficiently closely correlated to the sizes of the areas planted in winter crops that died by spring (in percentages of their overall planted area), according to data of the USSR Central Statistical Administration ($r = 0.66 \pm 0.03$). The correlational connections that were obtained made it possible for us to establish quantitative ratios between these amounts and to give an evaluation to the condition of planted areas in the winter [18, 22]. The evaluation is given individually for rayons where the main causes of the death of plants are freezing and perishing under the snow (taking into account the mean square error of the area with dead plants σ during the period from 1946 through 1974). Table 51 gives this evaluation for oblasts located in the forest zone where winter crops suffer in the winter primarily from perishing under the snow.

This evaluation makes it possible to objectively compare the condition of planted areas not only in various oblasts and republics, but also for various years. Moreover it makes it possible to compare the condition of planted areas in a specific year with the average indicator for a large number of years, taking into account the peculiarities not only of various soil and climate zones, but also the agrotechnology for the cultivation of winter crops (majority of area planted in winter rye or wheat, regionalized strains, the number of plantings with various predecessors, and so forth).

Table 51. Evaluation of Condition of Winter Crops (Points) With Various Quantities of Specimens With Increased Thinning of Plants on 23 February and Corresponding Area with Dead Winter Crop Plants in Spring S_B (% of Overall Planted Area; S_B (σ)-- in Proportions)

(1) Показатель	(2) Пробы с изреженностью ~ 10% растений (%)				
	0	1—10	11—20	21—30	>30
(3) Оценка посевов	5	4	3	2	1
S_B	0,0—3,0	3,1—5,0	5,1—10,0	10,1—17,0	>17,0
S_B (σ)	0—0,5σ	0,5—1,0σ	1,0—2,0σ	2,0—3,0σ	>3σ

Key:

1. Indicator
2. Specimens with thinning of less than 10% of the plants (%)
3. Evaluation of planted areas

Thus the results of continuing the growth of specimens of winter crops can be fully utilized when evaluating the condition of winter crops both on specific fields and on large areas. But here it is necessary for the continuation of the growth of the specimens to take place at no less than 8-10 stations which are spread out evenly throughout the oblast (autonomous repubic). With an increase in the number of plant specimens taken for continuation of growth, the precision of the evaluation of the condition of winter crops increases [20].

The quantitative evaluations of the condition of winter crops in the autumn, winter and spring that were given above characterize sufficiently the sizes of the areas on which plants died after wintering, the productivity and the gross harvest of grain. Therefore we used them when developing methods for long-term predictions of the wintering of planted areas and agroclimatic regionalization of the territory. They can also be used when solving the problem of the expediency of replanting areas planted in winter crops with spring crops in the spring.

THE EFFECTS OF AGROMETEOROLOGICAL CONDITIONS ON THE GROSS YIELD OF GRAIN AND THE AREA ON WHICH WINTER PLANTS PERISH UNDER THE SNOW

During years with unfavorable conditions for the wintering of plants, as shown by an analysis of the results of many years of agrometeorological observations (from 1949 through 1975), the gross yield of winter crops decreases significantly. This takes place not only as a result of complete destruction of all plants on part of the areas planted in winter crops, but also as a result of thinning of planted areas and the death of a large number of the more productive autumn stalks of plants that have survived the winter [22]. Thus in a number of oblasts of the nonchernozem zone in 1961, 1966, 1971 and 1974 there was perishing of winter crops under the snow. The number of stalks per 1 square meter in the spring either decreased significantly or almost did not increase at all as compared to autumn and during the period of tillering, despite the good moisture supply for the planted areas, the increase was even less. And only according to the data of certain stations did the number of stalks increase significantly in the summer as compared to their number at the time of spring examination of the planted areas. The supplies of productive moisture in the soil throughout the entire spring-summer period were good. Thus, for example, in June 1966, although they decreased slightly (table 52, nonetheless in the plowed layer the moisture supplies amounted to 40-50 mm in Vologodskaya Oblast and 20-40 mm in Kostromskaya Oblast. There could be no freezing of winter crops in 1966 since the minimum soil temperature at the depth of the tillering node during the winter did not drop below -10°C.

In Gor'kovskaya, Kirovskaya and Arkhangel'skaya Oblasts on the date of the spring examination, somewhat more stalks had survived the winter (60-100 percent of the autumn number), the maximum depths of the snow cover was less--70-90 cm (only in the region of Vetluga station was it 105 cm), and the depth of freezing of the soil was greater (60-80 cm). Moreover in these oblasts the planted areas were mainly in good condition in the fall (in the phase of tillering with 3-4 shoots). And although a snow cover of 30 cm and more remained here as well for 8-14 10-day periods, the temperature of the soil at the depth of the tillering node was lower and in places cropped to -10°C. Conditions were created that were more favorable than in other oblasts for wintering of winter crops. Nonetheless, as the result of research using F. M. Kuperman's method [8] showed, the vegetative cones of the majority of the plants were

Table 52. Supplies of Productive Moisture (mm) in Soil Planted in Winter Rye in 1966.

Область (1)	Станция (2)	(3) Слой почвы 0—20 см							(7) Слой почвы 0—100 см						
		апрель (4)	май (5)			июнь (6)			апрель (4)	май (5)			июнь (6)		
		3	1	2	3	1	2	3	3	1	2	3	1	2	3
(8) Архангельская	Емецк (14)	—	—	62	50	57	31	10	—	—	256	200	211	135	145
(9) Вологодская	Вологда-Молочная (15)	92	90	69	60	57	43	35	319	338	275	251	248	209	191
	Бабаево (16)	—	—	66	60	52	23	12	—	—	382	399	324	154	140
(10) Ивановская	Шуя (17)	42	39	33	21	—	1	0	109	103	111	93	65	20	17
	Юрьевец (18)	48	53	40	19	13	8	23	213	214	182	155	134	130	145
(11) Костромская	Макарьев (19)	—	58	48	39	17	41	14	—	297	235	202	177	165	156
	Галич (20)	64	58	56	22	18	6	15	237	195	188	129	105	88	84
	Солигалич (21)	—	54	.2	25	23	16	21	—	291	253	179	157	127	128
(12) Горьковская	Ройка (22)	39	36	27	13	8	11	5	170	154	146	139	79	67	53
	Ветлуга (23)	49	44	38	22	17	12	10	292	264	284	219	161	156	131
	Красные Баки (24)	46	47	39	36	31	13	8	178	179	145	155	83	53	38
(13) Кировская	Котельнич (25)	48	50	49	26	40	33	23	192	175	228	111	144	105	99
	Нагорск (26)	46	47	42	29	37	22	18	203	185	157	160	148	125	114

[Key on following page]

Key:

1. Oblast
2. Station
3. Layer of soil 0-20 cm
4. April
5. May
6. June
7. Layer of soil 0-100 cm
8. Arkhangel'skaya
9. Vologodskaya
10. Ivanovskaya
11. Kostromskaya
12. Gor'kovskaya
13. Kirovskaya
14. Yemetsk
15. Vologda-Molochnaya
16. Babayevo
17. Shuya
18. Yur'yevets
19. Makar'yev
20. Galich
21. Soligalich
22. Royka
23. Vetluga
24. Krasnyye Baki
25. Kotel'nich
26. Nagorsk

damaged. During the spring-summer growing period they died off. On the date of the beginning of waxy ripeness only 35-88 percent of the autumn number remained.

The death of a large number of stalks (even with a small number of plants that had fully died off during the winter) is one of the main reasons for a reduction in the yield of winter crops in the nonchernozem zone [6, 9, 22 and others]. In this zone large areas of winter crops that have been damaged during the winter are rarely replanted in the spring. But when even a small part of the areas planted in winter crops are destroyed (about 10 percent of the area), the remainder of them are severely damaged and the grain yield of winter crops decreases significantly during these years.

The dependency between the gross yield of winter crops W on the amounts of areas with dead plants S_B for individual oblasts during the period from 1957 through 1975, presented in figure 41, confirms this conclusion. In order to compare materials for various years the gross yield of winter crops is reduced to a single planted area (average for the period) and given in percentages of the average for 19 years. The destroyed area is taken in percentages of the overall area planted in winter crops in the oblast.

As one can see from figure 41, the gross yield of winter crops decreases significantly even with an increase in the area with damaged plantings to 5-10 percent. This begins to be especially manifested in the reduction of the gross yield after wintering when the area of damaged winter crops is greater than 10 percent.

Let us consider the dependency between the gross yield of winter crops and the area of destruction for Kostromskaya Oblast in which the range of the gross yield amounts to 130 percent. The lowest yield (60 percent or less than the average) is obtained when the destroyed area is 30 percent and more. When the destroyed area is 10 percent, the gross yield amounts to

80 percent of the average. The largest yield (150 percent) up to 1970 was obtained when the destroyed area was less than 5 percent and during the period of 1970-1975--when the destroyed area was less than 10 percent. When there was no destruction of winter crops ($S_B = 0$) the gross yield was obviously even greater.

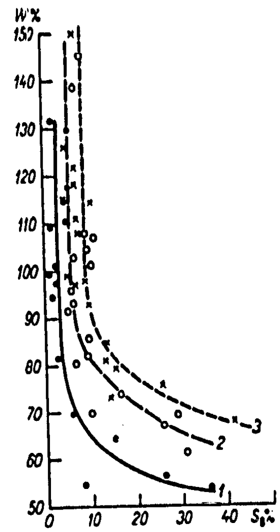

Figure 41. Dependency of Gross Yield W (%) of Winter Crops on Destroyed Area S_B (%)

Key:
1--Tul'skaya Oblast, 2--Kostromskaya, 3--Novgorodskaya

In Novgorodskaya Oblast, in addition to perishing under the snow, winter crops are damaged by soaking. When the crops on 40 percent of the area were damaged by spring the gross yield in this oblast decreased to 67 percent of the average (1965/66).

According to results of observations at meteorological stations from 1949 through 1970, it turned out that in the nonchernozem zone where the main cause of the death of winter crops is perishing under the snow, the sizes of the areas with dead plants are directly proportional to the depth of the snow cover and inversely proportional to the depth of freezing of the soil [22]. The ratio between the depths of freezing of the soil and the depths of the snow cover in the first 10 days after it increased to 30 cm and more, designated by K, is what we used as a comprehensive indicator of the wintering conditions for winter crops in regions with perishing under the snow (with a snow cover of more than 30 cm). The area with dead plantings S_B from 1949 through 1975 throughout the oblasts of the nonchernozem zone of the country's European territory turned out to be closely related to this indicator (figure 42). The less the coefficient K, the greater the area of destruction of winter crops. With an increase in the coefficient K the area of destruction of winter crops from perishing under the snow decreases. This is explained by the fact that in the nonchernozem zone when there is an increase in the depths of the snow cover and a reduction in the depth of freezing of the soil, conditions are created which accelerate processes of perishing of plants under the snow.

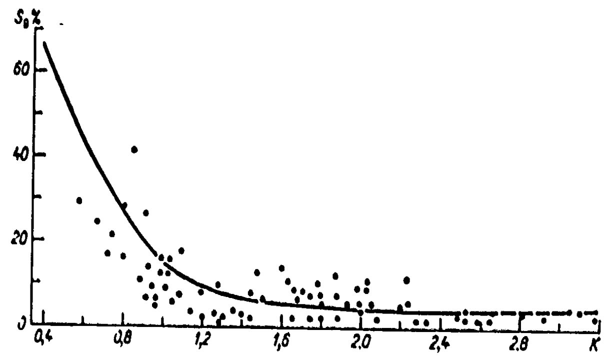

Figure 42. Dependency Between Area of Destroyed Winter Crops S_B (%) and Coefficient K.

In cases when in the first 10 days with a snow cover of 30 cm and more the soil has frozen to more than 50 cm, the value $K > 1$ and, as one can see from figure 42, the area with fully destroyed winter crops, decreases. When K = 2.0 the effects of wintering conditions on the planted areas are less. The value $K < 1$ is possible only when the depth of freezing of the soil in the first 10 days after the establishment of a snow cover of more than 30 cm on the fields with winter crops is not great--less than the depth of the snow cover. Most frequently the depth of the snow cover increases gradually. Therefore one can consider that K is less than 1 in cases where a snow cover of 30 cm is established on soil that is frozen to a depth of about 30 cm. Therefore the role of the correlation between the depth of freezing of the soil and the depth of the snow cover increases sharply. Even a small reduction in the coefficient K corresponds to a significant detioration of wintering conditions and to an increase in the sizes of areas with destroyed winter plantings. Thus if when K = 1 the area of destroyed winter crops is about 10 percent, when K = 0.8 it increases to 25 percent of the entire area of plantings in the oblast.

The quantitative connection between the sizes of the areas with plants that are destroyed by the beginning of spring in the nonchernozem zone and the value K is expressed by the equation

$$\lg S_B = -0.3565 \lg K + 0.5012 \quad (17)$$

or

$$S_B = \frac{3.17}{K^{0.44}}, \quad (18)$$

where S_B--the area with dead plantings in the oblast (percentage), K--the indicator of wintering conditions (ratio between depth of freezing of soil and depth of snow cover). The coefficient of the correlation between these amounts if $\iota = -0.795 \pm 0.011$. The error of the equation is $S_y = \pm 2.42$ percent. The equation is valid when a snow cover of 30 cm or more remains on the fields planted in winter crops for five 10-day periods and more when K is within the limits of from 0.40 to 3.0.

Not only wintering conditions, but also spring agrometeorological conditions are very important for obtaining large and stable harvests. In individual years when the snow cover disappears early the thinning can be insignificant even though in the winter conditions were created whereby it was possible for the winter crops to perish under the snow. A rapid disappearance of the snow cover, the lack of sharp changes in the temperature, good moisture supply and heat supply for the planted areas in the spring contribute to the restoration of a good condition for the plants. The third stage in perishing under the snow--the development of mycelia of fungi and their infection of the leaves and stalks--does not happen then. With top dressing and harrowing early in the spring, even in such years the plants quickly improve their condition, especially if in the autumn they were in the phase of the beginning of tillering. Conditions like these existed in the spring of 1968.

In order to establish the significance of wintering conditions of winter crops for the gross yield of grain, we analyzed materials for 27 years (1949-1975) for 26 oblasts of the nonchernozem zone of the European territory of the USSR. During all of the aforementioned years a comprehensive indicator was calculated for the wintering conditions of the planted areas K_1, which is the ratio between the maximum value of the depth of freezing of the soil during the winter and the maximum value of the depth of the snow cover. The dependency between the gross yield W and the coefficient K_1 is presented in figure 43. Line 1 indicates the connection between the gross yield of winter crops and the indicator K_1 for years when the maximum depth of freezing of the soil during the winter was 50 cm and less and the snow cover was more than 30 cm. The dependency between these amounts and these years is expressed by the equation:

$$y = 35.50x - 8.05x^2 + 58.56, \quad (19)$$

where y--gross yield translated into unit planted area and taken in percentages of average; x--coefficient K_1. The connection that was obtained was fairly close (correlational ratio n = 0.87). The guarantee of an error of the equation equal to or less than ± 20 percent of the range of the gross harvest is 87 percent.

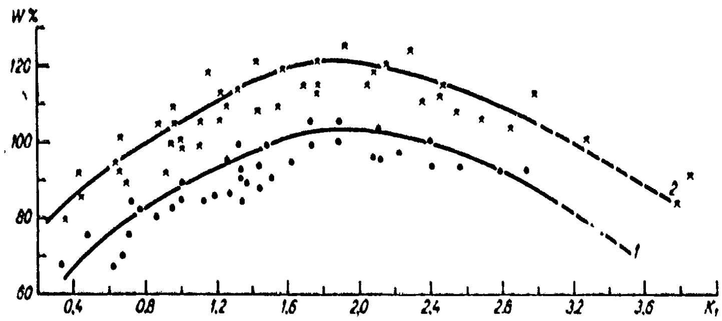

Figure 43. Dependency Between Gross Yield W (%) and Coefficient K_1.

Key:
1--with maximum depth of freezing of soil of 50 cm and less,
2--the same, with 51-80 cm

In this drawing line 2 shows the dependency of the gross yield of winter crops on K_1 when the maximum depth of freezing of the soil during the winter was 51-80 cm and the maximum depth of the snow cover was 30 cm and more. The coefficient of the correlation between the gross yield and the coefficient K_1 for these years turned out to be somewhat less ($r = 0.83$). The equation for the connection has the form

$$y = 14.80x - 34.91x^2 + 63.46; \quad (20)$$

Conventional symbols are the same. The guarantee of an error of the equation equal to or less than ± 20 percent of the range of the gross yield during 20 years is 83 percent. The equations are valid when $K_1 = 0.40 \div 3.00$.

The equations (19) and (20) are calculated from data for 1949-1968 and verified with the independent material for 1969-1975.

From figure 43 it is clear that when K_1 is less than 2.0 there is a reduction in the gross yield of winter crops as compared to the average for 20 years. When K_1 changes from 2.00 to 0.30 the gross yield of winter crops decreases from 100 to 70 percent during years with a maximum depth of freezing of the soil of 50 cm and less and from 120 to 80 percent during years when the maximum depth of freezing of the soil is 80 cm and less. When K_1 increases to more than 2.0 the gross yield also decreases. This is explained by the unfavorable effects on the plants of additional factors (soaking of the plants and their death in the spring). A comparison of curves 1 and 2 on figure 43 shows that the gross yield in the nonchernozem zone is sufficiently closely correlated to the depth of the snow cover and the depth of freezing. With an increase in the maximum depth of freezing from 50 to 80 cm, it increases by 20 percent.

When utilizing the connection between the gross yield and K_1, it is necessary to take into account the conditions of the early spring period. With a very warm and early spring in individual years even with a small value of K_1 the gross yield can turn out to be high, especially with prompt top dressing and harrowing of areas planted in winter crops.

Thus, for example, in 1968 in the Mari ASSR and Kirovskaya and Vladimirskaya Oblasts the gross yield of winter crops was considerably greater than the average for the period from 1959 through 1968 (table 53). The value K_1 for these oblasts in 1968 was 0.97-1.18.

The maximum depth of the snow cover on almost all the territory of the nonchernozem zone of the country's European territory was greater than 50 cm (with the exception of the northwest and extreme north of the country's European territory where it amounted to 30-50 cm). The maximum depth of freezing of the soil in northern and central regions of the nonchernozem zone ranged from 30 to 50 cm and in the south of the zone and in the extreme north it increased to 100 cm.

A snow cover 30 cm deep and more remained on the fields with winter crops in the northern and northeastern part of the country's European territory for 11-12 10-day periods, in Permskaya Oblast the Udmurt ASSR--13 10-day periods and in the central and southeastern regions of the nonchernozem zone--9-10 10-day periods.

Consequently in the winter of 1967/68 conditions were created that contributed to the perishing of winter crops under the snow. But the spring of 1968 was early and warm, and in the third 10-day period of March in the northeastern oblasts of the nonchernozem zone of the country's European territory and in the first 10-day period of April in the central and southern oblasts all of the snow disappeared from the fields (an exception was the northwestern regions where it disappeared in the second 10-day period of March) and the weather became sunny and very warm (maximum air temperature reached 16°C) with low air humidity. Therefore not all of the winter crops died from damage under the snow. Winter crops that halted growing in the autumn on 97 percent of the area in a good condition quickly adjusted to the unfavorable winter and, despite the loss of 20-50 percent of the stalks, produced a relatively large yield (table 53).

Table 53. Description of Favorable and Unfavorable Conditions for Wintering of Winter Crops

Область и АССР (8)	(1) Благоприятные условия					Неблагоприятные условия					
	(2) год	(3) максимальная за зиму высота снежного покрова $h_м$ (см)	(4) максимальная глубина промерзания почвы $H_м$ (см)	$K_1 = \frac{H_м}{h_м}$	(5) валовой урожай (% от среднего)	(2) годы	(3) максимальная за зиму высота снежного покрова $h_м$ (см)	(4) максимальная за зиму глубина промерзания почвы $H_м$ (см)	$K_1 = \frac{H_м}{h_м}$	(5) валовой урожай (% от среднего)	(7) валовой урожай (% от максимального)
(9) Кировская	1967/68	67	65	0,97	147,2	1965/66	88	89	1,01	89,6	60,8
(10) Коми АССР	1966/67	35	131	3,74	172,5	1957/58	66	33	0,50	76,4	44,3
(11) Архангельская	1966/67	26	148	5,70	152,4	1965/66	95	82	0,86	104,2	68,4
(12) Вологодская	1966/67	32	121	3,79	154,0	1965/66	97	34	0,35	68,7	44,5
(13) Костромская	1966/67	41	129	3,15	191,0	1965/66	84	39	0,49	70,0	36,5
(14) Горьковская	1967/68	59	105	1,78	134,0	1965/66	67	101	1,51	90,5	67,5
(15) Марийская АССР	1967/68	74	88	1,18	141,8	1965/66	95	124	1,31	112,2	79,1
(16) Удмуртская АССР	1966/67	48	110	2,29	124,7	1965/66	104	68	0,65	100,0	80,2
(17) Мордовская АССР	1967/68	51	94	1,84	141,2	1957/58	39	60	1,64	98,8	69,5
(18) Владимирская	1967/68	62	66	1,06	173,8	1958/59	50	52	1,11	84,5	48,5
(19) Ивановская	1966/67	29	139	4,80	148,9	1965/66	35	34	0,92	90,7	60,8
(20) Ярославская	1966/67	25	133	5,32	173,0	1964/65	44	66	1,60	96,4	55,5
(21) Калининская	1967/68	50	66	1,32	138,5	1964/65	48	60	1,09	97,5	70,0
(22) Московская	1967/68	55	61	1,11	183,0	1965/66	29	28	0,99	119,1	65,2
(23) Смоленская	1966/67	43	82	1,90	122,8	1957/58	37	25	0,79	82,0	66,7
(24) Новгородская	1966/67	34	99	2,91	150,0	1965/66	79	51	0,64	67,2	44,8
(25) Ленинградская	1966/67	42	77	1,83	199,0	1965/66	88	35	0,44	84,4	42,4

[Key on following page]

Key:

1. Favorable conditions
2. Years
3. Maximum depth of snow cover during winter (cm)
4. Maximum depth of freezing of soil H_M (cm)
5. Gross yield (% of average)
6. Unfavorable conditions
7. Gross yield (% of maximum)
8. Oblast and ASSR
9. Kirovskaya
10. Komi ASSR
11. Arkhangel'skaya
12. Vologodskaya
13. Kostromskaya
14. Gor'kovskaya
15. Mari ASSR
16. Udmurt ASSR
17. Mordov ASSR
18. Vladimirskaya
19. Ivanovskaya
20. Yaroslavskaya
21. Kalininskaya
22. Moskovskaya
23. Smolenskaya
24. Novgorodskaya
25. Leningradskaya

But in a number of oblasts not all of the potential of the winter crops was utilized and the death of productive stalks decreased the productivity. The yield was especially decreased in the northern and northwestern part of the country's European territory where losses of stalks turned out to be the greatest. The productivity there in 1968 was lower than in 1967 by 10-20 percent.

During the period from 1969 through 1975 when K was less than 1, the gross yield of rye amounted to 60-90 percent of the average (taking into account the tendency of a trend toward increase) for a number of oblasts of the nonchernozem zone: Smolenskaya Oblast--1974, 1975; Yaroslavskaya Oblast--1971, 1975; Gor'kovskaya Oblast--1971, 1975; Kirovskaya Oblast--1970, 1972-1974; and so forth.

The most unfavorable conditions for wintering in the last 20 years, when the winter crops suffered severely from perishing under the snow, were created during the winters of 1965/66 and 1973/74. The maximum depth of the snow cover in the northern and northeastern regions of the country's European territory in 1965/66 was 80 cm and more and in the central regions of the nonchernozem zone--51-80 cm. The maximum depth of freezing in the northwestern and central regions of the nonchernozem zone was less than 50 cm. In the southern part of the zone it was 51-80 cm and in the northeastern regions of the country's European territory it was more than 80 cm. A snow cover of 30 cm and more remained for 10-14 10-day periods and only in the central regions of the country's European territory did it last for 6-10 10-day periods.

As a result of these conditions the winter crops were severely damaged from perishing under the snow. In Leningrad and Kirovskaya Oblasts and the Udmurt ASSR about 80 percent of the plants survived and in the southern and central regions--only 30-70 percent of the plants did. An especially small number of live stalks of winter crops remained in the spring. Only in Gor'kovskaya and Ivanovskaya Oblasts did 100 percent of them remain, and in the remaining regions of the nonchernozem zone--from 30 to 70 percent of them. But with normal wintering conditions the number of stalks of winter plants increased in the spring by 20-50 percent as compared to autumn as the result of additional bushing.

The sizes of the areas with dead winter plants after wintering this year turned out to be maximum for the period from 1949 through 1975. The dependency between them and the indicator K_1 is presented in figure 44. The areas with dead plantings were considerably greater in those areas where the depth of the snow cover was greater during the winter and the depth of freezing of the soil was least ($K_1 \leq 0.60$). Points 1 (Novgorodskaya Oblast) and 2 (Kalininskaya Oblast) deviated somewhat from the curve. There some of the areas planted in winter crops did not suffer so much from perishing under the snow as from over moistening of the soil and flooding of the planted areas in the autumn. In these oblasts the areas on which the plants died turned out to be somewhat less. But even in those oblasts where the area on which the plants died was less than 10 percent and the gross yield amounted to 90-112 percent of the average, in the majority of oblasts it turned out to be 50 percent and less than in years that were favorable for wintering.

The change in the gross yield of winter crops W, the values of K_1 and the area with dead plantings S_B for the various years during the period from 1957/58 through 1970/75 for individual oblasts are given in figure 45a, 6. In the drawings it is clear that the gross yield of winter crops has considerably increased in recent years as compared to the beginning of the period under consideration. This is explained by the significant rise in the level of agrotechnology in recent years. Large planted areas are now being top dressed with mineral fertilizers in the spring, the planting of winter crops is done promptly, in a number of oblasts (Moscow, Bryanskaya and others) have introduced the production of new, more productive strains of winter crops on significant areas, including Mironovskaya 808 winter wheat.

The fluctuations in the yield during the period under consideration were great: this is obviously explained primarily by unfavorable conditions for the wintering of plants--perishing under the snow, since in years with the least K_1 they were also least (1957/58, 1960/61, 1965/66, 1967/68, 1973/74) and in years with the greatest K_1 they increased (1958/59, 1962/63, 1964/65, 1966/67, 1968/69, 1969/70).

The areas with dead plantings ranged within considerably smaller limits; in years with large gross grain harvests they were small and in years with small harvests they reached a maximum. This confirms the correctness of the dependencies introduced above between the amounts of the gross harvest and the areas with winter crops that perished under the snow in the nonchernozm zone of the country's European territory, on the one hand, and the depth of the snow cover and the depth of freezing of the soil, on the other.

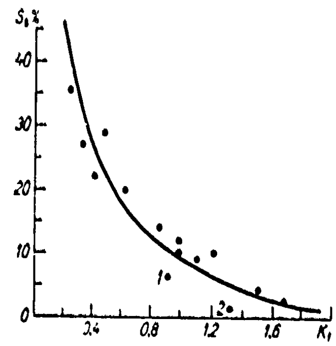

Figure 44. Dependency Between Area of Death of Winter Crops S_B (%) and K_1 During 1965/66 With Snow Cover 30 cm Deep and More in Nonchernozem Zone of the Country's European Territory.

METHODS OF COMPARING LONG-TERM PREDICTIONS OF PERISHING OF WINTER CROPS UNDER SNOW

The harm to the national economy caused by unfavorable wintering conditions can be significantly reduced and sometimes fully eliminated if agricultural planning agencies and agricultural specialists know ahead of time the degree of possible damage to winter crops and the regions where this can take place as a result of perishing under the snow. Therefore long-term agrometeorological predictions for the wintering of winter crops are of great practical significance not only in the steppe zone where the plantings most frequently perish as a result of freezing when there is no snow cover or a very small one on the fields, but also in the forest steppe and forest zones of the USSR where the death and damage of planted areas takes place because of perishing under the snow when a deep snow cover remains for an extended period of time on slightly frozen soil.

The results of physiological investigations of the causes of the death of plants when they perish under the snow which are presented above, the established patterns of the change in the vegetative cones of shoots that are formed in the autumn under the influence of agrometeorological conditions of wintering, the determination of the quantitative indicators of the main elements of these conditions and the patterns of their spatial and temperal changeability have made it possible to develop asynchronic connections between the meteorological conditions during a predicted or preceeding period of the winter and, on the basis of them, to create methods of long-term agrometeorological predictions of the perishing of winter grain crops under the snow [17, 18, 22].

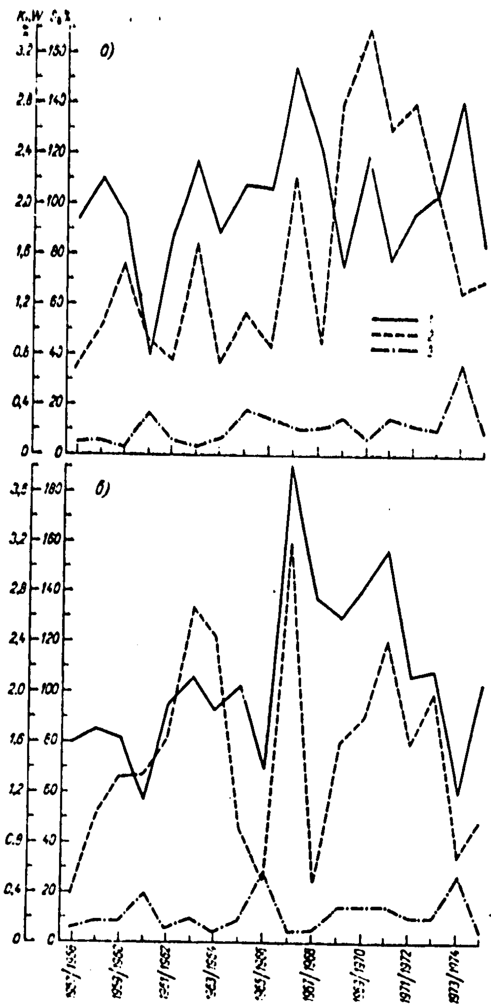

Figure 45. Change in Gross Yield W (1), Area of Death S_B of Winter Crops and Indicators of Wintering Conditions K_1 (2) From 1957/58 Through 1974/75 in Arkhangel'skaya (a) and Kostromskaya (б) Oblasts.

Since detailed long-term (for the season) synoptic predictions of the weather are not drawn up at the present time, methods for long-term prediction of the condition of winter crops in the spring are based on patterns of inertia processes of the formation of agrometeorological conditions of wintering that cause the perishing of plants under the snow. The latter include correlations between the length of time a deep snow cover remains on fields planted in winter crops and the time it is established and also the maximum depth of freezing of the soil during the winter and this amount at the time of the formation of a 30-cm snow cover on the fields and the absolute minimum temperature of the soil at the depth of the tillering nodes of winter crops during the winter and during the preceeding period before the establishment of a sufficiently deep snow cover on the fields, and many other things.

Methods of drawing up long-term predictions of the condition of winter crops [17] have been developed for calculating the number of surviving plants and stalks of winter crops by spring and the sizes of the areas with thinned plantings (in percentages of the areas on which they are planted) both on specific fields and on large territories (oblasts, krays, republics). When drawing up predictions for specific fields one uses local agrometeorological information from these fields: the autumn condition of the winter crops, the depth and compactness of the snow cover, the depth of freezing and the temperature of the soil, the air temperature and so forth.

In order to draw up predictions of wintering on large areas, a need has arisen to establish quantitative indicators of the agrometeorological conditions for the wintering of planted areas and to obtain prognostic dependencies in terms of average indicators for the territory of the oblasts, krays and republics and direct areas with dead plantings according to data of the USSR Central Statistical Administration.

Predictions drawn up for specific fields can be utilized directly by specialists in agricultural production (kolkhozes, sovkhozes, experimental stations and so forth). On the basis of them, with calculations from several stations (6-10), one can also give a prediction of the condition of areas planted in winter crops in the spring for the oblast, kray and republic.

Long-term predictions drawn up for entire oblasts and republics can be used by planning and agricultural agencies when developing measures for caring for the planted areas and distributing mineral fertilizers, fuel, agricultural machines and seeds that are necessary for undersowing and replanting winter crops that have died or been damaged during the winter with spring crops.

A method of compiling a long-term prediction of perishing of winter crops on specific fields: when predicting the expected condition of winter planted areas in the spring on specific fields one gives the number of surviving plants and stalks and also the area (in percentages of the entire of the field) on which the plantings have become thin or died [17, 18, 23]. Predictions of the perishing of winter crops are drawn up if a deep snow cover ($h \gtrsim 30$ cm) has been established during the first half of the winter with slight (less than 50 cm) freezing of the soil. On these fields, as was pointed out above, winter crops remain for an extended period of time under a deep snow cover when the temperature of the soil at the depth of the tillering node is above -8°C and is sometimes close to 0°C. Under these conditions the plants become exhausted and in the second half of the winter and especially in the early spring they are infected with various kinds of fungal diseases and are significantly damaged or completely die off.

A calculation of the expected degree of thinning u of winter planted areas in the spring is made taking into account their autumn condition (coefficient of tillering k) from the equation (6)

$$u = 59.07 + 6.82t_3 + 0.22t_3^2 - 5.14k + 0.40k^2,$$

where t_3--minimum soil temperature at the depth of the tillering node during the period with a deep snow cover of 30 cm and more. Of the latter is taken from its actual value during the 10 days of the establishment of the snow cover of 30 cm and more, taking into account a possible subsequent change in t_3, depending on the depth of freezing of the soil H (see figure 40). As one can see from figure 40, the absolute minimum temperature of the soil at the depth of the tillering node during the winter when the depth of freezing of the soil is 0-30 cm at the time of the establishment of a snow cover of 30 cm and more does not drop below -3 - -6°C; with a depth of freezing of the soil of 50 cm it is equal to -5 - -8°C; and when the soil is frozen to 80 cm, the absolute minimum is equal to -8 - -12°C. Therefore a calculation of the expected thinning of winter crops in the spring and the prediction of their perishing under the snow according to this equation is made not only for the 10 days of the establishment of a snow cover 30 cm deep or more on the field; it is refined again on 20 February since subsequently the minimum temperature of the soil in 97 percent of the years has been equal or greater (figure 46).

With this method of prediction it is also necessary to take into account the distribution of the snow cover on the fields (see figure 39) and, depending on it, to determine the area with perishing of winter crops under the snow.

More reliable, although also more labor-intensive, is the method of predicting the number of surviving plants and stalks on an average for the field during the years when they perish under the snow [17]. In order to make this kind of prediction it is necessary to know well ahead of time how long a snow cover 30 cm deep and more will remain on the fields.

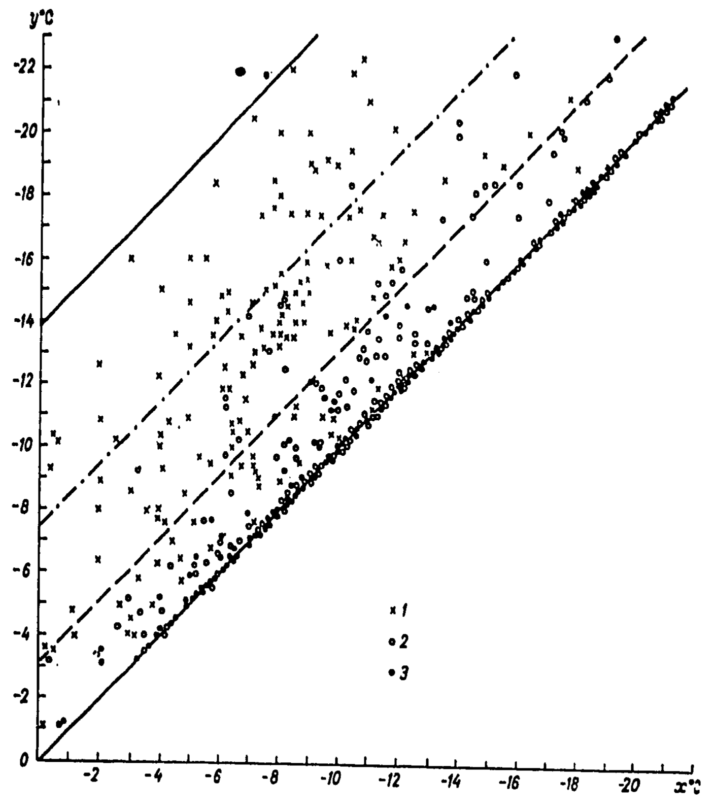

Figure 46. Connection Between Absolute Minimum Soil Temperature at Depth of Tillering Node x Before 1 January (1), 1 February (2), 20 February (3) and its Absolute Minimum During the Entire Winter y

In order to develop a method of long-term prediction of the length of time a deep snow cover will remain on the fields, we used materials of observations from snow surveys on fields with winter crops from 1932/33 through 1972/73 of meteorological stations of the northwestern, central and northern oblasts of the USSR European territory and Western Siberia. From these data it turned out that there is no instability in the deep snow cover (30 cm and more) in the zone located north of the line formed by Leningrad, Smolensk, Tula, Ul'yanovsk, Ufa, Omsk, Novosibirsk and Kemerovo. Therefore we took the first 10 days of its formation as the time of the establishment of a deep snow cover on the fields [17].

The time of the establishment of a deep snow cover (more than 30 cm) ranges in individual years within very large limits (up to 140 days). The earliest time of its establishment, according to data from observations of all the aforementioned stations, was the same--the third 10-day period in November; the latest time in the northern half of the USSR European territory was the second 10-day period in March and in the forest and forest steppe regions of Western Siberia--the first 10-day period in April.

The time of the beginning of the disappearance of the snow cover in the spring ranges in various years within the considerably smaller limits (40-60 days) than does the time of its establishment. This is explained by the different dates of the beginning of the snow thaw and therefore its different intensiveness. When the thaw begins late the intensiveness of the snow thaw is greater than when it begins early because of the increased length of the day and the greater amount of direct solar radiation on the earth's surface.

The length of time a deep snow cover remains on the fields ranges in individual years within very large limits--from 0 to 160 days. But when it is established at one and the same time in various regions of a large zone (from the northwestern oblasts of the USSR European territory to Tomskaya Oblast) it remains remains almost the same. This made it possible when deducing the dependency between the length of time the snow cover remains and the time of its establishment to generalize the results of the snow surveys from various stations located in various regions.

The dependency between these amounts is directly linear and inversely proportional (figure 47). The earlier the establishment of a snow cover of 30 cm and more, the greater its duration. The coefficient of the correlation between them is $r = -0.94 \pm 0.04$. The equation of the connection has the form

$$y = 17.540 - 1.126x, \tag{21}$$

where y--the length of time the snow cover of 30 cm and more remains, x--the time of the establishment of the snow cover of this depth in 10-day periods (for x = 1 we took the first 10 days of November). The mean square error of the equation is $E_y = \pm 1.18$ 10-day periods.

A verification of this equation showed that in 78 percent of the cases the error of the calculation lies within the limits of the probable error E_y and in 99 percent of the cases within the limits of $\lesssim (\pm 2.3)$. On the basis of this equation, knowing the time of the formation of a snow cover of 30 cm and more on the fields of winter crops, it is possible with sufficient accuracy (± 1 10-day period) and well ahead of time to give a prediction of the time it will remain and, by utilizing the dependency between the quantity of surviving plants and stalks (figures 36-38) to draw up a prediction of the condition of areas planted in winter crops

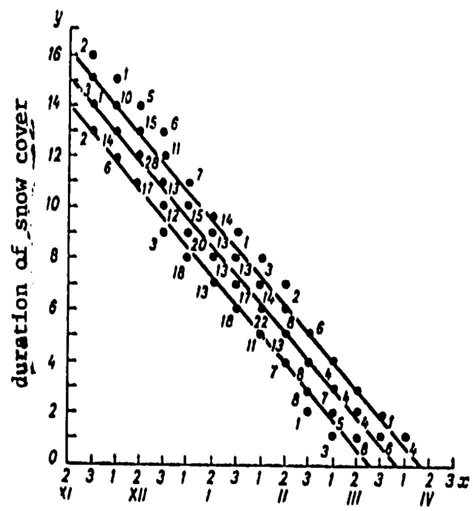

Figure 47. Connection Between Duration of Snow Cover y (10-day periods) and Time x (10-day periods) of the Establishment on the Fields of a Snow Cover of 30 cm and More.

Key:

Figures at points--number of cases

at the time of renewal of growth. In years that are dangerous for the wintering of the planted areas this prediction can be given from 100 to 160 days ahead of time.

A prediction of the number of surviving plants and stalks on areas planted in winter crops is drawn up in the first 10-day period after obtaining information from stations concerning the establishment of a snow cover of 30 cm and more on the fields.

A verification of the correctness of the prediction from materials from observations of 70 stations located in the zone where winter crops perish under the snow in 1965/66 showed that the divergence between the predicted and actual number of surviving stalks of winter crops, according to 65 (93 percent) of the stations, was within the limits of admissable error (± 15 percent). Moreover the actual number of surviving stalks was taken to be the ratio (in percentages) of the number of stalks per 1 square meter obtained in the spring and autumn examinations.

But in individual years the divergence between the calculated and actual number of surviving stalks was great. An analysis of materials for these eyars showed that when making a prediction of the perishing of winter crops under the snow, in addition to the length of time a snow cover of 30 cm and more remains on the field and the depth of freezing of the snow, one must take into account the air temperature. In years with a great negative anomaly of air temperature during the periods when a snow cover of 30 cm and more remains on the field, as was pointed out above, the percentage of surviving stalks is greater than in warm winters.

In order to calculate the correction for the severity of the winter Δt (table 40), when drawing up the prediction of the perishing of winter crops under the snow well ahead of time, it was necessary to find a dependency that made it possible to predict equally well ahead of time the total negative temperatures of the air during the period when a snow cover of 30 cm and more was on the field. An analysis of the values of this sum for the last 40-50 years showed that this prognosticational dependency can be obtained if one takes into account the sum of temperatures for the period preceding the predicted ones when the snow cover was 1-30 cm. The connection between the sums of air temperature during the period with a deep snow cover of 30 cm and more and with a deep snow cover of 1-30 cm turned out to be directly linear and inversely proportional (figure 48). The coefficient of the correlation between these amounts is $r = -0.83 \pm 0.002$. The equation for the connection has the form

$$y = -0.9x - 1158, \qquad (22)$$

where y--the sum of average daily air temperatures during the period when the snow cover is 30 cm and more, x--the same period when the snow cover is 1-30 cm. The mean square error of the equation is $E_y = \pm 172°$, the equation is valid with values of x and y from 0 to 1800°C.

When material for many years was analyzed it turned out that the sum of negative temperatures during the period when a snow cover of 30 cm and more remained on the field for more than 100 days is greater in years when more snow accumulates at the beginning of the winter than in years with slower accumulation. Therefore in those years when the period with a snow cover of from 1 to 10 cm was less than or equal to 20 days, its value should be taken from the upper line of the graph (figure 48) and when this period is equal to 40-60 days--from the lower line.

Finally a prediction of the number of surviving stalks of winter crops after wintering when there is perishing under the snow is thus constructed from an account of the obtained patterns of seasonal change in the soil temperature at the depth of the tillering node of winter crops, the depth of freezing of the soil and the depth of the snow cover. Moreover, one takes into account the quantitative dependencies between the condition of the planted areas in the fall and the conditions of wintering and also asynchronic prognosticatory dependencies between the length of time the deep snow cover remains and the total negative air temperatures.

The area on which there will be possible damage or death of plants under the snow is calculated, beginning with the 10-day period of the establishment of an average snow cover of 16 cm and more and ends in the third 10-day period of January (after which the period with a snow cover of 30 cm and more will be less than 80 days) or with the establishment on the fields of a snow cover with an average depth of 45 cm and more according to snow surveys when throughout the area of the field the depth is 30 cm and more (see figure 39). During the course of this period one calculates individually for each 10-day period the expected average number (in percentages) of surviving plants and stalks per 1 square meter on that part of the field where the depth of the snow cover is 30 cm and more. Then one calculates the average percentage of surviving plants and stalks of winter crops for the field and determines the area of the field on which less than 50 percent of the plants have survived [17].

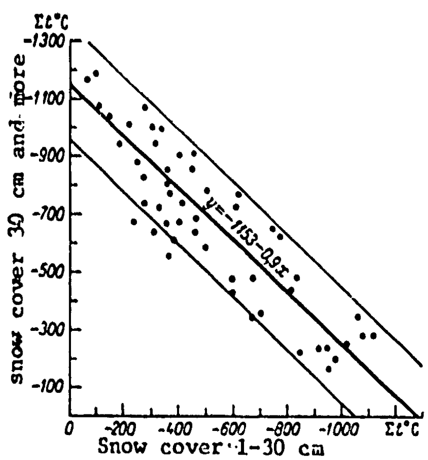

Figure 48. Connection Between Total Negative Average Daily Air Temperatures During Period When Snow Cover of 30 cm and More Remained on the Fields and During Period When Snow Cover was 1-30 cm Deep.

The method of predicting perishing of winter crops under the snow on the territory of the oblast or republic: the expected area on which winter crops will die throughout the territory of the oblast (kray) is determined by charting the results of the calculations for individual stations. To do this, one enters on the chart which indicates the overall areas planted in winter crops in various regions and the quantity of planted areas in poor condition in the autumn, the expected areas from the various stations with an average thinning of more than 50 percent of the plants on the fields. Then one separates out zones with an expected area of perishing of winter crops S_B greater than 50 percent and for each of these zones one calculates the quantity of plantings (in thousands of hectares). The sum of areas obtained this way for all zones will be the area of destruction of winter crops in the oblast (kray, republic) as a whole.

In a similar way one calculates on a second chart the planted areas (in thousands of hectares and percentages) for the oblast with thinning of plants of 30-50 percent on which the areas have been undersown with spring crops. The sum of these areas is taken as the most probable area with winter crops in a poor condition.

When calculating the most probable areas with a poor condition of the winter crops, one takes into account the area of winter crops for each region with a poor condition of winter crops in the fall, obtained by an autumn ground tour and aircraft examination of the planted areas and also when calculating the condition of planted areas in the autumn, taking into account planting times, heat availability and moisture availability during the period of autumn vegetation [2, 17, 18, 23].

In addition to the most probably area that will be in a poor condition, one gives the limits of its range. These limits are calculated taking into account the probable error of the method of prediction and possible damage to planted areas from other unfavorable factors (freezing in the spring after the disappearance of the snow cover, soaking and so forth).

The prediction also gives the expected area on which the plantings will be in a satisfactory or good condition in the oblast as a whole (in thousands of hectares and in percentages of the overall area planted in winter crops). Moreover, on the chart for all stations one enters the expected average number of surviving stalks for the field and separates out zones where their number per 1 square meter is: less than 350, 350-500, 500-700, 750-1,000 and more than 1,000 stalks. These data, like the areas with poor, satisfactory and good condition of the plantings, are taken into account when making predictions of the yield of winter crops.

The prediction of the condition of winter crops in the spring is also drawn up taking into account the actual condition of winter plantings in the autumn, obtained from the results of an autumn examination of the planted areas on individual fields, from the territory of regions and in the oblast as a whole, and also from the results of the quantity of plantings (in thousands of hectares and in percentages) with good, satisfactory and poor condition for each rayon and the oblast as a whole.

A consolidated table is drawn up for all stations of the oblast (kray, republic) from which one makes prognosticatory calculations of the expected quantity of surviving stalks and plants after wintering and also the expected areas with various conditions of the plantings in the spring. The model for this consolidated table for Vologodskaya Oblast is given in table 54.

This method of calculating the long-term prediction of the perishing of winter crops under the snow is labor-intensive. A great deal of time is needed to calculate it manually. Taking this into account, the USSR Hydrometeorological Center in conjunction with the Leningrad Hydrometeorological Institute and the Western Siberian Hydrometeorological Center in 1975 drew up a program for calculating this prediction on an electronic computer [24]. The calculation on a BESM-6 electronic computer using this program for one station takes less than one second of machine time. The introduction of this program into the practice of operational work considerably expands the possibility of increasing the precision and the length of the advance notice of predictions of the perishing of winter crops under the snow.

A prediction of the sizes of the area of plantings with poor condition of the winter crops which require replanting with spring crops can also be drawn up from the prognosticatory dependencies established by V. A. Moiseychik [18, 22] between the area with dead plants during wintering and the average for the oblast (republic) values of the main elements of the complex of agrometeorological conditions that cause plants to perish under the snow.

The main factors on which the sizes of the areas with winter crops that die in the winter depend were established with the help of an electronic computer.

Normed correlational matrices were calculated from materials for 15 years. The coefficient of correlation and the correlational relations were calculated for 18 elements that characterize both the condition of areas planted in winter crops (the sizes of the areas with dead plantings after wintering, the average bushiness, the area with poor condition of the plants in the autumn and the average planting of winter crops during the winter) and agrometeorological conditions of their wintering. The latter included minimum temperature of the air and the soil at the depth of the tillering node during the various periods of the winter, the total negative temperatures of the air, the depth of freezing of the soil, the maximum depth of the snow cover during the winter (at the end of the November, December, January and February), the duration of the period with a snow cover of 30 cm and more, the total precipitation during the autumn and winter periods, and so forth.

Table 54. Expected Condition of Areas Planted in Vyatka Strain of Winter Rye in Spring of 1966 According to Stations of Vologodskaya Oblast.

№ п/п	Станция (10)	Состояние озимых посевов осенью (11): срок сева (12)	число на 1 м² (13): растений (14)	число на 1 м² (13): стеблей (15)	кустистость (16)	Ожидаемое среднее по полю количество сохранившихся (17): % растений (14)	% стеблей (15)	число на 1 м² растений (14)	число на 1 м² стеблей (15)	Ожидаемая площадь (%) на поле с изреженностью (18): > 50	30–50	< 30	(19) Ожидаемые условия перезимовки
1	Чарозеро	30 VIII	548	879	1,6	44	42	241	293	100	0	0	Очень плохие (20)
2	Вологда-Молочное	21 VIII	350	952	2,7	75	62	252	590	0	8	92	Удовлетворительные (21)
3	Бабаево	5 IX	560	973	1,7	42	44	235	428	100	0	0	Очень плохие (20)
4	Устюжна	17 IX	602	602	1,1	19	17	114	120	100	0	0	То же (22)
5	Биряково	9 IX	252	252	1,0	51	52	128	131	0	100	0	Плохие (23)
6	Борисово-Судское	20 VIII	280	532	1,9	40	41	112	218	100	0	0	Очень плохие (20)
7	Великий Устюг	16 VIII	300	700	2,0	66	66	198	462	20	20	60	Удовлетворительные (21)
8	Кириллов	6 IX	376	376	1,0	55	65	207	248	46	13	41	Плохие (23)
9	Никольск	5 IX	287	684	2,2	68	60	195	410	8	7	85	Удовлетворительные (21)

[Key on following page]

Key:

1. Charozero
2. Vologda-Molochnoye
3. Babayevo
4. Ustyuzhna
5. Biryakovo
6. Borisovo-Sudskoye
7. Velikiy Ustyug
8. Kirillov
9. Nikol'sk
10. Station
11. Condition of areas planted in winter crops in autumn
12. Planting time
13. Number per 1 M^2
14. Plants
15. Stalks
16. Bushiness
17. Expected average number of surviving plants on field
18. Expected area (%) on field with thinning
19. Expected wintering conditions
20. Very poor
21. Satisfactory
22. The same
23. Poor

The area with plants that have died during the winter was determined as the difference between the area with dead winter crops (according to data of the USSR Central Statistical Administration) and the area with a poor condition of winter crops in the autumn, expressed in percentages of all the areas planted in winter crops in the oblast ($S_B - S_O$). The correlation between the amounts of area determined this way and the planted areas that died in the winter was established with average results of agrometeorological observations for the oblast (kray, republic).

The correlational matrices were calculated in terms of four soil and climate zones on whose territory strains of winter crops with various degrees of winter hardiness are cultivated:

1) the zone of cultivation of weakly winter hardy strains of winter crops (barley and wheat of the Bezostaya 1 strain)--southern regions of the country's steppe zone with unstable winters;

2) the zone of cultivation of medium and highly winter hardy strains of winter crops (wheat--Mironovskaya 808, Mironovskaya yubileynaya 50, Odesskaya 3, Odesskaya 51, Priboy, Priazovskaya, Belotserkovskaya 198; rye--Voronezhskaya SKhI, Khar'kovskaya 55, Vyatka and others)--the remaining regions of the steppe zone and the forest steppe zone;

3) the zone of cultivation of medium winter hardy and highly winter hardy strains of winter crops--western regions of the Ukraine, Belorussia and the Baltic area;

4) the zone of cultivation of winter hardy strains of winter crops (wheat--Ul'yanovka, PPG-186, Kuntsevskaya 45, Mironovskaya 808; rye--Vyatka, Vyatka 2, Kazanskaya and others)--the majority of the remaining regions of the nonchernozem zone.

Table 54a. Expected Condition of Areas Planted in Winter Crops in Spring of 1966 on Territory of Vologodskaya Oblast

(1) Общая посевная площадь (тыс. га)	(2) Площадь посевов на 15 I				(5) Ожидаемая площадь посевов весной								
	(3) с хорошим и удовлетворительным состоянием		(4) с плохим состоянием		(3) с хорошим и удовлетворительным состоянием		(6) с большой изреженностью (> 50%)		(7) с повышенной изреженностью (30—50%)		(8) наиболее вероятная площадь с посевами в плохом состоянии		(9) возможные пределы площади с посевами в плохом состоянии
	(10) тыс. га	%	(10) тыс. га	%	(10) тыс. га	%	(10) тыс. га	%	(10) тыс. га	%	(10) тыс. га	%	(10) тыс. га
149	137	93	12	7	103	69	20	13	26	18	46	31	36—57

[Key on following page]

Key:

1. Overall planted area (thousands of hectares)
2. Planted area on 15 January
3. With good and satisfactory condition
4. With poor condition
5. Expected planted area in spring
6. With great thinning (more than 50%)
7. With increased thinning (30-50%)
8. Most probable area with plantings in poor condition
9. Possible limits of area with plantings in poor condition
10. Thousands of hectares

As a result of the correlational analysis it turned out that in the first and second zones where the main causes of the death of winter crops are freezing, the ice crust ground into the soil and autumn drought, the sizes of the areas with dead plantings of winter crops mainly depend on the average oblast minimum soil temperature at the depth of the tillering node (correlational relation--n = 0.94, coefficient of correlation--r = 0.86); the average oblast depth of freezing of the soil (n = 0.92; r = 0.71); the sum of negative temperatures throughout the entire winter period (n = 0.60; r = 0.54); the average oblast depth to which the ice cover is ground into the soil (n = 0.78; r = 0.78); the average oblast thinning of planted areas with continuation of the growth of sample plants taken from the fields on 23 February (n = 0.92; r = 0.87); the sizes of the areas (in percentages of the overall areas of winter crops) with poor condition of the planted areas in the autumn (n = 0.40; r = 0.35); and the average oblast bushiness of the winter crops in the autumn after the end of the growing period (n = 0.50; r = 0.38).

In the third and fourth zones, where the main reasons for the destruction of plants are soaking and perishing under the snow, the correlational dependency between the area with dead plants by spring and the average oblast significance of agrometeorological elements turned out to be sufficiently close and in the majority of cases, as could be expected, inversely proportional. For example, the dependency between this area and the average oblast minimum soil temperature at the depth of the tillering node during the period from the first 10 days of November through 20 February is characterized by n = 0.76, r = -0.71; the average depth of freezing of the soil during the 10 days of the establishment of a deep snow cover (30 cm deep and more--n = 0.77, r = -0.70; the average number of 10-day periods with a snow cover 30 cm deep and more during the period from the first 10 days of November until 20 February--nonlinear and directly proportional, n = 0.70.

As one can see from the correlational relations and the coefficients of correlation that are given, the average oblast values of agrometeorological elements characterize sufficiently well the sizes of the areas on which winter crops have died in the winter and the greatest influence on the wintering of planted areas is exerted by a minimum temperature of the soil at the depth of the tillering node during the period from the first 10 days of November until 20 February. In the zone where plants perish under the snow, as in the zone of freezing, the correlational relationship between the area with dead plants and the soil temperature at the depth of the tillering node is sufficiently great (n = 0.75). Therefore we took as the main predictor in all prognosticatory dependency the minimum soil temperature at the depth of the tillering node, averaged for the oblast (kray, republic).

The precision of the determination of its average value is quite significantly reflected in the precision of the prediction and in the amounts of area with dead plants [15].

The prognosticatory dependency of the amounts S_B and the plants that perished under the snow, on the one hand, and the average oblast minimum soil temperature at the depth of the tillering node up to 20 February $\bar{t}_3$, on the other, has a parabolic nature and is expressed by the equation

$$S_B = 13.12\bar{t}_3 + 0.84\bar{t}_3^2 + 54.86. \qquad (22)$$

The correlational relationship--n = 0.75; the mean square error of the equation--$E_s = \pm 4.4$ percent. The dimension of the coefficient: percentage/0°C and percentage/0°C^2. The equation is valid with $\bar{t}_3$ greater than -10°C, n = 65 [18].

But in individual cases the deviation of the actual sizes of areas with dead plants from this theoretical curve reached great amounts (10 percent and more, figure 49). This was the case in 1965/66 when in individual oblasts the actual areas were somewhat greater than prediced according to the curve of the connection and in 1967/68 when they were, conversely, considerably less. This is explained by the fact that the equation does not take into account the length of time a deep snow cover remains on the fields or the pecularities of the weather conditions during the period when the snow is thawing. As was already pointed out, the latter, although in very rare cases (1968), can considerably reduce the area with fully destroyed plantings (up to 5 percent and less, figure 49) if the snow disappears from the fields within 3-5 days. On the basis of this one can presume that measures for accelerating the disappearance of the snow cover from the fields in the spring in the nonchernozem zone could have a great positive significance, especially if the plantings are promptly cared for also (top dressing from aircraft and early harrowing).

The overall prognosticatory dependency of the amounts of area with winter plants that have died under the snow S_B and the average oblast minimum soil temperature at the depth of the tillering node before 20 February $\bar{t}_3$ and the length of the period with a deep snow cover of 30 cm and more $\bar{n}$ is nonlinear and can be expressed by a family of parablic curves. The equation of this dependency has the form

$$S_B = 6.32t_3 + 0.29t_3^2 + 0.11n + 0.07n^2 + 30.93, \qquad (24)$$

the correlational relation of the connection--n = 0.78, the number of cases, n = 65, the error within limits of no more than 5 percent of the area is guaranteed to be 80 percent of the cases and equal to or less than 7 percent of the area--90 percent of the cases. The dimension of the coefficients of the predictors are, correspondingly: percentage/°C, percentage/°C^2, percentage/day and percentage/day^2.

The calculation of the expected area with dead plants of winter crops is made according to this formula on 20-22 February when the period with a snow cover of 30 cm and more has still not ended. Therefore the overall duration of this period is predicted initially from individual stations and then from data that are obtained one calculates the average value $\bar{n}$ for the oblast. In order to predict the length of the period n for individual stations one uses the dependency presented in figure 47.

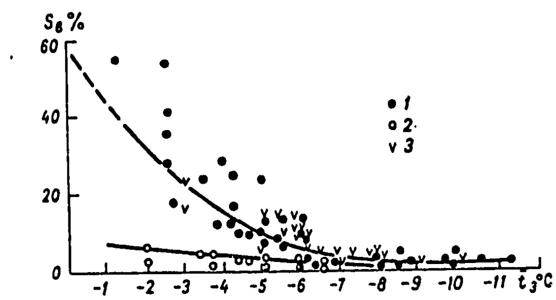

Figure 49. Dependency Between Area with Plants of Winter Crops That Have Perished Under the Snow S_B (%) and the Average Oblast Soil Temperature at the Depth of the Tillering node $\bar{t}_3$ (°C) Until 20 February

Key:
1--1965/66, 2--1967/68, 3--other years.

The prediction of the amounts of area with plantings of winter crops that have perished under the snow can be calculated from the two aforementioned prognosticatory dependencies. The first connection (only with the minimum soil temperature) produces best results in years with a very deep snow cover (maximum depth for the winter more than 50 cm) and a long duration (more than 100 days) when, obviously, there is not only perishing of winter plants under the snow in the winter, but also soaking of them in the spring (for example, in 1965/66 in the western part of the European territory of the USSR) and the second--in all other years.

Judging from the nature of these dependencies and analogous prognosticatory connections between the sizes of the areas and the areas planted in winter crops that have perished under the snow [18, 22], one can assume that the optimal conditions for wintering of winter crops are created with a minimum soil temperature at the depth of the tillering node within the range of from -7 to -8°C. The sizes of the areas on which the plants have died both from perishing under the snow and from freezing turned out to be least with this minimum soil temperature at the depth of the tillering node.

When the minimum soil temperature at the depth of the tillering node increases above -7°C the area on which the plants die increases as a result of the plant's perishing under the snow (of course, if there is a sufficient deep snow cover on the fields for a long period of time). When the soil temperature drops below -8°C they also increase, but as a result of freezing of the plants. Thus the dependency between the sizes of the areas on which the winter crops have died and the average oblast minimum soil temperature at the depth of the tillering node before 20 February have an identical nature both for freezing and perishing under the snow, but an inverse sine. Taking this into account, when drawing up long-term agrometeorological predictions for cases where the snow cover on the fields is less than 20 cm, one should use the prognosticatory connections we developed for freezing of planted areas [18, 22].

But if, according to snow surveys, the average depth of the snow cover on the fields reaches 20 cm and more, even on part of the oblast's territory, if the depth of freezing of the soil is not great (less than 50 cm) and if the minimum soil temperature at the depth of the tillering node is above -10°C, when drawing up a prediction of the sizes of the areas on which the plants will die, one should utilize the connections obtained for predicting the perishing of plants under the snow.
Under natural conditions the minimum soil temperature, the depth of freezing of the soil and the depth of the snow cover are interconnected. Therefore one can usually determine easily the main cause of the death of winter crops. To do this it is only necessary to have and take into account data concerning these main elements of agrometeorological conditions of wintering of winter grain crops throughout the entire winter period.

The area on which the plants have died in the spring is calculated only for the main grain crops as a whole (rye and wheat) since in the zone where plants perish under the snow the main crops that are cultivated are winter rye (80-100 percent of the area planted in winter crops) and winter wheat of those strains which, as research has shown, are almost identically damaged under the snow.

In regions where crops perish under the snow the poor plantings are the winter crops which will be written off and will not be included in the harvesting area. They include plantings that have fully died off and plantings with thinning of more than 50 percent of the plants on more than half of the field (if they are poorly developed, on 30 percent of the field). Plantings that have been damaged (even with thinning of 50 percent and more) on a smaller part of the field (30-50 percent) under the snow, as a rule, are not resown, despite the fact that they are evaluated as poor in the spring after the disappearance of the snow cover from the fields. After top dressing and harrowing (sometimes with undersowing) in certain years they improve their condition and the dead above-ground mass is restored. And although the main shoots die secondary shoots produce some yield. In these years the actual area with poor plantings, according to data from the spring examination (aircraft or ground tour), turns out to be close to the predicted area with poor plantings as a result of perishing under the snow and the planted area to be written off, according to data of oblast statistical administrations, turns out to be less (as, for example, in a number of oblasts in 1971).

Long-term predictions of the perishing of winter crops under the snow on the territory of the oblast (republic) are drawn up twice. The first--from the results of calculations of the expected thinning of planted areas and the area on specific fields--is given well ahead of time; in the second 10-day period after the establishment of a snow cover of 30 cm or more on the fields. The second--from average oblast indicators--on 20 February [18]. The second prediction is also given sufficiently well ahead of time for prompt preparations for caring for the damaged plantings and for spring resowing of dead winter crops with spring crops.

THE PROBABILITY OF PERISHING OF WINTER CROPS UNDER THE SNOW IN VARIOUS ZONES OF THE USSR

The perishing of plants under the snow takes place as a result of the extended effects on them of a complex of unfavorable factors in the external environment. As was shown above, the main elements of agrometeorological conditions which cause winter grain crops to suffer from perishing under snow are the snow cover, the depth of freezing and the soil temperature at the depth of the tillering node of tillering plants. The harmful effects of these elements on winter crops which cause damage and death to the plants under the snow are manifested when there is a snow cover of 30 cm and more on the fields and the depth of freezing of the soil is less than 80 cm and especially less than 50 cm for more than 50 days [17-22]. Under these conditions the minimum soil temperature at the depth of the tillering node remains within the limits of 0 to -5°C and contributes to the plants' extensive expenditure of hydrcarbons, their exhaustion and their infection with various kinds of fungal diseases and also to elongation of the vegetative cones and destruction of the more productive shoots that have formed in the autumn.

The cold period of the year, during which the plants are in a condition of forced dormancy has both in terms of duration and in terms of severity a great spatial variability on the territory of the USSR which must be taken into account when cultivating winter grain crops [43]. In the north of the country's European territory the wintering of winter crops usually began 1.5-2 months earlier and ends that much later than in the south. The duration of the period of winter dormancy of winter crops in the northern oblast is more than twice as great as in the southern oblasts (180 days instead of 80). In the Asian territory of the USSR it increases from the southwest to the northeast within even greater limits.

The severity of the winter, which can be characterized by the average many-year total of negative average daily air temperatures, also increases from the southwest to the northeast of the country. Thus in Permskaya and Sverdlovskaya Oblasts it is 20 times greater than in Krasnodarskiy Kray and Krymskaya Oblast. The total of negative air temperatures during the year in the south of the country's European territory is -100 - -200°C and in the northeast-- -1800 - -2000°C. The average of absolute minimum air temperatures has the same spatial variability. In the north of the country's European territory it is equal to -20°C and in Sverdlovskaya, Kirovskaya and Permskaya Oblasts-- -40 - -44°C.

But agroclimatic conditions for the wintering of winter grain crops are not under the influence of this pattern of change throughout the USSR territory. On the contrary, in the north and in the center of the country's European territory where the frosts are more severe the freezing of winter crops is observed rarely. Because of the early establishment of a snow cover on the fields and its great depth and duration, winter crops there frequently perish under the snow.

The snow cover in the northeast of the country's European territory is formed on the fields as early as the end of October or the beginning of November, in the central oblasts of the nonchernozem zone--at the end of November, and in the Ukraine (except for the southern oblasts)--at the end of December. There are years when the time of its establishment on the fields turns out to be 1-1.5 months earlier or later than the average for many years.

The fields are cleared of the snow cover in Rostovskaya and in the south of the Ukraine in the middle of March and on the territory that lies south of the line formed by Leningrad, Smolensk, Kaluga, Tambov and Saratov--by 10 April. But in Arkhangel'skaya, Kirovskaya, Permskaya and Tomskaya Oblasts the stable snow cover does not break up until the first 10 days of May.

The times of the establishment and disappearance of the snow cover are of great significance for the wintering of winter crops. In the forest zone an early formation and late disappearance of the snow cover from the fields, where it lasts for 160-190 days, leads to perishing of the plants under the snow.

The duration of the period with a snow cover of 30 cm and more in the central oblasts of the nonchernozem zone of the country's European territory is 60-80 days and on the territory southeast of the line formed by Petrozavodsk, Vologda, Ufa and Verkhotur'ye (Sverdlovskaya Oblast)--80-120 days. In the Baltic area, Belorussia and the central chernozem zone it is less than 20 days (figure 50) and therefore the probability of the perishing of winter crops under the snow is small.

The maximum depth of the snow cover during the winter is more than 30 cm on the territory north of the line formed by Pskov, Smolensk, Moscow and Bugul'ma in more than 50 percent of the year and north of the line formed by Leningrad, Yaroslavl', Kazan' and Izhevsk in 80-100 percent of the years. The average maximum depth of the snow cover on fields with winter crops and the number of times the maximum depth of the snow cover is 30 cm and more with various values for the average maximum depths are presented in figures 51 and 52. The maximum depth of the snow cover for the winter, as one can see from figure 52, increases from 10 cm in the southwest of the Ukraine to 60 cm in Kirovskaya and Permskaya Oblasts.

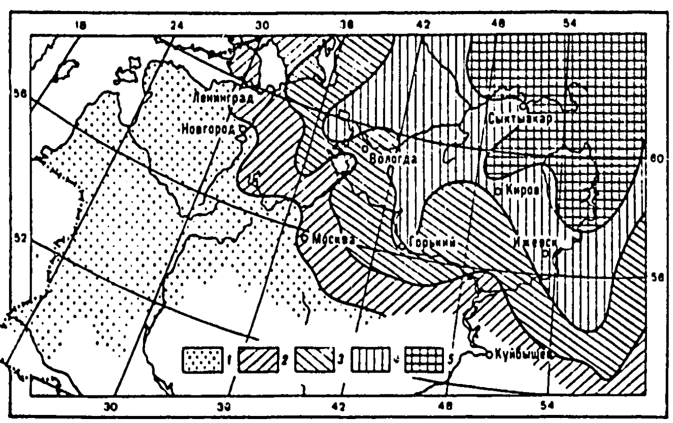

Figure 50. Many-Year Average Length of Time Snow Cover of 30 cm and More Lasts on Fields With Winter Crops (Days).

Key:
Number of days: 1) less than 20, 2) 21-50, 3) 51-80, 4) 81-120, 5) more than 120

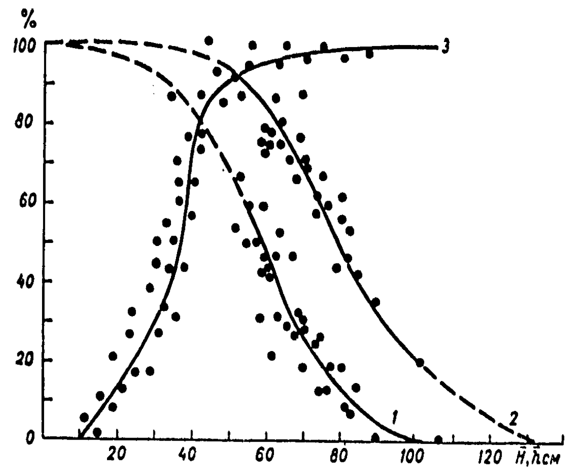

Figure 51. Recurrence of Years (%) With Maximum Snow Cover for Winter of 30 cm and More (3) and Depth of Freezing of Soil H less than 50 cm (1) and less than 80 cm (2) with Various Values of $\bar{h}$ and $\bar{H}$

Because of this distribution of the snow cover throughout the territory of the USSR, despite the great severity of the winter, in the northwestern and central regions of the country's European territory the depth of freezing of the soil is less than in the central chernozem zone, in the north of the Ukraine and in the central Volga area. The maximum depth of freezing of the soil during the winter on an average for 20 years in the north and northeast of the country's European territory turned out to be equal to 60-80 cm, in the Upper Volga--80-90 cm, in the northwestern, western and central oblasts--50-70 cm and in the central chernozem zone, the Central Volga Area and in north of the Ukraine--80-100 cm and more. In the country's European territory the soil freezes most deeply (100-130 cm) in the Volga regions of Kuybyshevskaya and Saratovskaya Oblasts and in Orenburgskaya Oblast. In the steppe regions of the Western Siberia, in the Urals and in the northern half of Kazakhstan it freezes to 120-150 cm and in places--down to 200 cm.

In the nonchernozem zone of the country's European territory in individual years the depth of freezing of the soil ranges from 0 to 150 cm and more. When the snow cover is established early the snow remains unfrozen throughout the entire winter or freezes to no more than 50 cm (1965/66, 1967/68). In Arkhangel'skaya, Vologodskaya, Kostromskaya, Yaroslavskaya, Ivanovskaya, Kirovskaya and Permskaya Oblasts and in the northern part of Gor'kovskaya

Oblast, the soil freezes to less than 50 cm in 50 percent of the years (see figure 50, 1) and south of the line formed by Smolensk, Kalinin, Moscow, Gor'kiy, Izhevsk and Verkhotur'--in 30-50 percent of the years [22].

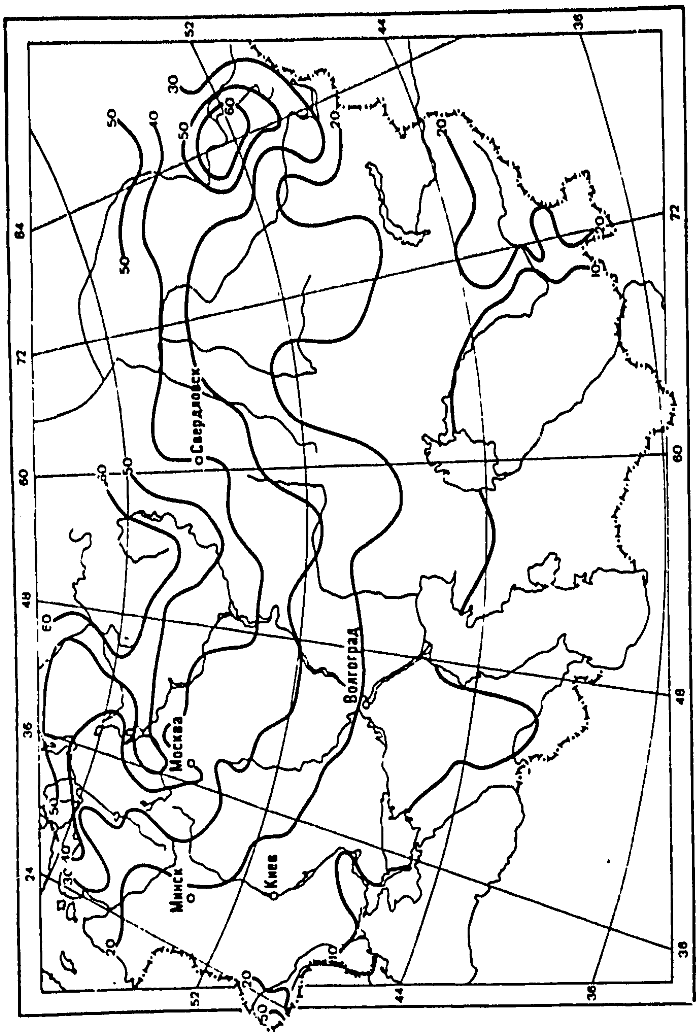

Figure 52. Average Maximum Depth of Snow Cover (cm) for Winter on Fields with Winter Crops

The average many-year minimum temperature of the soil at the depth of the tillering nodes of winter crops turned out to be greatest (-8 - -10°C) in the nonchernozem zone of the country's European territory (figure 53). The recurrence of years with a minimum winter soil temperature at the depth of the tillering nodes of winter crops of -5°C and more, when under a deep snow cover it was possible for the p!ants to perish (according to data from observations of meteorological sta ions over 20 years--from 1956 through 1975) amounted to more than 50 percent of the years in a number of regions of Vologodskaya, Kostromskaya, Kievskaya and Permskaya Oblasts; 31-50 percent of the years in Kalininskaya and Yaroslavskaya Oblasts, in the northern part of Gor'kovskaya Oblast and in the Udmurt ASSR; and 20-30 percent of the years in the remaining regions of the nonchernozem zone of the RSFSR and in the northern part of the Belorussia [22].

The perishing of plants under the snow takes place, as was shown above, when the plants remain for a long time under a deep snow cover, in the dark and with slight freezing of the soil with its temperature above -5°C. Therefore we have calculated the recurrence of years with the number of 10-day periods during the winter of 8 and more with the depth of the snow cover of 30 cm and more and the maximum depth of freezing of the soil of 50 cm and less (figure 54). It turned out that this duration of unfavorable win-ering conditions is observed most frequently in the northeast of the nonchernozem zone. East of the line formed by Vologda, Gor'kiy, Izhevsk and Ufa these conditions for 8 10-day periods and more recur in 30-50 percent of the years. The probability is also great (10-30 percent of the years) for a long duration of unfavorable wintering conditions in the majority of oblasts of the central region of the RSFSR. In the southern and western oblasts of the nonchernozem zone of the RSFSR and also in the Baltic area a great duration (dangerous for winter crops) of a deep snow cover with slight freezing of the soil is rare--less than 10 percent of the years.

But in the western regions of the country's European territory the temperature at the depth of the tillering node can remain close to 0°C not only when the snow cover is 30 cm and more, but also when it is less, since the air temperature there is higher and the depth of freezing of the soil is less. Moreover, winter crops in these regions undergo tempering during the autumn period with less favorable conditions, the quantity of sugars in them is less and therefore a shorter period is required for the expenditure of sugars on respiration. With an increase in the amount of time during which the snow cover on the fields is 30 cm and more with a depth of freezing of the soil of 50 cm and less there is an increase in the percentage of thinning of winter crops and the gross yield of winter crops decreases.

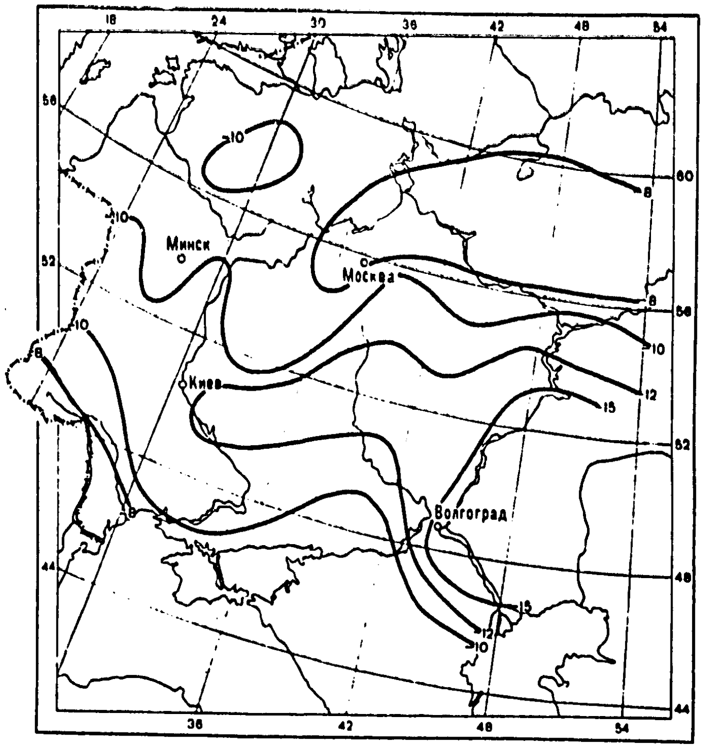

Figure 53. Minimum Soil Temperature at Depth of Tillering Nodes of Winter Crops (Average from Absolute Minimums from 1952 Through 1971)

In order to compare our regioning of the territory of the nonchernozem zone with respect to conditions for perishing of plants under the snow and actual data, we calculated the recurrence of years in which, according to data of the USSR Central Statistical Administration, the gross yield was equal to 80 percent and less than the many-year average. These calculations confirm our evaluation of the wintering conditions for winter crops. The yield decreases most frequently (in 20 percent of the years and more) in the northeastern and northern regions of the nonchernozem zone where it is more probable to find conditions that cause perishing of the plants under the snow. In the northwestern regions a certain reduction in the yield of winter crops in 10-20 percent of the years is explained by damage to the planted areas as a result of soaking and in the southern regions of the nonchernozem zone--as a result of freezing [22].

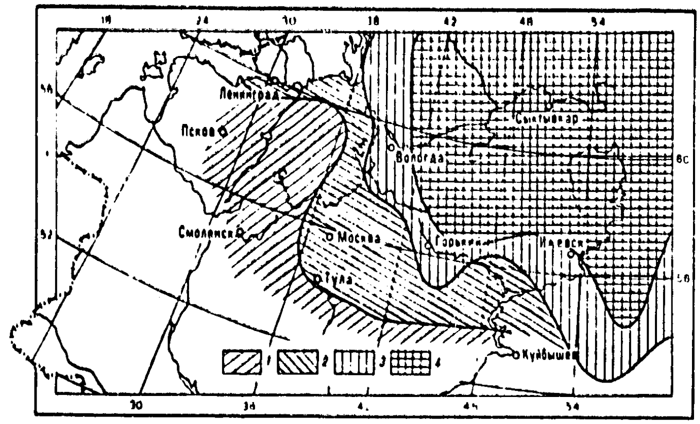

Figure 54. Recurrence of Years (%) With 8 and More 10-Day Periods With Snow Cover of 30 cm and More and Maximum Depth of Freezing of Soil During Winter of 50 cm and Less.

Key:
1) Less than 10%, 2) 11-20%, 3) 21-30%, 4) 31-50%.

The reduction in the gross yield of winter crops as a result of perishing under the snow in the nonchernozem zone of the RSFSR can be fully eliminated by taking into account the agrometeorological conditions for wintering and promptly taking the necessary measures for fighting against winter death of the plants.

IN LIEU OF A CONCLUSION

Perishing of plants under the snow, as one can see from an analysis of agrometeorological conditions for the wintering of winter crops, leads considerably less frequently to the mass destruction of planted areas than freezing and destruction by the effects of ice crusts do. Moreover perishing under the snow is found primarily in the nonchernozem zone of the country's European territory where until recently considerably less attention has been devoted to winter crops than in the chernozem zone of the USSR where winter crops are the leading grain crops. Yet an average 20 percent reduction in the yield of winter crops because of perishing under the snow has caused and now causes appreciable harm to grain farming in the RSFSR, the Baltic republics and also in many regions of the northwest and Belorussia. Now when large tasks have been set for the USSR nonchernozem zone for increasing the gross grain harvest, elimination of losses of the yield from perishing under the snow should contribute to their fulfillment.

Even in the very earliest works on perishing of winter crops under the snow it was noted that a deep snow cover has a destructive effect on the wintering of winter plantings. In the first stage when the factors causing the death of plants were not clear certain devices were proposed for compacting the snow or removing it from the fields early.

Fundamental research on the physiological factors causing the death of winter crops, the discovery of processes of intense expenditure of hydrocarbons, starvation of the plants, and infection of weakened plants with pathogenic organisms opened up new possibilities for scientific development and searches for effective methods of fighting against the phenomenon of perishing under the snow.

In recent years the attention of agrometeorologists working in the area of the wintering of winter crops has been drawn to a study of the phenomenon of plants perishing under the snow and diagnosis of the condition of winter crops. Along with agrometeorologists who have been investigating the complex of factors leading to perishing of winter crops under the snow, their distribution in various regions of the USSR and abroad, there has been considerably broader research on phenomena of perishing of crops under the snow by physiologists, morphophysiologists, phytopathologists and crop specialists.

Research on agrometeorological conditions, physiological and biochemical processes and also the study of morphophysiological peculiarities of the condition of vegetative cones in the autumn, winter and spring periods have considerably broadened and deepened our ideas about the causes of damage and death to planted areas and about the predictable connections between agroclimatic conditions that determine the perishing of winter crops under the snow and the level of their productivity.

On the basis of theoretical developments and experimental research a number of agricultural measures have been proposed which considerably reduce the harm caused to the national economy by the perishing of plants under the snow.

In the first place these are measures which in the autumn are directed toward reducing the harmfulness of factors that contribute to perishing of the plants under the snow, such as improving the structure and also the physical properties of the soil by applying manure, peat and green fertilizer; liming of acid soils; removal of excess moisture from winter fields in the autumn and preparing field ditches for the flow of melted snow in the autumn, winter and especially in the spring periods.

In the second place, these include agrotechnical devices directed toward creating favorable conditions for autumn tempering of winter crops, which is important for increasing their resistance both to freezing and to perishing under the snow and contributes to maximum accumulation of sugars in the above-ground organs and especially in the tillering nodes.

The agrotechnical devices include selecting and providing optimal planting times, planting norms and also autumn top dressing with potassium and phosphorus fertilizers; in cases where the soil is not infested with fusaria, preplanting disinfection of the seeds and their treatment with a tur preparation can be important. Selection of strains that are most resistant to perishing under the snow is quite essential.

In the third place, these measures include regular agrometeorological inspection, beginning in the autumn, of the change in temperatures at the depth of the tillering nodes and on the surface of the soil under the snow cover and also biological examination of the vegetative cones of the plants so that, if necessary, the snow cover can be compacted, thus contributing to reducing the temperature of the surface layers of the soil to -5 - -7°C.

In the fourth place, they include the creation of conditions that accelerate the melting of the snow on the fields in the spring, which reduces the harmful effects of snow mold and other pathogenic fungi and also root rot. The snow can be removed when there is no longer any danger of the return of frosts.

Early in the spring it is necessary to take special care of the areas planted in winter crops that have been damaged under the snow. First of all, it is necessary to use harrowing to remove leaves that have been infected with snow mold. At the same time early spring top dressing with mineral or liquid organic fertilizer intensifies the growth of tillering shoots that are stage I of organogenesis and accelerate their development; and a second top dressing during stem extension before advancing to stages III-IV of organogenesis will contribute to better development and growth of the rudimentary spike.

Existing methods of diagnosing the condition of plants on specific sections and on large territories make it possible to develop more successfully scientific fundamentals for protecting winter crops from perishing under the snow. These same methods make it possible to promptly draw up predictions of the wintering of plantings and their productivity, which is extremely important for economic and planting agencies.

The main tasks under the new five-year plan are the selection of new strains of winter wheat and winter rye of the intensive type which are resistant to conditions of wintering on the fields of the nonchernozem zone and also further development of the system of agricultural devices for protecting winter crops from perishing under the snow and their application on the kolkhozes and sovkhozes on which the areas planted in winter crops will be expanded in the next few years.

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