The influence of abiotic stress on the crop and seed setting

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Abstract. The potential productivity of an ear by the time of flowering is predetermined by the number of fertile flowers and the "planned" mass of 1000 grains - through the number of flowers with which the grain size is inversely correlated, by the resources of the shoot vegetative mass and by the possibility of realizing these resources. The influence of pinching and incomplete setting of seeds in the conditions of dry growing seasons of 2018 and 2020 for the formation of grain is considered. It was concluded that grains from the first three flowers have a predominant contribution to the productivity of a spikelet. The naked oat variety Nemchinovskiy 61 could not realize its biological potential due to abiotic stresses. Due to the incomplete seed setting, an average of 2.03 grains out of 5-6 flowers were preserved for harvesting. Reduction of flowers number in a spikelet in naked oats to two as the direction in breeding has no prospects. To increase the adaptability of naked oats to abiotic stresses, parental forms with a relatively small number of grains in a spike, which are capable to utilize precipitation, should be involved in hybridization, to increase the mass of 1000 grains.

1. Introduction

The naked oats have a number of morphological and biochemical differences in comparison with the husked oats. Husked oats have 2-3 flowered spikelets, while naked oats have multi-flowered ones (up to seven spikelets). The flower scales are hard, leathery in husked oats, while in naked oats they are soft, webbed, like spikelet scales. In husked oats, the grain is densely covered with flower scales without merging with them; in naked oats, the grain lies freely between the flower scales [1].

The multi-flowered spikelet in naked oats leads to a different quality of seeds in size; it is also characterized by incomplete setting of seeds. In biochemical terms, the grain of naked oats is superior to that of husked oats, having a higher content of protein balanced in amino acid composition, fat and starch [2, 3]. Naked and hulled oats respond differently to drought stress. In husked oats, dry weather results in formation of fine grains with high grain hull content. Dry weather causes incomplete setting of seeds in naked oats [4, 5, 6].

2. Materials and methods

An attempt was made at the Federal Research Center "Nemchinovka" in 2018-2020, to study the effect of stresses caused by both drought and excessive moisture on the formation of plant productivity in naked oats and yield in the variety Nemchinovskiy 61 and to clarify the optimal number of grains, as the direction in which selection should be carried out for the formation of a stable harvest. To achieve the latter, pinching was used.
It was assumed that if the two most developed flowers are left in a multiflorous spikelet, they will receive additional nutrients for the formation of a larger grain, thereby compensating for the productivity of a spikelet due to the removed flowers.

A number of studies have observed the effect of ear pinching on wheat plants. Thus, Konovalov in his studies on the effect of pinching on wheat plants, indicated that a doubled grain mass of a pinned ear shows the potential productivity inherent in the flowering phase [1].

The potential productivity of an ear by the time of flowering is predetermined by the number of fertile flowers and the "planned" mass of 1000 grains - through the number of flowers with which the grain size (1000 grains) is inversely correlated, by the resources of the vegetative mass of the shoot and by the possibility of realizing these resources (the force of attraction of the ear, the power of the conducting paths.

If the intact ear is sufficiently well supplied with plastic material, then pinching has no effect: additional nutrition cannot be realized. If the nutrition of the ear is insufficient, the reaction to pinching is manifested and the stronger, the worse the supply of the ear is [7, 8, 9, 10].

Pinching provides the remaining spikelets with excess nutrition, thereby increasing the size and, accordingly, the mass of 1000 grains. In varieties that have a higher number of grains, the mass of 1000 grains decreases due to competition. The resources of the vegetative sphere of plants are limited. When most of them are spent on creating a higher number of grains, their size turns out to be smaller than in the opposite case. For the sake of objectivity, it should be clarified - we had in mind the fact that, unlike other grain crops, oats are very sensitive to castration, and also that the pinned plants have already spent plastic substances on the formation of reproductive organs.

3. Results and discussion

The naked oat variety Nemchinovsky 61 was chosen as the subject for research, as the most adaptive Nemchinovsky 61 exceeded the yield of the Vyatsky variety by 0.5-1.0 t/ha. The growing seasons of 2018-2019 were characterized by the increased temperature regime and a moisture deficit in May-June. The cracks up to 1.0 cm wide were formed on the ground in July 2018 and 2019. Precipitation in the second decade of July 2019 allowed oat plants to form a higher crop in comparison with 2018 (Table 1).

| Month | Decade | Air temperature, °C | Precipitation, mm |
|-------|--------|---------------------|------------------|
|       |        | long-term average   | 2018  | 2019  | 2020  | long-term average | 2018  | 2019  | 2020  |
| May   | 1      | 11.1               | 16.5  | 13.5  | 11.1  | 14.7            | 5.1   | 37.4  | 14.7  |
|       | 2      | 12.5               | 17.0  | 16.0  | 12.5  | 18.0            | 29.0  | 3.9   | 18.0  |
|       | 3      | 14.2               | 16.7  | 18.6  | 14.2  | 19.7            | 0.0   | 8.8   | 19.7  |
| June  | 1      | 16.3               | 12.9  | 21.0  | 16.3  | 23.0            | 21.0  | 0.8   | 23.0  |
|       | 2      | 16.7               | 17.8  | 19.8  | 16.7  | 23.1            | 4.3   | 15.6  | 23.1  |
|       | 3      | 18.9               | 21.3  | 18.0  | 17.6  | 29.8            | 45.0  | 44.8  | 29.8  |
| July  | 1      | 17.8               | 17.4  | 16.0  | 17.8  | 29.8            | 46.0  | 6.7   | 29.8  |
|       | 2      | 18.3               | 21.9  | 15.4  | 18.3  | 27.2            | 59.0  | 28.8  | 27.2  |
|       | 3      | 18.3               | 21.5  | 18.1  | 18.3  | 28.8            | 6.9   | 5.8   | 28.8  |
| August| 1      | 18.2               | 21.1  | 13.9  | 18.2  | 27.4            | 1.7   | 26.2  | 27.4  |
|       | 2      | 15.9               | 19.4  | 17.4  | 15.9  | 26.1            | 19.0  | 10.5  | 26.1  |
|       | 3      | 14.8               | 18.3  | 17.2  | 14.8  | 25.7            | 9.8   | 0.0   | 25.7  |

The temperature regime and distribution of precipitation had an ambiguous effect on the formation of the structure of the crop and the yield of the variety Nemchinovsky 61. The grain of the 2018
harvest had higher indicator of volumetric mass. By the period of harvesting in 2018, 4.2% more plants remained, in the same year the number of spikelets in a panicle increased by 0.6 pieces. The grain content of the panicle was higher by 14.1 grains.

When reproductive organs were formed, as well as during flowering and formation of ovaries, plants experienced more severe stress in 2019. However, the abundant rainfall during the grain filling in 2019 made it possible to form mass of 1000 grains higher by 5.8 grams and yield higher by 1.2 dt (Table 2).

The growing season of 2020 was characterized by the increased temperature regime and heavy precipitation that fell at the beginning of growing. In June, green algae and oxide iron appeared on the surface of the soil.

The growing season of 2020 was characterized by the increased temperature regime and heavy rainfall at the beginning of the growing season. The green algae and ferrous iron appeared on the soil surface in June as the result. Due to waterlogging and soil compaction, the plants experienced stress, which affected the establishment of fewer reproductive organs. By the time of harvesting 90.8% of the plants have survived and a higher number of spikelets were formed in the panicle. However, weather conditions made it possible to form the mass of 1000 grains at the level of 2018, but with the lower volumetric mass. Abiotic stresses caused by drought and waterlogging did not allow the Nemchinovskiy 61 variety to realize its biological potential.

Table 2. Characteristics of Nemchinovsky 61 variety against the background of abiotic stresses in the 2018-2020 growing seasons.

| Traits                                      | 2018     | 2019     | 2020     | Average |
|---------------------------------------------|----------|----------|----------|---------|
| Yield, dt/ha                                | 2.05     | 3.25     | 2.24     | 2.51    |
| Lodging, score                              | 6        | 9        | 9        | 8       |
| Plant height, cm                            | 75       | 80       | 92       | 82.3    |
| Volumetric mass, g/l                        | 624.4    | 530.8    | 580.8    | 578.7   |
| Survival percentage, %                      | 70.9     | 66.2     | 90.8     | 75.9    |
| Mass of 1000 grains, g                      | 28.4     | 34.2     | 28.4     | 30.3    |
| Panicle granularity, pcs                    | 34.2     | 20.1     | 43.4     | 32.6    |
| Average number of spikelets in a panicle, pcs | 12.9     | 12.3     | 20.4     | 15.2    |
| Average number of flowers per spikelet, pcs | 7        | 7        | 7        | 7       |
| Grain yield, %                              | 35.1     | 35.9     | 40.7     | 37.2    |

On the plot with plants of the Nemchinovsky 61 we labeled 100 panicles, half of them were pinned - two flowers were left in a spikelet. The other half of the panicles remained as control ones. The comparison was made in terms of such traits as the number of spikelets and grains in a panicle, the number of grains in a spikelet, the mass of grains per panicle, and the mass of 1 grain. Table 3 demonstrates the results of pinching. It follows from Table 3 that there was an insignificant effect of pinching in 2018 - the grains in the experimental spikelets were larger than in the control ones (0.035 g versus 0.028 g).

However, we couldn’t fully restore the productivity of panicles with pinned spikelets, their grain mass was 85% of the grain mass from control panicles. The opposite results were obtained in 2019, with a negative effect from pinching. The panicles subjected to pinching had a grain mass of 0.63 g against 1.92 g in the control ones. This phenomenon is explained by the abortion of the first flower in a spikelet, which, apparently, was caused by severe drought, intensified by trauma from pinching. The pinned panicles had a slight advantage in average mass per grain in 2020. However, this advantage was insignificant in comparison with the difference in grain mass between pinned panicles and control. The results of the experiment allow to conclude: the decrease in the number of flowers in a
spikelet of naked oats to two pieces due to the increase in stress resistance has no prospects in breeding.

| Traits (average)                              | 2018  | 2019  | 2020  | Average |
|----------------------------------------------|-------|-------|-------|---------|
|                                              | trial | control | trial | control | trial | control | trial | control |
| Number of spikelets in panicle, pcs          | 27.94 | 24.62  | 27.86 | 39.22   | 18.6  | 29.1     | 24.8  | 24.9    |
| Number of grains in spikelet, pcs            | 1.06  | 1.76   | 1.01  | 1.27    | 1.37  | 2.00     | 1.1   | 2.03    |
| Number of grains in panicle, pcs             | 29.66 | 43.36  | 28.03 | 49.87   | 25.20 | 54.10    | 27.73 | 49.11   |
| Grain mass per panicle, g                    | 1.04  | 1.22   | 0.63  | 1.92    | 0.84  | 1.45     | 0.79  | 1.53    |
| Mass of 1 grain, g                           | 0.035 | 0.028  | 0.022 | 0.038   | 0.033 | 0.027    | 0.028 | 0.031   |

We had an opportunity to study in 2019 the drought resistance of three samples of naked oats received from the collection of the All-Russian Institute of Plant Genetic Resources named after N. I. Vavilov: Bai Yan 5, Yuan Za 1 and Ba You 14 originating from China, which were later included in hybridization. All three varieties have one peculiarity - they tend to form a relatively small number of grains per spikelet, which, as a rule, does not exceed 5 grains. Evaluation of the incomplete seed setting in separate varieties of the VIR collection is given in Table 4.

It follows from the data in Table 4 that the appearance of the incomplete seed setting in the second and third spikelets of the panicle is practically identical. The smallest percentage of incomplete seed setting was observed in the second grains (6.7-13.3%); in the first and third grains, this trait varied from 20.0% to 26.7% on average for three varieties with a tendency for the first grain to have a slight advantage over the third spikelet. The fourth grains had the largest incomplete seed setting (50.0-60.0%). The flowers that followed in the spikelets did not set any seeds at all.

| Variety      | Second spikelet from the top of panicle | Third spikelet from the top of panicle |
|--------------|----------------------------------------|---------------------------------------|
|              | first one grain | second two grains | third grains | forth grains | first 1 grain | second two grains | third grains | forth grains |
| Bai Yan 5    | 40          | 0                  | 10            | 60            | 30            | 20               | 0            | 20          |
| Yuan Za 1    | 40          | 0                  | 40            | 80            | 20            | 20               | 60           | 60          |
| Ba You 14    | 20          | 20                 | 30            | 40            | 10            | 0                | 20           | 70          |
| Average of 3 | 26.7        | 6.7                | 26.7          | 60.0          | 20.0          | 13.3             | 26.7         | 50.0        |

When assessing the contribution of separate grains of spikelet to panicle productivity, it was found out that the fourth grains set only 2.4-13.5% of productivity, while the main contribution was made by the grains set in the first three flowers.

In the second spikelets from the top, 70% of the panicle productivity was formed by the first and second grains, in the third spikelets from top - 68%. In the second spikelets, the largest contribution was made by grains from the second flower, in the third - from the first. The third flowers formed
21.1-22.0% of the panicle productivity and the fourth flowers made the smallest contribution with an average 7.9% to the panicle productivity.

4. Conclusions

The naked oat variety Nemchinovskiy 61 could not realize its biological potential due to abiotic stresses. Due to the incomplete seed setting, an average of 2.03 grains out of 5-6 flowers were preserved for harvesting. Reduction of flowers number in a spikelet in naked oats to two as the direction in breeding has no prospects. To increase the adaptability of naked oats to abiotic stresses, parental forms with a relatively small number of grains in a spike, which are capable to utilize precipitation, should be involved in hybridization, to increase the mass of 1000 grains.

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