The dependence of spring triticale yield and its structure on harvesting time and methods

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Abstract. The yield level of the spring triticale and its structure is largely determined by the timing and methods of harvesting, especially in the region where this crop was not cultivated previously. This issue is important for Amur region because it is located in the zone of risky agriculture and harvesting of spring triticale here runs in difficult conditions. The research aims to establish optimal terms and methods of harvesting, which will accelerate the introduction of this new crop in the region. In 2014-2016 field studies were conducted with methods generally accepted for grain crops. It was established that the highest grain yield at optimal terms of sowing, was obtained during harvesting on August 25th (in the phase of grain’s full ripeness). Earlier harvesting resulted in a 11-29% reduction of yield. It was especially noticeable in Carmen variety. During harvesting on August 4th, this variety’s yield decreased by 0.69 tons per hectare (metric, t/ha). Similarly, with a later harvest date (September 1st), all varieties showed lower yields. This was especially evident in Ukro variety with a 17% reduction. As for harvesting on August 4th and 11th, while grain moisture exceeded 20%, a separate method of cropping turned out to give the best results. Yields in these experiments amounted to 2.31 - 2.55 t/ha (Dill variety), 2.06 - 2.17 t/ha (Yarilo variety), and 1.81 - 2.26 t/ha (Carmen variety). August 18th is optimal for the two-phase method of harvesting when crops reach the spring triticale phase - the middle of grain wax ripeness. In this case, the yield amounted to 2.33 t/ha.

1. Introduction

The time and methods of harvesting are major technology elements on which the size and quality of grain yields largely depend. At that, it is important both to start harvesting at the maximum proper time and to end it [1,2]. Single and duplex mowing is a standard grain-crops harvesting technology. The advantage of direct combiner harvesting is in its independence from weather conditions and lower production cost, whereas two-phase harvesting normalizes grain by moisture using natural drying and leads to post-harvest (physiological) ripening, which in turn improves the quality of the grain [3]. Improper untimely harvesting can reduce to zero all the efforts to grow high-quality grain. Too early mowing in swaths during swath harvesting leads not only to a shortage of grain yield but also to a significant loss of quality indicators. Mowing delays, untimely direct combiner harvesting also can cause a decrease in productivity and technological parameters of grain [4]. To set them up properly, the characteristics of the variety should be considered, since each variety has its own optimal harvesting time [5]. The process of grain seed formation is divided into three stages: formation,
ripening, and maturation [6,7], so it is important to understand at which ripening stage to start harvesting the crop.

Currently, there is little information about the timing and methods of spring triticale harvesting, and considering the fact that this culture is new for Amur region, further research of timing and harvesting methods becomes relevant and requires comprehensive efforts [8]. Spring triticale, unlike other crops, is considered to be more resistant to stressful weather factors and soil conditions [9,10] and may well become an important link in the production of food grain in risky farming areas.

The following research aims to study the optimal methods and timing for harvesting new varieties of spring triticale of Russian selection in the southern agricultural zone of Amur region (Russian Far East).

2. Materials and Methods

Field studies were carried out on the experimental field of Far Eastern State Agrarian University (Blagoveshchensk district, Gribskoye village, Amur region). Crops were sown within the last 10 days (decade) of April. All field experiments were conducted according to generally accepted methods [11].

The effect of method and time of harvesting on triticale grain yield and its quality was studied in the experiments.

The experiments were multifactorial and studying the influence of three factors: (A) an exact variety; (B) its harvesting methods; (C) its harvesting time on the final result, i.e. grain's yield and its chemical composition. Three varieties of spring triticale were the objects of research: Ukro, Carmen, and Yarilo.

Ukro variety was selected out in cooperation of Russian scientists from Research Institute of Agriculture of the Central Chernozem Region named after V.V. Dokuchaev, Voronezh Agricultural University named after K.D. Glinka and Ukrainian researchers from Institute of Plant Cultivation of Ukraine named after V.Ya. Yuryev. It is the first spring triticale variety created in Russia. It is early ripening, with a 74 - 83 days vegetation period.

Carmen variety was cultivated by teams of scientists from the All-Russian Research Institute of Organic Fertilizers and Vladimir City Research Institute of Agricultural Sciences. The variety is mid-ripening with a 76 - 94 days vegetation period. It is featured by drought resistance and relatively tall stalks. Its target use is for fodder purposes for grain fodder and grain silage production.

Yarilo variety was cultivated by the team of Krasnodar Research Institute of Agricultural Sciences named after P.P. Lukyanenko. Its stalks' height is 65 - 91 cm (25.5 - 35.8 in). The plant is resistant to lodging. The vegetation period is 88 - 96 days. The variety was cultivated for feed grain and green fodder.

Two methods of harvesting were tested: direct combiner harvesting (direct method) and harvesting with pre-mowing into swaths (threshed in 3 days after mowing) with subsequent threshing (separate operations method). Five harvesting periods were considered:

1 period: 76 days from sprouting to harvesting (August 4th);
2 period: 86 days from sprouting to harvesting (August 11th);
3 period: 96 days from sprouting to harvesting (August 18th);
4 period: 106 days from sprouting to harvesting (August 25th);
5 period: 116 days from sprouting to harvesting (September 1st).

At that, the 1 harvesting period corresponds to the phase of the beginning of wax ripeness of grain, the 2 period - to the middle of wax ripeness, the 3 period - to the end of wax ripeness, the 4 period - to the full ripeness and the 5 period - to the phase of overripe grain.

In all tests, soybeans were the previous crop. The testing grounds were tilled before sowing and during the vegetation period, they were treated with a herbicide («Dianat», a trademarked name, BASF SE). Seeds were sown by a grain seeder in aggregate with a Dongfeng tractor, made in China. The sowing was done in rows with 15 cm (5.9 in) row spacing and sowing rate of 5 million seeds per 1 hectare. The total square area of the testing grounds was 30 m² (metric square meters) with 24 m² of
the discount area. Harvesting was done with a "Terrion" harvester (Sampo Rosenlev), the yield was calculated in tons per hectare (metric, t/ha) against standard humidity and 100% purity. The repetition in the test was 4-fold. All testing data were processed statistically according to the methods proposed by B.A. Dospekhov [11].

3. Results

The right choice of harvesting periods has always been given great importance. One way to determine them is to use grain moisture. So in the present studies, the moisture content of the grain varied from 12 to 40% during the harvesting period depending on the time and method of harvesting. Figure 1 illustrates herein that the highest grain moisture after threshing was observed at an early harvesting time and averaged 32.1%.

![Figure 1](image-url)

**Figure 1.** Changes in the moisture content in spring triticale grain depending on time and method of harvesting, %.

Moreover, if at the first harvesting period the difference in grain moisture between direct and separate harvesting was 12.3%, then during harvesting on August 18 it amounted only to 3.9%. However, even with the separate method of harvesting on August 4, grain moisture remained at a high level, which indicates the low efficiency of the first harvesting period. Therefore, the most optimal grain moisture in the two-phase method of harvesting was observed in the second period, i.e. the middle of the wax ripeness phase and the use of the direct harvesting method can be applied no earlier than August 18 after the crops reach the wax ripeness phase.

The moisture content of the grain only indicates the forthcoming of harvesting time without the use of additional drying of the grain, that is, the application of the direct combiner harvesting method (single-phase harvesting). For single-phase harvesting, the issue of loss-free harvesting is important. It is known that before the phase of full ripeness is reached, the process of dry substances accumulation in the grain is still going on, and when it reaches full ripeness, the biological yield and the grain quality of the standing crops remain unchanged for a short period, after which the yield starts decreasing [3].

The highest yield of grain in experiments was obtained during harvesting on August 25th (table 1). An earlier harvesting time resulted in yield reduction by 11 - 29%, especially in Carmen variety of spring triticale, where yield was 0.69 t/ha lower while harvested on August 4th compared to August
25th. However, with a later harvesting period (September 1st), all varieties showed a decrease in yield, especially the Ukro variety (by 17%), which is because the plants, due to delay in harvesting, begin to lose grain nutrients, furthermore losses and a decrease in yields are observed during threshing.

Table 1. Influence of a harvest period on spring triticale grain yield, t/ha (average value for 2014 - 2016).

| Phase (harvest period), A Factor | Varieties, B Factor | A Factor average |
|---------------------------------|--------------------|-----------------|
| The beginning of wax ripeness (August 4th) | Ukro 2.11 | Yarilo 1.75 | Carmen 1.65 | 1.84 |
| The middle of wax ripeness (August 11th) | Ukro 2.28 | Yarilo 1.86 | Carmen 2.08 | 2.07 |
| The end of wax ripeness (August 18th) | Ukro 2.51 | Yarilo 2.20 | Carmen 2.28 | 2.33 |
| The full ripeness (August 25th) | Ukro 2.61 | Yarilo 2.24 | Carmen 2.34 | 2.40 |
| The overripen grain on standing crops (September 1st) | Ukro 2.16 | Yarilo 1.96 | Carmen 1.97 | 2.03 |
| B Factor, average value | Ukro 2.33 | Yarilo 2.00 | Carmen 2.06 | - |

A study of spring triticale varieties productivity, depending on their harvesting time revealed that in the southern agricultural zone, on meadow-chernozem-like soils, the highest yield was shown by the Ukro variety. Its yield in all harvesting periods was higher than that of the Yarilo and Carmen varieties.

Analyzing the data of the two-factor field experiment, it should be noted that harvesting periods rather than variety diversification have a stronger effect on changes in crop productivity. The differences between the average yield values of spring triticale harvested in different periods are significantly higher than between individual varieties. The results of the study of spring triticale harvesting methods are presented in table 2.

Table 2. Impact of harvesting methods on spring triticale yields.

| Grain ripeness phase (harvesting date) | Methods of harvesting | 2014 | 2015 | 2016 | Average |
|---------------------------------------|-----------------------|------|------|------|---------|
|                                       | Ukro variety          |      |      |      |         |
| The beginning of wax ripeness (04.08) | Direct combiner       | 2.65 | 1.63 | 2.04 | 2.11    |
|                                       | harvesting            |      |      |      |         |
|                                       | Separate harvesting   | 2.80 | 1.83 | 2.30 | 2.31    |
| The middle of wax ripeness (11.08)    | Direct combiner       | 2.80 | 1.70 | 2.34 | 2.28    |
|                                       | harvesting            |      |      |      |         |
|                                       | Separate harvesting   | 3.16 | 1.84 | 2.65 | 2.55    |
| The end of wax ripeness (18.08)       | Direct combiner       | 2.89 | 1.69 | 2.94 | 2.51    |
|                                       | harvesting            |      |      |      |         |
|                                       | Separate harvesting   | 2.98 | 1.48 | 3.17 | 2.54    |
|                                       | Yarilo variety        |      |      |      |         |
| The beginning of wax ripeness (04.08) | Direct combiner       | 1.99 | 1.50 | 1.76 | 1.75    |
|                                       | harvesting            |      |      |      |         |
|                                       | Separate harvesting   | 2.54 | 1.61 | 2.03 | 2.06    |
| The middle of wax ripeness            | Direct combiner       | 2.06 | 1.49 | 2.03 | 1.86    |
|                                       | harvesting            |      |      |      |         |
Untimely interrupting the influx of nutrients into the grain resulted in yield losses of average 0.42 - 0.61 t/ha within three years of research. This pattern has stayed unchanged. At the same time, the number of losses fluctuated. With unstable weather conditions during the harvesting period (periodic rainfall in August) in 2016, the biggest decrease in yield during two-phase harvesting was noted in the last period (16.8%) with the Carmen variety and with the most favorable weather conditions during the vegetation period in 2014 when the largest yield was observed in experiments, grain loss due to early harvesting also reached the highest indices for the Carmen variety at 0.94 t/ha (harvesting at the beginning of wax ripeness). The weather was warm and dry during August in 2015, so the difference in yield between the first and second harvesting periods was insignificant. The Ukro and Yarilo varieties had it almost at the same level.

Over three years of observation, the most optimal for the two-phase method of harvesting was August 18, when spring triticale crops reached the middle of the wax ripeness phase where the average yield amounted to 2.33 t/ha. Weather conditions during the harvesting period had a significant impact on the grain yield. Assessing direct and separate (two-phase) combiner harvesting in the experiments, it was noted that for the first two harvesting periods, when the grain moisture exceeded 20%, the separate method proved to be the best. The yield in these periods reached 2.31 - 2.55 t/ha for the Ukro variety, 2.06 - 2.17 t/ha for the Yarilo variety, and 1.81 - 2.26 t/ha for the Carmen variety. However, harvesting the spring triticale on August 18 at the end of the wax ripeness phase revealed that the difference in the yield between harvesting methods was insignificant in the Ukro and Yarilo varieties, it was less than 2%. Moreover, in the Carmen variety, it led to a yield decrease by 0.61 t/ha. Given the fact that August in Amur region is characterized by unstable weather (periodic rainfall), direct combining looks more appropriate for the time of the end of the wax ripeness phase.

The yield structure of the crop is an important indicator to identify its elements due to which the given yield is obtained. In the present studies, the results of the bundle material analysis showed that the largest bulk of one plant, depending on the variety and harvesting period, was obtained on August 18 for three years of research on the average (figure 2).
Figure 2. Effect of harvesting period on the bulk of a spring triticale single plant, (average value for 2014-2016).

Obviously, by the end of the wax ripeness phase at that time, the spring triticale crops accumulated the largest amount of dry matter in their stalks. It reached 3.1 grams (g, metric) per single plant in the Ukro and Yarilo varieties and 2.6 g in the Carmen variety.

The number of grains in an ear is the most important indicator in yielding power evaluation. The following figure (figure 3) illustrates that in the experiments this number ranged from 17.1 to 34.3 grains. The largest number, regardless of the harvesting period, was observed in the Yarilo variety (24.5 - 34.3 pcs.). However, there was a decrease in the number of grains during spring triticale harvesting on September 1 by 34.9% in Ukro variety, by 28.6% in the Yarilo variety, and by 21.6% in the Carmen variety due to the grain shedding in the dead-ripe phase. At the same time, a high correlation between the number of ears and the grains in a single ear ($r = 0.86$) was observed.

Figure 3. Influence of harvesting periods on the number of spring triticale grains in an ear (average value for 2014-2016).
The 1000 grains mass index serves as one of the substantial elements of productivity of spring triticale and other crops and plays a significant role in high yield assessment [12]. In the present studies for three years of research, the bulk of 1000 grains varied on the average from 33.7 to 49.5 g, depending on the variety and harvesting period (figure 4).

**Figure 4.** Influence of harvesting periods on the bulk of 1000 seeds of spring triticale, (average value for 2014-2016).

The largest grains of 49.5 and 41.1 g were formed during the harvesting of the Ukro and Yarilo varieties on August 11 and 42.1 g of the Carmen variety on August 25. At that, both the early and the late harvesting periods led to a decrease in this indicator regardless of varietal features of spring triticale. In the context of all studied varieties, the largest weight fluctuation of 1000 grains was observed in the Ukro variety, where, at early and late harvesting, it decreased by 5.5 and 22.8%, respectively.

### 4. Conclusion

To compare different harvesting methods of spring triticale as a promising new grain crop in Amur region, it is worth noting that the difference in grain moisture in direct and separate combiner harvesting reaches up to 12.3%. Therefore, it is most advantageous to apply a separate combiner method to start harvesting before the phase of the middle of the wax ripeness as it helps to reduce the moisture content in the harvested grain and increases productivity to 2.51 t/ha. The best time for the direct combiner harvesting is the wax ripeness phase (106 days from germination to maturation). The highest yield of 2.61 t/ha was shown by the Ukro variety in this period. The harvesting period also affected the structure of the yield as the largest grains were formed during harvesting of the Ukro and Yarilo varieties on August 11 (49.5 g and 41.1 g, respectively), and the Carmen variety (42.1 g) on August 25. Moreover, both early and late harvesting led to a decrease in the yield structure, regardless of the varietal characteristics of spring triticale. Therefore, to choose properly the time and method of harvesting, it is necessary, besides ripening phase and weather conditions, to focus on the ability of the farm to carry out this technological operation in a certain time frame which will allow obtaining the largest volume of production at the lowest cost.

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