

# Agrotechnical Aspects of Sustainable Cultivation of *Secale cereale* L. in Arid Regions of Central Asia: Temperature, Drought and Seed Dormancy

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## Abstract

Today, with the observed global climate anomalies and disruption of the ecological balance, water scarcity is one of the serious environmental problems facing all of humanity. Drought became the main limiting factor in the development of agricultural production. Therefore, currently, the study of drought resistance of plants, especially grain crops, is one of the most important issues. Drought resistance is the ability of a plant to maintain physiological properties without significant changes under drought conditions. The drought resistance of rye is related to its physiological conditions. Because its root system has the ability to absorb water well. However, drought affects almost all physiological indicators of rye. First of all, drought leads to a shortening of the plant's vegetation period. Rye (*Secale cereale* L.) is one of the most beneficial grain crops. Rye has many benefits for the national economy. In agriculture, rye flour is used as bread, and grain as animal feed. Therefore, this research work, aimed at determining the growth, development, and vegetation of *Secale cereale* in drought conditions, is one of the important studies. The information presented in this article serves to explain how *Secale cereale* L. varieties grow, develop, and vegetate differently in arid environments.

## Keywords

Rye, Phenological Phases, Varieties, Drought, Vegetation Climate

## 1. Introduction

Drought is one of the most important factors limiting agricultural production and

has a serious impact on yields [1].

In addition, drought can cause serious damage to the physiological indicators of plants as one of the main inhibiting factors in the growth process of plants. In response to drought stress, plants activate drought response mechanisms such as morphological and structural changes, expression of drought-resistant genes, hormone synthesis, and osmotic regulators to alleviate drought stress [2]. Dry stress is the most common environmental factor limiting crop productivity, and global climate change increases the frequency of high water scarcity [3]. Recently, along with drought in the world, an increase in salinity has led to a decrease in the yield of agricultural crops [4] [5]. In response to drought stress, plants undergo various changes, such as biochemical, molecular, and physiological. When water deficiency occurs, the concentration of abscisic acid (ABA) in the cell increases, which leads to the activation of a number of stress-responsive genes, and the forms of expression of these genes are very complex, with some genes responding early, while others respond slowly [6].

Preventing drought involves changing plant living conditions to achieve root depth, rational use of available water by plants, and use of rainfall. Dehydration resistance consists of the ability of plants to grow again during partial dehydration and continued rainfall [7] [8].

Rye (*Secale cereale* L.) It is considered an important food crop in Central and Eastern Europe. In these regions, rye is grown mainly as a winter grain on an area of 4.8 million hectares. Rye has been recognized as more drought-resistant than other crops. Therefore, it is mainly cultivated on infertile and sandy soils. Although the regions of Central and Eastern Europe have a climate with high humidity, many climatologists predict that drought will pose a serious threat to these regions in the future, as well as a general increase in temperature. Therefore, drought can seriously damage rye and other grain crops [9].

Several rye-growing regions in Central Europe and Asia have been suffering from severe drought over the past decade. Rye has also been found to grow in sandy soils with low water retention capacity in areas where rainfall is usually low.

Therefore, today it is important to identify drought-resistant rye varieties [10]. Water scarcity negatively affects plant growth and manifests a number of morphological, physiological, and biochemical changes, leading to a deterioration in the productivity indicators of the main crops, including rye [11].

Drying is the most limiting abiotic factor in yields and has a significant impact on all phenological stages of grain crops. According to research conducted by many researchers, drought also affected different varieties of *tritosecale* differently, and a significant decrease in yield was observed [12].

Winter rye (*Secale cereale* L.) is currently grown mainly in the regions of Central and Eastern Europe. According to the data, in 2020, global rye production reached 4.45 million hectares and 15.02 million tons. In infertile and medium-sized soils, rye can yield more than wheat or barley under conditions of soil drought [13]. Rye's resistance to winter and cold, as well as drought, is relatively

superior to other grain crops. This is especially important in the arid climate of different regions [14].

According to research conducted by Chajkin, V.V. Torop, A.A. Rylkov, A.I. [15], new rye varieties are characterized by high resistance to cold and drought, and with adherence to cultivation technology, no cases of plant damage in natural conditions have been recorded at a high level. However, if the crops were not sufficiently provided with moisture in the following spring period, this led to a significant decrease in yield. Drought led to a significant decrease in rye yields (by 9.8% - 42.6%). The largest decline was observed mainly in June and July.

According to the data analyzed above, drought affects the physiological indicators of plants, including plant growth and vegetative development. Therefore, it is important to study the influence of this stress factor on the growth and vegetative development of rye (*Secale cereale* L.), which is considered one of the important plants among grain crops. The main goal of this study is to determine the growth and development of *Secale cereale* L. varieties under drought conditions, as well as the duration of vegetation.

## 2. Materials and Methods

### 2.1. Research Objects and Experimental Site

Seeds of rye varieties “Vakhsh-116”, “Shalola”, and “Savo” were used as the object of research. Seeds were taken from the seed collection of the Institute of Biochemistry of Samarkand State University. Field experiments were conducted in the laboratory of the Department of Plant Physiology and Microbiology of the Institute of Biochemistry of Samarkand State University at the “Ulug’ Baraka yerlari” farm in the Jomboy district of the Samarkand region.

### 2.2. Determination of the Optimal Temperature for Seed Germination

The method was used to determine the optimal temperature for the germination of rye seeds under laboratory conditions. In the experiments, seeds were placed for germination at 5 different temperatures in the range of 10°C - 30°C, differing from 5°C. Experiments were conducted on 50 seeds of each variety in 3 repetitions. Seed germination strength (1), germination rate (2) were calculated based on the following formulas.

$$\text{Germination power} = \frac{\text{The number of seeds germinated in 3 days}}{\text{Total number of seeds}} \times 100 \quad (1)$$

$$\text{Germination power} = \frac{\text{The number of seeds germinated in 7 days}}{\text{Total number of seeds}} \times 100 \quad (2)$$

### 2.3. Determination of the Optimal Dormancy Period for Seed Germination

Experiments to determine the influence of dormancy on seed germination were conducted using the method recommended by Klupczyńska *et al.* [16] In the ex-

periments, seeds 3, 6, 9, 12, and 15 days after harvesting were used. Seeds were germinated in a thermostat at 20°C. This temperature is optimal for the germination of rye seeds [16]. Seed germination strength and germination rate were calculated using the formulas (1, 2) given above.

#### 2.4. Determination of the Influence of Drought on Seed Germination

Determination of seed germination parameters of various rye varieties in arid conditions was carried out using the Li *et al.* Method [17]. Sucrose solutions of the following concentrations were used as a drought factor in the experiments (Table 1):

**Table 1.** Sucrose concentration vs. osmotic pressure.

No	Sucrose solution concentration (%)	Osmotic pressure atm
1.	11.9	10
2.	15.8	14
3.	17.7	16
4.	19.3	18
5.	22.4	22

#### 2.5. Identification of Field Experiments

Phenological observations and biometric measurements were carried out according to the methodology of the State Inspectorate for Variety Testing of Agricultural Crops. Sowing dates, seeding rates, and other agrotechnological measures were carried out according to the methods of the Beideman *et al.* [18]. In all experiments, the variants were made with four repetitions, were arranged sequentially in two tiers. The total area of the plots is 100 m<sup>2</sup>, accounting area 50 m<sup>2</sup>. The field was plowed and then the harrow was plowed. Potassium and phosphorus fertilizers used in the experiments were applied 100% before plowing. Nitrogen fertilizer is applied in two phases—50% during tillering and 50% during tube formation given. In addition to determining the germination rate and viability of seeds under laboratory conditions, the influence of sowing depth (from 1 cm to 10 cm) on seed germination in small plots (2 m<sup>2</sup>) under field conditions was determined.

#### 2.6. Statistical Analysis

Statistical analysis of the research results and their calculation were carried out using the Microsoft Excel 2013 (USA) computer program. The results of the experiment were statistically summarized by evaluating the arithmetic mean of 3 repeated experiments at a statistical significance level of  $p \leq 0.05$ . Mathematical and statistical analysis was carried out according to the method of calculating the mean values and deviations of indicators, as well as probabilities [19].

### 3. Results and Discussion

#### 3.1. Optimal Temperature for Rye Seeds

During our research, experiments were initially conducted to determine the optimal temperature for germination of rye seeds. We used sorted seeds in our laboratory research. For this, rye variety seeds were placed on Petri dishes on moistened filter paper and germinated in a laboratory thermostat at 5 different temperatures (10°C, 15°C, 20°C, 25°C, 30°C).

As can be seen from the data presented in **Table 2** below, the influence of temperature on the laboratory germination of rye varieties was observed. In the Vakhsh-116 variety, seed germination at a temperature of 10°C began on the 5th day, and the seed germination rate was 48.5%. On the 10th day, 79.1% germinated at a temperature of 10°C.

In the Shalola variety, germination was observed from 44.1% to 79.5%, and in the Savo variety from 41.2% to 78%. At a temperature of 15°C, rye seeds began to germinate on the 3rd day. On the 9th day, the germination rate was Vakhsh-116 (98.5%), Shalola (100%), and Savo (97.2%). At a temperature of 15°C, despite high germination, a longer germination period (8 - 10 days) was observed. Seeds germinated on the 2nd day at a temperature of 20°C - 25°C. At a temperature of 20°C, germination was 100% on the 9th day, and at a temperature of 20°C, germination was 100% on the 4th day. In the Vakhsh-116 variety, the degree of germination was 79.1%, 98.5%, 99.1%, in the Shalola variety 79.5%, 98.8%, 100%, in the Savo variety 78%, 97.2%, 98.6%, respectively, and increase in the minimum temperature from 10°C to 20°C was observed.

Seeds germinated on the 2nd day at a temperature of 30°C. In this case, the germination rate was within the range of 67.4% - 73.7%, on the 3rd day 76.7% - 85.8%, and seed germination on the 4th day 85.3% - 100%. Temperatures of 30°C reduced seed germination. At this temperature, the germination rate of the Vakhsh-116 variety by the 4th day was 90.5%, and germination did not occur in the following days. In the Shalola variety, germination by day 4 was 91.8%, and in the Savo variety, this indicator was 85.3%. Thus, the increase in temperature is inversely proportional to seed germination. According to the results of the conducted research, the germination rate of the Shalola variety was slightly higher than that of other varieties. A relatively low indicator was observed in the Savo variety (**Table 2**).

In general, it has been scientifically substantiated that the optimal temperature for the germination of rye varieties under laboratory conditions is 20°C. Temperatures above 25°C have been observed to reduce germination. The overall yield and quality of plants depend on the quality of sown seeds. Usually, high-yielding, sorted seeds are recommended for sowing. If low-yielding seeds are sown, the seeding rate should be increased by 25% - 30%, taking into account the degree of germination. One of the most important factors affecting plants is the dormancy period.

**Table 2.** Influence of temperature on the germination of rye seeds, %, n = 3 (field fertility).

T, °C	Days									
	1	2	3	4	5	6	7	8	9	10
Vakhsh-116										
10	-	-	-	-	43.5 ± 1.2	63.2 ± 1.2	72.1 ± 1.5	76.6 ± 1.3	78.6 ± 0.9	79.1 ± 1.0
15	-	-	50.1 ± 1.2	72.1 ± 1.2	81.5 ± 1.5	88.7 ± 0.9	92.9 ± 1.4	97.7 ± 1.3	98.5 ± 0.9	-
20	-	71.8 ± 1.3	93.8 ± 0.8	99.1 ± 0.3	-	-	-	-	-	-
25	-	83.1 ± 0.9	92.1 ± 0.6	100.0 ± 0.0	-	-	-	-	-	-
30	-	71.2 ± 1.0	85.2 ± 1.2	90.5 ± 1.1	-	-	-	-	-	-
Shalola										
10	-	-	-	-	44.1 ± 1.2	64.5 ± 1.3	72.6 ± 1.5	77.1 ± 1.4	78.7 ± 1.0	79.5 ± 1.1
15	-	-	55.6 ± 1.2	78.2 ± 1.1	88.4 ± 1.2	91.7 ± 0.9	94.5 ± 1.3	97.4 ± 0.7	100.0 ± 0.0	-
20	-	75.9 ± 0.9	97.1 ± 0.7	100.0 ± 0.0	-	-	-	-	-	-
25	-	85.6 ± 1.5	94.3 ± 0.9	100.0 ± 0.0	-	-	-	-	-	-
30	-	73.7 ± 1.1	85.8 ± 1.3	91.8 ± 1.2	-	-	-	-	-	-
Savo										
10	-	-	-	-	41.2 ± 1.2	61.3 ± 1.3	69.8 ± 1.3	74.3 ± 1.5	76.9 ± 1.0	78.0 ± 1.1
15	-	-	48.5 ± 1.2	71.0 ± 1.2	80.5 ± 1.4	86.7 ± 0.9	90.8 ± 1.5	96.4 ± 0.8	97.2 ± 0.9	-
20	-	70.3 ± 1.2	91.8 ± 0.7	98.6 ± 0.4	-	-	-	-	-	-
25	-	80.2 ± 0.7	86.4 ± 1.3	99.3 ± 0.4	-	-	-	-	-	-
30	-	67.4 ± 1.3	76.7 ± 1.3	85.3 ± 1.0	-	-	-	-	-	-

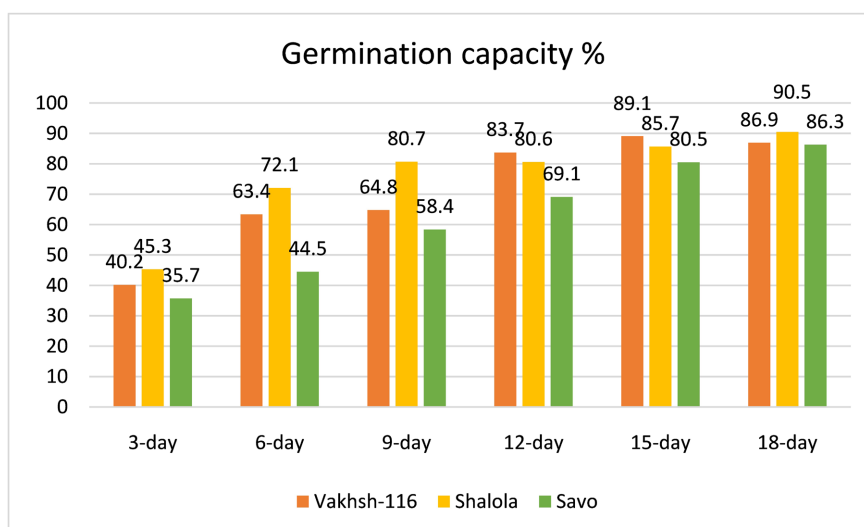
### 3.2. Determination of the Optimal Dormancy Period for Seed Germination

Therefore, the subsequent stages of our research were aimed at determining the influence of the tin period on the germination of rye seeds. In the experiment, after harvesting rye varieties, it was determined that 3; 6; 9; 12; 15; The germination strength and germination of seeds stored for 18 days were determined by germination in a special thermostat at a temperature of 20°C. From the data presented in **Figure 1**, it can be seen that the germination capacity and germination of rye seeds differ from each other depending on the shelf life (**Figure 1**).

When sowing rye seeds in laboratory conditions 3 days after harvesting the new crop, the germination energy and germination indicators of the seeds were lower. In the Vakhsh-116 variety, the germination rate was 40.2% and the germination rate was 75.1%, in the Shalola variety, the germination rate was 45.3% and the germination rate was 77.3%, in the Savo variety, the germination rate was 35.7% and the germination rate was 58.6%. Thus, when storing rye seeds for 3 days, the germination rate ranged from 35.7% to 45.3%, and the germination rate, depend-

ing on the variety, ranged from 58.6% to 77.3%.

The germination rate and germination rate of seeds stored for six days were higher in the Vakhsh-116 variety by 23.2% and by 7.4% compared to seeds stored for 3 days. In the Shalola variety, the germination rate of seeds stored for 6 days was 72.1%, germination rate 89.6%, in the Savo variety, the germination rate was 44.5%, germination rate 71.4% (Figure 1).

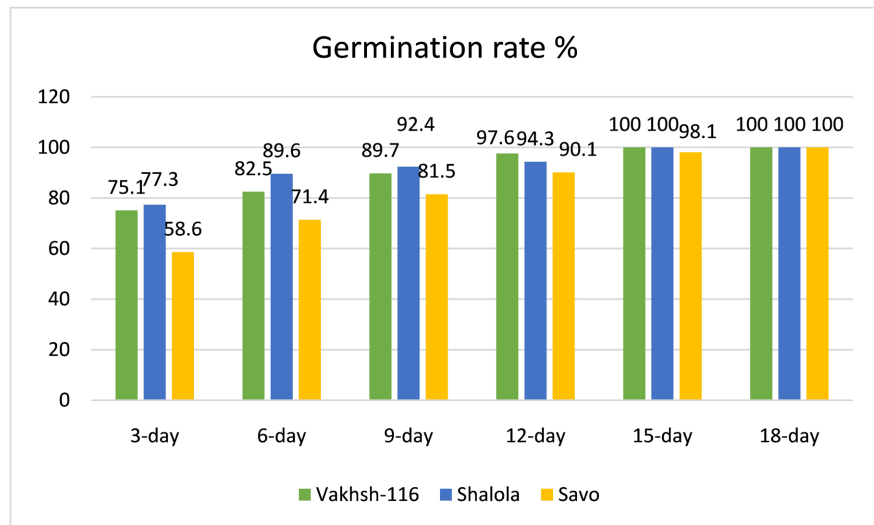


**Figure 1.** Influence of the dormancy period on the germination capacity of rye varieties, in %, n = 3.

After nine days, the germination capacity and germination rate of seeds sown under laboratory conditions were higher than that of seeds stored for six days. In the Vakhsh-116 variety, seed germination rate was 64.8% and germination rate was 89.7%, in the Shalola variety, germination rate was 80.7% and germination rate was 92.4%, in the Savo variety, germination rate was 58.4% and germination rate was 81.5%.

In seeds stored for twelve days, compared to seeds stored for nine days, the germination capacity of the Vakhsh-116 variety was higher by 15.8%, germination by 4.6%, in the Shalola variety the germination capacity increased by 3.0%, germination by 5.2%, in the Savo variety the germination capacity was higher by 10.7%, germination by 8.6%. When germinating seeds stored for fifteen days, the germination rate of the Vakhsh-116 variety was 85.7% and germination rate was 100%, the Shalola variety 89.1% and germination rate was 100.0%, the Savo variety 80.5% and 98.1%.

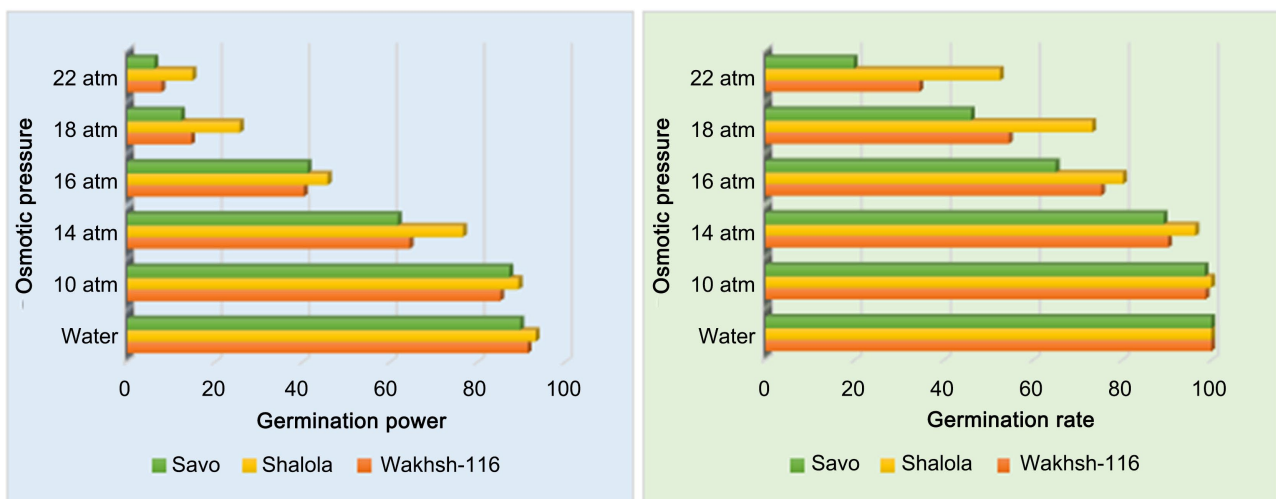
When germinating seeds stored for eighteen days, the germination rate of the Vakhsh-116 variety was 89.6% and germination rate 100.0%, the Shalola variety—90.5% and germination rate 100.0%, the Savo variety 86.3% and germination rate 100.0%. According to the results of the conducted research, the dormancy period of rye seeds is short, and they can be sown in the laboratory and field 15 days after harvesting (Figure 2).



**Figure 2.** Influence of the dormancy period on the germination rate of rye varieties, in %, n = 3.

### 3.3. The Effect of Drought on Rye Seed Germination

Today, it is important to select and recommend for production drought-resistant, high-yielding varieties. Therefore, it is important to study the degree of drought resistance of rye varieties. In our studies, we determined the degree of drought resistance by studying the influence of sucrose solutions of various concentrations on the germination of rye seeds. In laboratory conditions, selected seeds with high germination were placed on filter paper in Petri dishes with a sucrose solution of 10 atm (11.9%), 14 atm (15.8%), 16 atm (17.7%), 18 atm (19.3%), 22 atm (22.4%), and germinated in a thermostat at a temperature of 20°C (**Figure 3**).



**Figure 3.** Influence of drought (different concentrations of sucrose solution) on the germination capacity and viability of rye variety seeds.

According to the research results shown in **Figure 3**, in the control (clean water) variant, seeds germinated on the 3rd day, and on the 7th day, seed germination

was 100% in all varieties. Seed germination in 11.9% (10 atm) sucrose solution was close to the control variant. In a 22.4% (22 atm) sucrose solution, the germination energy and viability of the seeds decreased.

High germination in solutions of sucrose of various concentrations was observed in the Shalola variety. In the Shalola variety, germination was 96.4% in a 15.8% (14 atm) sucrose solution, 80.2% in a 17.7% (16 atm) sucrose solution, 73.3% in a 19.3% (18 atm) sucrose solution, and 52.6% in a 22.4% (22 atm) sucrose solution. According to the results of laboratory studies, it was established that the germination of rye seeds of the “Shalola” variety is more drought-resistant than other varieties.

### 3.4. Influence of Sowing Depth on Field Germination of Rye Varieties

For each soil and climatic condition, it is important to conduct experiments taking into account the germination of plant seeds.

**Table 3.** Influence of sowing depth on field germination of rye seeds (in %).

Planting depth, cm	Varieties		
	Vakhsh-116	Shalola	Savo
1	85.8 ± 2.2	88.3 ± 1.9	84.3 ± 2.3
2	88.5 ± 1.9	90.1 ± 1.6	86.2 ± 2.8
3	90.6 ± 1.6	91.4 ± 1.2	88.7 ± 1.9
4	91.8 ± 1.6	96.2 ± 2.0	90.1 ± 1.4
5	93.7 ± 2.1	96.8 ± 1.9	91.4 ± 1.2
6	89.1 ± 2.2	93.9 ± 1.2	87.7 ± 1.3
7	74.1 ± 2.1	85.1 ± 2.1	72.9 ± 1.9
8	72.1 ± 2.0	80.0 ± 1.6	70.2 ± 1.8
9	61.9 ± 1.8	66.8 ± 2.2	60.0 ± 2.2
10	52.5 ± 1.6	60.7 ± 1.4	50.1 ± 0.9

In our studies, field germination was determined by sowing rye seeds to a depth of 1 cm to 10 cm, and the obtained results are presented in **Table 3**.

According to the data in **Table 3**, low germination was observed when sowing seeds to a depth of 1 cm.

It was established that when rye seeds were sown to a depth of 1 - 2 cm, under the influence of autumn soil drought, the upper soil layer dried up, and a certain part of the seeds fell into the dry soil layer. This led to a low indicator of field germination of seeds. As a result of increasing sowing depth, even with sufficient moisture, the lack of the necessary temperature led to a decrease in germination. In our experiment, it was scientifically substantiated that when sowing seeds to a depth of 3 - 5 cm, under the influence of sufficient moisture and favorable temperature, the field germination of seeds is relatively high.

Thus, according to the research results, in our experiment, it was observed that the influence of sowing depth on the field germination of rye seeds was slightly higher in the “Shalola” variety compared to other varieties. In conclusion, in the soil and climatic conditions of the Zarafshan Valley, relatively high germination of rye seeds was achieved when sown to a depth of 3.0 - 5.0 cm. The highest field germination was observed in all studied varieties when sown to a depth of 5.0 cm (from 91.4% to 96.8%).

The subsequent stages of our research are also aimed at determining the influence of limited humidity conditions on the growth and development of rye varieties. In this case, the limited moisture content did not have the same effect on rye varieties.

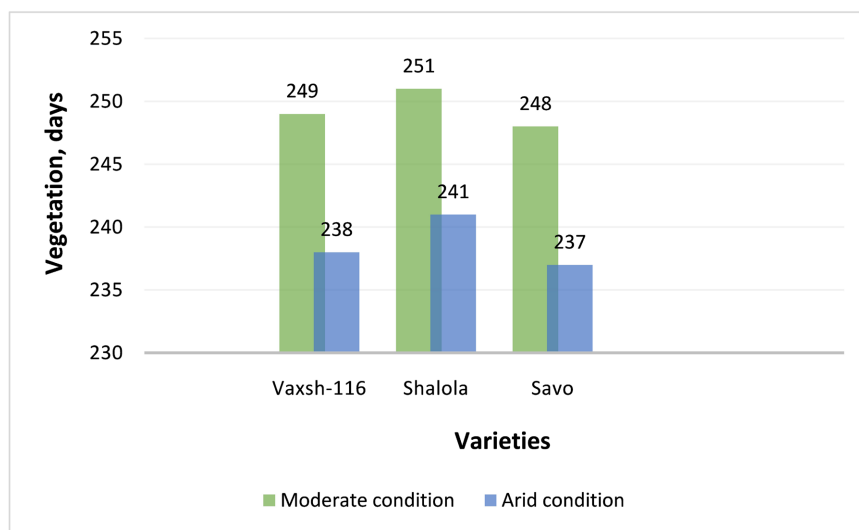
During our experiments, it was established that the periods of transition to the development phases of rye varieties differ from each other, and the lack of moisture significantly affects the development phases, causing a shortening of the growing season. In our studies, rye seeds were sown at the same time in moderate and limited humidity conditions, that is, on October 8, and seed germination was observed at different times in both conditions.

Under moderate humidity conditions, the seeds of all three varieties germinated within 7 days. Relatively warm temperatures and sufficient moisture influenced the rapid germination of seeds. The time between germination and tillering in the Vakhsh-116 variety was 35 days, the time between tillering and heading was 149 days, the time between heading and heading was 24 days, the time between heading and flowering was 11 days, the time between flowering and milk ripening was 10 days, and the time from milk ripening to wax ripening was 15 days. Thus, it was established that the longest time is between tillering and tubing, and the shortest time is between the flowering and milk ripening phases. In the Shalola variety, the time from germination to tillering was 37 days, the time between tillering and heading was 155 days, the time between tillering and heading was 25 days, the time between heading and flowering was 7 days, the time between flowering and milk ripening was 11 days, and the time from milk ripening to wax ripening was 14 days.

It was noted that in the Shalola rye variety, the longest time is between tillering and stem elongation, and the shortest time is between the flowering and milk ripening phases (**Figure 4**).

In the Savo variety, the time from germination to tillering is 35 days, the time between tillering and stem elongation is 148 days, the time between stem elongation and heading is 22 days, the time between heading and flowering is 10 days, the time between flowering and milk ripening is 7 days, and the time from milk ripening to wax ripening is 15 days. Thus, the above pattern was repeated in this variety, and it was calculated that the longest time is between germination and tillering, and the shortest time is between the flowering and milk ripening phases. The grain ripening phase is divided into 3 periods: milk ripening, wax ripening, and grain ripening. The duration of the grain ripening phase depends on the bio-

logical characteristics of the varieties. *Secale cereale* In L. varieties, the grain ripening phase lasted 30 - 31 days.



**Figure 4.** Growing season of rye varieties.

In general, the vegetation period for the Vakhsh-116 variety was 249 days, and for the Shalola and Savo rye varieties 251 and 248 days.

Important processes in the life of plants are directly related to water exchange. Water plays an important role in the synthesis of organic substances in plants, that is, in the process of photosynthesis, mineral nutrition through the roots, in the turgor state of the plant, in the regulation of such processes as the movement of substances in the plant body. In our studies, insufficient water also influenced the reduction of vegetative development of rye varieties as a limiting factor. As a result, a shorter duration of the developmental phases was observed in rye varieties. For example, in the Vakhsh-116 variety, seed germination was delayed compared to moderate humidity, and the transition to the tillering phase began 10 days earlier. The time between emergence and tillering was 35 days, the period from tillering to stem elongation was 131 days, from stem elongation to heading—23 days, from heading to flowering—6 days, from flowering to milking—9 days, from milking to waxing—20 days. When studying the developmental phases of the Shalola rye variety, it was established that the period from germination to tillering was 37 days, from tillering to heading 136 days, from heading to heading 22 days, from heading to flowering 7 days, from flowering to the milk ripeness phase 9 days, and from the milk ripeness phase to the wax ripeness phase 19 days. It was substantiated that the time between germination and tillering in the Savo rye variety is 32 days, the period from tillering to stem elongation is 132 days, from stem rolling to heading is 24 days, from heading to flowering is 5 days, from flowering to milk ripeness is 9 days, and from milk ripeness to wax ripeness is 22 days. Under these conditions, when calculating the vegetation period for all three varieties, it was calculated that it lasted 238 days for the Vakhsh-116 variety, 241 days for the Shalola variety, and 237 days for the Savo variety. Thus, in conclusion, it has

been scientifically substantiated that under conditions of sufficient humidity, the vegetation period of rye varieties is longer compared to varieties grown with limited humidity.

The main factor contributing to the shortening of the growing season is insufficient moisture. Thus, although rye plants are relatively drought-resistant compared to other grain crops, drought affects the normal implementation of its developmental phases.

In general, under the conditions of the Samarkand region, it was established that the individual development period of rye varieties is shorter by 10 - 11 days due to the influence of growing conditions and moisture deficit.

During the development period of rye varieties, environmental conditions, agrotechnological measures, and the biological characteristics of the varieties significantly influence the duration of developmental phases and the growing season. The development process of rye varieties consists of the following phases: germination, tillering, stem elongation, heading, flowering, ripening (milk ripening, wax ripening, and grain ripening). In our research, we conducted phenological observations of rye varieties during the full vegetation period in two different conditions: temperate and arid. The growth rate and average height of plants were initially determined 30 days after seed germination, 12 times during ontogenesis, and at the end of the growing season. According to the results of our research, when determining the height of plants for the first time 30 days after germination, it was found that in moderate humidity it ranged from 1.5 cm to 1.8 cm, and in arid conditions from 1.5 cm to 1.7 cm. When determining the height of plants for the second time after 40 days, it was established that the height of varieties, depending on their biological characteristics, ranged from 3.3 cm to 3.7 cm in moderate humidity and from 3.3 cm to 3.6 cm in arid conditions (**Figure 5**).



**Figure 5.** Overview of the field experiment.

When determining the height of the plant 3 times (after wintering) after 130 days, at moderate humidity, it was 7.3 cm for the Vakhsh-116 variety, 7.6 cm for the Shalola variety, and 7.1 cm for the Savonavi variety. In arid conditions, it was 6.7 cm for the Vakhsh-116 variety, 6.9 cm for the Shalola variety, and 6.6 cm for the Savo variety. When measuring the height of plants 4 times (after 140 days), it was found that in moderate conditions it ranged from 17.5 cm to 17.8 cm, and in arid conditions it ranged from 15.2 cm to 15.5 cm. When determining the height of plants 5 times after 150 days, at moderate humidity, the plant height was 32.1; 32.8; It was found that it increased by 32.4 cm. In arid conditions 27.6; 28.1; 27.5 cm was observed. When measuring plant height 6 times (after 160 days), it was found that the height of varieties varied from 71.1 cm to 71.7 cm in moderate humidity, and from 65.1 cm to 65.5 cm in arid conditions, depending on their biological characteristics.

In rye varieties, relative growth intensity was observed on day 170 (in the stem elongation phase) when plant height was determined 7 times, and under moderate conditions, the average plant height ranged from 88.5 cm to 92.3 cm. In arid conditions, the average height of the varieties ranged from 81.2 cm to 86.6 cm.

When measuring plant height 8 times (after 180 days), it was found that the height of the varieties in moderate humidity ranged from 101.2 cm to 120.2 cm, and in arid conditions, the average height of the varieties ranged from 87.4 cm to 97.8 cm, depending on their biological characteristics. When measuring the height of rye varieties after 190 days, it was found that in moderate conditions it ranged from 123.4 cm to 135.7 cm, and in arid conditions, the average height of the varieties reached from 110.9 cm to 120.8 cm (**Table 4**).

**Table 4.** Influence of sowing depth on field germination of rye seeds (in %).

Navlar	Plant height, cm (moderate conditions)					
	Pile up	Tubing	Heading	Flowering	Milk ripening	Wax ripening
Vakhsh-116	18.3	110.5	155.2	160.3	166.8	173.5
Shalola	25.1	120.2	162.1	168.5	174.6	182.1
Savo	16.4	101.2	146.6	152.3	158.3	167.4
Arid conditions						
Vakhsh-116	13.2	72.3	115.1	138.5	143.5	152.4
Shalola	15.6	76.3	125.6	144.1	148.3	157.4
Savo	14.1	72.3	120.1	140.2	144.5	155.2

When determining the plant height 10 times after 200 days, it was found that it increased to 155.2 cm (Vakhsh-116 variety), 162.1 cm (Shalola variety), 146.6 cm (Savo variety), respectively, under moderate humidity. In arid conditions, it increased to 139.6 cm (variety Vakhsh-116), 145.3 cm (variety Shalola), 134.7 cm (Savo) (**Table 4**).

When determining the height of rye varieties 210 days after the 11th germina-

tion, it was found that in moderate conditions it ranged from 149.4 cm to 165.1 cm, and in arid conditions the average height of the varieties ranged from 138.9 cm to 149.6 cm. In the grain ripening phase, a decrease in the growth rate of rye varieties was observed, which is due to the beginning of the end of the vegetation of the plant's leaves with yellowing.

When determining the plant height 12 times (after 220 days), it was observed that in moderate conditions it ranged from 152.3 cm to 168.5 cm, and in arid conditions, the average height of the varieties ranged from 143.3 cm to 153.5 cm. At the end of the growing season, the average height of the varieties at moderate humidity was 163.5 cm for the Vakhsh-116 variety, 171.6 cm for the Shalola variety, and 154.7 cm for the Savo variety. In arid conditions, the average height of the varieties was 150.1 cm for the Vakhsh-116 variety, 154.4 cm for the Shalola variety, and 145.6 cm for the Savo variety.

In conclusion, plant growth is relatively high during the tillering and stem elongation phases, which are considered the most favorable periods for plant growth. In this case, of course, sufficient moisture is one of the most important factors for plant growth.

Growth of rye varieties under conditions of water scarcity, according to data obtained from height measurements, limited moisture negatively affected the growth process. As a result, it was found that the plant height was lower compared to plants grown in moderate humidity conditions.

It was noted that even under conditions of limited humidity, the growth process in plants is higher in the tillering and stem elongation phases compared to other phases. In subsequent phases of development, a significant decrease in growth was observed.

Consequently, the lack of moisture acts as a limiting factor in the height of plants. During our experiments, it was established that among rye varieties grown in conditions of water scarcity, the Shalola variety has a higher height compared to the other two varieties. In our experiment, it was observed that the shortest height was observed in the Savo variety, and the average height was observed in the Vakhsh-116 variety.

The germination rate of rye seeds when stored in different media differs significantly. Prolonged storage of seeds leads to a decrease in their viability. This leads to an increase in homozygosity [7]. To assess the influence of temperature and dormancy on the germination of rye seeds (*Secale cereale* L.), an experiment was conducted to assess the germination of rye seeds stored for a long time in the Gatersleben gene bank, as well as in the seed bank of the Warsaw Botanical Garden. Seeds with a moisture content of 5.5% were stored at a temperature of  $-15^{\circ}\text{C}$  and  $10^{\circ}\text{C}$  in hermetically sealed cups filled with  $\text{CO}_2$ ,  $\text{N}_2$  under vacuum. The experiment was conducted on rye seeds stored for 1, 5, 15, 17, and 26 years. According to the results of the analysis, rye seeds stored for 1 year in closed cups filled with  $\text{N}_2$  under vacuum at a temperature of  $15^{\circ}\text{C}$  showed a high germination rate. It has been established that seeds stored under vacuum with  $\text{CO}_2$  have relatively

low germination rates [20].

In studies conducted by L.V. Chumikina, L.V. Arabova, *et al.* [21], the highest germination of wheat seeds was observed at 20°C, rye and triticale seeds showed the highest germination at 15°C and 30°C. However, these indicators were not acceptable for subsequent stages of development, since at these temperatures the development of the root system and stem slowed down. The optimal temperature for the germination of wheat and triticale was 22°C, and for rye 18°C - 19°C. Among wheat and rye seeds, triticale seeds differed from each other in this indicator, since the processes of preparation for the beginning of cell growth by stretching in triticale are more heat-resistant than the processes leading to the further growth of the most necessary organs through the stretching, division, and differentiation of stem and root cells [21].

Cultivation of grain crops for agriculture based on the most optimal agrotechnological methods is the key to a high yield. High-quality sowing of field crops, i.e., the distribution of seeds to the required depth in agricultural plots, forms the basis for ensuring uniform distribution of plants throughout the planting area. In studies conducted in Northern Kosovo, good results were obtained when sowing winter rye seeds with a row spacing of 5 cm and a sowing depth of 3.5 cm to 4 cm (on average 3.75 cm) [22].

In the experiments conducted by researchers at the University of Vermont, data on the date and depth of sowing rye seeds are presented. According to this, rye seeds were sown at 5 different dates, that is, on September 24, October 3, October 10 - 16, and October 22, where early sown seeds influenced the height of the plant and the relatively high yield indicator. The tallest plants were 169 cm on the first planting date (September 24), and the lowest plants were 112 cm on the fifth planting date (October 22) [23].

#### 4. Conclusions

The results of the above-mentioned studies show that the vegetation period of various rye varieties grown in the soil and climatic conditions of the Samarkand region lasted an average of 248 - 251 days in a moderate environment.

In conditions of limited humidity, the vegetation period of plants is shorter than in temperate conditions. It was established that the average vegetation period lasts 237 - 241 days.

Drought is one of the most common stress factors for a plant organism, altering many of its physiological processes. In particular, during our experiments, this factor influenced the lower plant height compared to plants grown in optimal conditions.

In general, moisture plays an important role in the life of organisms. Determining the physiological characteristics that determine the resistance of plants to water scarcity is the most important task, the solution of which has great theoretical and practical significance. Dehydration changes such important parameters as the viscosity and permeability of the protoplasm, the degree of hydration of its col-

loids, and the pH level of the system. This inevitably leads to fundamental changes in the state and function of the cell's enzyme systems.

Based on the above experiments, it is recommended for rye farmers to sow rye seeds to a depth of 4 - 5 cm, and in arid regions, to sow the shalola rye variety.

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### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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