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Assessment of water-retaining capacity of wheat seedlings after exposure to laser radiation

The article presented the results of assessing the effect of hydration and water-holding capacity of soft wheat seedlings after preliminary treatment of seeds with a laser with a wavelength of 632,8 nm. The processing timer anged from 15 seconds to 15 minutes. The watering of raw seedlings during drying and air-dry weight was higher than the control values. Thus, the water content of 3-week-old wheat seedlings in all experimental variants exceeded the control by 12.5–45.2 %. The weight of the experimental seedlings after 2 hours of drying exceeded the control value by 23.5–159.4 %, after 4 hours — by 5.6–74.5 %. The dry weight of the seedlings turned out to be 6.7–44.4 % higher than the control in the experimental variants. The water-holding capacity of wheat seedlings according to the experimental variants turned out to be approximately at the control level or higher than the control values. These parameters indicated a positive effect of laser processing of a certain duration on the increase in drought resistance. The best indicators of seedling water content and water-holding capacity were noted for pre-sowing treatments with laserir radiation — 1 minute, 2 minutes, 2 minutes 30 seconds, 4 minutes, 10 minutes.

Keywords: seed material, seedlings, wheat, watercontent, water-holding capacity, laserir radiation, experimental options

Introduction

Water is an internal environment where all the processes of vital activity take place actively; it is a transport link between various structures of a living organism.

The territory of Kazakhstan differs in the amount of precipitation, and most of it is in the arid climate zone [1]. The climate of Central Kazakhstan (Karaganda region) is characterized by sharp continental, arid in the summer months and a small amount of precipitation from 180 to 310 mm [2]. The greatest harm is caused by drought in the spring and summer, during which there is an active growth of crops and the formation of generative organs [3].

In natural conditions, a favorable combination of soil-climatic and agrometeorological factors is extremely rarely achieved throughout the growing season. Often crop failures in the Central and the Northern Kazakhstan are caused by frequent droughts in the first half of summer [4], which determines the need to find ways to increase drought tolerance of agricultural plants.

The resistance of plants to drought is determined by a number of factors, the most important of which is the water regime of plants [5–7], that is, the ability of the plant's aboveground organs to retain water. As noted by a number of authors [8–12], the rate of water return is often used as an indicator of drought tolerance of plants; therefore, plants with high water retention capacity are highly resistant to adverse environmental conditions. Therefore, when establishing the resistance of plants to drought, this indicator is used as a diagnostic sign.

The aim of research is to study the dynamics of changes in water content and water holding capacity of wheat seedlings irradiated with different doses of coherent laser radiation.

Methodology

The object of the study was soft wheat seeds (*Triticale aestivum* L.) of "Karaganda-29" variety, obtained in 2018 from the Karaganda Research Institute of Plant Growing and Breeding of the Ministry of Agriculture of the Republic of Kazakhstan. Seed samples were irradiated with a helium-neon laser; a wavelength of 650 nm was used, the irradiation time varied from 15 seconds to 15 minutes. The control was seeds that were not exposed to laser irradiation.

All irradiated seed samples were planted in boxes with standard soil for growing seedlings. Each version of the experiment was in 6 replicates, in each repetition — 50 pieces of seeds. After 3 weeks of cultivation in closed ground, plant seedlings were dug up, washed from the ground and weighed on wet weight.

The water content of plants was estimated by the ratio of the wet and dry weight of the seedlings. Water retention capacity was determined after 2 and 4 hours of wilting (in % of fresh weight) according to the method of M.D. Kushnirenko [13] and Yu.V. Makarova [14].

In the final phase, the plants were placed in filter bags and dried in weights to constant weight at 100 °C. Mass fraction of moisture (%) was calculated by the formula:

$$100\ \% - A,$$

where, A is the mass of absolutely dry matter, %.

$$A = (m - m_1) \times 100\ \% / m_2,$$

where, m is the mass of the seedling drying, g; m_1 is the mass of the seedling after drying, g; m_2 is the mass if fresh seedling weight, g.

The water-holding ability of seedlings (%) was estimated by the formula:

$$B = \frac{C - D}{E} * 100\ \%,$$

where E is the absolute water content; C is the raw mass of seedlings before drying; D is the dry mass of seedlings.

Statistical processing of the results was carried out according to the method of N.L. Udolskaya [15].

Results and discussion

The results of the experiments showed that the content of free water and the water-holding ability of wheat seedlings differed in the experiment variants (Table 1).

Table 1

Indicators of the water-holding ability of wheat seedlings after laser irradiation of various durations

Experience options	Wetweight, g	Weight after 2 hours of drying, g	Weight after 4 hours of drying, g	Air-dry weight of seedlings, g
Control	0.239±0.001	0.170±0.001	0.110±0.001	0.045±0.001
15 seconds	0.290±0.002	0.190±0.002	0.135±0.002	0.060±0.002
30 seconds	0.299±0.002	0.207±0.003	0.132±0.002	0.055±0.002
1 minute	0.322±0.003	0.252±0.002	0.168±0.002	0.067±0.002
1 min 30 sec	0.243±0.002	0.157±0.001	0.118±0.002	0.048±0.002
2 minutes	0.333±0.001	0.270±0.001	0.192±0.002	0.064±0.001
2 min 30 sec	0.306±0.002	0.225±0.002	0.165±0.002	0.058±0.002
3 minutes	0.340±0.003	0.251±0.002	0.182±0.002	0.064±0.002
3 min 30 sec	0.269±0.002	0.174±0.001	0.116±0.002	0.050±0.001
4 minutes	0.272±0.001	0.206±0.002	0.152±0.001	0.056±0.002
4 min 30 sec	0.369±0.003	0.271±0.001	0.186±0.002	0.067±0.002
5 minutes	0.309±0.003	0.219±0.001	0.151±0.002	0.059±0.002
10 minutes	0.339±0.001	0.241±0.001	0.176±0.002	0.065±0.001
15 minutes	0.347±0.002	0.237±0.001	0.165±0.001	0.060±0.002

An analysis of the results shows that the wet weight of 3-week-old wheat seedlings was higher in all variants of experiments with laser irradiation, exceeding the control values by at least 12.5 % (3 minutes 30 seconds) and a maximum of 45.2 % (15 minutes) (Fig. 1). Similar results were obtained when drying after 2 (with the exception of the experiment with a processing time of 1 minute 30 seconds) and 4 hours. After 2 hours, the weight of the seedlings exceeded the control values by 0.04–0.1 g, that is, from 23.5 to 159.4 %. The maximum excess values are noted in the processing options 1 minute, 2 minutes, 4 minutes 30 seconds, 10 minutes.

After drying for 4 hours, all experimental options exceeded the control, showed from 0.06 to 0.082 g, or 5.6 to 74.5 %. At this stage of the experiment, the maximum showed the weight of the seedlings marked for variants with a processing time of 1 minute, 2 minutes, 3 minutes, 4 minutes, 4 minutes 30 seconds, 5 and 10 minutes.

The dry weight of plants in all cases exceeded the control; the difference was 0.003–0.02 g or 6.7–44.4 % (Fig. 2). That is, we can observe an increase in plant water content after laser treatment, which is a sign of an increase in the ability of plants to tolerate drought [16, 17].

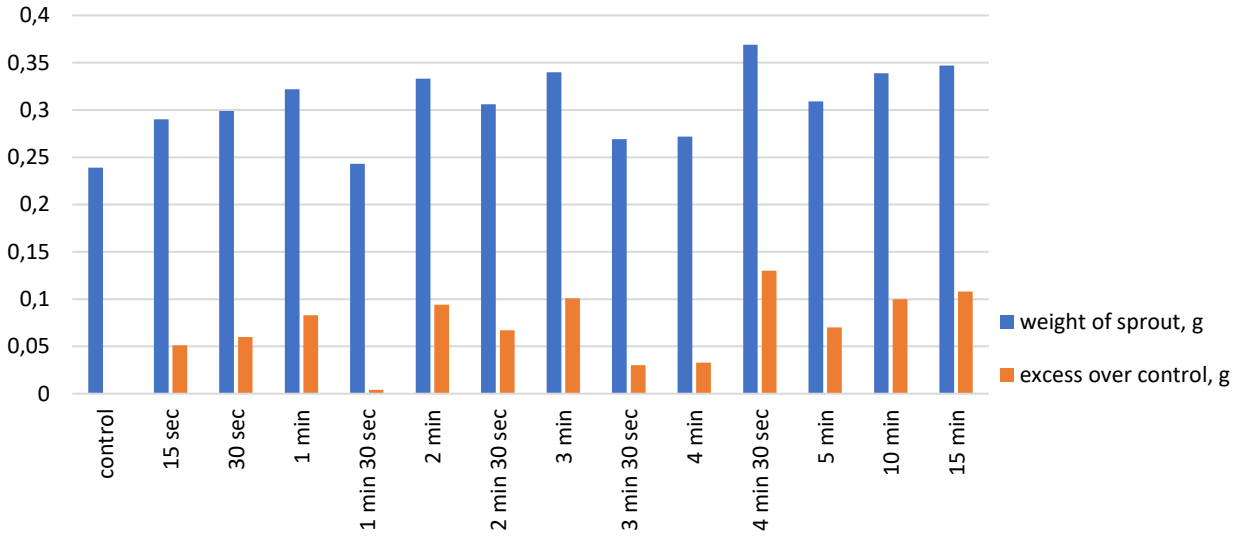

Figure 1. Indicators of fresh weight of seedlings and data of excess over control for experimental options

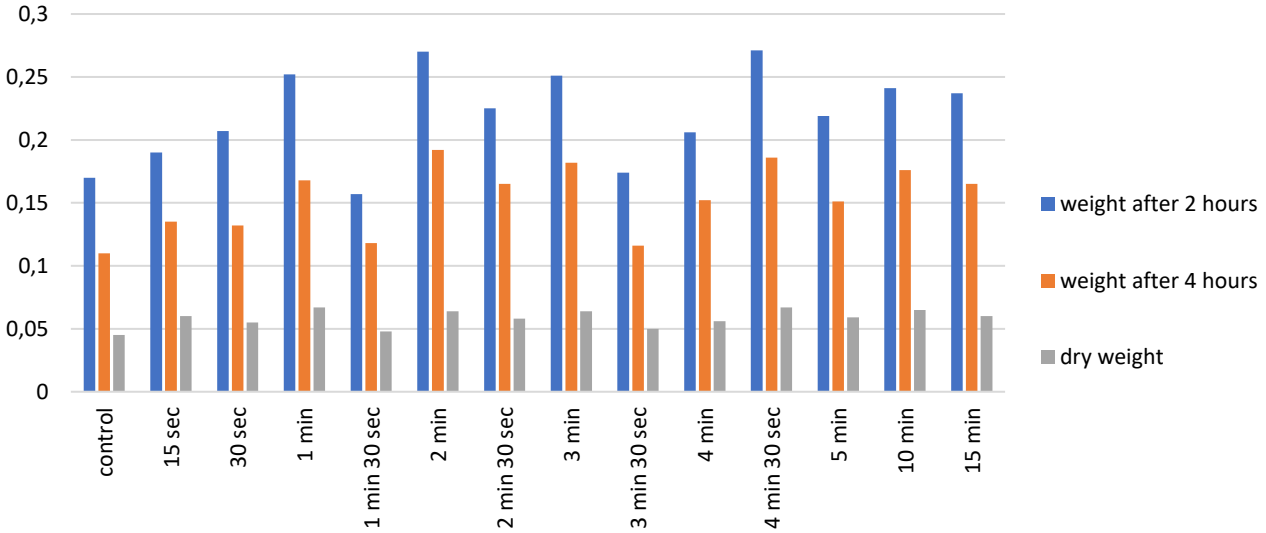

Figure 2. Indicators of the weight of seedlings during drying and dry weight according to the options of experience

We have determined the water holding capacity of seedlings. Significant differences were expressed in terms of hydration (water content) of seedlings before drying in the range of 43 and 58 %. A more significant decrease in humidity was observed during irradiation in the indicated interval: 3 min 30 seconds. In this irradiation interval, the water holding capacity decreased by 3 % (from 33 % to 30 %) compared with the control. The second peak of the water holding capacity of the seeds was observed in the intervals of 2, 3, 4 minutes. At these doses of laser radiation, the values increased by 10–18 % (from 30 to 40–48 %) (Table 2).

Compared with the control, the water-holding ability increased by 10–15 % in samples that were under the influence of laser radiation for 2, 3, and 4 minutes. The indicated irradiation time intervals are the most optimal for water retention in wheat seedlings.

However, laser radiation of seeds not all variants of the experiment led to an increase in water retention capacity. So, samples those were irradiated for 15, 30 and 210 seconds showed values below the control. For example, wheat seedlings in the control variant had indicators of water holding capacity of 33 %, and in some variants this value slightly decreased by 2–3 % (Fig. 3).

Table 2

Water content and water holding capacity of wheat seedlings at different laser irradiation times

Experience Options	Water content, %			Waterholding capacity, %
	In 2 hours	In 4hours	Dry seedlings	
Control	71	46	18	33
15 seconds	66	47	21	32
30 seconds	69	44	18	31
1 minute	78	52	21	40
1 min 30 sec	65	49	20	36
2 minutes	81	58	19	48
2 min 30 sec	74	54	19	43
3 minutes	74	54	19	43
3 min 30 sec	65	43	19	30
4 minutes	76	56	21	44
4 min 30 sec	73	50	18	39
5 minutes	71	49	19	37
10 minutes	71	52	19	41
15 minutes	68	48	17	37

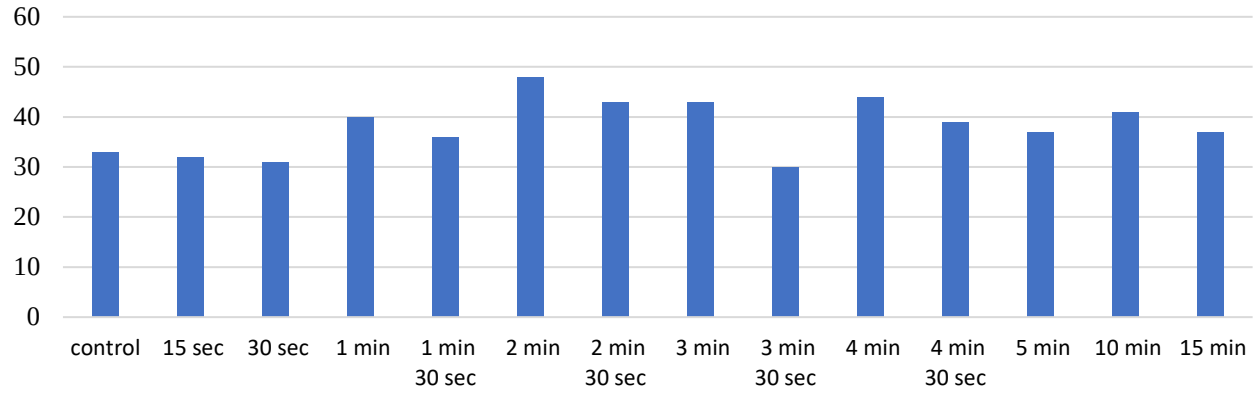

Figure 3. Indicators of the water-holding ability of wheat seedlings according to the experimental variants after laser irradiation

In general, the results show that most variants of pre-sowing treatment of seeds with a coherent laser lead to an increase in the water content of seedlings and an increase in water retention capacity.

Conclusion

Processing of seeds of agricultural plants leads to an increase in germination and activates the growth of seedlings. We carried out pre-sowing treatment of seeds with a laser with a wavelength of 650 nm and the duration of 15 seconds to 15 minutes. The irrigation of 3-week-old seedlings obtained in closed ground in all experimental variants using laser treatment turned out to be higher than the control values. The excess over control was 12.5–45.2 %. The loss of moisture during drying took place approximately the same in all variants of the experiment. The weight of the seedlings after 2 and 4 hours of drying exceeded the control by 23.5–159.4 % and 5.6–74.5 %, respectively.

The dry weight of the seedlings turned out to be 6.7–44.4 % higher than the control in the experimental variants.

The water-holding ability of wheat seedlings according to the experimental variants turned out to be approximately at the control level or higher than the control values. The best indicators of seedling water content and water-holding ability were noted for pre-sowing treatments with laser irradiation — 1 minute, 2 minutes, 2 minutes 30 seconds, 4 minutes, 10 minutes.

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Д.М. Әменова, Д.В. Агеев, М.Ю. Ишмуратова, А.К. Зейнидинов

Лазер сәулесін қолданғаннан кейін бидай дақылы өскіндерінің суды ұстап тұру қабілетін бағалау

Мақалада толқын ұзындығы 632,8 нм лазермен алдын ала өңделген жұмсақ бидай өскіндерінің суды ұстап тұру қабілеті мен суландыруға әсер етуін бағалау келтірілген. Өңдеу уақыты 15 секундтан 15 минутқа дейінгі аралықты қамтиды. Кептіру кезінде ылғал өскіндердің сулануы мен олардың ауадағы құрғақ массалары бақылау үлгісімен салыстырғанда жоғарырақ болды. Сонымен, бидайдың 3 апталық өскіндерінің сулануы бақылаумен салыстырғанда 12,5–45,2 %-ға артты. Тәжірибелік массалардың 2 сағат кептірілгеннен кейінгі мәндері бақылаумен салыстырғанда 23,5–159,4 %-ға, ал 4 сағаттан кейін 5,6–74,5 %-ға жоғары болды. Тәжірибедегі өскіндердің құрғақ массалары бақылаумен салыстырғанда 6,7–44,4 %-ға артты. Бидай өскіндердің суды ұстап тұру қабілеті бақылаумен тең және жоғары мәндерге ие болды. Берілген көрсеткіштер белгілі бір ұзақтықта лазер сәулесімен алдын ала өңдеу шөлге тұрақтылық көрсеткіштерін арттырып, оң әсер береді. Өскіндердің сулануы мен суды ұстап тұруға қабілеттілігінің ең жақсы көрсеткіштері лазер сәулесімен атқыланған мына нұсқаларда: 1 минут, 2 минут, 2 минут 30 секунд, 4 минут, 10 минутта байқалды.

Кілт сөздер: тұқым материалы, өскіндер, бидай, сулану, суды ұстап тұру қабілеті, лазер сәулесі, тәжірибе нұсқалары.

Д.М. Аменова, Д.В. Агеев, М.Ю. Ишмуратова, А.К. Зейнидинов

Оценка водоудерживающей способности проростков пшеницы после применения лазерного облучения

В статье приведены оценки влияния оводненности и водоудерживающей способности проростков пшеницы мягкой после предварительной обработки семян лазером с длиной волны 632,8 нм. Длительность обработки составляла от 15 сек до 15 мин. Оводненность сырых проростков в процессе высушивания и на воздушно-сухой вес оказалась выше контрольных значений. Так, оводненность 3-недельных проростков пшеницы по всем вариантам опыта превысила контроль на 12,5–45,2 %. Вес опытных проростков после 2-х ч высушивания превышал значения контроля на 23,5–159,4 %, после 4-х ч — на 5,6–74,5 %. Сухой вес проростков оказался в опытных вариантах выше контроля на 6,7–44,4 %. Водоудерживающая способность проростков пшеницы по вариантам опыта оказалась примерно на уровне контроля или выше контрольных значений. Данные показатели свидетельствуют о положительном влиянии лазерной обработки определенной длительности на повышение показателей устойчивости к засухе. Лучшие показатели оводненности проростков и водоудерживающей способности отмечены при вариантах предпосевной обработки лазерным облучением — 1 мин, 2 мин, 2 мин 30 сек, 4 мин, 10 мин.

Ключевые слова: семенной материал, проростки, пшеница, оводненность, водоудерживающая способность, лазерное облучение, варианты опыта.

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