IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

International Journal of Design & Nature and Ecodynamics
Vol. 18, No. 6, December, 2023, pp. 1493-1502
Journal homepage: http://iieta.org/journals/ijdne

Optimizing Wheat and Barley Yield Through Programming Techniques: Mineral Fertilizers, Plant Protection, and Agricultural Practices in South-Eastern Kazakhstan

Nadira Sultanova[1*], Bakhytzhan Duissembekov[2], Madina Bekezhanova[1], Semby Arystangulov[1], Ulan Yessimov[1], Alibek Uspanov[2]

[1] Department of Pesticide Registration, Kazakh Research Institute of Plant Protection and Quarantine named after Zh. Zhiembayev, Almaty A30M0H6, Republic of Kazakhstan
[2] Kazakh Research Institute of Plant Protection and Quarantine named after Zh. Zhiembayev, Almaty A30M0H6, Republic of Kazakhstan

Corresponding Author Email: sultanovanadira@yahoo.com

https://doi.org/10.18280/ijdne.180624

Received: 20 July 2023
Revised: 11 October 2023
Accepted: 27 October 2023
Available online: 26 December 2023

Keywords:
wheat, barley, fertilizers, photosynthetic active radiation, Zhetysu region, protective-stimulating compounds, yield programming

ABSTRACT

Ensuring the health and safety of crops through the mitigation of harmful microorganisms is essential for maintaining agricultural productivity and food security. The yield of grain crops constitutes a critical metric for optimizing agricultural planning. The primary objective of this research is to investigate the efficacy of integrating common programming principles with the employment of mineral fertilizers and enhanced plant protection to augment the yield of grain crops under the prevailing natural conditions of the Zhetysu region in the Republic of Kazakhstan. The methodological framework of this study is grounded in the application of practical, applied research methods to assess the potential of yield programming for wheat and barley. This assessment is contingent upon the utilization of fertilizers and plant protection products within the specific agro-climatic context of southeastern Kazakhstan. It was observed that the treatment of seeds with protective-stimulating agents significantly improves the health and viability of cereal crops. These benefits are evidenced by the suppression of infections and enhancements in germination rates and pest resistance. Field experiments conducted within the Zhetysu region indicate that the sowing of pre-treated seeds in late April is conducive to optimal plant development and yield. The findings suggest that further research should concentrate on refining the application of fertilizers and protective agents to enhance predictive models and yield outcomes at a national scale.

1. INTRODUCTION

This study addresses the challenge of augmenting future grain crop yields by implementing a strategy to mitigate the deleterious effects of agricultural pests. The focus is on refining the programming methods for cultivating crops, incorporating preventative measures against harmful organisms. These methods include the strategic use of protective and stimulating compounds for seed treatment prior to sowing. This approach has been shown to significantly enhance crop health and reduce the accumulation of harmful substances [1-6].

In the northern regions of Kazakhstan, field and production experiments with grain crops have demonstrated that the optimal structuring of crops can lead to yield increases of approximately 40-50%, with outcomes contingent upon the biological and morphological characteristics of the crops and the moisture conditions [7, 8]. Under natural moisture conditions, grain crops have been found to develop leaf surface areas ranging from 13 to 40 thousand m^2/ha, with dry matter yields reaching 20-35 centners/ha, or 10-18 centners/ha of grain [9-14]. The urgency of this research is underscored by the necessity to apply these findings to enhance wheat and barley yields in specific regions of Kazakhstan.

The southeast of Kazakhstan, a critical region for the nation's grain production, has been selected as the study area due to its unique pest profile and environmental sensitivities. The economic dependence of local communities on grain crops, coupled with the potential ecological impact of pesticide use, mandates the development of tailored pest management strategies. These strategies aim to boost yields while preserving both the economic and environmental well-being of the region. Collaboration with local experts, who possess in-depth knowledge of the agricultural landscape and pest dynamics, is integral to the study's success.

Dukhovny et al. [15] considered various aspects of yield programming within a systems approach to reclamation, highlighting the necessity for a complex of interrelated reclamation and agrotechnical measures to achieve pre-calculated crop volumes. Additionally, Kazakhstan's rank as the third-largest wheat producer among CIS member states and emphasized the natural and climatic potential of southeast Kazakhstan for wheat and barley cultivation [16-18].

Further, Esimbekova et al. [19] conducted research on the properties of soft wheat in the international breeding classification, emphasizing the importance of considering fertilizer quality and composition in yield programming. Chen et al. [20] explored the effects of organic fertilizers on clay mineral transformation and phosphorus retention, finding that organic fertilizers enhance the bioavailability of phosphorus, a key element in yield programming [21, 22]. Song et al. [23] studied the increase in grain crop yields through leaf nitrogen and phosphorus resorption, concluding that this process, in conjunction with improved fertilizer quality, significantly boosts soil nutrient restoration and productivity. This allows a significant increase in grain production even in semi-arid geographic regions [24-26].

The prevalence of agricultural pests in southeast Kazakhstan, including aphids, grasshoppers, and fungal pathogens, causes substantial yield losses and economic damage [27, 28]. The reliance on chemical pesticides poses environmental concerns, compounded by climatic variability that complicates pest management. Addressing these issues is vital for sustaining agricultural productivity and environmental health in the region, making the investigation of pest management strategies a critical endeavor [29-31].

The primary aim of this research is to examine the fundamental principles of programming wheat and barley yield growth, focusing on the use of mineral fertilizers and plant protection products within the context of the foothill-steppe zone of southeast Kazakhstan.

2. MATERIALS AND METHODS

The research methodology employed in this study consists of practical experiments and theoretical foundations to investigate the principles of programming wheat and barley yields in the specific conditions of south-eastern Kazakhstan. Practical experiments were conducted to explore the impact of various factors, including sowing dates, seeding rates, and fertilizer application, on grain crop yields. Phenological observations were made to monitor key developmental phases of wheat and barley. The study involved three sowing terms and two fertilizer backgrounds, with temperature, day length, and other parameters taken into account. The field experiments were conducted in 2022, with detailed data collected on crop growth and yield. Statistical analysis was applied to the collected data to assess the effectiveness of protective and stimulating compounds and fertilizer use.

An applied study of improving the principles of programming grain crops (spring wheat, spring barley) in the conditions of the Zhetysu region involved practical, field experiments to study the effect of sowing dates, seeding rates, calculated doses of fertilizer and protective measures on the yield of grain crops. In this scientific study, phenological observations were made on the main trends in the growth and development of grain crops of wheat and barley, which were used in field experiments. This made it possible to determine the key phases of development, such as the emergence of seedlings, the period of maturation, as well as the duration of the vegetative period.

In the field experiment, spring wheat and spring barley were sown in three terms with three seeding rates and two backgrounds: without the use of mineral fertilizers (control) and with the use of fertilizers in active ingredients (P20 in rows and N30 in top dressing). For each plant species, their own minimums and maximums of temperature, day length, and other parameters were noted. The study was carried out in 2022. For spring wheat of the first sowing period, the tillering phase began on May 11, the beginning of the tube growth was noted on May 25, earing-on June 12, the culture began to bloom-on July 01-03, the ripening phase began by August 12. On a fertilized background, the plants matured later than in the variants without the use of fertilizers by 2-3 days. Consequently, the length of the growing season of spring wheat of the first period was 105-108 days. The second term for sowing spring wheat of the Kazakhstanskaya-4 variety was made on May 07. Seedlings appeared on May 14-15, after 7-8 days, ripening occurred on August 18-20, the duration of the growing season was 101-103 days. The third term was sown on May 16, with soil temperature at a depth of 0-10cm, at 10-12°C, it should be noted that the spring period was rainy and cool. Seedlings appeared in 5-6 days, and the full ripeness of the wheat grain came at the end of August. The duration of the growing season was 97-99 days, which is 8-10 days shorter than in the first period.

Based on the results of the field experiments, statistical processing of the obtained data was carried out, reflecting the experimental indicators of wheat and barley yields. This made it possible to determine in the field the practical effectiveness of protective and stimulating compounds, the fertilizers used, and also to assess the real prospects for programming the yield of these grain crops, which is of fundamental importance from the point of view of the prospects for predicting the yield of wheat and barley in the conditions of the southeast of Kazakhstan.

3. RESULTS

The study on spring wheat and barley utilized varying sowing dates, seeding rates, and fertilizer treatments to understand the nuanced impacts of these variables on crop growth and yield. Different sowing dates capture the effects of diverse environmental conditions on plant development, providing insights into optimal planting times. Varying seeding rates assess intra-crop competition and determine the ideal plant density for maximal yield. The comparison between fertilized and non-fertilized plots offers a direct analysis of nutrient impact on growth, showcasing the potential benefits and economic viability of fertilizer application, especially in a season characterized by cool and rainy conditions.

One of the principles for determining the size of a possible harvest is the development of effective pest control measures. In this regard, in order to improve the methods of programming crops in various systems of measures to protect against damage by pests, experiments were laid out with the use of protective and stimulating compounds for the planned treatment of spring wheat and barley seeds before sowing and in field and experimental conditions in order to improve their health and reduce the accumulation of infection in the soil. The biological effectiveness of the developed protective and stimulating compositions against root rot of spring wheat in the field during the tillering phase varied according to the variants within 59.4-85.5%, in the phase of full ripeness 58.1-82.9%, respectively, the highest efficiency was noted in the variants in combination Celeste top 312.5, k.s. 1.0 l/t + Extrasol, F, 1.0 l/t and TMTD (Tetramethylthiuram disulfide, Thiuram), v.s.k. 3.0 l/t + Celeste top 312.5, k.s. 1.0 l/t + Extrasol, F, 1.0 l/t, both in the tillering phase and in the full ripeness of the grain 84%; 77.5%; 85.5% and 82.9% respectively (Table 1).

Similar data were also obtained on spring barley, here a rather high biological efficiency against root rot was also noted in the tillering phase and full ripeness of the grain. In the tillering phase, these indicators amounted to 66.6-77.7%, in the phase of full ripeness of the grain 60.2%-76.1%, respectively (Table 2).

Table 1. Biological effectiveness of protective and stimulating compositions against root rot of spring wheat, Zhetysu region, LLP "zholbarys agro", 2021-2022

Option, Consumption Rate l/t, kg/t	Plants Afflicted with Root Rot, %		Biological Efficiency Against Root Rot, %	
	in the tillering phase	before harvesting	in the tillering phase	before harvesting
Celeste top 312.5, k.s. 1.0 l/t+extrasol, zh 1.0 l/t	1.1	2.7	84	77.5
Pilgrim, k.s. 0.4 l/t+humat K, zh 1.0 l/t	2.4	5.5	65.2	60.9
Yunta, k.s. 1.5 l/t+humat K, zh 1.0 l/t	2.8	5.9	59.4	58.1
Yunta, k.s. 1.5 l/t+scarlet, m.e. 0.3 l/t+humat K, l. 1.0 l/t	1.3	3.8	81.1	73
Agrostimulin, 2.6% v.s.r. 10.0 ml/t+inshur perform, 12% k.s. 0.3 l/t+taboo, v.s.k. 0.5 l/t	1.5	3.3	78.2	76.5
Yunta, k.s. 1.5 l/t+biosil, 10% v.e. 0.05 l/t	1.8	4	73.9	71.6
Vial trio v.s.k. 0.8 l/t+yunta, k.s. 1.5 l/t+extrasol, zh, 1.0 l/t	2	4.2	71	70.2
Tetramethylthiuram disulfide, thiuram 3.0 l/t+celeste top 312.5, 1.0 l/t+extrasol, zh, 1.0 l/t	1	2.4	85.5	82.9
Control	6.9	14.1	-	-

Source: compiled by the authors.

Table 2. Biological effectiveness of protective and stimulating compositions against root rot of spring barley, Zhetysu region, LLP "zholbarys agro", 2021-2022

Option, Consumption Rate l/t, kg/t	Plants Afflicted with Root Rot, %		Biological Efficiency Against Root Rot, %	
	in the tillering phase	before harvesting	in the tillering phase	before harvesting
Celeste top 312.5, k.s. 1.0 l/t+extrasol, zh, 1.0 l/t	1.8	3.9	75	70.4
Pilgrim, k.s. 0.4 l/t+humat k, zh 1.0 l/t	2.4	5.2	66.6	65.5
Yunta, k.s. 1.5 l/t+humat k, zh 1.0 l/t	2	4.9	72.2	67.5
Yunta, k.s. 1.5 l/t+scarlet, m.e. 0.3 l/t+humat k, l. 1.0 l/t	1.9	5.4	73.6	64.2
Agrostimulin, 2.6% v.s.r. 10.0 ml/t+inshur perform, 12% k.s. 0.3 l/t+taboo, v.s.k. 0.5 l/t	2	4.9	72.2	67.5
Yunta, k.s. 1.5 l/t+biosil, 10% v.e. 0.05 l/t	2.2	5.9	69.4	60.9
Vial trio v.s.k. 0.8 l/t+yunta, k.s. 1.5 l/t+extrasol, zh, 1.0 l/t	2.1	6	70.8	60.2
Tetramethylthiuram disulfide, thiuram 3.0 l/t+celeste top 312.5, 1.0 l/t+extrasol, zh, 1.0 l/t	1.6	3.6	77.7	76.1
Control	7.2	15.1	-	-

Source: compiled by the authors.

Table 3. Influence of protective and stimulating compounds on the crop structure and yield of spring wheat, Zhetysu region, LLP "zholbarys agro", 2021-2022

Option	Bushiness, pcs.	Plant Height, cm.	Spikelet Length, cm.	Number of Spikelets, pcs.	Weight 1000 Seeds, g	Yield, Centner/ha
Celeste top 312.5, k.s. 1.0 l/t+extrasol, zh, 1.0 l/t	2.4	93.3	6.2	21.6	44.7	19.9
Pilgrim, k.s. 0.4 l/t+humat k, zh 1.0 l/t	2	91.1	5.8	20.9	43.5	17.1
Yunta, k.s. 1.5 l/t+humat k, zh 1.0 l/t	2.1	86.2	5.7	19.7	41.3	17.9
Yunta, k.s. 1.5 l/t+scarlet, m.e. 0.3 l/t+humat k, l. 1.0 l/t	2.2	86.4	6	21.1	44	19.4
Agrostimulin, 2.6% v.s.r. 10.0 ml/t+inshur perform, 12% k.s. 0.3 l/t+taboo, v.s.k. 0.5 l/t	2.4	87.9	5.9	21	43.6	19.8
Yunta, k.s. 1.5 l/t+biosil, 10% v.e. 0.05 l/t	2.1	86.1	6	19.8	40	17.7
Vial trio v.s.k. 0.8 l/t+yunta, k.s. 1.5 l/t+extrasol, zh, 1.0 l/t	2.2	86.7	6	21.1	43.8	19.7
Tetramethylthiuram disulfide, Thiuram 3.0 l/t+celeste top 312.5, 1.0 l/t+extrasol, zh, 1.0 l/t	2.2	87.1	5.8	20.7	43.1	19.3
Control	1.9	79.6	5.4	19.6	38.4	16.6
P value at 95% confidence interval	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Source: compiled by the authors.

Table 4. The influence of protective and stimulating compounds on the biometric indicators of spring barley, Zhetysu region, LLP "zholbarys agro", 2021-2022

Option	Bushiness, pcs.	Plant Height, cm.	Spikelet Length, cm.	Number of Spikelets, pcs.	Weight 1000 Seeds, g	Yield, Centner/ha
Celeste top 312.5, k.s. 1.0 l/t+extrasol, zh, 1.0 l/t	2.3	61.6	6.4	20.3	43.8	18.3
Pilgrim, k.s. 0.4 l/t+humat k, zh 1.0 l/t	2.6	64.5	6.5	20.6	40.2	17.9
Yunta, k.s. 1.5 l/t+humat k, zh 1.0 l/t	2.5	60.8	6.3	19.7	39.9	15.3
Yunta, k.s. 1.5 l/t+scarlet, m.e. 0.3 l/t+humat k, l. 1.0 l/t	2	58.9	6	19.2	40.8	15.8
Agrostimulin, 2.6% v.s.r. 10.0 ml/t+inshur perform, 12% k.s. 0.3 l/t+taboo, v.s.k. 0.5 l/t	2.1	58	5.9	18.7	40.5	15.9
Yunta, k.s. 1.5 l/t+biosil, 10% v.e. 0.05 l/t	1.9	60.3	6.7	21	41.1	16.4
Vial trio v.s.k. 0.8 l/t+yunta, k.s. 1.5 l/t+extrasol, f, 1.0 l/t	1.9	58.4	5.9	19.7	41.9	16.9
Tetramethylthiuram disulfide, thiuram 3.0 l/t+celeste top 312.5, 1.0 l/t+extrasol, zh, 1.0 l/t	2.3	62.9	6.3	21.4	42.8	17.9
Control	1.5	55.9	5.2	16.7	38.3	14.1
P value at 95% confidence interval	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Source: compiled by the authors.

Table 5. Influence of sowing time, seeding rate on field germination, standing density in the germination phase and plant safety before harvesting spring wheat, Zhetysu region, LLP "zholbarys agro", 2021-2022

Sowing Dates	Seeding Rates, mln pcs/ha	Background	Field Germination of Seeds, %	Number of Seedlings, $1m^2$/pc.	Plant Density During Germination, pcs/ha	Preservation Plants, %	Plant Density During the Harvesting Period, thousand units/ha
1 term-3rd decade of April	3	without fertilizers (k)	84.2	252.6	2526	92.5	2336.5
		with fertilizer	84.5	253.5	2535	93.3	2365.1
1 term-3rd decade of April	3.5	without fertilizers (k)	83.8	293.3	2933	92.2	2704.2
		with fertilizer	84.1	294.4	2943.5	93.1	2740.4
1 term-3rd decade of April	4	without fertilizers (k)	83.4	333.6	3336	90.6	3022.4
		with fertilizer	83.7	334.8	3348	91.7	3070.1
2nd term-1st decade of May	3	without fertilizers (k)	87.3	261.9	2619	92.8	2430.4
		with fertilizer	88.1	264.3	2643	93.9	2481.8
2nd term-1st decade of May	3.5	without fertilizers (k)	86.9	304.1	3041.5	92.5	2813.4
		with fertilizer	87.7	306.9	3069.5	93.4	2866.9
2nd term-1st decade of May	4	without fertilizers (k)	86.2	344.8	3448	92.3	3182.5
		with fertilizer	87.4	349.6	3496	93.1	3254.7
3 term-2nd decade of May	3	without fertilizers (k)	89.5	268.5	2685	93.2	2502.4
		with fertilizer	90.1	270.3	2703	93.6	2530
3 term-2nd decade of May	3.5	without fertilizers (k)	89.3	312.6	3125.5	92.7	2897.3
		with fertilizer	89.8	314.3	3143	93.1	2926.1
3 term-2nd decade of May	4	without fertilizers (k)	88.9	355.6	3556	92	3271.5
		with fertilizer	89.7	358.8	3588	92.9	3333.2
P value	Factor	Background	<0.05	<0.05	<0.05	<0.05	<0.05
		Sowing term	<0.05	<0.05	<0.05	<0.05	<0.05

Source: compiled by the authors.

Thus, the developed protective-stimulating compositions showed their effectiveness in the field, all options suppressed the development and spread of root rot. Data on biometric indicators also showed a fairly high efficiency of the developed protective and stimulating compositions in the field on spring wheat and barley crops, an increase in business, plant height, spike length and the number of spikelets per 1 plant in the treated variants was noted. The height of spring wheat plants exceeded the control from 8.1% to 17.2%, on spring barley these figures were 3.7-15.3%, respectively (Tables 3 and 4).

The performed study of the parameters of biometric measurements and the constituent elements of the crop revealed that in the case of seed treatment of spring wheat and barley, protective-stimulating compounds increase tillering, vegetative growth, the number of spikelets, yield, and weight of 1000 seeds. As a result, during the treatment of seeds of spring wheat and barley, due to the protective and stimulating effects of pre-prepared compositions, the harvested crop by elements varied on spring wheat in the range of 0.5-3.3c/ha, on spring barley 1.2-4.2c/ha, the yield in control variants on spring wheat, 16.6c/ha; on spring barley, 14.1c/ha, respectively. Table 5 shows the effect of sowing time and seeding rate on field germination and survival of spring wheat plants.

The optimal ratio of these factors contributes to obtaining maximum seedlings per unit area. In the experiment, with an early sowing period, the field germination of seeds averaged 84%, and on a fertilized background, seedlings were more than on an unfertilized background by 0.3%. According to the sown seeds and field germination per $1m^2$ sprouted from 252.6 to 334.8 seedlings of spring wheat. The safety of plants during the harvesting period was 90.6-93.3% of the emerging seedlings. It should be noted that in the fertilized variants, the safety of plants was higher by 0.8-1.1% than in the experimental plots where fertilizers were not used.

Similar results were obtained in the second sowing period, where on the fertilized variants the field germination and safety of plants were higher than in the variants without the use of mineral fertilizers. It should also be noted that the field germination of spring wheat seeds was higher in the second term than in the first by 3.1-3.4%. This can be explained by the optimal ratio of temperature and humidity environmental factors. During the growing season, the safety of plants fluctuated in the range of 92.3-93.9%, this figure was higher than in the early period by 0.6%. In general, it should be taken into account that the studied agricultural year turned out to be wet, due to frequent rain, i.e., was favourable for the growth and development of crops. Before harvesting, there were from 2.4 to 2.9 million plants with productive stems per hectare.

Spring wheat for the third term was sown on May 17, where seedlings appeared 5-6 days after sowing. The completeness of seedlings was in the range of 88.9-90.1%, and the safety of plants for harvesting ranged from 92.0-93.6%. During the harvesting period, depending on the standard value of sowing, from 2.5 to 3.3 million plants per hectare were preserved. Similar results were obtained on crops of spring barley (Table 6).

The culture was also sown in three terms, with three norms and two backgrounds. Depending on the biological characteristics of plants and adaptation to environmental conditions, the following data were obtained: in the 1st period, the field germination of seeds was in the range of 83.4-84.5% with some fluctuations within the sowing rate. Plant safety was also quite high 91.7-93.3%. On the fertilized variants, these indicators were higher than without fertilization; in the end, before harvesting, the plant density was in the range of 2.3-3.1 million units/ha, depending on the seeding rate of spring barley.

Table 6. Influence of sowing dates, seeding rate on field germination, standing density and safety of plants before harvesting spring barley, Zhetysu region, LLP “zholbarys agro”, 2021-2022

Sowing Dates	Seeding Rates, mln pcs/ha	Background	Field Germination of Seeds, %	Number of Sprouts, $1m^2$/pcs.	Plant Density During Germination, pcs/ha	Preservation Plants, %	Plant Density During the Harvesting Period, thousand units/ha
1	2	3	4	5	6	7	8
1 term-3rd decade of April	3	without fertilizers (k)	85.1	255.3	2553	93.1	2376.9
		with fertilizer	85.8	257.4	2574	93.6	2409.2
1 term-3rd decade of April	3.5	without fertilizers (k)	84.7	296.5	2964.5	92.8	2751
		with fertilizer	85.3	298.6	3380	93.3	2785.5
1 term-3rd decade of April	4	without fertilizers (k)	84.5	338	3404	92.2	3116.3
		with fertilizer	85.1	340.4	2658	92.9	3162.3
2nd term-1st decade of May	3	without fertilizers (k)	88.6	265.8	2676	92.7	2463.9
		with fertilizer	89.2	267.6	3090.5	93.2	2494
2nd term-1st decade of May	3.5	without fertilizers (k)	88.3	309.1	3108	92.4	2855.6
		with fertilizer	88.8	310.8	3516	93	2890.4
2nd term-1st decade of May	4	without fertilizers (k)	87.9	351.6	3536	92.1	3238.2
		with fertilizer	88.4	353.6	2685	92.6	3274.3
3 term-2nd decade of May	3	without fertilizers (k)	89.5	268.5	2721	93.1	2499.7
		with fertilizer	90.7	272.1	3122	93.8	2552.3
3 term-2nd decade of May	3.5	without fertilizers (k)	89.2	312.2	3160.5	92.7	2894
		with fertilizer	90.3	316.1	3556	93.6	2958.2
3 term-2nd decade of May	4	without fertilizers (k)	88.9	355.6	3556	92.2	3278.6
		with fertilizer	89.8	359.2	3592	92.9	3336.9
P value	Factor	Background	<0.05	<0.05	<0.05	<0.05	<0.05
		Sowing term	<0.05	<0.05	<0.05	<0.05	<0.05

Source: compiled by the authors.

Table 7. Yields of spring wheat and spring barley in experiments with sowing dates, seeding rate and fertilizers, Zhetysu region, LLP “zholbarys agro”, 2021-2022

Sowing Dates	Seeding Rate, mln pcs/ha	Background	Yield of Spring Wheat, c/ha	Yield of Spring Barley c/ha
1 term-3rd decade of April	3	without fertilizers (k)	27.5	19.1
		with fertilizer	30.2	21.2
1 term-3rd decade of April	3.5	without fertilizers (k)	38.1	23
		with fertilizer	41.3	29.2

1 term-3rd decade of April	4	without fertilizers (k)	37.5	20.9
		with fertilizer	39.2	24
	$NSR_{0.05}$		2	1.7
2nd term-1st decade of May	3	without fertilizers (k)	26.9	15
		with fertilizer	29.3	19
2nd term-1st decade of May	3.5	without fertilizers (k)	35.4	16.9
		with fertilizer	39.3	21.4
2nd term-1st decade of May	4	without fertilizers (k)	34.5	17.7
		with fertilizer	37.1	20.3
	$NSR_{0.05}$		2.2	1.5
3 term-2nd decade of May	3	without fertilizers (k)	25.8	20
		with fertilizer	27.5	22.5
3 term-2nd decade of May	3.5	without fertilizers (k)	32.1	21.4
		with fertilizer	36.6	25.2
3 term-2nd decade of May	4	without fertilizers (k)	33.2	19.3
		with fertilizer	35.8	23.1
	$NSR_{0.05}$		2	1.5

*Note: $NSR_{0.05}$-non-significant difference at the 0.05 significance level.
Source: compiled by the author.

In subsequent sowing periods, one can observe an increase in the field germination of seeds on average from 3.1 to 5.2%, from the early sowing period, as well as stabilization of the plant safety index from germination to ripeness of barley grain within 92-93%. The results obtained give hope for obtaining the maximum yield with high baking qualities. Plant height growth is characterized by an increase in the height and mass of plants. Indicators of the intensity of plant growth after germination are of great importance, since more powerful plants tolerate weather fluctuations better and are resistant to harmful organisms. The sowing time had a significant impact on the formation of the crop structure and grain yield of spring wheat (Table 7).

At the first sowing term with a rate of 3.5 million germinating seeds, 38.1 were obtained per hectare in the variant without fertilizers; and 41.3c/ha of grain yield, depending on the use of mineral fertilizers, in the second period with the same norm, the yield was in the range of 35.4-39.3c/ha, with a yield difference of 2.0-2.7c/ha in favour of the first period, and in the third period (the second decade of May), this indicator decreased to 4.6-6c/ha compared with the early period. The same pattern can be seen in other sowing dates with other seeding rates. It should be noted that the earlier sowing time contributed to obtaining the largest grain yield, compared with other sowing dates.

The study of various seeding rates showed that the largest grain yield in all sowing periods was obtained at a rate of 3.5 million viable seeds per hectare. Both a decrease in this indicator to 3.0 million pieces/ha and a consistent increase to 4.0 million pieces/ha reduce the yield of spring wheat grain. The yield of field crops is formed in the process of the photosynthetic activity of crops. This means that in order to increase the yield, it is necessary to strive to increase the utilization factor of photosynthetically active radiation (PAR), creating crops of optimal structure with the appropriate photosynthetic surface area. The area of the leaf (photosynthetic) surface of most crops depends on the number of plants and the size of the leaf surface of them and in total per unit area (m^2/ha), biological and morphological characteristics of the crop, variety, meteorological conditions and the level of agricultural technology.

This research is an important contribution to agricultural research today, particularly in the areas of pest management and crop yield optimisation. The research shows the effectiveness of using protective and stimulating components in seed treatments to prevent the spread of root rot in both spring wheat and barley. These findings are important because root rot can seriously reduce agricultural output. In addition, biometric measures showing increased plant growth, spikelet counts and crop production support the efficacy of these protective and stimulating compounds. In particular, the study shows that these treatments can increase spring wheat yield by 0.5-3.3c/ha and spring barley yield by 1.2-4.2c/ha, providing growers with real economic benefits. The results on seeding rates and sowing periods further highlight their significant impact on germination, plant survival, and ultimate output. The findings, particularly those concerning the ideal balance of temperature and humidity environmental parameters, can help farmers choose the most effective sowing techniques.

The study provides insightful information for crop protection and yield optimisation, but there are a number of issues and limitations that need to be addressed. As the study was conducted in a particularly wet year, the results may not apply in drier seasons due to environmental variability. Although the short-term benefits of the treatments are emphasised, their long-term effects on soil health, potential accumulation of chemical residues and future yields are not investigated. The cost implications of these treatments are not considered in the economic analysis, which appears to be lacking. The focus on specific wheat and barley varieties raises concerns about the generalisability of the results to other varieties or crops. Results could be biased if other agronomic practices, such as crop rotation or irrigation, are not taken into account. Potential pest resistance development to the applied treatments remains unexplored, which could be a critical factor for long-term agricultural sustainability.

4. DISCUSSION

The research team of Gupta et al. [32] considered a number of problematic aspects of wheat and barley grain biofortification. Scientists note that the successful solution of the issues of biological enrichment of wheat and barley allows over time to achieve the elimination of the problem of malnutrition in many parts of the world. Researchers draw attention to the fact that the interaction of cultivated plants with harmful microorganisms negatively affects the supply of nutrients to wheat and barley, which makes it necessary to increase yields through the use of fertilizers. According to the authors, this will facilitate the biological enrichment of microelements and will improve the conditions for the growth of wheat and barley. The conclusions of scientists correlate with the results obtained in this scientific work, while the selection of fertilizers to ensure yields in the planned volumes require additional study.

In turn, the group of authors He et al. [33] in a study on the sensitivity and uncertainty of the winter wheat crop rotation ecosystem model, draws attention to the fact that the accuracy of modeling soil nitrogen cycles is critical in terms of assessing food security and agricultural resource use efficiency. According to scientists, the accuracy of the yield forecast model largely depends on its parameterization, which determines the efficiency of programming the yield of wheat varieties, depending on the fertilizers used. The conclusions of the researchers are indirectly confirmed by the results of this scientific work, while the issues of modeling nitrogen cycles in the soil require additional study.

Guo et al. [34] considered various aspects of the effect of nitrogen fertilizers on the condition of agricultural soils. Scientists note that numerous studies confirm the likelihood of soil degradation from the use of nitrogen fertilizers, while the nature of what is happening remains completely unclear. The researchers believe that the correct determination of the actual degree of influence of these fertilizers on soil aggregation will improve the structure of the soil layer and ensure the maintenance of high yields over an extended period. The opinion of the researchers correlates with the results obtained in this scientific work, while the question remains regarding the methodology for calculating the dosage of nitrogen fertilizers, which would avoid harming the soil.

The research group consisting of Foloni et al. [35] considered several problematic aspects of forecasting the yield of wheat and other grain crops due to the qualitative alignment of the processes of chemical tillage. According to a group of scientists, the increased acidity of the soil surface, combined with a lack of nitrogen, inevitably turns into problems for crops like wheat and barley, as well as other crops. A way out can be found in the use of fertilizers that reduce the acidity of agricultural soils, which allows later planning the yield. The results obtained by the researchers do not fundamentally contradict the results of this scientific work.

Research team consisting of Celestina et al. [36] conducted a scientific study on the classification schemes of wheat and barley. Scientists have found that the correct classification of grain crops at the stage of yield planning significantly affects the final quality of the crop and its volume. In addition, it is noted that the timely processing of emerging crops reduces the likelihood of the development of harmful microorganisms on the leaves, which is of fundamental importance from the point of view of the prospects for increasing yields. According to the researchers, new varieties of grain crops entering the market can be ranked by their comparative thermal time to flowering and assigned to specific classes, which makes it possible to more effectively plan yields based on these indicators in the future. The conclusions of the researchers do not contradict the results of this scientific work, while the issues of ranking grain crop varieties according to the thermal regime seem to be quite controversial and require additional practical verification.

In turn, the research group consisting of Lü et al. [37], in their joint work, considered the presence of a common gene in wheat and barley that can effectively control the vegetative period. Scientists note the importance of the vegetative period as one of the fundamental in determining the resistance of cereals to changes and adaptation to environmental conditions, subject to the proper use of fertilizers. In their opinion, the presence of a common BVP gene in wheat and barley makes it possible to control the early flowering of these crops, which opens up wide opportunities in programming yields for short and long-term periods. The opinions of researchers are correlated with the results of this scientific work, while the importance of the growing season in determining the resistance of crops to adaptation deserves special attention.

At the same time, the team of scientists Chu et al. [38] conducted a joint scientific study on the degree of influence of delayed sowing on grain quality, its weight, quantity, as well as protein concentration at individual points of the ears. It is noted that delays in sowing extremely negatively affect the yield of grain crops, yield components, as well as protein concentration in ears [39]. Scientists came to the conclusion that when planning the yield of grain crops, one should take into account the dependence of changes in yield volumes on varying sowing time and the characteristics of the fertilizers used, which will allow regulating the quality of the crop and its volume. The conclusions of the scientists are fundamentally consistent with the results of this scientific work, in the context of assessing the significance of the variation in sowing time for the final yield of grain crops.

Pozza and Field [40] in a scientific study aimed at studying a number of problematic aspects of food and soil security, note that the issues of competent use of fertile land are directly related to a number of aspects of crop planning. Soil security, through good crop planning and fertilizer use, helps create the conditions for sustainable food, fiber, and water quality improvements through improved soil care and innovative land management practices, scientists say. The results of the scientists are fundamentally consistent with the results of this scientific study in the context of assessing the provision of soil security through planning grain yields.

Thus, the discussion of the results obtained in this research work, in the context of their analytical comparison with the results of a number of scientific studies of related topics, clearly illustrates their fundamental correspondence in a number of key aspects. This is evidence of the scientific reliability of these results and the expediency of their practical application in order to program the yield of wheat and barley.

5. CONCLUSIONS

The experimental design was focused on enhancing seed quality and resistance against fungal and bacterial infections through the utilization of protective-stimulating compounds. Laboratory evaluations confirmed the efficacy of these treatments in suppressing seed infections and augmenting their sowing attributes. More specifically, the pre-sowing treatment of spring wheat seeds incorporated a mix of fungicides, insecticides, and growth stimulants. This combination not only deterred infections of various origins but also amplified the seeds' vital potential. This boost in potential translated to enhanced germination rates, robust root system development, and heightened resistance to pests and diseases, which are pivotal aspects in crop planning.

Moreover, statistical analysis underscored a significant correlation between field germination and grain yield, reinforcing the effectiveness of the protective treatments. The study revealed that in the Zhetysu region of Kazakhstan, spring crops like wheat and barley, under semi-provided rainfed conditions, should be conventionally sown in late April. The recommended seeding rate is 3.5-4 million germinating seeds per hectare. These seeds should be pre-treated with the studied protective and stimulating compounds and planted following a structured crop rotation system, supplemented with a calculated dose of mineral fertilizers for the anticipated grain harvest. The overarching objective of this research was to pinpoint an optimal blend of fertilizers and plant protection treatments to forecast wheat and barley yields, pivotal for agricultural productivity in southeast Kazakhstan and the country at large.

The observed enhancements in seed quality and growth characteristics play a foundational role in augmenting grain yield. Enhanced seed quality, characterized by improved germination rates and resistance against infections, ensures a higher number of viable seedlings per sown seed. This increased germination rate ensures a denser and more uniform crop stand, optimizing the utilization of available resources like sunlight, water, and nutrients. Furthermore, the robust growth characteristics, especially the development of a stronger root system, enable plants to efficiently extract water and nutrients from the soil, supporting vigorous vegetative growth and greater grain filling.

A healthy root system also enhances the plant's resilience against stress conditions like drought, which otherwise could hinder grain development. Additionally, improved resistance to pests and diseases means fewer losses during the growth phase, ensuring that a larger proportion of plants reach maturity and contribute to the final grain yield. In essence, by fortifying the initial stages of plant growth through superior seed quality and growth attributes, the plants are better positioned to thrive throughout their lifecycle, culminating in an increased grain yield.

Based on the study's findings, several practical recommendations emerge for farmers and agricultural practitioners to optimize crop yield. Firstly, pre-treating seeds with protective-stimulating compounds is paramount, as these treatments not only fend off fungal and bacterial infections but also enhance seed germination and overall vitality. The integration of fungicides, insecticides, and growth stimulants during pre-sowing treatment is especially advised for spring wheat and barley. For optimal germination and growth, sowing in the third decade of April is recommended, especially in semi-rainfed conditions like those observed in the Zhetysu region of Kazakhstan.

A seeding rate of 3.5-4 million germinating seeds per hectare should be targeted, ensuring a dense and uniform crop stand. Alongside seed treatment, a structured crop rotation system is advocated to benefit soil health, mitigate pest and disease build-up, and increase soil fertility. Lastly, the application of mineral fertilizers should be done in calculated doses aligned with the anticipated grain harvest. By following these guidelines, farmers can enhance the likelihood of obtaining maximum grain yields with high quality, ensuring both ecological sustainability and economic profitability in their agricultural endeavours.

While protective and stimulating compounds offer undeniable benefits to crop health and yields, their usage also brings forth potential challenges and constraints. Environmentally, there's the looming concern of these compounds seeping into the soil and waterways, possibly disrupting ecosystems and harming non-target organisms. The bioaccumulation of these chemicals might pose long-term environmental threats, affecting both flora and fauna. From an economic standpoint, the consistent application of these treatments might not always be cost-effective, especially for small-scale farmers.

The initial outlay for these compounds, combined with any specialized equipment or training required, could outweigh the potential increase in yield, making it a less viable solution for some. Additionally, there's the perpetual concern of pests or diseases developing resistance over time. As with antibiotics in medicine, the recurrent exposure of pests to these compounds can lead to the evolution of strains that are harder to control, necessitating even more potent chemicals or entirely new treatment methodologies in the future. Such a scenario not only undermines the efficacy of existing protective measures but could also escalate costs and environmental impacts. While these compounds present promising avenues for enhancing agricultural output, their long-term implications, both ecological and economic, necessitate careful consideration and continuous monitoring.

REFERENCES

[1] Arystangulov, S., Konysbaeva, D., Gorbulya, V., Nurkuzhaev, J., Turganbaev, T., Sadykov, B., Bekenova, S. (2019). Comparative study and adaptation of promising varieties of safflower (carthamus tinctorius L.) for the production of fodder and seeds in a desert-steppe zone. Bioscience Research, 16(2): 2034-2046.

[2] Beloev, H.I., Stoyanov, K.E., Dimitrov, P.D., Kravchuk, V., Kangalov, P.G., Marinov, S.Z. (2020). Study of the operational efficiency indicators of soil-protecting machine-tractor aggregates used for vertical mulching by importing organic matter in the soil. In 2020 7th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE), Ruse, Bulgaria, pp. 1-3. https://doi.org/10.1109/EEAE49144.2020.9279006

[3] Chen, X., He, S., Jiang, L., Li, X., Guo, W., Chen, B., Zhou, J., Skliar, V. (2021). An efficient transient transformation system for gene function studies in pumpkin (cucurbita moschata D.). Scientia Horticulturae, 282: 110028. https://doi.org/10.1016/j.scienta.2021.110028

[4] Skliar, V., Kovalenko, I., Skliar, I., Sherstiuk, M. (2019). Vitality structure and its dynamics in the process of natural reforestation of quercus robur L. AgroLife Scientific Journal, 8(1): 233-241.

[5] Píšová, S., Tokarieva, O., Sendonin, S. (2023). The experience of preserving ancient trees in Vienna, Austria. Ukrainian Journal of Forest and Wood Science, 14(2): 83-95. https://doi.org/10.31548/forest/2.2023.83

[6] Korkhova, M., Drobitko, A., Panfilova, A., Smirnova, I. (2022). The role of winter wheat plant height in the formation of grain yield depending on varietal characteristics and weather conditions. Scientific Horizons, 25(11): 41-50. https://doi.org/10.48077/SCIHOR.25(11).2022.41-50

[7] Montoya, M., Juhanson, J., Hallin, S., Garcia-Gutierres, S., Garcia-Marco, S., Vallejo, A., Recio, J., Gaurdia, G. (2022). Nitrous oxide emissions and microbial communities during the transition to conservation agriculture using N-enhanced efficiency fertilisers in a semiarid climate. Soil Biology and Biochemistry, 170: 108687. https://doi.org/10.1016/j.soilbio.2022.108687

[8] Murchie, E.H., Burgess, A.J. (2022). Casting light on the architecture of crop yield. Crop and Environment, 1(1): 74-85. https://doi.org/10.1016/j.crope.2022.03.009

[9] Frene, J.P., Figuerola, E., Gabbarini, L.A., Erijman, L., Wall, L.G. (2022). Impact of diversification and intensification of crop rotation (DICR) in soil bacterial microbiota in on-farm study after four and seven years. Applied Soil Ecology, 179: 104592. https://doi.org/10.1016/j.apsoil.2022.104592

[10] Khan, S.T. (2022). Consortia-based microbial inoculants for sustaining agricultural activities. Applied Soil Ecology, 176: 104503. https://doi.org/10.1016/j.apsoil.2022.104503

[11] Maienfisch, P., Mangelinckx, I.S. (2021). Recent highlights in the discovery and optimization of crop protection products. Academic Press.

[12] Gamayunova, V., Sydiakina, O. (2023). The problem of nitrogen in modern agriculture. Ukrainian Black Sea Region Agrarian Science, 27(3): 46-61. https://doi.org/10.56407/bs.agrarian/3.2023.46

[13] Zhumadilova, A., Zhigitova, S. (2023). Features of modern areas of solid waste disposal. Evergreen, 10(2): 640-648. https://doi.org/10.5109/6792809

[14] Kuts, O., Kokoiko, V., Paramonova, T., Mykhailyn, V., Syromiatnykov, Y. (2022). Influence of the fertiliser system on the soil nutrient regime and onion productivity. Plant and Soil Science, 13(4): 17-26. https://doi.org/10.31548/agr.13(4).2022.17-26

[15] Dukhovny, V.A., Nerozin, S.A., Stulina, G.V., Solodkiy, G.F. (2015). Crop harvest programming. http://www.cawater-info.net/library/rus/crop-yield-programming-ru.pdf.

[16] Skura, E., Koto, R., Lika, E., Shahini, S., Sallaku, F. (2023). Comparative characteristics of plant protection against copper and sulphur influence. Scientific Horizons, 26(1): 52-61. https://doi.org/10.48077/scihor.26(1).2023.52-61

[17] Lipińska, H., Lipiński, W., Shuvar, I., Korpita, H., Shuvar, A. (2023). Invasive plant species and their threat to biodiversity. Plant and Soil Science, 14(1): 51-65. https://doi.org/10.31548/plant1.2023.51

[18] Kerimkhulle, S., Kerimkulov, Z., Bakhtiyarov, D., Turtayeva, N., Kim, J. (2021). In-field crop-weed classification using remote sensing and neural network. In 2021 IEEE International Conference on Smart Information Systems and Technologies (SIST), Sultan, Kazakhstan, pp. 1-6. https://doi.org/10.1109/SIST50301.2021.9465970

[19] Esimbekova, M.A., Nurpeyisov, I.A., Mukin, K.B., Erzhanova, S.T. (2022). Additional soft wheat in international selection gene resources of the south-east Kazakhstan classification of agricultural valuable characteristics define. Bulletin of Kyzylorda University named after Korkyt Ata, 1: 22-26. https://doi.org/10.32634/0869-8155-2019-326-1-22-26

[20] Chen, M.M., Zhang, S.R., Liu, L., Ding, X.D. (2023). Influence of organic fertilization on clay mineral transformation and soil phosphorous retention: Evidence from an 8-year fertilization experiment. Soil and Tillage Research, 230: 105702. https://doi.org/10.1016/j.still.2023.105702

[21] Shahini, E., Berxolli, A., Kovalenko, O., Markova, N., Zadorozhnii, Y. (2023). Features of growing garden strawberries in open ground conditions. Scientific Horizons, 26(7): 106-117. https://doi.org/10.48077/scihor7.2023.106

[22] Kalenska, S., Falko, G., Antal, T., Hordyna, O., Fediv, R. (2023). Iodine-containing preparations in grain growing technologies. Plant and Soil Science, 14(2): 33-45. https://doi.org/10.31548/plant2.2023.33

[23] Song, Y.T., Li, G.D., Lowrie, R. (2021). Leaf nitrogen and phosphorus resorption improves wheat grain yield in rotation with legume crops in south-eastern Australia. Soil and Tillage Research, 209: 104978. https://doi.org/10.1016/j.still.2021.104978

[24] Chauhan, N.S., Gill, S.S. (2023). The impact of nanoparticles on agriculture and soil. Elsevier Science & Technology.

[25] Tyliszczak, B., Drabczyk, A., Kudłacik-Kramarczyk, S., Bialik-Wąs, K., Sobczak-Kupiec, A. (2017). In vitro cytotoxicity of hydrogels based on chitosan and modified with gold nanoparticles. Journal of Polymer Research, 24: 1-7. https://doi.org/10.1007/s10965-017-1315-3

[26] Sobczak-Kupiec, A., Malina, D., Tyliszczak, B., Piątkowski, M., Bialik-Wąs, K., Wzorek, Z. (2012). Evaluation of bioactivity of poly (acrylic acid)-hydroxyapatite-nanogold composites in vitro conditions. Digest Journal of Nanomaterials & Biostructures (DJNB), 7(2): 459-467.

[27] Medvedkov, Y., Nazymbekova, A., Tlevlessova, D., Shaprov, M., Kairbayeva, A. (2021). Development of the juice extraction equipment: Physico-mathematical model of the processes. Eastern-European Journal of Enterprise Technologies, 1(11(109)): 14-24. https://doi.org/10.15587/1729-4061.2021.224986

[28] Tlevlessova, D., Medvedkov, Y., Kairbayeva, A., Nazymbekova, A. (2022). Mechanisation of the primary processing of watermelons without destroying the rind. Food Science and Technology, 43: e86622. https://doi.org/10.1590/fst.86622

[29] Dibrova, A., Dibrova, L., Dibrova, M., Chmil, A. (2022). Forecasting the consequences of the cost of mineral fertilisers on the development of the corn market in Ukraine using AGMEMOD models. Ekonomika APK, 29(3): 23-41. https://doi.org/10.32317/2221-1055.202203023

[30] Atamanyuk, I.P., Kondratenko, Y.P., Sirenko, N.N. (2016). Forecasting economic indices of agricultural enterprises based on vector polynomial canonical expansion of random sequences. In Proceedings of the 12th International Conference on Information and Communication Technologies in Education, Research, and Industrial Applications (ICTERI), 1614: 458-468.

[31] Shahini, E., Luhovyi, S., Kalynychenko, H., Starodubets, O., Trybrat, R. (2023). Rational use of oilseed waste to increase dairy productivity. International Journal of Environmental Studies, 80(2): 442-450. https://doi.org/10.1080/00207233.2022.2147727

[32] Gupta, O.P., Pandey, V., Narwal, S., Sharma, P., Ram, S., Singh, G.P. (2020). Wheat and barley grain biofortification. Woodhead Publishing.

[33] He, L.H., Mo, X.G., Hu, S., Liu, S.X. (2021). Global sensitivity and uncertainty analysis of the VIP ecosystem model with an expanded soil nitrogen module for winter wheat-summer maize rotation system in the North China Plain. Pedosphere, 31(5): 822-838. https://doi.org/10.1016/S1002-0160(20)60048-0

[34] Guo, Z.C., Li, W., Islam, M.U., Wang, Y.K., Zhang, Z.B., Peng, X.H. (2022). Nitrogen fertilization degrades soil aggregation by increasing ammonium ions and decreasing biological binding agents on a vertisol after

12 years. Pedosphere, 32(4): 629-636. https://doi.org/10.1016/S1002-0160(21)60091-7
[35] Foloni, J.S.S., Silva, S.R., Abati, J., de Oliveira Junior, A., de Castro, C., de Oliveira, F.A., Nogueira, M.A., Bassoi, M.C. (2023). Yield of soybean-wheat succession in no-tillage system and soil chemical properties affected by liming, aluminum tolerance of wheat cultivars, and nitrogen fertilization. Soil and Tillage Research, 226: 105576. https://doi.org/10.1016/j.still.2022.105576
[36] Celestina, C., Hunt, J., Kuchel, H., Harris, F., Porker, K., Biddulph, B., Bloomfield, M., McCallum, M., Graham, R., Mattheus, P., Aisthorpe, D., Al-Yaseri, G., Hyles, J., Trevaskis, B., Wang, E.L., Zhao, Z.G., Zheng, B.Y., Huth, N., Brown, H. (2023). A cultivar phenology classification scheme for wheat and barley. European Journal of Agronomy, 143: 12673. https://doi.org/10.1016/j.eja.2022.126732
[37] Lü, R.H., Xu, Y.H., Boyd, R., Zhang, X.Q., Broughton, S., Jones, M., Li, C.D., Chen, Y.F. (2013). Barley and wheat share the same gene controlling the short basic vegetative period. Journal of Integrative Agriculture, 12(10): 1703-1711. https://doi.org/10.1016/S2095-3119(13)60351-2
[38] Chu, J.P., Guo, X.H., Zheng, F.N., Zhang, X., Dai, X.L., He, M.R. (2023). Effect of delayed sowing on grain number, grain weight, and protein concentration of wheat grains at specific positions within spikes. Journal of Integrative Agriculture, 22(8): 2359-2369. https://doi.org/10.1016/j.jia.2023.02.002
[39] Bahatska, O., Melnyk, V., Snarovkina, O. (2023). Assessment of drought resistance in plants of the genus Aristolochia L. Ukrainian Journal of Forest and Wood Science, 14(3): 8-20. https://doi.org/10.31548/forest/3.2023.08
[40] Pozza, L.E., Field, D.J. (2020). The science of soil security and food security. Soil Security, 1: 100002. https://doi.org/10.1016/j.soisec.2020.100002