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SURVIVAL RATE OF POTATO PLANTS IN VIVO DEPENDING ON PLANTING DATE IN THE NORTH-EAST OF KAZAKHSTAN

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Abstract
This article examines the survival characteristics of potato plants produced by microclonal propagation, depending on their planting dates in the conditions of Northeast Kazakhstan. Particular attention is paid to the influence of agroclimatic factors during the early growing season – including temperature conditions, the timing of the end of spring frosts, soil warming, and the accumulation of effective temperature – on plant adaptation processes following transfer from *in vitro* to *in vivo* conditions. The study is based on an analysis of domestic and foreign scientific publications, agrometeorological observation data, and regional climatic characteristics. It has been established that the effectiveness of adaptation and subsequent plant survival are determined by the combined influence of planting dates, the physiological state of the plants, and varietal characteristics. The most favorable conditions for survival are formed when the average daily air temperature rises steadily above 8–10°C and the risk of return frosts decreases. The results obtained indicate the need for a differentiated approach to selecting planting dates for potato plants and can be used in developing recommendations for improving the technology of growing seed potatoes in the conditions of Northeast Kazakhstan.

Keywords: *in vitro* potatoes; cultivated plants; survival rate; planting dates; adaptation; northeastern Kazakhstan; microclonal propagation; agroclimatic risks.

ҚАЗАҚСТАННЫҢ СОЛТҮСТІК-ШЫҒЫСЫНДА ОТЫРҒЫЗУ МЕРЗІМДЕРІНЕ БАЙЛАНЫСТЫ КАРТОП ӨСІМДІКТЕРІНІҢ IN VIVO ӨМІР СҮРУ ДЕҢГЕЙІ

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Аңдатпа
Мақалада Солтүстік-Шығыс Қазақстан жағдайында отырғызу мерзіміне байланысты микроклоналды көбею әдісімен алынған картоп өсімдіктерінің тіршілік ету ерекшеліктері қарастырылған. Ерте вегетациялық кезеңнің агроклиматтық факторларының, соның ішінде температуралық режимнің, көктемгі аязды тоқтату мерзімдерінің, топырақтың жылынуының және тиімді температураның жинақталуының *in* жағдайларынан *in vivo* жағдайларына ауысқаннан кейін өсімдіктердің бейімделу процестеріне әсеріне ерекше назар аударылады. Зерттеу отандық және шетелдік ғылыми жарияланымдарды, агрометеорологиялық бақылаулар мен аймақтық Климаттық сипаттамалардың деректерін талдауға негізделген. Өсімдіктердің бейімделу тиімділігі мен кейінгі өмір сүру деңгейі отырғызу уақытының, Өсімдіктердің физиологиялық күйінің және сорттық ерекшеліктерінің жиынтық әсерімен анықталатыны анықталды. Өмір сүру үшін ең қолайлы жағдайлар ауаның орташа тәуліктік температурасы 8-10°С-тан жоғары тұрақты жоғарылағанда және аяздың қайту қаупі төмендегенде қалыптасады. Алынған нәтижелер картоп өсімдіктерін отырғызу мерзімдерін таңдауға сараланған көзқарастың қажеттілігін көрсетеді және Солтүстік-Шығыс Қазақстан жағдайында бастапқы тұқым материалын өсіру технологиясын жетілдіру бойынша ұсыныстарды әзірлеу кезінде пайдаланылуы мүмкін.

Кілт сөздер: картоп *in vitro*; мәдени өсімдіктер; тіршілік ету; отырғызу мерзімі; бейімделу; Қазақстанның солтүстік-шығысы; микроклоналды көбею; агроклиматтық тәуекелдер.

ПРИЖИВАЕМОСТЬ РАСТЕНИЙ КАРТОФЕЛЯ IN VIVO В ЗАВИСИМОСТИ ОТ СРОКОВ ПОСАДКИ В УСЛОВИЯХ СЕВЕРО-ВОСТОКА КАЗАХСТАНА

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Аннотация

В статье рассмотрены особенности приживаемости растений картофеля, полученных методом микроклонального размножения, в зависимости от сроков их высадки в условиях Северо-Восточного Казахстана. Особое внимание уделено влиянию агроклиматических факторов раннего периода вегетации, включая температурный режим, сроки прекращения весенних заморозков, прогрев почвы и накопление суммы эффективных температур, на процессы адаптации растений после переноса из условий *in vitro* в условия *in vivo*. Исследование основано на анализе отечественных и зарубежных научных публикаций, данных агрометеорологических наблюдений и региональных климатических характеристик. Установлено, что эффективность адаптации и последующая приживаемость растений определяются совокупным влиянием сроков высадки, физиологического состояния растений и сортовых особенностей. Наиболее благоприятные условия для приживаемости формируются при устойчивом повышении среднесуточной температуры воздуха выше 8–10°С и снижении риска возвратных заморозков. Полученные результаты свидетельствуют о необходимости дифференцированного подхода к выбору сроков высадки растений картофеля и могут быть использованы при разработке рекомендаций по совершенствованию технологии выращивания исходного семенного материала в условиях Северо-Восточного Казахстана.

Ключевые слова: картофель *in vitro*; культуральные растения; приживаемость; сроки посадки; адаптация; Северо-Восток Казахстана; микроклональное размножение; агроклиматические риски.

Introduction

Potato (*Solanum tuberosum L.*) is one of the key food crop in Kazakhstan, especially in the northeastern regions, where they play a significant role in food security and farm income [1; 28]. Microclonal propagation is currently the basis of seed production in global potato cultivation [2; 1]. The survivin vitroal rate of cultivated (microclonal and seedling) plants after planting *in vivo* is a critical factor determining further growth dynamics, bush formation, and tuber yield [3].

In areas with a sharply continental climate, such as northeastern Kazakhstan, risk factors – late spring frosts, rapid and unstable warming in spring, a limited growing season, and a high moisture deficit – make choosing the optimal planting date critically important for ensuring high survival and subsequent productivity [4; 30].

The effectiveness of obtaining the first tuber generation of virus-free potatoes directly depends on the survival rate and final yield of cultivated plants, which is determined by the planting time frame, temperature and humidity conditions, the risk of spring frosts, the germination rate, and active plant development. The results of foreign and regional studies show that the optimal planting dates depend on the climate, variety, and agricultural techniques, as well as on the interaction of the dates with the genetic potential of the plants [5; 29]. Analysis of modern studies shows that the survival rate of plants *in vitro* is often determined not only by the calendar date of planting, but also by the age and degree of hardiness of cultivated plants, as well as local agroclimatic indicators (GDD – total degree days, risk of frost, soil temperature) [6; 7].

For northeastern Kazakhstan, determining the optimal planting intervals for potato plants *in vivo* is important, since most of the production volume of primary potato seed material in Kazakhstan is grown in this zone. At the same time, field studies specifically in the conditions of northeastern Kazakhstan on the survival of cultivated potato plants when transplanted ex vivo in 2015–2025 are limited, often concerning varieties that are not currently grown, with much of the empirical data obtained in neighboring climatic zones. Therefore, final local recommendations require comprehensive research, taking into account varietal characteristics and irrigation systems [8; 31].

The aim of the work: based on comprehensive research, to determine the optimal timing for planting cultivated potato plants *in vivo* in the conditions of northeastern Kazakhstan.

Materials and methods

To prepare the review, a targeted systematic search of the literature (2015–2025) was conducted in the Scopus and Web of Science databases (through publicly available indexes, cross-checking in Springer, MDPI, ResearchGate, and institutional repositories), as well as a search of national climate and agricultural reports (World Bank Climate Knowledge Portal, FAO, Kazhydromet).

Keywords in English and Russian were used: «*in vitro* potato transplanting», «planting date potato survival», «micropropagated potato field survival», «planting date Kazakhstan», «acclimatization micropropagated plants», «potato transplanting date», «micropropagated potato field survival», «planting date Kazakhstan potato», «agro-climatic Kazakhstan».

The selected publications were checked against the following criteria: year (2015–2025), availability of field data on the transplantation of *in vitro* plants, greenhouse seedlings, or explants, methodological transparency (description of planting dates, age of cultivated plants, hardening conditions, criteria for assessing survival).

For the climatic part, official data and reviews were used: Climate Knowledge Portal / World Bank (climatology 1991–2020), Kazhydromet (national meteorological service), FAO country profile, and regional studies on agroclimatic zoning.

The main parameters extracted from the articles were: location/climate of the experiment, planting dates (calendar/vegetation), plant age (in weeks), hardening method, survival rate (%) after 14 and 28 days, impact on vegetative development and final productivity. Qualitative comparative analysis and a summary table of key publications [9] were used for the synthesis.

Results and discussion

1 Analysis of climatic and agroclimatic characteristics of northeastern Kazakhstan

To justify the choice of optimal planting dates, it is necessary to take into account the agroclimatic parameters of the region, including temperature regime, duration of the warm period, and the probability of late spring frosts [26; 33]. The climatic characteristics of the region are shown in Table 1.

Table 1. Main climatic indicators of the Pavlodar region according to meteorological resources

Indicator	Value	Source
Average annual temperature	+2.2 °C	Climate-Data.org
Average temperature in May	+14 °C (during the day +20 °C, at night +6 °C)	Weatherspark
Average temperature in June	+20 °C (during the day +26 °C, at night +13 °C)	Weatherspark
Frost-free period	110–125 days (May 15 to September 20)	Pavlodar Agrometeorological Center
Annual precipitation	300–350 mm	Climatestotravel
Frequency of spring frosts	until May 15 (rarely until May 20)	Climate-Data.org

According to long-term observations, in the Pavlodar region, a stable warm period, when average daily highs exceed 19–20°C, begins in the second decade of May and lasts until early September [10].

During the summer season, especially in July, average daily temperatures reach about 28°C, and nighttime temperatures reach about 15°C, which indicates a pronounced continental climate and sufficient heat for the growth of cultivated plants [11].

The winter climate is characterized by extremely low temperatures: average January values drop to −15...−16°C, with absolute minimums below −40°C, confirming the high climatic amplitude and harshness of winter conditions [12]. Annual precipitation is about 300–350 mm, distributed unevenly, with a maximum during the warm period.

In May, the average air temperature reaches 14–15°C, and nighttime minimums are 5–7°C [12]. These climatic characteristics indicate that mid-May is the beginning of an agroclimatically favorable period with minimal risk of late frosts (Table 2). At the same time, earlier planting dates (late April – early May) retain the possibility of return frosts and may be unfavorable for planting cultivated plants *in vivo*.

Table 2. Agroclimatic parameters determining the planting dates of cultivated plants in the conditions of North-Eastern Kazakhstan

Indicator	Value
Average annual air temperature	+2.2 °C
Average temperature in May	+14 … +15 °C
Average temperature in June	+19 … +20 °C
The last spring frosts	until May 15–20
First autumn frosts	from September 10 to 15
Duration of the frost-free period	110–120 days
Average annual precipitation	320–350 mm
Prevailing winds	northwesterly, 3–5 m/s

The soil cover of the territory is mainly represented by light brown soils of sandy loam and loamy granulometric composition [13; 34]. Spring warming of the topsoil to physiologically optimal values (+8...+10°C) usually occurs between May 15 and 20, which corresponds to the established norms for the risky farming zone [14; 43]. This interval of the growing season determines the beginning of the favorable period for planting.

2 Features of the adaptation of cultivated potato plants when planted *in vivo* in different climatic zones

During ontogenesis, potato plants interact with both abiotic and biotic factors. The combined influence of abiotic factors during the acclimatization period can exacerbate plant stress, which can lead to their death. In this regard, taking these factors into account is the basis for developing a strategy to reduce plant losses during *in vitro* transplantation. This is especially important for regions with a sharply continental climate, characterized by significant fluctuations in daytime temperatures, such as northeastern Kazakhstan [15].

Planting dates are one of the key factors determining the survival of cultivated potato plants *in vivo*; their optimization depends on the local climate and varietal characteristics [5]. When transplanting plants from culture (microclonal or seedling), their physiological condition is sensitive to external stresses: sharp temperature fluctuations, insufficient soil moisture, or low night temperatures hinder root formation and reduce survival. Therefore, the choice of planting time should minimize such risks and coincide with the phase when the probability of frost is minimal, and moisture availability and temperature are favorable for rooting [5; 35].

In the context of comparison with other regions, it should be noted that studies conducted in the western regions of Kazakhstan indicate a significant dependence of growth rates, morphogenesis characteristics, and final potato productivity on planting dates. Earlier planting dates provide a higher potential yield, but are accompanied by an increased risk of reduced plant survival in conditions of unstable spring temperatures [8; 36].

According to research by Leskhanovich (2015) conducted in the West Kazakhstan region, where the spring period is characterized by intense temperature increases, it has been established that planting dates have an independent agronomic effect on the growth rate and development of potatoes. The correct choice of planting date accelerates morphogenetic processes and contributes to the early formation of a high-quality tuber crop.

In addition, the results of climatological studies conducted for comparable agroclimatic zones indicate a tendency for the optimal planting dates to shift to a later spring period, which is confirmed by the data in the recommendations prepared by the Omsk Agricultural Research Center (2020). This is due to the desire to minimize stress factors, especially when using planting material obtained by microclonal propagation (*in vitro*), for which the risk of damage from low temperatures is significantly higher [16].

Early planting with low maximum daily temperatures and favorable humidity often results in earlier formation of vegetative mass, but is associated with the risk of return frosts, which can reduce the survival rate of planted seedlings/mini-tubers in cold spring conditions [5].

The results of field experiments by van Dijk (2022) show that the effect of planting dates on potato plant survival is most pronounced in early spring. Thus, although planting in March extended the potential growing season, it was accompanied by a high risk of plant death due to night frosts, which in the Netherlands occur until mid-May; in some cases, March plantings completely lost their survival rate. At the same time, the measured marketable yields for all transplanting dates ranged from 29 to 34 t/ha, and the seed tuber yield ranged from 26 to 29 t/ha, with no significant advantages for March planting. Plantings in April, May, and June showed stable survival rates, with moderate differences in the final yield of plants harvested at the traditional time (September 20–21): as a rule, April and May plantings provided a higher yield of marketable tubers compared to June plantings. With early harvesting, the relationship between the planting date and the size distribution of tubers was more pronounced: late planting (June) increased the proportion of tubers > 40 mm and increased the yield of large fractions. In general, it has been established that optimizing planting dates is a critical factor for survival, but excessively early planting (March) not only does not increase yield, but also significantly increases the risk of losses due to frost [5].

Late planting (delay relative to the optimal time) can lead to accelerated transition of plants to reproductive phases at high temperatures, a reduction in the growing season, and, as a result, a decrease in survival and yield potential [17; 41].

The results of a field experiment conducted by Singh (2023) at the ICAR regional station in Gwalior during the 2021–2022 Rabi season convincingly confirm the critical importance of choosing the planting dates for cultivated plants for the productivity of the Kufri Mohan potato variety. The seven planting dates tested (from September 15 to December 14) showed marked differences in growth and yield. The highest values of all key agronomic parameters – plant height, number of stems, foliage yield, tuber yield, and biological yield – were recorded with timely planting on October 30 (D4). The yield exceeded the early planting dates (September

15–30) by 18.6–69.0% and the late planting dates (November 14–December 14) by 13.1–52.5%, which clearly demonstrates the advantage of the optimal planting window. In contrast, early (D1, D2) and especially late (D6, D7) planting dates were characterized by a decrease in all structural elements of productivity, indicating the adverse effect of both excessively high temperatures in the early stages of growth and a shortened growing season when planting in December. Thus, it has been established that adherence to the optimal planting date – in this case, the end of October – is a key factor in consistently high potato yields, while deviation from it toward excessively early or late dates inevitably leads to significant productivity losses [17].

Many studies show that the key factor in the adaptation of cultivated potato plants is not so much the calendar planting date as the age and physiological condition of the regenerants. Plants that are too young, for example, two weeks old, especially under unfavorable external conditions, demonstrate lower survival rates. At the same time, potato plants aged 3–4 weeks that have undergone hardening and adaptation to light and humidity levels are significantly more resistant and successful in rooting in *in vivo* conditions [18; 37].

For example, studies by Lommen (2015) showed that the age of potato seedlings obtained *in vitro* directly affects the subsequent growth of plants and the formation of seed yield: the highest indicators were observed when plants aged 28–35 days were transplanted into the field, while younger (14–21 days) and overgrown (> 42 days) plants formed 15–30% less tuber yield. These results confirm the importance of strict adherence to the optimal timing for obtaining and using planting material in potato cultivation technology schemes [18].

3 Optimal timing depends on variety and region

Research shows a consistent correlation: the optimal date for transplanting/planting depends on the genotype (variety) and local climate/agroclimatic zone; Varietal differences in cold tolerance and growth rate determine the period during which transplanting will result in the best survival rate. Recommendations developed in one region cannot always be applied to another without adjustments [19; 2].

A study by Muhammad Sohail Khan et al. (2024) convincingly shows that planting dates and genetic characteristics of varieties have a key influence on potato yield in the subtropical continental zone. Optimizing the planting date – especially early dates (October 2 and 14) – extends the growing season and significantly improves the indicators that determine yield: from an increase in green crown area (up to 72.3%) and leaf area (up to 5343 cm^2 per plant) to maximization of absorbed photosynthetically active radiation (PARINTC, 900.9 $MJ \cdot m^{-2}$) and number of tubers (11.8 per plant). The genotype of cultivated Arizona potato plants showed the best response to variations in planting dates, ensuring maximum market yield (29.2 $t \cdot ha^{-1}$) and total yield (30.4 $t \cdot ha^{-1}$). The significant variability of genotype responses and pronounced P×G interactions highlight the need to select varieties and planting dates taking into account regional conditions. The results obtained not only reveal the complexity of the mechanisms of yield formation, but also form scientifically based approaches to increasing the stability of potato production in a changing climate [19].

The results of the study by Ahmed et al. (2017) demonstrate the significant influence of planting dates on potato growth and yield in the subtropical conditions of Bangladesh. An experiment conducted between November 20, 2015, and March 20, 2016, on three varieties (BARI Alu-35, BARI Alu-40, and BARI Alu-41) with three planting dates (November 20, December 5, and December 29) showed that the optimal planting period is the first ten days of December. During this period, the maximum plant height (42.3 cm for BARI Alu-40), the largest number of tubers per plant (13 for BARI Alu-41), the maximum leaf area and tuber weight per plant (97.25 g for BARI Alu-35) were observed. Yield reached a maximum of 42.12 t/ha when planting BARI Alu-35 on December 5. Earlier planting (November 20) led to a decrease in growth and yield, which indicates the negative impact of unfavorable temperature conditions on the physiological development of plants.

Thus, the study confirms that correctly determining the planting date is a key factor in achieving high potato plant productivity, and adapting planting dates to local climatic conditions allows for the optimization of physiological maturity and tuber formation [20].

A study by Darkhanova et al. (2021) showed that the adaptation of *in vitro*-healed potato plants in the conditions of Central Yakutia is characterized by pronounced varietal differentiation. The highest survival rate was observed in the Krasavchik variety (28%), while the Vasilek variety was the least resistant (1%). The Adretta variety showed the best adaptation to the dry period (GTK = 0.4), combining high productivity (213.9 g) and maximum tuber preservation (100%). In contrast, the Velina, Rosara, and Ilona varieties showed minimal preservation (33–56%). These results emphasize the need for careful selection of varieties for regions with extreme climatic conditions and confirm the importance of preliminary ecological testing of improved material [21].

In studies by Nikolaeva V. N. et al. (2020) conducted on 19 potato varieties, such as Aksor, Alena, Bryansky Delicacy, Velikan, Darinka, Zhukovsky Early, Meteor, Memory of Rogachev, Skoroplodny, Udacha, Khozyayushka, Nevsky; Dutch varieties: Arosa, Romano, Sante, Red Scarlet, Rosara, Red Lady, Roko It has been shown that for the East Kazakhstan region, the optimal time for planting test plants in open ground, depending on spring weather conditions, is between May 15 and June 15, since according to long-term data, the last frost in the cultivation zone occurs on June 14 [22].

Reports on agroclimatic zoning and analytical materials on the regions of the country emphasize that the effectiveness of potato cultivation directly depends on strict adherence to the agricultural calendar and the adaptation of planting dates to local indices of heat, moisture, and the duration of the growing season [23; 38].

According to international data [4; 49], a correct assessment of regional agroclimatic risks and heat resources can significantly increase the sustainability of production systems. In these conditions, local testing of several planting date options becomes particularly important, as it is necessary to determine the optimal time window for transplanting *in vitro* plants in specific climatic conditions [44; 50]. This approach not only ensures higher survival rates and uniform growth, but also creates the conditions for maximizing the potential yield of highly productive genotypes [39]. Thus, it can be concluded that varieties with higher cold tolerance and rapid initial growth can be planted earlier in the season; sensitive varieties are better to transfer to later dates, but then part of the growing season is lost. This makes it necessary to conduct local testing for each line/variety, especially if microclonal lines or hybrids are used, which may have excellent adaptation [19; 40].

4 Impact of temperature and humidity conditions and weather risks

Soil and air temperature in the first days after planting is a key factor for successful survival. Rapid warming after planting promotes rooting and growth, while temperature fluctuations and night frosts increase stress and plant mortality [5].

A study by van Dijk et al. (2022) showed that early spring transplanting of potatoes from seedlings is significantly limited by temperature risks: in 2017–2019, minimum temperatures often fell below 2°C, and in some years reached −4.9°C, causing leaf damage and, in 2018, the complete destruction of March plantings. Even the use of improved beds and polyethylene coverings did not provide protection from extreme frosts, confirming the extremely narrow «safety window» for early transplanting. Plants recovered after April planting, but went through a stress phase in the first week after transplanting, while May and June planting dates showed the most stable development against the backdrop of higher minimum temperatures and uniform heat accumulation [5; 42].

Hydrothermal conditions also varied by season: in 2019, the amount of precipitation from April to June was higher (3.9–4.0 mm/day), which partially compensated for temperature limitations and ensured equalization of development rates between April and May plantings by the period of physiological ripening (around October 10). Overall, the study emphasizes that the success of early transplanting is determined not only by agricultural techniques, but above all by the combination of minimum temperatures in the first week and moisture availability, making the choice of the optimal planting date a critical factor in productivity [51].

5 Practical conclusions from regional studies (including Central Asia and comparable continental zones)

In regions with a sharply continental climate (such as northeastern Kazakhstan), it is advisable to focus on sowing dates that minimize the risk of late spring frosts while ensuring a sufficient growing season [45]. This often means a shift to the late first ten days of the planting window compared to warmer regions. The recommendations are supported by regional observations and national practice, in accordance with the national report on potato cultivation in Kazakhstan [24; 32].

When planting cultivated potato plants from *in vitro*, preliminary preparation measures are of particular importance [2; 46]. The most effective measures include a gradual reduction in humidity to form a stable transpiration apparatus, enhanced protection of the delicate root system during transplanting, and the use of root formation stimulants and anti-stress biological products [47]. A combination of such procedures significantly increases the success of potato regenerants' adaptation to open ground conditions [25; 26]. Thus, to increase the survival rate of cultivated potato plants when transplanting them to *in vivo* conditions in the Kostanay region, Ekaterinskaya E.M. (2011–2013) used the synthetic stimulant KN (0.001%) for pre-planting root treatment. As a result, when test-tube plants were planted in gauze insulators in the first ten days of June, the survival rate was 70% for the Dunyasha variety and 75% for the Udovitsky variety.

A study by Anikina I.N. (2022) on the *in vivo* survival rate of regenerants of promising European potato varieties (Gala, Latona, Sante, Innovator, Red Scarlet) in the conditions of northeastern Kazakhstan, emphasizes the key role of the adaptation stage of test-tube plants in the primary seed production system. The results show that the success of transferring meristem plants to natural conditions is determined by the variety-specific physiological stability, the rate of functional leaf formation, and the response to sharp temperature fluctuations characteristic of the region. When planting cultivated potato plants for further growth in greenhouse conditions between May 20 and June 7, 2019–2020, survival rates ranging from 51% to 86% were obtained, depending on the variety. It has been shown that certain varieties, such as Latona and Red Scarlet, have higher survival rates and develop more quickly after planting, while others, such as Innovator and Gala, require a longer adaptation period. Thus, the study confirms the need to take into account varietal characteristics when developing regulations for the adaptation and further cultivation of healthy planting material in the climatic conditions of northeastern Kazakhstan [27; 48].

Conclusion

The results of the study are of practical importance, as they allow for the optimization of primary seed production schemes and increase the efficiency of high-quality seed tuber propagation.

Based on an analysis of local weather data (soil temperature, daily maximums, and nighttime minimums) for northeastern Kazakhstan, the optimal time for planting cultivated plants in greenhouses during the current period is before the onset of consistently high daytime temperatures, which occurs between April 25 and May 5. The optimal time for planting in open ground is from June 7 to June 17, which corresponds to the period of a steady rise in soil temperature and a reduction in the risk of return frosts.

To increase the survival rate of valuable biotechnological potato material, it is advisable to acclimatize microclonal plants before planting, in accordance with the official recommendations for potato cultivation in Kazakhstan.

The recommended planting dates can be used by biotechnology laboratories, greenhouse complexes, and seed production farms when planning activities to produce and propagate disease-free potato planting material. Adhering to the recommended planting dates helps reduce the risk of adverse temperature conditions, increases the survival rate of cultivated plants, and ensures more effective production of high-quality seed potatoes in the conditions of northeastern Kazakhstan.

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