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SCIENTIFIC AND METHODOLOGICAL FRAMEWORK FOR COMPARATIVE EVALUATION OF POTATO CULTIVARS UNDER THE SOIL AND CLIMATIC CONDITIONS OF KARAKALPAKSTAN

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Abstract. *Potato production in the Republic of Karakalpakstan is constrained by soil salinity, high evaporative demand, recurrent heat episodes and limited irrigation water. Cultivars selected under temperate and non-saline environments may therefore perform inconsistently when introduced into this region. This paper develops a rigorous field-evaluation framework for a collection of 22 potato cultivars and clones originating from Belarus, Hungary, Germany, Korea, the Netherlands, Türkiye and Uzbekistan. The framework integrates phenological development, field emergence, plant survival, canopy traits, tuber number and weight, size distribution, marketable yield, visible physiological injury and disease incidence. A randomized complete block design with four replications is proposed, with uniform seed-tuber quality, planting geometry, nutrient supply, irrigation and crop protection across treatments. Soil electrical conductivity, pH, nutrient status and weather variables are incorporated to distinguish genotypic responses from environmental effects. Yield is expressed on an area basis, while marketability is calculated from the proportion of defect-free tubers meeting the predefined commercial grade. Analysis of variance, standard errors and Fisher's least significant difference at $p \leq 0.05$ are used for cultivar comparison; multi-year observations permit separation of cultivar, year and cultivar $\times$ year effects. The framework avoids selection based on yield alone and instead identifies cultivars that combine earliness, stand persistence, marketable productivity and tolerance to interacting salinity, heat and water-deficit stresses. It provides a reproducible basis for subsequent production trials and locally adapted seed-potato development in the Aral Sea region.*

Keywords: *Solanum tuberosum L.; cultivar evaluation; marketable tuber yield; salinity; heat stress; water deficit; genotype $\times$ environment interaction; Karakalpakstan.*

Annotatsiya. *Maqolada Qoraqalpog'iston Respublikasining sho'rlangan tuproqlari, keskin kontinental quruq iqlimi, yuqori harorat va sug'orish suvi cheklangan sharoitida kartoshka navlarini qiyosiy baholashning ilmiy-uslubiy asoslari ishlab chiqilgan. Belarus, Vengriya, Germaniya, Koreya, Niderlandiya, Turkiya va O'zbekiston seleksiyasiga mansub 22 ta nav va klonni yagona agrotexnik fonda o'rganish nazarda tutilgan. Baholash tizimi fenologik rivojlanish, dala unuvchanligi,*



o‘simliklarning yig‘imgacha saqlanishi, morfologik belgilar, tuganaklar soni va vazni, fraksion tarkibi, tovarbop hosil, fiziologik shikastlanish va kasallik alomatlarini qamrab oladi. Tajribani tasodifiylashtirilgan bloklar usulida to‘rt takrorlanishda o‘tkazish, tuproqning elektr o‘tkazuvchanligi va agrokimyoviy xususiyatlari hamda meteorologik ko‘rsatkichlarni qayd etish tavsiya qilingan. Navlarni taqqoslashda dispersiya tahlili, standart xato va $p \leq 0,05$ darajadagi eng kichik ishonchli farqdan foydalaniladi. Taklif etilgan yondashuv navlarni faqat umumiy hosil bo‘yicha emas, balki ertapisharlik, tup sonining saqlanishi, tovarbop mahsuldorlik va stress omillariga chidamlilik majmui bo‘yicha tanlash imkonini beradi.

Kalit so‘zlar: *Solanum tuberosum* L.; navlarni baholash; tovarbop tuganak hosili; sho‘rланish; issiqlik stressi; suv tanqisligi; genotip $\times$ muhit o‘zaro ta‘siri; Qoraqalpog‘iston.

Аннотация. В статье разработаны научно-методические основы сравнительной оценки сортов картофеля в условиях засоленных почв, резко континентального засушливого климата, высоких температур и ограниченности оросительной воды Республики Каракалпакстан. Предусматривается изучение на едином агротехническом фоне 22 сортов и клонов селекции Беларуси, Венгрии, Германии, Кореи, Нидерландов, Турции и Узбекистана. Система оценки включает фенологическое развитие, полевую всхожесть, сохранность растений к уборке, морфологические признаки, количество и массу клубней, фракционный состав, товарную урожайность, физиологические повреждения и симптомы болезней. Рекомендуется проводить опыт методом рандомизированных блоков в четырех повторениях с регистрацией электропроводности и агрохимических свойств почвы, а также метеорологических показателей. Для сравнения сортов используются дисперсионный анализ, стандартная ошибка и наименьшая существенная разница при $p \leq 0,05$. Предлагаемый подход позволяет отбирать сорта не только по общей урожайности, но и по комплексу признаков, включающему скороспелость, сохранность растений, товарную продуктивность и устойчивость к стрессовым факторам.

Ключевые слова: *Solanum tuberosum* L.; оценка сортов; товарная урожайность клубней; засоление; тепловой стресс; дефицит воды; взаимодействие генотип $\times$ среда; Каракалпакстан.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a globally important food crop because it produces substantial quantities of carbohydrate, high-quality protein, minerals and vitamin-rich food per unit area. It also supports processing industries, seed systems and rural livelihoods. Continued expansion of potato production into water-limited and salt-affected regions, however, depends on cultivars that maintain acceptable tuber yield and quality under multiple, simultaneously acting stresses [1–3].

The Republic of Karakalpakstan lies in the lower Amu Darya basin and is characterized by a sharply continental arid climate. Potato crops may encounter saline soils, low relative humidity, hot winds, high air and soil temperatures and restrictions in irrigation-water supply. These factors are especially damaging during canopy



establishment, tuber initiation and tuber bulking. Salinity reduces the soil-water potential and may disturb nutrient acquisition; water deficit restricts leaf expansion and accelerates senescence; and high temperature can delay tuber initiation while shifting assimilate allocation toward shoots [4, 6–9].

Cultivar performance is the result of genetic potential expressed within a particular environment and production system. A cultivar that performs well at one location may change rank when temperature, soil salinity, water availability or crop management differs. Consequently, catalogue descriptions and country of origin cannot substitute for replicated local testing. Candidate cultivars must be compared under a common agronomic background and assessed using traits that explain both yield formation and yield loss [5–7].

The Karakalpakstan Scientific Experimental Station received potato material representing several breeding programmes and production regions. This diverse set provides an opportunity to establish a locally relevant screening platform. The objective of this paper is to define a scientifically defensible methodology for comparative evaluation of these cultivars and clones under Karakalpakstan conditions. The framework is intended to identify material combining early crop development, stand persistence, marketable tuber production and tolerance to the region's major abiotic constraints.

LITERATURE REVIEW

Breeding and cultivar testing for climate-resilient potato production increasingly focus on combinations of earliness, yield stability, resource-use efficiency, resistance to pests and diseases, and tuber quality. Earliness is particularly relevant in hot environments because it may allow a cultivar to complete a larger proportion of tuber bulking before the most severe summer temperatures occur. A short growth cycle is not automatically advantageous, however, if rapid maturity is accompanied by poor canopy establishment, low tuber number or insufficient mean tuber weight [3–5].

Drought affects potato through reductions in leaf area, stomatal conductance, radiation interception and assimilate supply to developing tubers. Genotypic differences occur in rooting, canopy duration, water-use patterns and recovery following rewatering. Reliable evaluation therefore requires observations at several growth stages rather than a single visual score. Plant survival, onset of senescence, tuber number and tuber size distribution provide complementary information about the mechanism and agronomic consequence of stress response [6, 7, 9].

Heat stress is closely linked to water demand. Temperatures above the optimum for tuberization can prolong vegetative growth, inhibit tuber initiation, reduce dry-matter partitioning to tubers and increase physiological disorders. Under saline conditions, osmotic and ionic effects may further restrict water uptake and accelerate canopy injury. Because these stresses interact in the field, ranking cultivars by total yield alone can conceal important differences in stand establishment, phenology and marketability [4, 8].

Genotype $\times$ environment interaction is central to cultivar recommendation. Replication within a season estimates experimental error, whereas testing across seasons measures the stability of cultivar responses under naturally varying weather



and soil-water regimes. A credible recommendation should consequently be based on both mean performance and stability, with explicit consideration of whether a candidate offers higher marketable yield, earlier maturity, better stand retention or another practical advantage relative to the standard cultivar [5].

RESEARCH METHODOLOGY

3.1 Study site and environmental characterization

Field trials are designed for the experimental fields of the Research Institute of Vegetables, Melons and Potatoes, Karakalpakstan Scientific Experimental Station, Republic of Karakalpakstan, Uzbekistan, during 2026–2028. Before planting, composite soil samples are collected from the 0–30 and 30–50 cm layers. Soil texture, organic matter, total nitrogen, available phosphorus, exchangeable potassium, pH, electrical conductivity and the composition of water-soluble salts are determined using validated laboratory procedures. Daily minimum and maximum air temperature, precipitation, relative humidity and, where available, reference evapotranspiration are obtained from the nearest meteorological station. Irrigation dates and applied water are recorded for each crop cycle.

3.2 Plant material

The experimental collection comprises 22 named cultivars and clones supplied to the station. Names and stated origins are retained as recorded in the station inventory; D-3 and Korona require passport verification because their origin was not specified in the source record. The three unnamed protection samples numbered 001–003 are excluded because they do not have cultivar names and therefore cannot be reported as identifiable accessions.

No.	Cultivars	Stated origin	Experimental status
1.	D-3	Not specified	Collection accession
2.	Liliya	Belarus	Collection accession
3.	Mastak	Belarus	Collection accession
4.	Korona	Not specified	Collection accession
5.	Garantiya	Belarus	Collection accession
6.	Uladar	Belarus	Collection accession
7.	Balaton Rozsa	Hungary	Collection accession
8.	Balaton Sarga	Hungary	Collection accession
9.	Botond	Hungary	Collection accession
10.	Demon	Hungary	Collection accession
11.	White Lady	Hungary	Collection accession
12.	Gala	Germany	Collection accession
13.	Golden Egg	Korea	Collection accession
14.	Royal	The Netherlands	Collection accession
15.	Sante	The Netherlands	Collection accession
16.	Silvana	The Netherlands	Collection accession
17.	Evolution	The Netherlands	Collection accession
18.	Yaprak	Türkiye	Collection accession
19.	Pitek	Türkiye	Collection accession



20.	Quvonch	Uzbekistan	Collection accession
21.	Ultraeshim	Uzbekistan	Collection accession
22.	Umid	Uzbekistan	Collection accession

Table 1. Potato cultivars and clones included in the comparative field evaluation

3.3 Experimental design and crop management

The trial is established as a randomized complete block design with four replications. Each accession occurs once in each block, and plot positions are randomized independently within blocks. Seed tubers are graded to a common size range and selected for uniform physiological age and health status. Planting date, row and in-row spacing, planting depth, fertilizer rates, irrigation scheduling, hilling and crop-protection practices are identical for all plots. Guard rows and border plants are excluded from harvest measurements. The standard cultivar must be designated before planting and maintained consistently across years.

3.4 Phenology, growth and stress assessment

Dates of 50% and 75% emergence, budding, flowering, onset of natural senescence and physiological maturity are recorded for each plot. Field emergence and survival to harvest are expressed as percentages of planted seed tubers. Plant height and number of main stems are measured on preselected, non-border plants. Canopy uniformity, chlorosis, marginal necrosis, premature senescence and other visible stress symptoms are scored using a predefined ordinal scale applied by the same trained observers. Disease incidence is recorded separately from abiotic injury to reduce misclassification.

3.5 Yield and marketability

Each net plot is harvested separately. Tuber number and fresh weight per plant, mean tuber weight, total plot yield and size-class distribution are determined. Yield is converted to tonnes per hectare as $Y = 10M/S$, where Y is yield ($t\ ha^{-1}$), M is tuber mass from the net plot (kg), and S is net plot area (m^2). Before the trial, marketable grades are defined by tuber size and absence of greening, cracking, severe malformation, mechanical injury and disease symptoms. Marketability is calculated as $T = (Mm/Mt) \times 100$, where Mm is marketable tuber mass and Mt is total tuber mass. Dry matter, starch and nitrate concentration may be included when validated analytical facilities are available.

3.6 Statistical analysis and selection rule

Data are analysed by analysis of variance appropriate to the randomized complete block design. Cultivar means are reported with standard errors, and pairwise differences are evaluated using Fisher's least significant difference at $p \leq 0.05$ when the overall cultivar effect is significant and model assumptions are satisfied. Residuals are examined for normality and homogeneity of variance; percentage or count data are transformed when necessary. For multi-year analysis, cultivar and year effects and the cultivar $\times$ year interaction are estimated. Cultivar advancement is based on a predefined decision rule integrating marketable yield, earliness, survival and stress injury rather than on the most favourable single trait.



ANALYSIS AND RESULTS

The proposed framework treats establishment as the first selection stage. Rapid emergence is desirable, but it must be interpreted together with stand survival. A cultivar that emerges quickly and subsequently loses plants under salinity or heat cannot be considered well adapted. Plot-level emergence and survival data also help determine whether low yield results from weak stand establishment or from poor productivity of surviving plants.

Phenological escape and physiological tolerance are distinct adaptation strategies. Early cultivars may avoid peak heat by initiating and bulking tubers sooner, whereas longer-duration cultivars may succeed if they maintain canopy function and water acquisition under stress. Recording tuber initiation indirectly through flowering, senescence and sequential harvest observations helps distinguish these strategies. This distinction is important when matching cultivars to early-market production, main-season production or seed multiplication.

Canopy size should not be used as a proxy for tuber productivity. Vigorous vegetative growth may increase radiation capture, but under hot conditions it can also indicate delayed allocation to tubers. Plant height and stem number therefore require joint interpretation with tuber number, mean tuber weight and harvest index-related traits. Cultivars with many small tubers may be valuable for seed production but less desirable for a market that rewards larger ware potatoes.

Marketable yield is the principal production-oriented endpoint because total yield may include tubers that cannot be sold or stored. A cultivar with moderate total yield but uniform, defect-free tubers can provide greater practical value than a high-yielding cultivar with excessive small tubers, cracking or physiological defects. Reporting both total and marketable yield prevents this distinction from being obscured. Environmental measurements strengthen biological interpretation. Soil electrical conductivity indicates the salinity pressure present during the experiment, while irrigation and temperature records locate periods of water and heat stress relative to crop development. These covariates do not replace replication, but they allow year-to-year changes in cultivar ranking to be interpreted mechanistically rather than described as unexplained variation.

The 22-accession collection should be screened in stages. Accessions with poor emergence, severe injury or unacceptable marketability can be removed after sufficient replicated evidence. Accessions equal to the standard in yield may still be advanced if they provide a clear advantage in maturity, survival, tuber uniformity or stress tolerance. Conversely, an apparent yield advantage should not justify advancement if it is inconsistent across replications or accompanied by poor tuber quality.

Multi-year testing is essential before a recommendation is made. The first season establishes trait ranges and identifies operational problems in the protocol; subsequent seasons test repeatability under different weather and soil-water conditions. The resulting dataset can support production recommendations, targeted agronomic trials and, for locally adapted material, development of a reliable seed-potato multiplication pathway.



CONCLUSION AND RECOMMENDATIONS

1. Potato cultivar selection for Karakalpakstan requires replicated local testing because salinity, heat and limited irrigation water may alter cultivar ranking relative to non-saline temperate environments.
2. A randomized complete block design with four replications, uniform agronomic management and explicit environmental characterization provides a defensible basis for comparison of the 22 cultivars and clones.
3. Selection should integrate emergence, survival, phenology, tuber number and weight, size distribution, marketable yield and symptoms of abiotic and biotic injury.
4. Analysis of variance, measures of uncertainty and multi-year assessment of cultivar × year interaction are required before claims of superiority or adaptation are made.
5. Cultivars that combine stable marketable productivity with earliness, stand persistence or reduced stress injury should be advanced to larger production and seed-multiplication trials.

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