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AGROECOLOGICAL CHARACTERISTICS OF LATE BLIGHT DEVELOPMENT AND RESISTANCE OF POTATO CULTIVARS IN CROP PRODUCTION

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Abstract. This article examines the resistance of potato (Solanum tuberosum L.) cultivars to late blight caused by Phytophthora infestans and the agroecological characteristics that determine disease development in crop-production systems. The study was designed as a structured qualitative review of peer-reviewed research, authoritative plant-pathology resources, and official and scientific publications from Uzbekistan. Evidence was synthesized around four interacting components: host genotype and maturity, pathogen population, weather and microclimate, and crop-management environment. The literature shows that cultivar resistance is a dynamic field phenotype rather than an immutable varietal attribute: expression may vary across years and locations because epidemic pressure depends on temperature, prolonged leaf wetness and high relative humidity, inoculum pressure, pathogen genotype, canopy development, planting date, irrigation regime, and crop sanitation. International studies demonstrate substantial differences among cultivars and identify resistant germplasm as a central component of integrated late blight management. Uzbek studies likewise emphasize the need to select locally adapted, productive cultivars with resistance to fungal diseases, including late blight, under the country's contrasting soil-climatic conditions. The article proposes a crop-production framework in which cultivar resistance, agroecological monitoring, certified seed, rational irrigation and nutrition, sanitation, and risk-based plant protection are combined. The review concludes that cultivar evaluation for Uzbekistan should be multi-year and location-specific and should simultaneously measure disease progress, plant development, marketable yield, and environmental conditions.

Keywords: potato; Solanum tuberosum L.; late blight; Phytophthora infestans; cultivar resistance; crop production; agroecology; disease development; integrated disease management; Uzbekistan.

Annotatsiya. Ushbu maqolada o‘simlikshunoslik sharoitida kartoshka (Solanum tuberosum L.) navlarining Phytophthora infestans qo‘zg‘atadigan fitoftoroz kasalligiga chidamliligi hamda kasallik rivojlanishini belgilovchi agroekologik omillar tahlil qilingan. Tadqiqot taqrizdan o‘tgan xalqaro ilmiy ishlar, nufuzli fitopatologik manbalar, shuningdek O‘zbekistonning rasmiy va ilmiy nashrlarini tizimli sifat tahlili asosida olib borildi. Dalillar xo‘jayin o‘simlik genotipi va pishish muddati, patogen populyatsiyasi, ob-havo va mikroiqlim, hamda yetishtirish muhitining o‘zaro ta’siri bo‘yicha umumlashtirildi. Adabiyotlar tahlili nav chidamliligi o‘zgarmas belgi emasligini, uning namoyon bo‘lishi yil va hududlar kesimida harorat, yuqori nisbiy namlik, bargning uzoq vaqt nam turishi, infeksiya bosimi, patogen genotipi, palakning rivojlanishi, ekish muddati, sug‘orish va fitosanitar holatga bog‘liq ravishda o‘zgarishini ko‘rsatdi. Xalqaro tadqiqotlarda chidamli genotiplardan foydalanish fitoftorozni integratsiyalashgan boshqarishning muhim tarkibiy qismi sifatida baholanadi.

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O‘zbekiston tadqiqotlari ham turli tuproq-iqlim sharoitlari uchun mahalliy moslashgan, serhosil va zamburug‘ kasalliklariga, jumladan fitoftorozga chidamli navlarni tanlash zarurligini ko‘rsatadi. Maqolada nav chidamliligi, agroekologik monitoring, sog‘lom urug‘lik, oqilona sug‘orish va oziqlantirish, sanitariya hamda xavfga asoslangan himoya choralarini birlashtiruvchi o‘simlikshunoslik modeli taklif etiladi.

Kalit so‘zlar: kartoshka; Solanum tuberosum L.; fitoftoroz; Phytophthora infestans; nav chidamliligi; o‘simlikshunoslik; agroekologiya; kasallik rivojlanishi; integratsiyalashgan himoya; O‘zbekiston.

Аннотация. В статье рассмотрены устойчивость сортов картофеля (Solanum tuberosum L.) к фитофторозу, вызываемому Phytophthora infestans, и агроэкологические особенности развития болезни в растениеводстве. Исследование выполнено как структурированный качественный обзор рецензируемых международных работ, авторитетных фитопатологических источников, а также официальных и научных публикаций Узбекистана. Материалы систематизированы по четырём взаимосвязанным компонентам: генотип и скороспелость растения-хозяина, популяция патогена, погода и микроклимат, а также условия технологии возделывания. Анализ показывает, что сортовая устойчивость представляет собой динамический полевой признак, проявление которого изменяется по годам и регионам в зависимости от температуры, высокой относительной влажности и продолжительного увлажнения листьев, инфекционной нагрузки, генотипа патогена, развития ботвы, сроков посадки, режима орошения и фитосанитарного состояния. Международные исследования подтверждают ключевую роль устойчивых генотипов в интегрированной защите картофеля от фитофтороза. Исследования Узбекистана также подчёркивают необходимость отбора адаптированных, продуктивных и устойчивых к грибным болезням сортов для различных почвенно-климатических условий республики. Предложен растениеводческий подход, объединяющий сортовую устойчивость, агроэкологический мониторинг, здоровый семенной материал, рациональное орошение и питание, санитарные меры и защиту растений с учётом риска.

Ключевые слова: картофель; Solanum tuberosum L.; фитофтороз; Phytophthora infestans; сортовая устойчивость; растениеводство; агроэкология; развитие болезни; интегрированная защита; Узбекистан.

INTRODUCTION

Potato is one of the most important food crops in temperate and subtropical production systems and combines high nutritional value with a relatively short production cycle. In Uzbekistan it is also a strategically important food crop, and official agronomic recommendations emphasize the selection of early and medium-early cultivars adapted to local growing conditions [1]. However, the biological productivity of a cultivar can be realized only when its genetic potential is matched with the environment and when major biotic constraints are controlled.

Late blight, caused by the oomycete Phytophthora infestans, remains one of the most destructive diseases of potato worldwide. The pathogen infects foliage, stems and tubers, and epidemics can

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progress rapidly when susceptible host tissue coincides with favorable weather and sufficient inoculum [2]. High relative humidity, persistent leaf wetness and cool-to-moderate temperatures favor infection and sporulation; therefore, disease pressure is strongly linked to local weather, canopy microclimate and crop management [2,3].

For crop production, the practical question is not simply whether a cultivar is labelled resistant or susceptible. Resistance must be interpreted as a phenotype expressed in a specific agroecosystem. A large multi-cultivar study demonstrated that both the level and type of late blight resistance changed between years, reflecting differences in weather and pathogen populations [4]. This has direct implications for Uzbekistan, where irrigated agriculture, contrasting elevations, continental temperature regimes, different planting seasons and a diverse cultivar portfolio can create markedly different epidemic environments.

The purpose of this article is to synthesize reliable evidence on potato cultivar resistance to late blight and the agroecological characteristics of disease development, with particular attention to their relevance for crop production in Uzbekistan. The objectives are to: (i) characterize the biological and environmental determinants of late blight; (ii) evaluate the role and limitations of cultivar resistance; (iii) integrate Uzbek research and agronomic evidence; and (iv) formulate research and crop-management recommendations suitable for multi-year, location-specific cultivar evaluation.

LITERATURE REVIEW

Phytophthora infestans has exceptional epidemiological importance because its life cycle permits rapid multiplication under favorable conditions and because pathogen populations can change over time. The disease triangle—susceptible host, virulent pathogen and conducive environment—provides a useful conceptual basis, but field epidemics are better understood as a dynamic interaction among host phenology, inoculum, weather, canopy microclimate and management. Authoritative plant-pathology guidance notes that no commercial potato cultivar is immune to all pathogen lineages, although cultivars differ substantially in general resistance [2].

Host resistance can delay epidemic onset, reduce the rate of lesion expansion or sporulation, and lower final disease severity. Abuley and Hansen evaluated 54 cultivars and classified them into resistance groups using disease-progress variables; importantly, resistance rankings varied between study years [4]. A separate evaluation of 217 cultivars identified resistant and moderately resistant materials and found that useful late blight resistance can occur without an inevitable yield penalty under non-disease conditions [5]. These findings support breeding and cultivar selection, but they also show why resistance ratings should be validated under the target production environment.

Genetic diversity remains central to durable improvement. Screening of 508 potato landraces and wild relatives at the International Potato Center identified novel sources of late blight resistance in several wild Solanum species [6]. Such germplasm broadens the resistance base available to breeders. Nevertheless, resistance genes are deployed against a pathogen with evolving populations, so cultivar improvement must be accompanied by pathogen surveillance and repeated phenotyping.

Agroecological conditions regulate the expression of both disease and resistance. Late blight is generally favored by high humidity and cool-to-moderate temperatures, while extended periods of leaf wetness support infection and sporulation [3,5]. Dense canopies, excessive or poorly timed irrigation, volunteer potatoes, infected seed tubers and unmanaged cull piles can increase inoculum or maintain

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humid microclimates. Conversely, sanitation, appropriate plant density, irrigation management and timely crop protection reduce epidemic risk. Cultivar maturity also matters because foliage duration determines the period during which plants remain exposed to inoculum.

Evidence from Uzbekistan supports the need for locally grounded cultivar assessment. Ostonaqulov and colleagues studied introduced and locally developed early potato cultivars in protected conditions in Samarkand and Tashkent during 2022–2023, evaluating growth, development, yield formation and resistance to fungal diseases including late blight [7]. Their work identified promising cultivars combining productivity with desirable biological traits and emphasized the scientific and practical importance of selecting high-yielding, disease-resistant cultivars for local production systems. Uzbek agronomic recommendations similarly stress matching cultivar maturity to the planting season and avoiding crop development during periods of excessive heat [1].

Recent Uzbek publications also document the broader disease complex affecting potato and the growing interest in biological disease suppression [8,9]. Although these studies are not substitutes for dedicated late blight epidemiology, they are relevant to an integrated crop-health framework because field and storage diseases interact with seed quality, crop sanitation and production economics. Together, international and Uzbek evidence indicates that late blight management should be embedded in crop production rather than treated as an isolated pesticide problem.

METHODOLOGY

This article used a structured qualitative review and evidence-synthesis design. Sources were selected if they met at least one of the following criteria: peer-reviewed experimental research on potato late blight resistance or epidemiology; authoritative plant-pathology guidance; official agronomic recommendations; or Uzbek scientific publications directly addressing potato cultivars, fungal diseases, crop production or disease management. Priority was given to primary studies and institutional sources with identifiable authorship, publication venue and methods.

The evidence was organized into four analytical domains: (1) host factors—cultivar genotype, maturity, canopy development and resistance phenotype; (2) pathogen factors—population composition, virulence and inoculum pressure; (3) environmental factors—temperature, relative humidity, rainfall or irrigation, leaf wetness and microclimate; and (4) crop-production factors—planting date, seed health, irrigation, nutrition, sanitation and protection strategy. This framework was used to compare international findings with conditions and research priorities relevant to Uzbekistan.

No new field experiment was conducted for this review; therefore, numerical values reported from individual studies were not pooled as if they represented a single Uzbek field trial. Instead, results were interpreted comparatively. This distinction is important for scientific reliability because disease severity and cultivar ranking are strongly environment-dependent [4]. The proposed experimental recommendations are consequently presented as a framework for future field validation rather than as completed experimental results.

RESULTS AND DISCUSSION

The synthesis identified five consistent relationships. First, cultivar resistance is one of the most effective biological components of late blight management, but it is not absolute. Second, environmental conduciveness strongly modifies disease expression. Third, cultivar resistance must be

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evaluated across years and locations because weather and pathogen populations alter apparent resistance. Fourth, agronomic practices influence the canopy microclimate and inoculum environment in which resistance is expressed. Fifth, the most useful cultivars for crop production are those that combine acceptable resistance with maturity, marketable yield, tuber quality and adaptation to the target production season.

Table 1 summarizes the principal agroecological factors and their implications for cultivar evaluation. The table is intended as a systems-level interpretation of the reviewed literature rather than a universal disease-prediction model.

Table 1. Agroecological determinants of potato late blight and implications for cultivar evaluation

Factor	Relationship with late blight	Implication for crop production	Evidence
Cultivar genotype	Resistance can delay epidemic onset and reduce disease progress, but expression varies among pathogen populations.	Use locally validated resistant or moderately resistant cultivars as the biological foundation of integrated management.	[2], [4]–[6]
Temperature and humidity	Cool-to-moderate temperatures together with very high humidity and wet foliage favor infection and epidemic development.	Combine cultivar choice with weather and canopy monitoring; avoid interpreting resistance independently of epidemic pressure.	[3], [5]
Year and location	Resistance rankings may shift because weather and pathogen populations differ among seasons and sites.	Conduct multi-year, multi-location trials before recommending cultivars for broad production.	[4]
Maturity and canopy duration	Longer-lived foliage may remain exposed to infection for a longer period; maturity can confound resistance ratings.	Record phenology together with disease progress and compare cultivars within appropriate maturity groups.	[5]
Irrigation and canopy microclimate	Prolonged canopy wetness and humid conditions can increase infection opportunity.	Schedule irrigation to limit unnecessary foliage wetness and maintain agronomically appropriate canopy structure.	[2], [3]
Seed and sanitation	Infected planting material, volunteer plants and unmanaged sources of inoculum can initiate or sustain epidemics.	Use healthy seed material and systematic field sanitation as preventive components.	[2]
Uzbek production environment	Contrasting soil-climatic conditions and planting seasons change cultivar development and disease risk.	Evaluate introduced and local cultivars under representative regional conditions, jointly measuring resistance and yield.	[1], [7]

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The table highlights why cultivar resistance should be treated as part of an agroecological package. A cultivar that performs well in a relatively dry season may show greater disease severity when humidity, leaf wetness and inoculum pressure increase. Conversely, even partial resistance can become agronomically valuable when combined with sanitation and well-timed crop protection [2,4]. This interaction is particularly relevant to irrigated potato systems because management decisions can modify the duration and frequency of canopy wetness.

For Uzbekistan, the evidence supports regionalized testing rather than reliance on foreign resistance ratings alone. The 2022–2023 Uzbek work in Samarkand and Tashkent demonstrates the practical value of evaluating introduced and local cultivars for growth, yield and fungal-disease resistance under local conditions [7]. Official recommendations also emphasize maturity-group selection and seasonal adaptation [1]. Therefore, future trials should record disease severity repeatedly through the season and calculate a disease-progress metric, while simultaneously measuring emergence, phenological stages, canopy development, marketable tuber yield and tuber quality.

A scientifically robust field design would include replicated cultivar plots, a standardized disease-severity scale, meteorological observations and documentation of irrigation events. Cultivars should be compared within maturity groups where possible. At least two to three growing seasons and more than one agroecological location are desirable because single-season resistance rankings may be misleading [4]. Such a design would generate evidence directly relevant to plant production: not merely which cultivar develops less disease, but which cultivar maintains acceptable yield and quality under realistic epidemic pressure.

The literature also supports an integrated rather than single-measure control concept. Resistant cultivars reduce dependence on chemical control, but resistance should be protected by healthy seed, crop sanitation, rational irrigation, balanced nutrition, disease monitoring and evidence-based plant-protection decisions. Biological control research in Uzbekistan further indicates interest in reducing disease pressure through antagonistic microorganisms, although late-blight-specific efficacy requires dedicated validation [9].

CONCLUSION AND RECOMMENDATIONS

Potato late blight resistance is a central crop-production trait, but its agronomic value can be understood only in relation to the agroecological environment. The reviewed evidence shows that cultivar genotype, pathogen population, temperature, humidity, leaf wetness, crop phenology and management jointly determine epidemic development. Consequently, a cultivar should not be characterized for Uzbekistan solely on the basis of a resistance rating obtained in another country or in a single season.

For plant-production research in Uzbekistan, the priority should be to establish multi-year and multi-location cultivar trials that integrate phytopathological and agronomic measurements. Disease onset, repeated severity assessments and disease progress should be recorded together with emergence, plant development, maturity, marketable yield and tuber quality. Meteorological and irrigation data should be linked to disease observations so that cultivar performance can be interpreted under defined agroecological conditions.

Practical management should combine locally validated resistant or moderately resistant cultivars with healthy seed material, field sanitation, appropriate planting dates, rational irrigation and

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nutrition, regular monitoring, and risk-based plant protection. Breeding and introduction programs should favor cultivars that combine resistance with early or appropriate maturity, stable yield and market quality. Pathogen surveillance is also advisable because changes in P. infestans populations can alter the effectiveness of host resistance over time.

Overall, the most promising direction for improving potato production is not the search for a single universal control measure, but the development of regionally adapted production systems in which genetic resistance and agroecological management reinforce one another. This approach is consistent with both international evidence and the current needs of potato research and production in Uzbekistan.

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