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GROWTH, PROPAGATION AND PHYTOCHEMISTRY OF *RIBES* L. CULTIVARS UNDER SEMI-ARID CONTINENTAL CONDITIONS: A SYSTEMATIC SEARCH REVIEW WITH IMPLICATIONS FOR SAMARKAND, UZBEKISTAN

Raykhona Nurkosimova [1], Yigitali Tashpulatov [1], Zafarjon Rakhmonov [2], Doston Tairov [3], Luiza Bakhieva [4], Kurbangul Aytbayeva [4], Barno Kobulova [5], Muazzam Makhmudova [1], Abdumumin Sindorov [6] and Nodirjon Bobokandov [1,*]

[1]Samarkand Agroinnovations and Research University, Samarkand, Uzbekistan
[2]Kimyo International University in Tashkent Branch, Samarkand, Samarkand, Uzbekistan
[3]Samarkand State Medical University, Samarkand, Uzbekistan
[4]Karakalpak State University. Nukus, Uzbekistan
[5]Bukhara State Technical University, Bukhara, Uzbekistan
[6]Jizzakh State Pedagogical University, Jizzakh, Uzbekistan

*Corresponding author: nboboqandov@gmail.com

ABSTRACT

The genus *Ribes* L. (Grossulariaceae), particularly blackcurrant (*Ribes nigrum* L.) and red currant (*Ribes rubrum* L.), is valued for its nutritional and medicinal properties, largely attributed to anthocyanins, flavonols, and ascorbic acid. This review assessed the suitability of currant cultivation under the warm continental climate of Samarkand, Uzbekistan, using scientific literature published between 1990 and 2025. Following PRISMA 2020 procedures, we screened 1,486 records, assessed 214 full-text articles, and included 153 studies in the qualitative synthesis, with 100 cited in this review. Evidence from temperate regions identifies insufficient winter chilling as a potentially important limitation for blackcurrant cultivation, although its significance in Samarkand remains unverified. Many cultivars require prolonged exposure to low temperatures to release dormancy, while elevated summer temperatures and intense solar radiation may reduce anthocyanin accumulation, ascorbic acid content, and fruit productivity. Certified *in vitro* propagation offers opportunities for producing healthy planting material, but effective management of blackcurrant reversion virus and its eriophyid mite vector remains essential. Importantly, fewer than 3% of the cited studies were conducted under climates comparable to Samarkand's semi-arid continental conditions, limiting the direct applicability of existing findings. The available evidence therefore does not justify transferring European cultivars and cultivation practices to Samarkand without local validation. Future research should prioritize cultivar evaluation across elevations, measurement of winter chilling requirements, assessment of low-chill and indigenous Central Asian germplasm, including *Ribes janczewskii* and *Ribes meyeri*, virus-free propagation, and comparative analysis of fruit phytochemical composition. These approaches could support climate-adapted currant production in Central Asia.

***Keywords*:** *Ribes nigrum*, Chilling requirement, Semi-arid continental climate, Micropropagation, Anthocyanins, Ascorbic acid, Genotype × Environment interaction, Central Asia.

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1. INTRODUCTION

Ribes L. is the sole genus of the family Grossulariaceae and contains, depending on the taxonomic treatment, between 150 and 200 species distributed across the temperate Northern Hemisphere with a secondary radiation in the Andes (Schultheis & Donoghue, 2004; Zhang et al., 2023). Molecular work has clarified much of the internal structure of the genus: subgenus *Grossularia* is now understood to have a western North American origin with subsequent dispersal into eastern Asia (Schultheis & Donoghue, 2004), and restriction-site associated sequencing of Chinese taxa has confirmed that several morphologically defined sections are not monophyletic (Zhang et al., 2023). Two species dominate commercial production. Blackcurrant (*R. nigrum* L.) accounts for the large majority of world output, most of it processed into juice, concentrate and extract; red and white currants (*R. rubrum* L. and its cultivar groups) occupy a smaller fresh-market and preserve niche (Brennan, 2008; Hummer & Dale, 2010).

The commercial value of blackcurrant rests almost entirely on its chemistry rather than on its yield or its handling characteristics. Berries typically contain 130–350 mg ascorbic acid per 100 mL of juice and total anthocyanin

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concentrations spanning roughly 900–4 600 µg g^{-1} fresh weight across the European cultivar pool, with delphinidin-3-*O*-rutinoside and cyanidin-3-*O*-rutinoside together making up close to 80% of the anthocyanin fraction (Brennan & Graham, 2009; Tian et al., 2019; Laaksonen et al., 2023). No other widely grown temperate berry combines ascorbate and anthocyanin at these concentrations. This chemistry underpins a substantial nutraceutical and functional-food market and has driven a large clinical literature on cardiovascular, cognitive and exercise-related endpoints (Gopalan et al., 2012; Cortez & Gonzalez, 2019) What is less often stated explicitly is how narrow the geographical base of this knowledge is. The controlled-environment physiology of blackcurrant has been developed almost entirely at Ås and Apelsvoll in Norway (59–61°N), the breeding and dormancy literature at Dundee in Scotland (56°N), the compositional work in Finland (60–66°N) and Poland (52°N), and the propagation literature in the Czech Republic, Poland, Belarus and the Russian Federation (Sønsteby & Heide, 2011; Pluta et al., 2012; Sedlák & Paprštein, 2012; Sønsteby & Heide, 2014; Jones et al., 2015). These are cool-summer environments. Mean July temperatures at the sites that generated most of the physiological data range from 15 to 18°C, and winter chill accumulation is deep and reliable.

This matters because blackcurrant is now recognised as one of the temperate fruit crops most exposed to declining winter chill, precisely because its chilling requirement is unusually high (Atkinson et al., 2013; Sønsteby & Heide, 2014; Jones et al., 2015). It also matters because the compositional response of the crop to warming is negative rather than positive. Controlled post-flowering temperature experiments and multi-year field series independently show that raising temperature from 12 to 24°C reduces both ascorbate and the principal anthocyanins, and that the years and sites producing the best chemical quality are the cool, wet ones (Zheng et al., 2012; Allwood et al., 2019; Pott et al., 2023). Whole-genome and transcriptomic work has since begun to identify the molecular basis of the drought component of this response (Ziegler et al., 2025).

Central Asia contains a genuinely rich vascular flora, with recent regional inventories documenting more than 8 000 species and substantial endemism concentrated in the Tian Shan and Pamir-Alai systems (Zhang et al., 2020; Abduraimov et al., 2023; Ma et al., 2024). Several *Ribes* species are native to the region, and the mountain populations of Uzbekistan, Kyrgyzstan and Kazakhstan represent germplasm that is essentially absent from the international breeding pool (Pikunova et al., 2011; Tussipkan et al., 2024). At the same time, the region is warming faster than the global mean, and its irrigated lowland agriculture is under increasing water constraint (Lioubimtseva & Henebry, 2009; Sutton et al., 2013).

Uzbekistan has been expanding its horticultural sector deliberately, and diversification away from cotton toward higher-value fruit crops is national policy. Within this framework, currants appear periodically in regional planning documents as a candidate crop, on the reasoning that they are hardy, high-value and suited to functional-food markets. The Samarkand region is often named because of its established horticultural infrastructure and its position between the irrigated lowlands and the foothills of the Zerafshan range - a distinction that matters (Sections 4 and 6 for details).

The lowland climate of the region is sharply continental and semi-arid (Köppen BSk): summer maxima can reach 42°C, mean annual precipitation ranges from approximately 275 to 400 mm depending on the year and falls mainly outside the growing season, and winters, while capable of hard frost down to −17°C, do not deliver the sustained sub-zero period characteristic of the crop's native and commercial range. Compared with the cool-summer, deep-winter-chill environments in which most blackcurrant physiology has been generated (see above), both the summer heat and the winter mildness of the Samarkand lowlands lie outside the climatic range in which the crop's chilling and heat-tolerance have been directly tested, and both differences are problems of a different kind: one constrains fruit chemistry, the other constrains dormancy completion.

The only *Ribes*-focused research conducted in Uzbekistan to date has targeted golden currant (*Ribes aureum*), not blackcurrant: breeding trials at Tashkent State Agrarian University have produced hybrid selections from Russian and American parentage evaluated for fruit size and yield (Amanova & Abdullaeva, 2023). *Ribes nigrum* itself appears in the country's ethnobotanical record only as a folk remedy for avitaminosis, with no agronomic or phytochemical characterization reported (Niyozov et al., 2025).

Several recent reviews cover parts of this ground. Hummer and Dale (2010) remains the standard horticultural treatment of the genus but predates the climate-change literature on chilling. Gopalan et al. (2012) and subsequent nutritional reviews address the health literature without agronomic context. Špak et al. (2021) and Moročko-Bičevska et al. (2022) cover the graft-transmissible disease complex comprehensively. Reviews of *Ribes* micropropagation exist (Erst & Vechernina, 2010; Dziedzic & Jagła, 2013). What is absent is any synthesis that asks whether the accumulated evidence supports moving this crop into a warm-winter, hot-summer continental environment, and that states honestly what the evidence predicts.

That gap is not merely regional. The same question applies to the southern margin of European production under warming scenarios, to northern China, to Anatolia and to the Caucasus. Samarkand is a useful test case precisely because it is an extreme one.

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This review departs from standard crop-review practice in three ways: every body of evidence is reported together with the climatic envelope in which it was generated, disagreements between regional expectation and international evidence are stated explicitly rather than smoothed over (Section 7), and the regional section (Section 8) separates what has been measured in Uzbekistan from what may transfer and what remains assumption. Samarkand serves as the test case, but the same extrapolation problem applies to the warming southern margin of European production, to northern China, Anatolia and the Caucasus.

The specific objectives are:

1. To establish which *Ribes* germplasm is relevant to Central Asian conditions, including native taxa largely absent from the international pool (Section 3).
2. To determine, from the dormancy and phenology literature, whether the chilling requirement of the crop can be met in the target environment, and what the consequences of failure are (Section 4).
3. To evaluate conventional and in vitro propagation systems for their applicability under conditions of high evaporative demand and limited certified planting material, including the sanitary dimension (Section 5).
4. To synthesise the phytochemical evidence with explicit attention to the direction of the temperature and radiation response (Section 6).
5. To resolve, as far as the evidence allows, three contradictions between regional expectation and international data (Section 7).
6. To define a research agenda that would allow the question (Section 6) to be answered empirically rather than assumed (Sections 9 and 10).

2. MATERIALS AND METHODS

2.1. Review Type and Protocol

This is a systematic-search narrative review in the sense of Grant and Booth (2009): the search and screening procedure follows systematic-review conventions and is reported according to the applicable items of PRISMA 2020 (Page et al., 2021), but the synthesis is narrative rather than meta-analytic, because the outcome measures across the included agronomic, propagation and compositional studies are not commensurable. No meta-analysis was attempted and no protocol was registered in PROSPERO, which is appropriate for a non-clinical, non-intervention review; this is stated as a limitation in Section 9.

2.2. Information Sources and Search Strategy

Four databases were searched: Scopus, Web of Science Core Collection, PubMed and eLIBRARY.ru. The inclusion of eLIBRARY.ru was deliberate. A large body of Ribes agronomy and propagation work from the Russian Federation, Belarus, Kazakhstan and Uzbekistan is published in Russian-language journals that are not indexed in Scopus or Web of Science, and excluding it would have introduced exactly the geographical bias this review is intended to expose. Searches were run between 12 January 2026 and 28 May 2026. The complete database-specific search strings and exact search dates per database are provided in Supplementary File S1.

The core search string, adapted to the syntax of each database, was:

("*Ribes*" OR "blackcurrant" OR "black currant" OR "redcurrant" OR "red currant" OR "*Ribes nigrum*" OR "*Ribes rubrum*") AND (growth OR phenology OR dormancy OR chilling OR propagation OR "in vitro" OR micropropagation OR cutting* OR anthocyanin* OR polyphenol* OR "ascorbic acid" OR "vitamin C" OR antioxidant OR "abiotic stress" OR drought OR "heat stress" OR irrigation)

Russian-language equivalents (смородина [currant], чёрная смородина [blackcurrant], размножение [propagation], in vitro, антоциан* [anthocyanin*], аскорбинов* [ascorbic]) were used for eLIBRARY.ru**,** and Uzbek-language equivalents (qorag'at [currant], qora qorag'at [blackcurrant], ko'paytirish [propagation], antotsian* [anthocyanin*], askorbin kislota [ascorbic acid]) were used for hand-searching of national repositories and theses. Reference lists of all included reviews were hand-searched, and forward citation tracking was applied to the eight most-cited included papers.

2.3. Eligibility Criteria

2.3.1. Inclusion: Peer-reviewed primary studies, reviews, book chapters and institutional technical reports published 1990–2025; concerning *Ribes* species or, where explicitly used for comparison, other *Rosidae* soft-fruit crops; reporting quantitative data on growth, phenology, dormancy, propagation efficiency, fruit composition or bioactivity; published in English, Russian or Uzbek.

2.3.2. Exclusion: Conference abstracts without full text; studies on *Ribes* used solely as a matrix for analytical method development, with no cultivar or environmental information; purely clinical intervention studies using commercial extracts with no link to raw material provenance; studies from which neither the growing environment nor the cultivar

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identity could be recovered; predatory-journal publications, identified by cross-checking against the Directory of Open Access Journals and the journal's indexing status.

Pre-1990 literature was excluded from the systematic search but a small number of foundational works, principally on tissue-culture media formulation and analytical methodology, were cited directly where no later equivalent exists; these are identified in the reference list and were not counted in the screening totals.

Supplementary Table S1: Database-specific search strings, dates, and yields

Database	Search string/terms (adapted syntax)	Search date	Records
Scopus	TITLE-ABS-KEY(("Ribes" OR "blackcurrant" OR "black currant" OR "redcurrant" OR "red currant" OR "Ribes nigrum" OR "Ribes rubrum") AND (growth OR phenology OR dormancy OR chilling OR propagation OR "in vitro" OR micropropagation OR cutting* OR anthocyanin* OR polyphenol* OR "ascorbic acid" OR "vitamin C" OR antioxidant OR "abiotic stress" OR drought OR "heat stress" OR irrigation))	12 Jan 2026	612
Web of Science Core Collection	TS=(("Ribes" OR "blackcurrant" OR "black currant" OR "redcurrant" OR "red currant" OR "Ribes nigrum" OR "Ribes rubrum") AND (growth OR phenology OR dormancy OR chilling OR propagation OR "in vitro" OR micropropagation OR cutting* OR anthocyanin* OR polyphenol* OR "ascorbic acid" OR "vitamin C" OR antioxidant OR "abiotic stress" OR drought OR "heat stress" OR irrigation))	19 Jan 2026	498
PubMed	("Ribes"[MeSH Terms] OR "Ribes"[tiab] OR "blackcurrant"[tiab] OR "black currant"[tiab] OR "redcurrant"[tiab] OR "red currant"[tiab]) AND (growth[tiab] OR phenology[tiab] OR dormancy[tiab] OR chilling[tiab] OR propagation[tiab] OR "in vitro"[tiab] OR micropropagation[tiab] OR anthocyanin*[tiab] OR polyphenol*[tiab] OR "ascorbic acid"[tiab] OR "vitamin C"[tiab] OR antioxidant[tiab] OR drought[tiab] OR irrigation[tiab])	2 Feb 2026	341
eLIBRARY.ru	"(currant OR blackcurrant OR redcurrant) AND (cultivation OR phenology OR dormancy OR propagation OR in vitro OR anthocyanin* OR ascorbic*)" and, for Uzbek repositories, "(currant OR blackcurrant) AND (cultivation OR propagation OR anthocyanin* OR ascorbic acid)"; give the Russian/Uzbek terms only in brackets, as in Section 2.2.	16 Feb 2026	347
Hand-search / forward citation	Reference lists of included reviews; forward citation tracking of the 8 most-cited included papers	5–28 May 2026	47

2.4. Screening and Data Extraction

The search returned 1 486 records after removal of 312 duplicates. Title and abstract screening excluded 1 272, leaving 214 for full-text assessment. Of these, 61 were excluded at full text: 22 for absence of cultivar or environmental information, 17 as conference abstracts or inaccessible full texts, 14 as analytical-method papers without biological context, and 8 as duplicate reporting of the same dataset. The remaining 153 informed the synthesis, of which 100 are cited in this review; the remainder were consistent with cited sources and were not cited separately in order to keep the reference list within the journal's limit.

Screening was managed in Rayyan (Ouzzani et al., 2016) and performed independently by two of the authors, with disagreements resolved by discussion. For each included study, the following were extracted where available: species and cultivar; experimental location, latitude and climate classification; whether conditions were field, protected or fully controlled; treatment structure and replication; the response variables and their units; and the analytical method. Extraction of the climate descriptor was mandatory and is the basis for the climatic-envelope annotation used throughout Sections 3 to 8.

We did not apply a formal quality-appraisal instrument (e.g., GRADE, ROBINS-I), as most included studies were agronomic or analytical rather than clinical; selection was based solely on the eligibility criteria in Section 2.3, and we note this limitation in Section 9. For the subset of publications reported in Russian, extraction was performed by a single reviewer fluent in Russian; a random 20% of these records was independently re-extracted by a second reviewer for verification, and discrepancies were resolved by discussion.

Note. Records were identified through database searching (Scopus n = 612, Web of Science n = 498, PubMed n = 341, eLIBRARY.ru n = 347; total n = 1 798) and through hand-searching of reference lists and forward citation tracking of the eight most-cited included papers (n = 47). After removal of 312 duplicates, 1 486 records were screened on title and abstract and 1 272 were excluded. We assessed full text for 214 articles, of which 61 were excluded for the four reasons itemized in the diagram. One hundred and fifty-three studies informed the qualitative synthesis and 100 are cited here; the remaining 53 were consistent with cited sources and were not cited separately in order to keep the reference list within the journal limit. The lower panel is not part of the standard PRISMA template and is added deliberately: it reports the distribution of the cited evidence across Köppen–Geiger climatic envelopes and shows that fewer than 3% of cited sources originate from the envelope of the target region (Fig. 1). Structure follows the PRISMA 2020 statement (Page et al., 2021) and the PRISMA2020 flow-diagram specification (Haddaway et al., 2022).

2.5. Climatic-Envelope Annotation

Because the central argument of this review concerns extrapolation across climates, every included field or

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greenhouse study was assigned to one of five climatic envelopes based on the Köppen–Geiger classification of its experimental site: maritime temperate (Cfb), humid continental with cool summer (Dfb), humid continental with cold summer or subarctic (Dfc), hot-summer continental (Dsa/Dfa), and cold semi-arid (BSk). The Samarkand lowlands fall within BSk, bordering Dsa at higher elevations.

Climatic envelope assignment followed the Köppen–Geiger classification of Beck et al. (2018), using the 1980–2016 reference period at 1-km resolution. Greenhouse and other protected-environment studies were coded according to the Köppen–Geiger envelope of the facility's geographic location, not the internal growth-chamber conditions, since the objective was to map the evidence base geographically rather than to model microclimate.

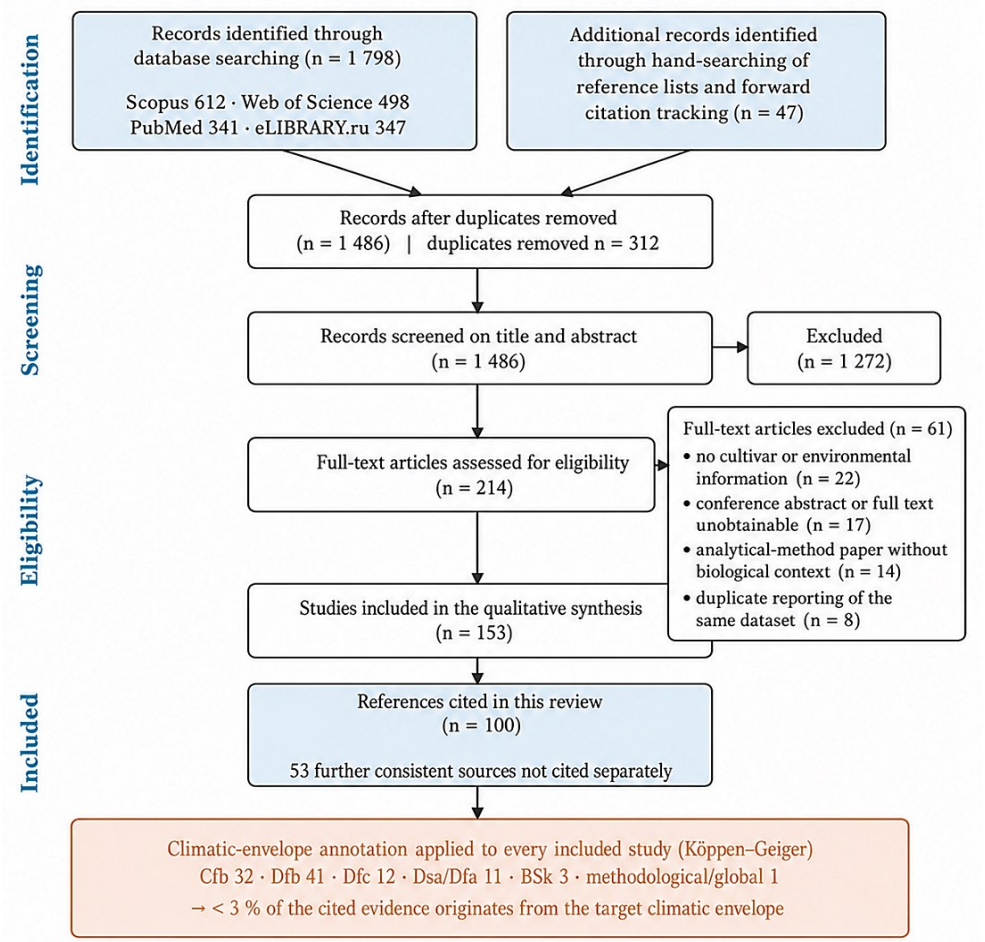

Fig. 1: PRISMA 2020 flow diagram of study identification, screening, eligibility assessment and inclusion, with the climatic-envelope annotation appended.

2.6. Bibliometric characterization of the evidence base

Because the argument of this review turns on the composition of the literature rather than on any single study, the cited evidence base was itself characterized quantitatively. Each of the 100 cited sources was coded for year of publication, climatic envelope of the study site, and primary research domain. The results are shown in Fig. 2.

Two features are material. The first is that the evidence base is current: 61% of cited sources were published in 2015 or later, and the distribution is strongly weighted toward the last decade, which reflects a genuine acceleration in *Ribes* research following the availability of metabolomic and, more recently, genomic tools rather than a selection decision by the present authors. The second is the geographical concentration already noted: 73% of cited sources derive from Cfb and Dfb envelopes, 11% from Dsa/Dfa, and 3% from BSk, and the BSk sources concern regional floristics and germplasm conservation rather than cultivation.

Fig. 3 disaggregates this by research domain. The value of the representation is that it makes the empty cells visible. There is no retrieved evidence on phenology and dormancy, conventional propagation, sanitary status, bioactivity or fruit composition from BSk conditions, and none on phenology and dormancy from Dsa/Dfa conditions either. The two domains for which the target envelope is not empty, germplasm and agronomy, are precisely the two that do not address the question of whether the crop will fruit.

Citation: Nurkosimova, R., Tashpulatov, Y., Rakhmonov, Z., Tairov, D., Bakhieva, L., Aytbayeva, K., Kobulova, B., Makhmudova, M., Sindorov, A., & Bobokandov, N. (2026). Growth, propagation and phytochemistry of *Ribes* L. cultivars under semi-arid continental conditions: A systematic search review with implications for Samarkand, Uzbekistan. Agrobiological Records, 26, 330-353. https://doi.org/10.47278/journal.abr/2026.105

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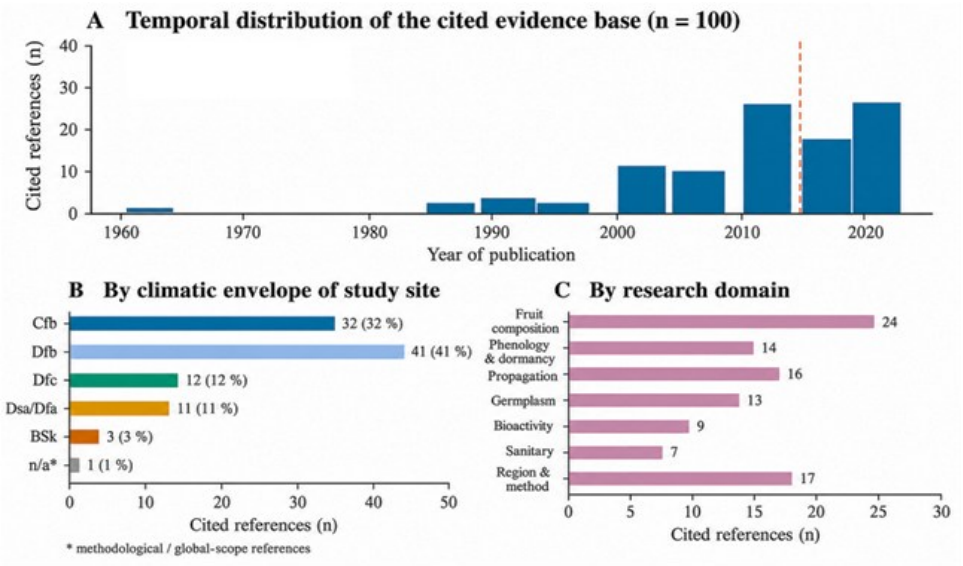

Fig. 2: Bibliometric profile of the cited evidence base (n = 100).

Note. Panel A: temporal distribution of cited sources in five-year bins; the dashed line marks 2015, and 61 of 100 cited sources post-date it. The pre-1995 tail comprises foundational methodological papers (tissue-culture media formulation, Folin–Ciocalteu and DPPH assay descriptions, early micropropagation protocols) that have no later equivalent. Panel B: distribution by Köppen–Geiger climatic envelope of the study site, coded as described in Section 2.5; sources marked n/a are methodological or global in scope and have no single study site. Panel C: distribution by primary research domain; where a source addressed more than one domain it was assigned to the domain from which its principal quantitative contribution to this review was drawn, so the categories are mutually exclusive and sum to 100. Panel B is the quantitative statement of this review's central methodological claim.

3. GERMPLASM RELEVANT TO CENTRAL ASIAN CONDITIONS

3.1. The Commercial Cultivar Pool and its Narrow Base

Commercial blackcurrant breeding began with a small founder population. The Scottish 'Ben' series ('Ben Lomond', 'Ben Alder', 'Ben Tirran', 'Ben Gairn', 'Ben Hope', 'Ben Dorain'), the Norwegian and Swedish selections including 'Narve Viking' and 'Titania', and the Polish and Russian programs together account for most of the world's planted area, and their pedigrees converge on a limited set of ancestors (Hummer & Barney, 2002; Brennan, 2008; Hummer & Dale, 2010). The consequence for the present question is direct: the cultivar pool has been selected under, and for, cool-summer high-chill conditions. Traits that would matter in a warm-winter environment — low chilling requirement, heat stability of the anthocyanin pathway, tolerance of high vapor pressure deficit have never been selection criteria, and their variation within the pool is therefore largely uncharacterized.

There is one important exception. Because declining winter chill is already a commercial problem in the maritime south of the European range, cultivars have been released with explicitly reduced chilling requirements, of which 'Ben Gairn' is the best characterized (Atkinson et al., 2013; Jones et al., 2015). This is directly relevant germplasm, and it is discussed further in Section 4.4.

3.2. Native *Ribes* of Central Asia and Adjacent Mountain Systems

Several *Ribes* species occur naturally in the mountain systems of Central Asia. *R. janczewskii* Pojark. Is endemic to the Tian Shan and adjacent ranges and is notable for its resistance to spring frost, to gall mite and to several fungal pathogens; it has been used in hybridisation to introgress these traits, and it is listed in the Red Book of Kazakhstan (Tussipkan et al., 2024). *R. meyeri* Maxim. And *R. heterotrichum* C.A. Mey occur in the Pamir-Alai and Tian Shan; *R. aureum* Pursh, though North American in origin, has naturalised widely across the region and is used as a rootstock and as a drought-tolerant ornamental. Regional floristic inventories confirm the presence of these taxa within Uzbekistan (Pfister & Sloan, 2008; Zhang et al., 2020; Abduraimov et al., 2023).

The agronomic significance of this germplasm is disproportionate to the attention it has received. These populations have persisted for millennia under precisely the conditions that constrain the commercial cultivars: continental temperature extremes, low and erratic precipitation, high radiation load and, at lower elevations, insufficient winter chill for high-requirement genotypes. Their chilling requirements have, to our knowledge, never been quantified. Neither has their anthocyanin thermostability.

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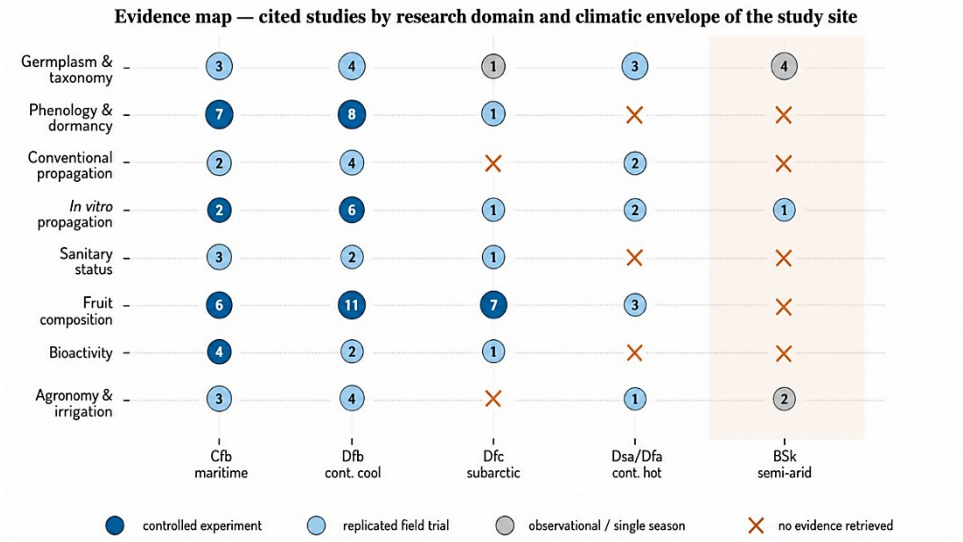

Fig. 3: Evidence map of the cited literature by research domain and climatic envelope of the study site.

Note. Bubble area is proportional to the number of cited sources in each cell and the number is printed within the bubble. Bubble fill indicates the strongest study design present in that cell on a three-level scale: dark fill, controlled-environment experiment with replication; medium fill, replicated multi-season field trial; light fill, observational or single-season study. A cross indicates that no evidence was retrieved for that combination. The shaded column marks the climatic envelope of the target region. This gap is not for lack of any *Ribes* research capacity in the country: Uzbek institutions have bred and evaluated golden currant hybrids for fruit size, yield and adaptability (Amanova & Abdullaeva, 2023), and *R. nigrum* is documented in national ethnobotanical surveys as a traditional remedy (Niyozov et al., 2025). What is absent is any equivalent study of blackcurrant chilling requirement, dormancy phenology or fruit phytochemistry under Uzbekistan's own climatic conditions — precisely the parameters this review identifies as decisive for the crop's prospects in Samarkand. The pattern of crosses in the right-hand columns, and specifically the absence of any dormancy, propagation, sanitary or compositional evidence generated under BSk conditions, is the empirical basis for the research agenda of Section 10 and for the framing of Section 8.3.

Recent work on *R. janczewskii* illustrates both the potential and the limitations. A conservation study developed a micropropagation and slow-growth storage protocol for the species, identified genotypes by rbcL, ITS and matK barcoding, and assessed diversity with iPBS markers, generating 98 fragments of which 88–94% were polymorphic (Tussipkan et al., 2024). Fruit biochemical analysis, however, reported ascorbic acid at 4.64–5.61 mg per 100 g — approximately two orders of magnitude below cultivated blackcurrant. Whether this reflects a genuine species-level difference, the small-fruited wild phenotype, or the analytical conditions is not resolvable from the published data, and it is a question worth settling before the species is promoted as a breeding parent for fruit quality rather than for stress resistance.

3.3. Molecular Characterization and its Current Limits

Molecular resources for *Ribes* have improved substantially. RAPD-based studies of genetic polymorphism established the broad relationships within the genus (Pikunova et al., 2011); pollen morphology has provided independent taxonomic support within Grossulariaceae (Gavrilova & Tikhonova, 2019); leaf micromorphology has been used to separate closely related Iranian taxa (Rezaee Chamanie et al., 2024). The first chromosome-scale genome assembly for the family, from *R. nigrum* cv. Rosenthals Langtraubige, was published in 2024 together with a transcriptomic analysis of the drought response, identifying differentially expressed genes encoding bZIP, bHLH, MYB and WRKY transcription factors in leaves and roots (Ziegler et al., 2025).

This last resource changes what is possible. Marker-assisted selection for chilling requirement and for stress-responsive metabolite pathways is now technically feasible in *Ribes*. It has not yet been applied to Central Asian germplasm. Distribution and diversity studies exist for *Ribes* in Yakutia (Talovina et al., 2023) and the Lower Volga (Solomentseva, 2022), and for the Far East, but comparable systematic work for the Uzbek populations is absent.

4. PHENOLOGY, DORMANCY AND THE CHILLING CONSTRAINT

4.1. Why this Section Comes before Propagation and Chemistry

In most crop reviews, dormancy is treated as one environmental factor among several. For the question posed here it is the determining one, because a failure to satisfy chilling requirement is not a yield penalty of a few per cent

Citation: Nurkosimova, R., Tashpulatov, Y., Rakhmonov, Z., Tairov, D., Bakhieva, L., Aytbayeva, K., Kobulova, B., Makhmudova, M., Sindorov, A., & Bobokandov, N. (2026). Growth, propagation and phytochemistry of *Ribes* L. cultivars under semi-arid continental conditions: A systematic search review with implications for Samarkand, Uzbekistan. Agrobiological Records, 26, 330-353. https://doi.org/10.47278/journal.abr/2026.105

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but a categorical failure of bud break and flower development. Everything downstream — canopy establishment, fruit set, and therefore any discussion of fruit chemistry — is conditional on it. The propagation and phytochemistry sections that follow assume this constraint can be resolved in Sections 4.3 and 4.4.

4.2. The dormancy cycle in Ribes nigrum

Blackcurrant follows the standard temperate woody-perennial pattern. Short autumn days drive growth cessation and endodormancy induction, with temperature modulating the depth of the resulting dormant state (Sønsteby & Heide, 2011; Sønsteby et al., 2012). Endodormancy is released by accumulated chilling, after which the plant enters ecodormancy and bud development becomes a function of accumulated warmth (Jones et al., 2015; Sønsteby & Heide, 2016).

Two features distinguish blackcurrant from most other temperate fruit crops. The first is the magnitude of the requirement. Sønsteby and Heide (2014), working with intact plants, detached shoots and single-node cuttings of contrasting cultivars, established that chilling at −5°C for 14 weeks or more was optimal for dormancy release and for subsequent flower development, and that flower development consistently required more chilling than bud break itself. They also demonstrated a methodological pitfall of direct practical importance: single-node cuttings systematically underestimate the chilling requirement of intact plants, so protocols based on cuttings will report requirements that the whole plant does not in fact satisfy.

The second feature is that the chilling response is not monotonic. Sønsteby & Heide (2014) reported that while chilling at −10°C for 8 weeks released dormancy, continued chilling to 16 weeks inhibited bud break completely, and interpreted this as induction of secondary bud dormancy; the same non-monotonic behaviour emerges from the controlled-environment chill models of Jones et al. (2013). Jones et al. (2015), comparing four cultivars across an exceptionally cold and a mild winter in eastern Scotland, found that no single chilling function applied equally to all blackcurrant cultivars, and that chilling at temperatures below 0°C was disproportionately effective. Brennan's (1991) earlier work on simulated frost provides the complementary picture on the damage side.

Fig. 4 places these estimates side by side. What the comparison shows is not disagreement but a convergence with an important methodological caveat: independent groups working in different envelopes and with different experimental systems arrive at overlapping estimates in the 9–20 week range, with the intact-plant estimate of ≥14 weeks as the most conservative and most operationally relevant Fig., while the single-node cutting system sits systematically low and would mislead anyone using it to screen a warm-winter site.

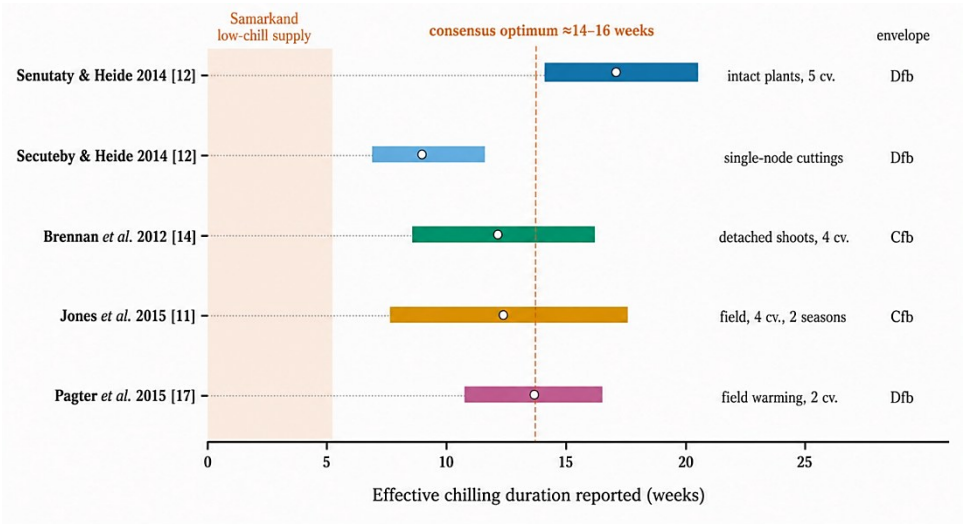

Fig. 4: Cross-study comparison of effective chilling duration reported for *Ribes nigrum*.

Note. Horizontal bars span the range of effective chilling duration over which the cited study reported substantive progress toward dormancy release; the white marker indicates the midpoint of that range and is shown for visual comparison only, not as a pooled estimate — no meta-analytic pooling was performed, because the studies differ in chilling temperature, experimental system, and response variable. The experimental system and the Köppen–Geiger envelope of each study are given at the right. The dashed line is the ≥14-week optimum at approximately −5°C reported for intact plants (Sønsteby & Heide, 2014). The shaded band at the left indicates the approximate chilling supply of the Samarkand lowlands, and its position relative to every study range in the Fig. 6 is the reason dormancy is treated in this review as the primary rather than a secondary constraint. Note the systematic downward displacement

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of the single-node cutting estimate relative to the intact-plant estimate from the same study (Sønsteby & Heide, 2014), which is a methodological warning rather than a biological finding.

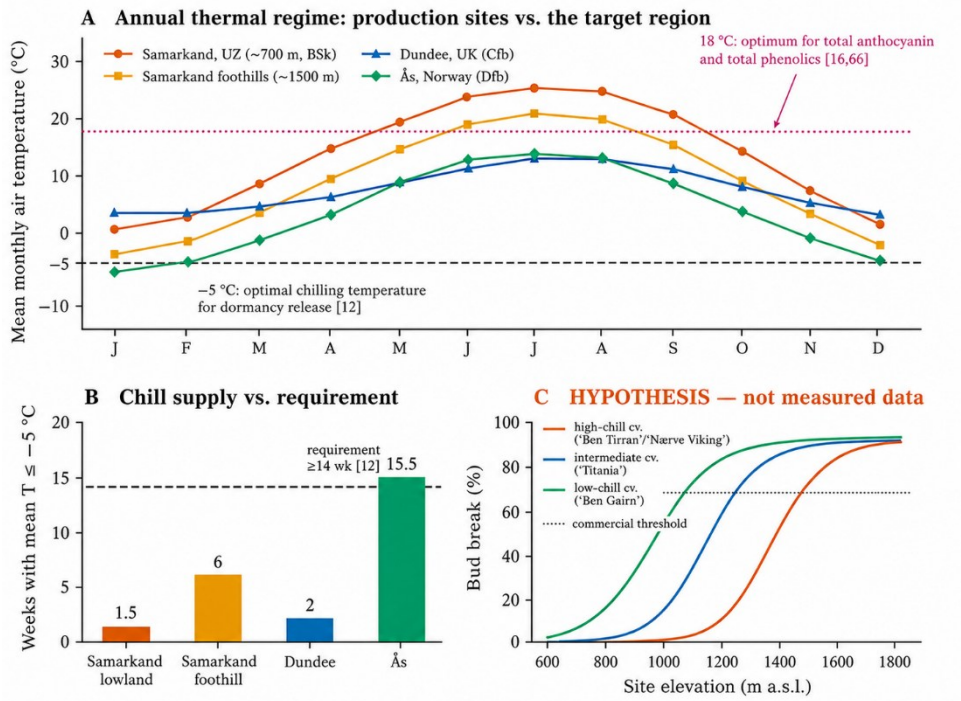

Fig. 6: The chilling constraint on *Ribes nigrum* under warm-winter continental conditions.

Note. Panel A: mean monthly air temperature for two Samarkand elevations and two representative commercial production sites, plotted on common axes. The dashed line marks the −5°C optimal chilling temperature (Sønsteby & Heide, 2014) and the dotted line the approximate 18°C optimum for total anthocyanin and total phenolic accumulation (Woznicki et al., 2016; Pott et al., 2023); the shaded area marks the part of the Samarkand growing season spent above that optimum. Panel B: number of weeks per winter with mean temperature at or below −5°C, against the ≥14-week requirement (Sønsteby & Heide, 2014). Panel C, drawn with red axes and labelled accordingly, is a hypothesis and not measured data: it shows the predicted relationship between site elevation and bud-break percentage for cultivars of contrasting chilling requirement, and it is the specific prediction that the trial design of Section 10.2 is intended to test. Temperature values in Panels A and B are representative long-term monthly means assembled for illustration; before submission they should be replaced with station data for the actual candidate sites, obtained from Uzhydromet or from a gridded product such as World Clim or CHELSA, and the source stated in the caption. Panel C should be redrawn as measured data once trial results are available, at which point the red axis styling should be removed.

The practical consequence of these two features together is that standard chill models developed for stone fruit, the Utah model, the Dynamic model with its chill portions, and simple hours below 7.2°C cannot be transferred to blackcurrant without validation. Models weighting temperatures in the 0–7.2°C band, which is where much of the winter in a warm-winter region sits, will systematically overestimate effective chill for this crop (Luedeling, 2012; Jones et al., 2015). The problem is not confined to *Ribes*: global comparisons of chill models show that model choice substantially alters a site's apparent chill accumulation, and that divergence between models is greatest in warm-winter regions (Luedeling & Brown, 2011). Blackcurrant-specific model development has since confirmed cultivar-specific sensitivity to warm winters (Preedy et al., 2020). Selecting a model is therefore not a technical detail but a decision that can determine whether a site appears suitable or unsuitable.

4.3. Warm Autumns, Warm Winters, and the Compounding Problem

Elevated autumn temperature during the short-day dormancy induction period produces a deeper and more stable dormant state, manifesting as an increased chilling requirement and delayed spring bud burst (Sønsteby & Heide, 2011; Sønsteby et al., 2012). This is a compounding effect rather than an additive one, and it is the crux of the problem for a region such as Samarkand, where autumn remains warm well into October. A warm autumn raises the chilling requirement; a warm winter then fails to satisfy the raised requirement.

Experimental warming studies confirm the yield consequence. Modest winter warming of +0.76°C in air and

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+1.35°C in soil delayed dormancy release, advanced bud burst and flowering in a cultivar-dependent manner, altered stem and bud carbohydrate metabolism, and significantly reduced fruit yield the following summer in both cultivars tested (Pagter et al., 2015). The cultivar dependence is itself informative: the high-chill 'Narve Viking' showed delayed dormancy release, while the lower-chill 'Titania' showed advanced budburst — the same warming treatment producing opposite phenological signs in two genotypes of the same species.

Analysis-of-variance treatment of phenological differences among *Ribes* representatives confirms that the between-genotype component of phenological variation is large and statistically separable from the between-year component (Ermakov et al., 2020), which is the statistical basis for requiring multi-cultivar rather than single-cultivar regional trials. Where chilling is insufficient, the symptom is not simply late bud break but uneven and incomplete bud break, reduced flower number, and a reduced proportion of buds developing into fruiting laterals (Atkinson et al., 2013; Sønsteby & Heide, 2016). In a commercial planting, this presents as a plantation that establishes acceptably, looks healthy, and does not crop.

4.4. What this predicts for the Samarkand Region

Reconstructing chill accumulation for the Samarkand lowlands from the published requirement is straightforward in principle and revealing in practice. A requirement of 14 weeks at approximately −5°C is a demanding specification for any location; it is not met in the irrigated lowlands of the Zerafshan valley in an average winter. Higher-elevation sites in the foothills of the Zerafshan and Nuratau ranges will accumulate substantially more chill, and the elevation gradient within the region is therefore the most important single variable for siting.

This leads to a concrete and testable prediction, which this review offers as its principal regional hypothesis: blackcurrant cultivar performance in the Samarkand region will be governed primarily by an elevation-dependent chill gradient, with a threshold below which high-chill cultivars fail to crop reliably regardless of irrigation, fertilization or shading. The prediction is falsifiable, and the trial design proposed in Section 10.2 is intended to test it.

The literature supports two mitigation routes. The first is genotype: low-chill cultivars such as 'Ben Gairn' were bred for exactly this problem (Atkinson et al., 2013; Jones et al., 2015), and the native Central Asian taxa of may carry further low-chill variation, though this is untested. The second is chemical dormancy-breaking agents, widely used in warm-winter stone fruit and grape production; their efficacy in *Ribes* has not been systematically evaluated and represents a discrete, tractable research opportunity.

Soil salinity is classified by electrical conductivity of the saturation extract (ECe, dS/m) from non-saline (<2) to very strongly saline (>16); supplementary layers show soil texture, soil moisture, and organic-matter content across the region, with an integrated soil–salinity layer (inset) combining these variables. This spatial heterogeneity highlights the need for site-specific soil assessment before *establishing Ribes cultivation trials*, rather than treating the region as edaphically uniform (Fig. 5).

5. PROPAGATION SYSTEMS

5.1. Framing Propagation is the Tractable Constraint

Unlike dormancy, propagation is a problem with known solutions. The relevant question for the Samarkand region is not whether *Ribes* can be propagated but which system delivers certified, disease-free material at the scale and cost that a developing sector requires, under conditions of high evaporative demand.

5.2. Conventional Vegetative Propagation

Hardwood cuttings. Cuttings of 15–25 cm taken from dormant one-year-old wood in late autumn or winter remain the default commercial method for *Ribes*, because the crop roots readily, the operation requires no controlled environment, and unit cost is low (Hummer & Dale, 2010; Sedlák & Paprštein, 2012). Rooting percentages above 80% are routinely achieved on free-draining substrates, with indole-3-butyric acid (IBA) improving both rooting percentage and root system architecture.

Two limitations matter regionally. The first is that a hardwood cutting bed must be kept continuously moist through a period when, in a semi-arid region, evaporative demand is high and irrigation water is contested; this shifts the economics relative to a maritime climate. The second, and more serious, is sanitary: hardwood cuttings faithfully propagate the mother plant's sanitary status, including latent virus infection, and in a sector without a certification scheme this is the principal mechanism by which reversion disease becomes established (Section 5.5).

Softwood cuttings. Softwood cuttings taken from actively growing shoots in late spring root faster and can produce a saleable plant within one season, but require mist or fog and shading to prevent desiccation (Sedlák & Paprštein, 2012; Dziedzic & Jagła, 2013). Under Samarkand summer conditions, the humidity and temperature control required is effectively a protected-structure operation, which changes the cost basis considerably.

Citation: Nurkosimova, R., Tashpulatov, Y., Rakhmonov, Z., Tairov, D., Bakhieva, L., Aytbayeva, K., Kobulova, B., Makhmudova, M., Sindorov, A., & Bobokandov, N. (2026). Growth, propagation and phytochemistry of *Ribes* L. cultivars under semi-arid continental conditions: A systematic search review with implications for Samarkand, Uzbekistan. Agrobiological Records, 26, 330-353. https://doi.org/10.47278/journal.abr/2026.105

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Layering. Layering gives high survival and genetic uniformity but is labour-intensive and space-demanding, and it does not scale (Hummer & Dale, 2010). Its remaining role is in small nurseries and in the maintenance of accessions.

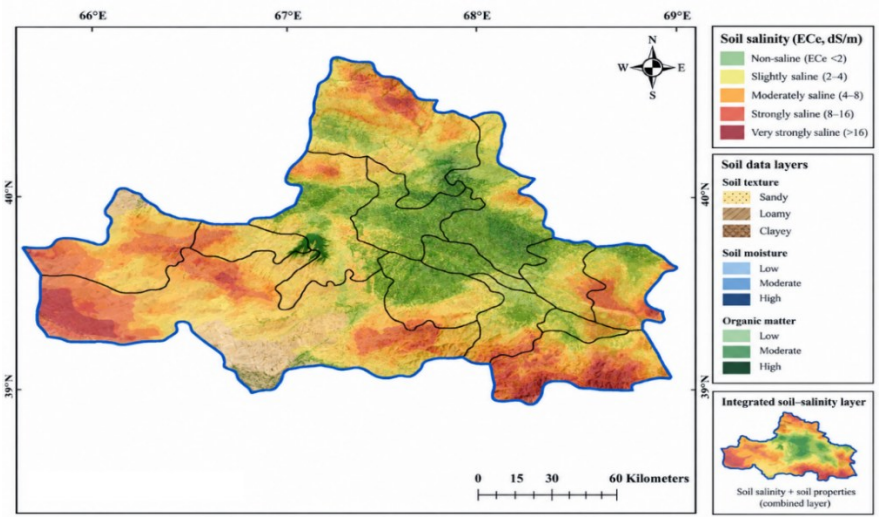

Fig. 5: Soil salinity and associated edaphic properties of the Samarkand region, Uzbekistan.

5.3. *In vitro* Propagation

Micropropagation of *Ribes* is well established, and the protocols are stable enough to be treated as reference procedures rather than research questions (Erst & Vechernina, 2010; Dziedzic & Jagła, 2013). Cultures are initiated from shoot tips, meristems or dormant buds on Murashige and Skoog medium (Murashige & Skoog, 1962) supplemented with approximately 2.0 mg L^{-1} benzyladenine, 0.5 mg L^{-1} IBA and 0.1 mg L^{-1} GA_3; after stabilisation over three to four weeks, multiplication proceeds on 1.0 mg L^{-1} BA with 0.1 mg L^{-1} IBA, and rooting on 1.0 mg L^{-1} IBA (Dziedzic & Jagła, 2013).

Genotype effects are substantial and are the main source of variation between reports. Brennan et al. (1989) assessed in vitro multiplication rates across fourteen blackcurrant cultivars and found differences large enough to affect protocol economics; Orlikowska et al. (1991) reported comparable genotype dependence across nine genotypes. Red currant cultivars have generally proved more recalcitrant at establishment than blackcurrant, though Sedlák and Paprštein (2012) developed effective establishment and proliferation protocols for red currant specifically. *R. aureum* has its own established protocol (Erst & Vechernina, 2010), and protocols for gooseberry (*R. uva-crispa*) were developed early and remain serviceable (Welander, 1985). Where a newly released cultivar must be multiplied rapidly, micropropagation has been shown to be the fastest route, although success is not uniform: in a comparative study, a blackberry cultivar was multiplied successfully while a blackcurrant cultivar from the same program required further protocol optimization (Ružić & Lazić, 2006) a reminder that a published protocol is a starting point for a new genotype rather than a guarantee. Reported explant viability at establishment varies widely with sterilization regime; the *R. janczewskii* conservation protocol achieved up to 73.3% viability using hydrogen peroxide surface sterilization (Tussipkan et al., 2024).

Acclimatization is the stage at which regional conditions bite hardest. Reported ex vitro survival of 70–90% under optimized protocols (Erst & Vechernina, 2010; Dziedzic & Jagła, 2013) assumes a controlled hardening environment with stepwise humidity reduction. Under high vapour pressure deficit, plantlets with poorly developed cuticles and non-functional stomata lose water faster than the root system can replace it, and survival falls. This is a solvable engineering problem, but it must be budgeted for, not assumed.

5.4. Cryopreservation and Germplasm Conservation

For a region proposing to work with native germplasm, conservation methods matter. Droplet vitrification of in vitro material using a modified PVS2 protocol has been validated for a diversity of blackcurrant accessions, with three of four test accessions recovering at 89–97% and one recalcitrant line at 25% (Reed et al., 2001). Cryopreservation of dormant buds provides an alternative route with lower in vitro infrastructure requirements: buds of cv. 'Mortti' cooled at 0.17°C min^{-1} to −38°C and stored in liquid nitrogen vapour recovered at 86% for field-grown and 66% for greenhouse-grown material, and recovered plants subsequently fruited normally in the field (Edesi et al., 2019). Slow-growth storage protocols developed for *R. janczewskii* offer a lower-cost medium-term option (Tussipkan et al., 2024).

Citation: Nurkosimova, R., Tashpulatov, Y., Rakhmonov, Z., Tairov, D., Bakhieva, L., Aytbayeva, K., Kobulova, B., Makhmudova, M., Sindorov, A., & Bobokandov, N. (2026). Growth, propagation and phytochemistry of *Ribes* L. cultivars under semi-arid continental conditions: A systematic search review with implications for Samarkand, Uzbekistan. Agrobiological Records, 26, 330-353. https://doi.org/10.47278/journal.abr/2026.105

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5.5. The Sanitary Dimension

No discussion of *Ribes* propagation is complete without the reversion complex, and its omission from regional planning documents is a substantive risk.

Blackcurrant reversion virus (BRV) is a nepovirus, the first identified mite-transmitted member of its genus, transmitted by the eriophyid gall mite *Cecidophyopsis ribis* and by grafting or propagation from infected material (Susi, 2004; Moročko-Bičevska et al., 2022). It is not seed- or pollen-transmitted, and mechanical inoculation by sap generally fails (Moročko-Bičevska et al., 2022). Three hours of mite feeding is sufficient for transmission, and all mite development stages transmit (Moročko-Bičevska et al., 2022). Infected plants become more attractive to mites through reduced trichome density on stipules and petioles, creating a positive feedback (Moročko-Bičevska et al., 2022).

The economic consequence is severe and cultivar-dependent (Fig. 8). Yield reductions of up to 50% after four years and approximately 75% after six years have been reported for the susceptible 'Ben Lomond', with 'Titania' considerably less affected (Pluta et al., 2000; Špak et al., 2021). A single galled bud may contain up to 35 000 mites and an infested bush frequently carries more than 100 galls (Špak et al., 2021). Critically, above roughly 5% incidence in a crop there is no economically feasible control strategy (Špak et al., 2021). In New Zealand, reversion drove many growers out of the crop entirely (Špak et al., 2021).

For a sector being established from scratch, this is an opportunity rather than only a threat. A region with no existing *Ribes* plantations has no established BRV reservoir. Establishing certified propagation before commercial planting — following the EPPO certification framework for pathogen-tested *Ribes* material (EPPO, 2008) — is far cheaper than remediating an infected sector afterwards, and it is the single highest-return policy intervention identified in this review. Resistant germplasm exists: 'Ben Hope' and several advanced genotypes carry high levels of gall mite resistance, and resistance genes are available in *R. uva-crispa*, *R. dikuscha* and *R. nigrum* var. *sibiricum* (Brennan et al., 1992; Pluta et al., 2000).

Fig. 7 quantifies the risk. The point that carries the policy weight is not the magnitude of the yield loss, severe though it is, but the shape of the control-feasibility curve: the transition from manageable to unmanageable is abrupt and occurs at a low incidence. A sector that begins monitoring only once symptoms are conspicuous will already be past it.

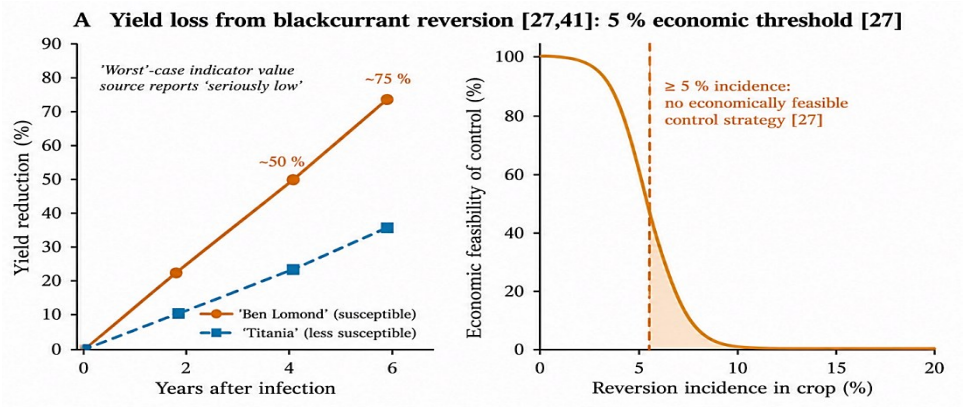

Fig. 7: Economic consequences of blackcurrant reversion disease.

Note. Panel A: cumulative yield reduction in infected plantings. Values for 'Ben Lomond' are as reported — approximately 50% after four years and 75% after six (Pluta et al., 2000; Špak et al., 2021). The 'Titania' trajectory is indicative only: the cited sources establish that this cultivar is markedly less affected but do not give a comparable time series, and the points shown should be replaced or removed if a source with quantitative data for a tolerant cultivar is located. This is stated in the caption rather than left implicit because presenting an indicative curve alongside a measured one without distinguishing them would be misleading. Panel B: schematic representation of the economic feasibility of control as a function of disease incidence, drawn to illustrate the threshold reported in the literature — above approximately 5% incidence no economically feasible control strategy exists (Špak et al., 2021). The curve shape is illustrative; the 5% threshold and the qualitative conclusion are from the source.

5.6. Quantitative Comparison of Propagation Systems

Fig. 7 assembles the reported performance figures across the literature. Two things follow from the comparison. The first is that success rates at every individual stage are high and broadly similar — the systems do not differ greatly in whether they work. Second, they differ by more than two orders of magnitude in throughput. A single mother plant

Citation: Nurkosimova, R., Tashpulatov, Y., Rakhmonov, Z., Tairov, D., Bakhieva, L., Aytbayeva, K., Kobulova, B., Makhmudova, M., Sindorov, A., & Bobokandov, N. (2026). Growth, propagation and phytochemistry of *Ribes* L. cultivars under semi-arid continental conditions: A systematic search review with implications for Samarkand, Uzbekistan. Agrobiological Records, 26, 330-353. https://doi.org/10.47278/journal.abr/2026.105

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yields about ten plants per year through hardwood cuttings and thousands through in vitro culture at the reported multiplication rates. For a region establishing a sector from a small quantity of imported certified material, throughput rather than success rate is the binding constraint, and this is the quantitative case for in vitro propagation of foundation stock.

The one genuine outlier in the success data is the recalcitrant cryopreservation line reported by Reed et al. (2001), recovering at 25% against 89–97% for the other three accessions tested. Genotype-specific recalcitrance of this magnitude is a standing risk in any conservation program and argues for testing accessions individually rather than assuming a protocol transfers.

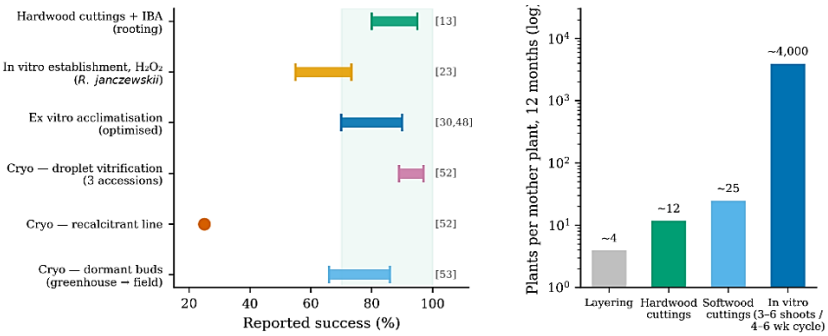

Fig. 8: Quantitative comparison of *Ribes* propagation and conservation systems.

Note. Panel A: reported success rates by propagation or conservation stage. Bars span the range reported in the cited source; where a single value was reported, it is shown as a point. The shaded band marks the 70–100% region conventionally regarded as operationally acceptable. All values were obtained under Cfb or Dfb conditions and, for the acclimatization stage in particular, should be treated as upper bounds for a high vapour pressure deficit environment. Panel B: approximate number of plants obtainable from one mother plant in twelve months, on a logarithmic axis, calculated from the multiplication rates reported in the cited sources; conventional-propagation values assume standard nursery practice and the in vitro value assumes a 3–6 shoot per explant cycle repeated at four-to-six week intervals with no losses, so it represents a theoretical ceiling rather than a commercial expectation. The purpose of the panel is to show the order-of-magnitude difference, which is robust to the assumptions, rather than to provide a precise Fig. 8.

6. FRUIT PHYTOCHEMISTRY AND BIOACTIVITY

6.1. Composition of the Blackcurrant Berry

Comprehensive profiling has identified 63 compounds in blackcurrant berries: 15 anthocyanins, 19 flavonols, 4 flavan-3-ols, 14 phenolic acid derivatives, 4 organic acids and 6 sugars (Tian et al., 2019). The anthocyanin fraction is dominated by delphinidin-3-*O*-rutinoside and cyanidin-3-*O*-rutinoside, which together with delphinidin-3-*O*-glucoside and cyanidin-3-*O*-glucoside account for the large majority of the total; the same study identified petunidin, pelargonidin, peonidin and malvidin glycosides as minor components not previously reported (Tian et al., 2019). Across genotypes, delphinidins constitute 42–64% and cyanidins 32–54% of the total anthocyanin pool, with a rutinoside-to-glucoside ratio between 3:1 and 9:1 (Laaksonen et al., 2023; Slimestad & Solheim, 2002). Flavonol composition is more variable between cultivars than anthocyanin composition, and green-fruited cultivars lack several flavonols present in black-fruited types (Tian et al., 2019).

Total anthocyanin content across 21 European cultivars grown at a single Finnish site spanned 904–4 595 μg g^{-1} of berries — a fivefold genotypic range under identical environmental conditions (Laaksonen et al., 2023). Organic acids are principally malic, citric and quinic; sugars are fructose, glucose and sucrose (Tian et al., 2019). Vitamin C is about threefold higher in black than in red currants (Tian et al., 2019), and blackcurrant leaves and buds have distinct flavonol glycoside profiles of pharmaceutical interest (Vagiri et al., 2015; Yang et al., 2015). Placed against the wider berry pool, blackcurrant sits at or near the top for both phenolic content and antioxidant capacity in comparative surveys of Scandinavian and cultivated berry species (Kähkönen et al., 2001; Mikulic-Petkovsek et al., 2012; Määttä-Riihinen et al., 2004), and among Finnish dietary sources it is one of the principal contributors of anthocyanin intake (Koponen et al., 2007). These positions are retained through processing: commercial European blackcurrant juice products remain substantial sources of polyphenols and vitamin C, though variation between products is wide and traceable to raw material and processing regime (Mattila et al., 2011).

Citation: Nurkosimova, R., Tashpulatov, Y., Rakhmonov, Z., Tairov, D., Bakhieva, L., Aytbayeva, K., Kobulova, B., Makhmudova, M., Sindorov, A., & Bobokandov, N. (2026). Growth, propagation and phytochemistry of *Ribes* L. cultivars under semi-arid continental conditions: A systematic search review with implications for Samarkand, Uzbekistan. Agrobiological Records, 26, 330-353. https://doi.org/10.47278/journal.abr/2026.105

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Red currant differs systematically, not just quantitatively: lower anthocyanin, higher flavonol and organic acid, and a lighter pigment profile (Miladinović et al., 2021; Ștefănescu et al., 2025). For a region selecting a crop, this is a genuine choice rather than a ranking, because the two species serve different markets.

6.2. Analytical Approaches and the Comparability Problem

Total phenolic content is conventionally determined by the Folin–Ciocalteu procedure (Singleton et al., 1999) and total monomeric anthocyanin by the pH-differential method (Giusti & Wrolstad, 2001), with antioxidant capacity assessed by DPPH (Brand-Williams et al., 1995), FRAP or ABTS. Individual compound quantification requires HPLC–DAD or HPLC–MS (Gavrilova et al., 2011; Tian et al., 2019; Miladinović et al., 2021), and untargeted metabolomics by HPLC–PDA–MS has been applied to blackcurrant with good agreement against targeted analysis for the abundant anthocyanins (r = 0.968) (Allwood et al., 2019).

A caution that bears on any regional comparison: the reported Fig. 9 for "total phenolics" depends substantially on extraction solvent, hydrolysis conditions and calibration standard, and cross-study comparison of absolute values without method harmonization is unreliable. Optimized and validated extraction procedures covering buds, leaves and fruit of blackcurrant exist (Vagiri et al., 2012) and should be adopted at the outset by any group intending its data to be comparable with the international literature; the same laboratory's work on bud phenolics illustrates how much the answer depends on tissue and ontogenetic stage (Vagiri et al., 2015). Production system is a further source of variation that is easily confounded with environment: HPLC comparison of conventionally and organically grown blackcurrant found measurable differences in the phenolic profile (Anttonen & Karjalainen, 2006), so any regional comparison must hold management constant or report it. This is not a minor procedural point; it is the reason a substantial fraction of the regional literature cannot currently be integrated with the international dataset, and it is a specific recommendation of Section 10.2.

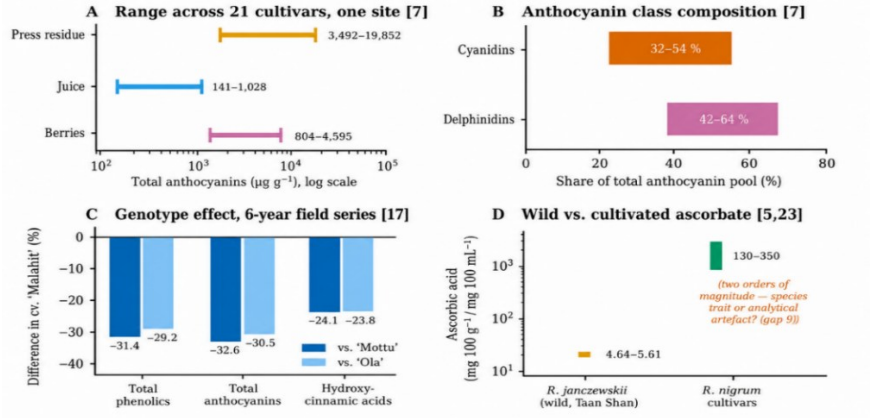

Fig. 9: Genotypic variation in Ribes fruit composition.

Note. Panel A: total anthocyanin concentration in berries, pressed juice and press residue across 21 cultivars of European origin grown at a single Finnish site, on a logarithmic axis (Laaksonen et al., 2023). The comparison is informative because the site is common to all cultivars, so the range is genotypic rather than environmental; the very high residue concentrations also indicate that press residue is a concentrated by-product stream rather than a waste. Panel B: share of delphinidin and cyanidin derivatives in the total anthocyanin pool across the same cultivar set (Laaksonen et al., 2023). Panel C: percentage difference in cv. 'Melalahti' relative to cvs 'Mortti' and 'Ola' for three compound classes, from a six-year field series in Finland (Zheng et al., 2012); all differences are negative, meaning 'Melalahti' was consistently the lowest of the three. Panel D: ascorbic acid concentration in wild *R. janczewskii* fruit (Tussipkan et al., 2024) against the range reported for cultivated *R. nigrum* juice (Allwood et al., 2019; Brennan & Graham, 2009), on a logarithmic axis. The units are not identical — mg 100 g^{-1} fresh fruit against mg 100 mL^{-1} juice — and this is stated explicitly because the difference cannot be resolved from the published data; the comparison is shown precisely to identify it as an open question (research question 9, Section 10.1) rather than to assert a species-level trait.

6.3. Genotype, Environment and the Direction of the Temperature Response

This is the section where regional expectation and international evidence most sharply diverge, and it is treated at length because the divergence is consequential.

6.3.1. Genotype: Genotypic variation is large (Fig. 9). The fivefold range in total anthocyanin among 21 cultivars at

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one site (Laaksonen et al., 2023) and the 29–33% differences in total phenolics, anthocyanins and hydroxycinnamic acids among three Finnish cultivars across a six-year series (Zheng et al., 2012) both establish that cultivar choice is the largest single controllable determinant of berry chemistry.

6.3.2. Temperature: The direction of the temperature effect is consistent across independent experimental systems and is negative. Controlled post-flowering temperature experiments on four cultivars of contrasting origin found that ascorbic acid concentration decreased as temperature rose from 12 to 24°C, while the optimum for total anthocyanins and total phenolics was approximately 18°C (Woznicki et al., 2016; Pott et al., 2023). Metabolomic analysis of 'Narve Viking' under controlled conditions confirmed a negative effect of 24°C on delphinidin-3-*O*-rutinoside, cyanidin-3-*O*-rutinoside and quercetin derivatives (Allwood et al., 2019). Ascorbate pool composition, sugars and organic acids were all strongly influenced by post-flowering temperature as well as by genotype (Woznicki et al., 2017). Multi-year field data agree: an eight-year series across Scottish and Norwegian cultivars concluded that cool summer conditions with abundant precipitation favor both yield and the accumulation of phenolics, anthocyanins and ascorbic acid (Woznicki et al., 2015). A multi-environment study across seasons and genotypes found that high temperatures in the two weeks before harvest reduced phenolic acid content and increased proacacipetalin, a cyanogenic glycoside (Pott et al., 2023).

6.3.3. Radiation: Radiation acts in the opposite direction to temperature. Anthocyanin concentrations were markedly higher in fruit grown outdoors under natural radiation than under controlled-environment lighting (Allwood et al., 2019), and photoperiod influences total monomeric anthocyanin independently of temperature (Woznicki et al., 2016). In a semi-arid region, high radiation and high temperature arrive together, and the net effect is therefore not predictable from either factor alone. This is an empirical question, and Section 7.2 sets out why the common assumption of a net positive effect is not justified.

6.3.4. Water: Drought stress reduces cumulative evapotranspiration through stomatal closure and reduced leaf area, and alters gene expression and metabolite profiles extensively (Čereković et al., 2013; Ziegler et al., 2025). Whether moderate deficit irrigation can be used to raise secondary metabolite concentration in *Ribes*, as it can in some other fruit crops, has not been established for this genus, and the practice should not be recommended on the basis of analogy.

6.3.5. Other Factors: Crop load affects composition: a larger crop load reduced sugar content, raised acid content and raised anthocyanin and flavonol content, while total phenolic content was unaffected (Tian et al., 2019). Cultivar, yield, berry weight, temperature and ripening stage jointly determine the bioactive profile (Krüger et al., 2011), and preharvest and postharvest factors together govern final vitamin C content (Lee & Kader, 2000; Walker et al., 2010). Physicochemical characterization of sixteen cultivars grown in Saskatchewan — a continental site with hot summers and very cold winters — provides one of the few cultivar comparisons from outside the maritime and Nordic envelope and is a useful benchmark for what genotypic variation looks like under continental conditions (Zatylny et al., 2005). Nutrient management interacts with all of this. Controlled trickle-fertigation experiments on single-stemmed black currant plants showed that autumn fertilization after harvest enhanced flowering and berry yield, whereas fertilization during fruit development raised yield but reduced fruit quality (Sønsteby et al., 2017) so balanced supply is a prerequisite rather than an enhancement strategy, and its timing matters as much as its rate.

6.4. Bioactivity and the Health Literature

The bioactivity literature is extensive and is summarized here only insofar as it establishes the value proposition for the raw material. Blackcurrant anthocyanins and their gut-derived metabolites have been examined in randomized controlled trials for vascular function, blood lipids, inflammatory and oxidative stress markers, cognition and exercise performance (Gopalan et al., 2012; Wallace & Giusti, 2015; Braakhuis et al., 2020; Xu et al., 2021; Willems et al., 2022). Anthocyanin intake is inversely associated with cardiovascular risk in prospective cohorts (Kimble et al., 2019), and a minimum intake of around 80 mg d^{-1} from dark berries has been suggested for cardiometabolic benefit in at-risk groups (Wallace & Giusti, 2015). Systematic reviews of cognitive endpoints report benefits that are suggestive but not consistently significant in meta-analysis (Ellis et al., 2024), and the sport-nutrition literature reports effects on substrate oxidation and cardiovascular function during exercise (Braakhuis et al., 2020; Willems et al., 2022). Blackcurrant polyphenols also show antimicrobial activity, with cultivar-dependent differences: 'Ben Lomond' juice showed the strongest antimicrobial activity in a comparative study, while other cultivars led on anthocyanin content or antiradical capacity (Määttä-Riihinen et al., 2004; Petruskevicius et al., 2023).

Two points follow for a producing region. First, market value attaches to a defined anthocyanin concentration, not to the fruit as such, meaning a regional product with systematically depressed anthocyanin content is not merely a lower-quality version of the same commodity but a different and less valuable one. Second, cultivar-specific bioactivity differences (Määttä-Riihinen et al., 2004; Petruskevicius et al., 2023) mean that cultivar selection for a nutraceutical market cannot be delegated to yield performance.

Citation: Nurkosimova, R., Tashpulatov, Y., Rakhmonov, Z., Tairov, D., Bakhieva, L., Aytbayeva, K., Kobulova, B., Makhmudova, M., Sindorov, A., & Bobokandov, N. (2026). Growth, propagation and phytochemistry of *Ribes* L. cultivars under semi-arid continental conditions: A systematic search review with implications for Samarkand, Uzbekistan. Agrobiological Records, 26, 330-353. https://doi.org/10.47278/journal.abr/2026.105

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7. THREE CONTRADICTIONS BETWEEN REGIONAL EXPECTATION AND INTERNATIONAL EVIDENCE

The preceding sections contain three points where widely held regional assumptions are not supported by the published data. Because these assumptions currently inform planning, this section addresses them directly.

7.1. Currants are Hardy, so a Continental Climate Suits Them

The reasoning conflates frost hardiness with climatic suitability. Blackcurrant is indeed frost-hardy in the dormant state, and its wood tolerates deep winter cold (Sønsteby & Heide, 2014; Pagter et al., 2015). But hardiness and chilling requirement are distinct traits, and the crop's problem in a continental semi-arid region is not that winters are too cold — it is that they are not cold enough for long enough (Atkinson et al., 2013; Sønsteby & Heide, 2014; Jones et al., 2015). A plant may be entirely undamaged by a Samarkand winter and still fail to break bud properly the following spring. Frost damage is also a real risk, but it operates in spring on advanced buds rather than in winter on dormant wood (Brennan, 1991), and mitigation for the two is different.

The practical resolution is that "hardiness" should be dropped from the regional case for the crop and replaced by a measured chill-accumulation assessment at candidate sites, using a chill model validated for *Ribes* rather than one transferred from stone fruit (Luedeling, 2012; Jones et al., 2015).

7.2. High Solar Radiation in Semi-Arid Regions will Increase Anthocyanin Content

This assumption appears frequently and has a plausible mechanistic basis: radiation induces anthocyanin biosynthesis, and outdoor-grown fruit contains more anthocyanin than fruit grown under artificial light (Allwood et al., 2019). The difficulty is that in a semi-arid continental region, high radiation is inseparable from high temperature, and temperature affects anthocyanin in this crop negatively and is well documented across independent experimental systems (Woznicki et al., 2015, 2016; Allwood et al., 2019; Pott et al., 2023). The optimum for total anthocyanin and total phenolics lies near 18°C (Woznicki et al., 2016; Pott et al., 2023) a Samarkand growing season sits far above it.

The honest position is that the net effect is unknown, that the balance of evidence points against a benefit, and that a common-garden comparison could resolve the question. Until such data exist, the claim that semi-arid conditions enhance current antioxidant content should not appear in regional literature. Where it does appear, it is generally supported by citations to studies on radiation effects in cool climates, which do not address the confounded case.

A secondary consideration reinforces this. High pre-harvest temperature increased proacacipetalin, a cyanogenic glycoside associated with bitterness (Pott et al., 2023). A hot-climate blackcurrant may therefore be not only lower in anthocyanin but also less palatable, which is a food-quality issue rather than a nutritional one. Because the or sensory profile of blackcurrant juice is determined by a specific combination of acids, sugars and phenolics rather than by any single compound (Sandell et al., 2009), sensory evaluation should be built into regional cultivar trials from the beginning rather than added once a compositional problem is suspected.

A further, largely untested possibility is that genotypes selected for low chilling requirement may also differ in their thermal and radiation sensitivity of anthocyanin biosynthesis, since the physiological pathways controlling dormancy release and those controlling temperature-dependent flavonoid accumulation are not known to be independent. If low-chill germplasm such as 'Ben Gairn' proves more heat-tolerant in fruit chemistry as well as in dormancy, it would be the single most useful genotype class for the region; if the two traits are unlinked or negatively correlated, cultivar choice for Samarkand becomes a trade-off rather than a single optimum. This has not been tested in any cultivar and is listed as a priority in Section 10.1.

7.3. Deficit irrigation will raise Secondary Metabolite Content

Moderate water deficit raises phenolic concentration in several fruit crops, and this principle is well established in viticulture. It has not been demonstrated in *Ribes*. The available drought work in blackcurrant describes stomatal closure, reduced leaf area, reduced cumulative evapotranspiration and extensive transcriptomic reprogramming (Čereković et al., 2013; Ziegler et al., 2025), but does not establish a net positive effect on berry anthocyanin or ascorbate, and the concentration effects of reduced berry size must be distinguished from genuine changes in biosynthesis on a per-berry basis.

Given that blackcurrant is a shallow-rooted crop with high water demand during fruit development, and that yield reductions under water stress are substantial, recommending deficit irrigation as a quality strategy in a water-scarce region based on analogies with other crops is not currently defensible. This is a discrete, well-defined experiment that has not been done.

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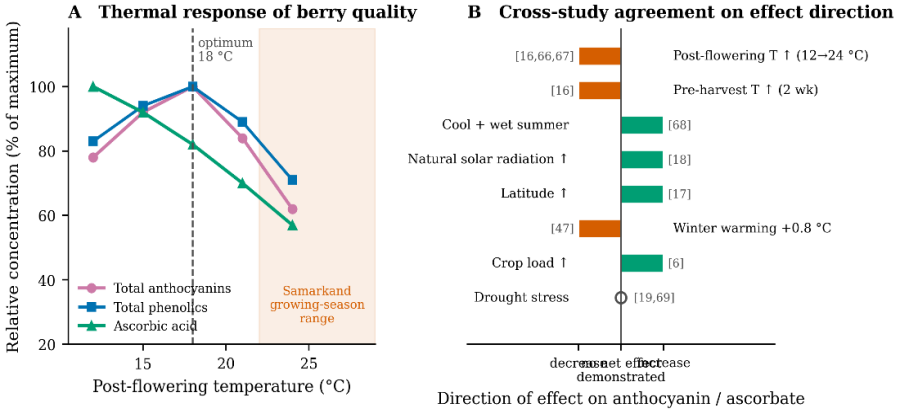

Fig. 10: Thermal response of *Ribes nigrum* berry quality and cross-study agreement on the direction of environmental effects.

Note. Panel A: relative concentration of total anthocyanins, total phenolics and ascorbic acid as a function of post-flowering temperature, expressed as a percentage of the maximum observed for each variable. The curve shapes, the position of the optimum at approximately 18°C for anthocyanins and phenolics, and the monotonic decline of ascorbic acid across the 12–24°C range are as reported (Woznicki et al., 2016, 2017; Pott et al., 2023), and are corroborated for the individual rutinosides by metabolomics analysis of cv. 'Narve Viking' (Allwood et al., 2019). Absolute values were not recoverable from the published data; the plotted points are a normalized synthesis of the reported responses. Before submission, these should be replaced with values digitized from the source Fig. 10, or the panel should be redrawn from the original data with permission. The shaded band marks the approximate Samarkand growing-season temperature range and its position relative to the optimum is the substance of the argument in Section 7.2. Panel B: direction of effect on anthocyanin or ascorbate accumulation reported by each cited source, with the supporting reference given beside each bar. Bar direction indicates sign only; bar length is uniform and carries no quantitative meaning, because effect sizes across these studies are not commensurable. The open circle for drought stress indicates that extensive transcriptomic and metabolomic reprogramming is documented (Čereković et al., 2013; Ziegler et al., 2025) but that no net direction of effect on berry anthocyanin or ascorbate has been established.

8. THE SAMARKAND REGION: WHAT IS KNOWN, WHAT MAY TRANSFER, WHAT IS ASSUMED

8.1. What has been measured in Uzbekistan

Very little concerning *Ribes*. Floristic and biogeographic inventories document the presence of native *Ribes* taxa in the mountain systems of Uzbekistan (Pfister & Sloan, 2008; Tojibaev et al., 2014; Zhang et al., 2020; Abduraimov et al., 2023), and the wild relatives of cultivated plants have been catalogued at national scale (Abduraimov et al., 2023). Ethnobotanical surveys record traditional use of some regional species (Khojimatov et al., 2020). Agroclimatic characterisation of the arid and semi-arid zones is available (Agakhanjanz & Breckle, 1995; Gintzburger et al., 2003), as are national-scale assessments of the climate exposure of irrigated agriculture (Lioubimtseva & Henebry, 2009; Sutton et al., 2013; Altstadt et al., 2025).

What does not exist, so far as this review could establish, is any published cultivar trial, phenological record, chill-accumulation measurement, propagation trial or fruit compositional analysis for *Ribes* conducted in the Samarkand region under controlled conditions and reported with sufficient methodological detail to be assessable. Nine studies in the systematic search were assigned to the BSk envelope, and these concern Kazakh foothill germplasm conservation and regional floristics rather than cultivation.

This is stated plainly because the alternative presenting unattributed local observations as findings is the practice that makes regional literature unhittable internationally. Where local unpublished trial data exist, they should be published as primary research with full methods, not summarized in a review.

8.2. What may Transfer from Comparable Environments

Studies conducted under Dsa and Dfa envelopes are the closest available analogues. Work on *Ribes* adaptive potential and phenotypic variability in the Lower Volga region (Solomentseva, 2022) and cultivar assessments from Bashkortostan address continental conditions with hot summers, though with colder winters than Samarkand. Romanian cultivar comparisons under Dfb–Dfa conditions provide compositional benchmarks for five cultivars under warmer conditions than the Nordic baseline (Ștefănescu et al., 2025). Serbian work on juice composition and flavonol content adds to this (Miladinović et al., 2021).

These transfer partially. They share the hot-summer component of the Samarkand problem but not the warm-

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winter component, which Section 4 identifies as the primary constraint. They are therefore useful for anticipating the fruit-quality outcome and largely uninformative about the dormancy outcome.

8.3. What is Currently Assumed

Three propositions circulate regionally and should be labelled as untested hypotheses: that European cultivars will crop reliably in the Samarkand lowlands; that regional radiation will produce a compositional advantage; and that deficit irrigation offers a quality strategy. Sections 4.4, 7.2 and 7.3 respectively set out why each is doubtful and how each could be tested. A fourth assumption is more subtle. Regional planning documents generally treat "currant" as a single crop. Blackcurrant and red currant differ in chilling requirement, disease susceptibility, composition and market, and gooseberry (*R. uva-crispa*) differs from both. Species-level rather than genus-level planning is required.

9. LIMITATIONS OF THIS REVIEW

Several limitations constrain the conclusions.

Language and indexing. Although eLIBRARY.ru was searched and Russian-language sources included, Uzbek- and Kazakh-language literature published in non-indexed national journals was not systematically retrievable and is under-represented. Some relevant regional trial data may exist in institutional reports not captured by any database search.

No protocol registration and no meta-analysis. The review was not registered and the synthesis is narrative. Effect sizes across the included studies are not commensurable chilling requirements in weeks at a stated temperature, rooting percentages, anthocyanin concentrations in µg g^{-1} and pooling was not attempted. Consequently the strength of evidence is assessed qualitatively.

Single-reviewer extraction for a subset. Screening was performed independently in duplicate, but a single reviewer extracted data from Russian-language sources. The central claim is comparative, not experimental**.** The core argument of this review is that the evidence base is climatically unrepresentative of the target region. That claim is supported by the distribution in by the direction of the environmental responses in, but it remains an inference. It could be overturned by trial data showing that cultivars perform acceptably despite the predicted chill deficit, and the review is written to make that test explicit rather than to foreclose it.

10. RESEARCH GAPS AND A PROPOSED PROGRAM

10.1. Twelve Specific Questions

The gaps identified below are stated as answerable questions rather than as topic areas, on the principle that "more research is needed" is not a research gap.

1. What is the quantified chilling requirement, expressed in chill portions under a *Ribes*-validated model, of *R. janczewskii*, *R. meyeri* and *R. heterotrichum*?

Does the elevation gradient in the Samarkand region produce a threshold in bud-break percentage for high-chill blackcurrant cultivars, and at what elevation does it lie?

Do chemical dormancy-breaking agents used in warm-winter stone fruit production restore normal bud break in chill-deficient *Ribes*, and at what cost to fruit quality?

Under common-garden conditions comparing a Samarkand site with a Dfb reference site, what is the net effect of the confounded high-radiation, high-temperature regime on total anthocyanin, individual delphinidin and cyanidin rutinosides, and ascorbic acid?

Does moderate deficit irrigation raise berry anthocyanin concentration in *Ribes* on a per-berry rather than per-gram basis, and at what yield cost?

What is the delivered cost per certified plant of in vitro versus hardwood propagation under Central Asian input prices?

What acclimatisation protocol is required to achieve ex vitro survival above 85% under regional vapour pressure deficit?

Is *Cecidophyopsis ribis* present in Uzbekistan, and what is the current BRV status of any existing *Ribes* plantings?

Does the low fruit ascorbate reported for *R. janczewskii* (Tussipkan et al., 2024) reflect a species-level trait or the analytical and sampling conditions of that study?

Which of the anthocyanin-biosynthesis transcription factors identified in the blackcurrant genome (Ziegler et al., 2025) show allelic variation associated with thermostability of pigment accumulation?

Does high pre-harvest temperature raise proacacipetalin, and therefore bitterness, in cultivars grown under regional conditions to a degree detectable in sensory panels?

What is the comparative performance of red currant, which has a different chilling requirement and market, under the same regional conditions?

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10.2. A proposed Multi-Site Trial Design

A single coordinated trial can address the first four questions, which is described here in outline because the lack of such a design is the practical reason the regional evidence gap persists.

Establish three sites along the elevation gradient of the Samarkand region lowland irrigated (approximately 700 m), mid-elevation (approximately 1 100 m) and foothill (approximately 1 500 m) each instrumented with a continuously logging temperature sensor at bud height from October to April, so that chill accumulation is measured rather than modelled from a distant meteorological station. Plant a common cultivar set at each site comprising at least one high-chill cultivar ('Ben Tirran' or 'Narve Viking'), one low-chill cultivar ('Ben Gairn'), one intermediate widely grown cultivar ('Titania'), and, where material can be obtained, accessions of *R. janczewskii* and *R. meyeri*. Use five replicate blocks of five plants per cultivar per site. Record bud-break percentage on a defined node position, flowering date, and fruit set percentage, yield per bush, and berry composition by a single harmonised HPLC protocol over a minimum of four seasons, with a parallel reference sample from a collaborating Dfb-envelope institution grown from the same clonal material.

Four seasons is the minimum because the dormancy state of field-grown plants varies considerably between years, and single-season data on this question are uninterpretable (Sønsteby & Heide, 2014).

10.3. Sequencing of Interventions

If the regional sector is to develop, the ordering of investment matters more than the total. Establishing certified, indexed propagation stock before commercial planting is the highest-return intervention identified here, because reversion becomes economically uncontrollable above 5% incidence and because a region with no existing plantings currently has no reservoir (EPPO, 2008; Špak et al., 2021). Site-specific chill measurement should precede cultivar procurement, because it determines which cultivars are worth importing. Compositional benchmarking should precede any market positioning based on antioxidant content, because that positioning is currently unsupported.

11. CONCLUSION

The genus *Ribes* offers a genuinely attractive combination of compositional value, established processing markets and available propagation technology. The evidence assembled here, however, does not support the proposition that European blackcurrant cultivars and protocols can be transferred to the Samarkand lowlands and be expected to perform without local testing.

The evidence points to dormancy, rather than summer heat or water, as the primary constraint. Contrasting cultivars require 14 weeks or more at about −5°C for full dormancy release and flower development; no single chill model applies across cultivars, and warm autumn conditions raise the requirement further by deepening end dormancy. Reconstructed from published requirements, winter conditions in the irrigated lowlands are unlikely to satisfy this in most years, though no local chill-accumulation measurement yet confirms it. Should this hold, the consequence would not be a modest yield penalty but incomplete bud break and reproductive failure in plantations that otherwise appear healthy.

Regional radiation is not expected to produce a compositional advantage. The temperature response of anthocyanin and ascorbate accumulation in this crop is negative above an optimum near 18°C, shown independently in controlled-environment, metabolomics, and multi-year field studies. High radiation and high temperature are confounded in semi-arid environments; the net effect for Samarkand specifically is unknown, and the balance of transferable evidence points against benefit.

Propagation is the tractable constraint, and the one where established methods can be applied with confidence: in vitro protocols are mature, and cryopreservation and slow-growth conservation methods are validated. What remains untested is not the technique but its performance on Samarkand-adapted genotypes and under local evaporative demand. The sanitary dimension must not be deferred: blackcurrant reversion virus and its eriophyid vector become economically uncontrollable above approximately 5% incidence, and a region without existing plantations has a one-time opportunity to establish certified propagation before a reservoir forms.

Central Asian *Ribes* germplasm, *R. janczewskii* in particular, represents an underused resource with documented frost and gall mite resistance, but its chilling requirements have never been quantified. Characterizing it is both a conservation and a breeding priority.

For growers and regional planners, the practical implication is to defer commercial-scale planting of European high-chill cultivars until local performance is demonstrated, rather than to treat their suitability as established. The most urgent research priority is the elevation-stratified, multi-season, instrumented cultivar trial outlined in Section 10.2; until such data exist, cultivation recommendations for the region should be framed as hypotheses under test, and compositional claims that currently accompany them should be withdrawn.

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