**UO‘K: 635.21:631.527:577.2**

# KARTOSHKA SELEKSIYASIDA MARKERGA ASOSLANGAN SELEKSIYA (MAS) VA GENOTIPLASHNING AHAMIYATI HAMDA ISTIQBOLLARI

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**Annotatsiya:** *Maqolada kartoshka (Solanum tuberosum L.) seleksiyasida markerga asoslangan seleksiya (MAS) va genotiplashning ilmiy-metodik asoslari, amaliy samaradorligi hamda Namangan ilmiy-tajriba stansiyasi seleksiya dasturida qo‘llash imkoniyatlari tahlil qilingan. PVY (Ry_adg, Ry_sto), oltinsimon nematoda (H1, Gro1), kartoshka raki (Sen1) va PVX (Rx1) ga chidamlilik genlari uchun amalda tasdiqlangan PCR markerlari umumlashtirilgan. Markerlar seleksiya materialining 29–80 foizini erta bosqichda chiqarib tashlash, allel dozasini aniqlash esa ota-onalarni aniqroq tanlash imkonini berishi ko‘rsatilgan. Stansiyada MAS ni bosqichma-bosqich joriy etish rejasi asoslangan.*

**Kalit so‘zlar:** *kartoshka, markerga asoslangan seleksiya, genotiplash, PCR markerlar, allel dozasi, SNP, genomik seleksiya, PVY, Ry genlari.*

**Аннотация:** *В статье проанализированы научно-методические основы и практическая эффективность маркер-ориентированной селекции (МОС) и генотипирования в селекции картофеля (Solanum tuberosum L.), а также возможности их применения на Наманганской научно-опытной станции. Обобщены подтверждённые ПЦР-маркеры генов устойчивости к Y-вирусу (Ry_adg, Ry_sto), золотистой нематоде (H1, Gro1), раку (Sen1) и X-вирусу картофеля (Rx1). Показано, что маркеры позволяют отбраковать 29–80 % материала на ранних этапах, а определение дозы аллелей повышает точность подбора родителей. Обоснован поэтапный план внедрения МОС на станции.*

**Ключевые слова:** *картофель, маркер-ориентированная селекция, генотипирование, ПЦР-маркеры, доза аллеля, SNP, геномная селекция, Y-вирус картофеля, гены Ry.*

**Abstract:** *The article analyses the methodological foundations and practical efficiency of marker-assisted selection (MAS) and genotyping in potato (Solanum tuberosum L.) breeding and their application potential at the Namangan Scientific-Experimental Station. Validated PCR markers for resistance to Potato virus Y (Ry_adg,*

*Ry_sto), golden cyst nematode (H1, Gro1), potato wart (Sen1) and Potato virus X (Rx1) are summarised. Markers allow 29–80 % of breeding material to be discarded early, and allele-dosage assays improve the choice of parents. A stepwise plan for implementing MAS at the station is substantiated.*

**Keywords:** *potato, marker-assisted selection, genotyping, PCR markers, allele dosage, SNP, genomic selection, PVY, Ry genes.*

**KIRISH**

Kartoshka (Solanum tuberosum L., 2n = 4x = 48) — dunyodagi eng muhim nodon oziq-ovqat ekini: 2023-yilda uning jahon bo‘yicha yalpi hosili 383 mln tonnaga yetgan [1]. O‘zbekistonda kartoshka 253 ming gektarga ekiladi, o‘rtacha hosildorlik 163 s/ga ni tashkil etadi [2], importi esa 2017–2021-yillarda 193,6 dan 547,2 ming tonnagacha ortgan [3]. Shu sababli mahalliy sharoitga moslashgan, kasalliklarga chidamli navlar yaratish dolzarb vazifa hisoblanadi.

Madaniy kartoshka autotetraploid, yuqori geterozigotali va vegetativ ko‘payadi; genlarning dozasi fenotipga ta’sir qiladi, an’anaviy seleksiya sikli esa 10–12 yil davom etadi [4]. Markerga asoslangan seleksiya (MAS) maqsadli gen bilan birikkan DNK markeri orqali urug‘ ko‘chatlari bosqichida saralash va bir nechta chidamlilik genlarini bitta genotipda jamlash imkonini beradi [5], biroq uning iqtisodiy samarasi qo‘llash bosqichiga bog‘liq [6]. Kartoshka genomining sekvensiyalanishi [7], tetraploid navlarning gaplotiplari ajratilgan genomlari [8] va 44 ta diploid namuna asosidagi pangenom [9] yangi diagnostik markerlar yaratish uchun mustahkam asos bo‘ldi.

Maqolaning maqsadi — kartoshka seleksiyasida amalda tasdiqlangan markerlar va genotiplash platformalarini tahlil qilish hamda Sabzavot, poliz ekinlari va kartoshkachilik ilmiy-tadqiqot instituti Namangan ilmiy-tajriba stansiyasi dasturida ularni joriy etish imkoniyatlarini asoslash.

Tadqiqot materiallari va usullari. Tadqiqot ob’ekti — Namangan ilmiy-tajriba stansiyasining kartoshka seleksiyasi va urug‘chiligi dasturidagi navlar kolleksiyasi va istiqbolli seleksiya namunalari. Farg‘ona vodiysining yozgi yuqori harorati sharoitida urug‘lik kartoshkaning viruslar bilan zararlanishi bu yerda asosiy muammolardan biridir. Ishda 1997–2026-yillarda Web of Science, Scopus va Google Scholar bazalarida chop etilgan, markerning seleksiya materialida amaliy tekshirilganligi to‘g‘risida miqdoriy ma’lumot keltirilgan manbalar qiyosiy-tahliliy usulda o‘rganildi.

MAS ish jarayoni quyidagi bosqichlardan iborat (1-rasm): (1) markerni tanlash va o‘z materialida fenotip bilan qayta tekshirish (validatsiya); (2) ota-onalarni genotiplash va allel dozasini aniqlash; (3) chatishtirish; (4) urug‘ ko‘chatlari yoki klon avlodlarida PCR tahlili; (5) marker-ijobiy genotiplarni dala sinovlarida baholash. Markerning diagnostik samaradorligi ijobiy bashorat qiymati (PPV) va sezgirlik orqali baholanadi. Tetraploid kartoshkada allel dozasi — nullipleks (rrrr), simpleks (Rrrr), dupleks (RRrr), tripleks (RRRr) va kvadrupleks (RRRR) holatlari ham aniqlanadi:

simpleks ota-ona chidamlilikni avlodning taxminan yarmiga, tripleks va kvadrupleks ota-ona esa barcha avlodga o‘tkazadi.

Natijalar va ularning tahlili

MAS seleksiya sikli. 1-rasmdagi sikldan ko‘rinadiki, MAS da saralash fenotip sinovlaridan oldin amalga oshiriladi va dala sinovlariga faqat maqsadli genni tashuvchi genotiplar o‘tadi. Iqtisodiy tahlilga ko‘ra, MAS ni ikkinchi klon avlodida qo‘llash barcha seleksiya modellarida samarali [6].

1-rasm. Kartoshka seleksiyasida markerga asoslangan seleksiya sikli

Chidamlilik markerlari. MAS ning eng muvaffaqiyatli qo‘llanish sohasi — yirik ta’sirli chidamlilik genlari (1-jadval).

1-jadval

Kartoshka seleksiyasida amalda tekshirilgan chidamlilik markerlari

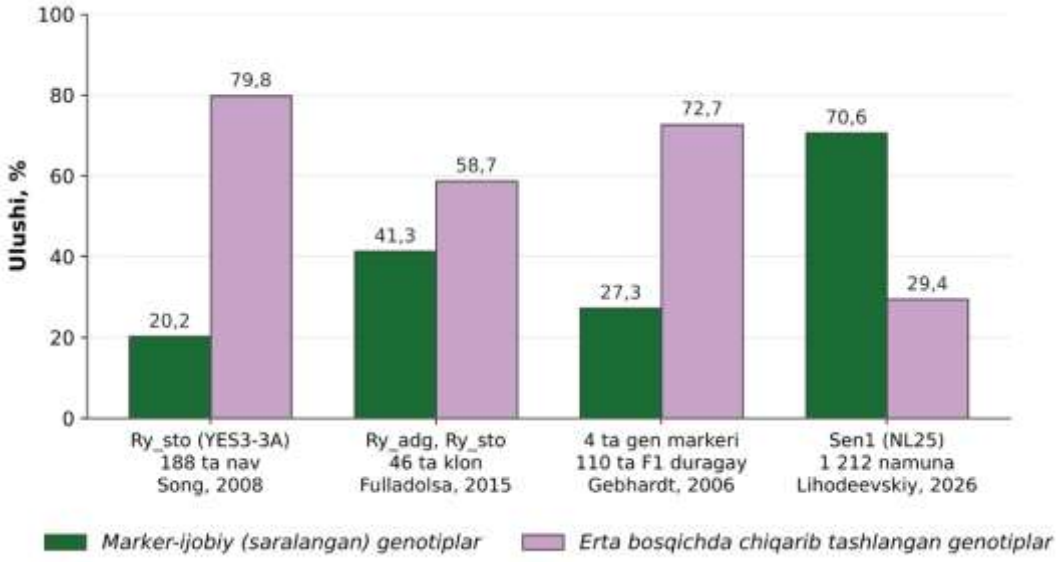
| Gen | Belgi (patogen) | Xromo-soma | Marker (turi) | Amaliy tekshiruv natijasi |
|---|---|---|---|---|
| Ry_adg | PVY ga o‘ta chidamlilik | XI | RYSC3, M45, M6 (SCAR, CAPS) | Multipleks PCR 6 521 ta avlodda sinalgan; HRM doza testi [10, 4] |
| Ry_sto | PVY ga o‘ta chidamlilik | XII | YES3-3A, YES3-3B (STS) | 188 ta navdan barcha 38 ta o‘ta chidamli nav aniqlangan [11] |
| Gro1, Rx1 | Nematoda, PVX | VII, XII | Gen asosidagi PCR | Ry_adg bilan bitta genotipda jamlangan [12] |
| H1 | Oltinsimon nematoda (Ro1) | V | TG689, N195 (SCAR) | 1 212 namunada yuqori diagnostik qiymat [13] |
| Sen1 | Kartoshka raki (1-patotip) | XI | NL25 (SCAR) | PPV = 98,54 %, imkoniyat nisbati 48,75 [13] |

Ispaniyaning Appacale kompaniyasi RYSC3 markerini 1998-yildan beri amaliy seleksiyada qo‘llaydi [14], Oregon dasturida esa RYSC3 va ADG2 markerlari PVY ga chidamli klonlarni aniqlash vositasi sifatida tasdiqlangan [10].

Viskonsin universitetida RYSC3 va YES3-3B markerlari bilan 46 ta klondan 19 tasi chidamli deb topilgan [15].

Gebhardt va hamkasblari 110 ta F1 duragaydan maqbul marker kombinatsiyasiga ega 30 ta o‘simlikni tanlab, Ry_adg genini Gro1 va Rx1 bilan birlashtirgan [12].

Ural mintaqasida 2018–2025-yillarda 1 212 ta namuna 12 ta SCAR markeri bilan genotiplangan, ularning 70,6 foizida rak kasalligiga chidamlilik aniqlangan [13].




2-rasm. Marker yordamida saralangan va erta chiqarib tashlangan genotiplar ulushi

2-rasmdan ko‘rinadiki, markerlar materialning 29,4–79,8 foizini dala sinovlaridan oldin chiqarib tashlash imkonini beradi; bu ulush boshlang‘ich materialdagi chidamlilik manbalari chastotasiga bog‘liq.

Biroq marker va gen orasidagi bog‘lanish mutlaq emas: RYSC3 ning «chidamli» alleli PVY ga sezgir A6 klonida ham topilgan [4].

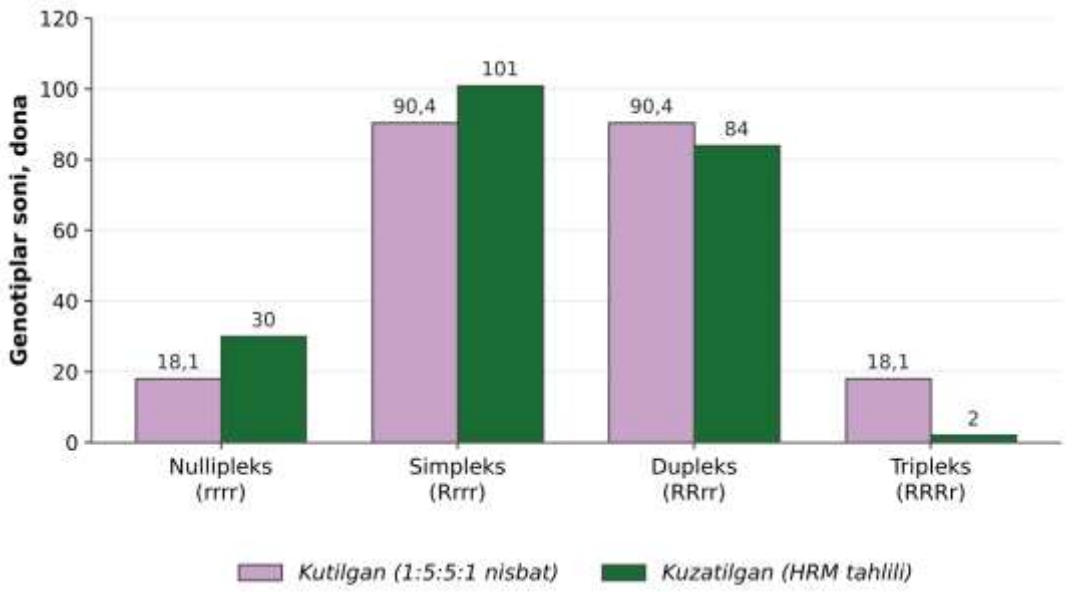
Shu sababli har bir marker o‘z materialida qayta tekshirilishi zarur.

Allel dozasini aniqlash. Xalqaro kartoshka markazida (CIP) M6 markeri bo‘yicha yuqori aniqlikdagi erish (HRM) testi simpleks × dupleks chatishtirishdan olingan 217 ta avlodda sinalgan (3-rasm) [4].

Kuzatilgan taqsimot (30 : 101 : 84 : 2) nazariy 1:5:5:1 nisbatdan farq qilgan ($\chi^2$ = 23,85; $p < 0,001$).

Avlod sinovi bo‘yicha «tripleks» deb baholangan ota-ona marker testida dupleks bo‘lib chiqqan, ya’ni marker asosidagi doza bahosi ishonchliroq bo‘lgan.

Shu tadqiqotda ishlab chiqilgan ishqorli DNK ajratish usuli 384 ta namunani 1,5 soatda qayta ishlash imkonini bergan [4].




3-rasm. Simpleks × dupleks avlodida Ry_adg allel dozasining kutilgan va kuzatilgan taqsimoti

Genotiplash platformalari va genomik seleksiya. 20K SNP massivi 569 ta genotipda R-genlar bilan bog‘langan SNP larni aniqlagan [16]. 4 000 nishonli DArTag testi SNP massivi bilan bir xil natija bergan va PVY, nematoda hamda rak kasalligiga chidamlilik markerlarini ham qamragan [17], ya’ni bitta tahlil MAS va genomik seleksiya uchun ma’lumot beradi. Hosildorlik kabi murakkab belgilar bo‘yicha genomik bashorat aniqligi 0,06–0,63 ni tashkil etgan, allel dozasi hisobga olinmaganda esa o‘rtacha 0,13 ga pasaygan [18].

Diploid duragay seleksiyada Sli geni markeri o‘z-o‘zidan changlanuvchi liniyalarni urug‘ ko‘chati bosqichida tanlash imkonini beradi [19]; genom markerlari yordamida yaratilgan inbred liniyalardan olingan duragaylar esa kuchli geterozis ko‘rsatgan [20].

Namangan ilmiy-tajriba stansiyasida MAS ni joriy etish. Tahlil asosida stansiya dasturi uchun bosqichma-bosqich reja ishlab chiqildi (2-jadval).

Oltinsimon nematoda va kartoshka raki karantin ahamiyatiga ega bo‘lgani sababli, ularga chidamlilik markerlari import qilinayotgan navlarni baholashda ham foydali. Markerlarning mahalliy materialdagi aniqligi stansiya tajribalarida alohida tasdiqlanishi lozim.

2-jadval

Namangan ilmiy-tajriba stansiyasida MAS ni joriy etish bosqichlari

| Bosqich | Mazmuni | Kutilayotgan natija |
|---|---|---|
| 1. Genofondni inventarizatsiya qilish | Kolleksiyani Ry_adg, Ry_sto, Rx1, H1, Sen1 markerlari bilan genotiplash | Chidamlilik manbalari reyestri |
| 2. Markerlarni validatsiya qilish | Marker natijalarini sun’iy zararlash va ELISA natijalari bilan solishtirish | Mahalliy material uchun PPV va sezgirlik |
| 3. Ota-onalar fondi | HRM yoki SNP asosida allel | Dupleks va tripleks ota-onalar |

| | | |
|---|---|---|
| | dozasini aniqlash | |
| 4. Urug‘ ko‘chatlarida MAS | Multipleks PCR tahlilini muntazam qo‘llash | Dala sinovi hajmining qisqarishi |
| 5. Genomik seleksiyaga tayyorgarlik | Ko‘p yillik sinov ma’lumotlarini genotip bilan birga to‘plash | O‘rgatuvchi populyatsiya |

Xulosa. O‘tkazilgan tahlil asosida quyidagi xulosalarga kelindi:

1. MAS yirik ta’sirli chidamlilik genlari uchun amalda tasdiqlangan vosita: PVY, PVX, oltinsimon nematoda va kartoshka rakiga chidamlilik uchun ishonchli PCR markerlari mavjud.

2. Markerlar seleksiya materialining 29–80 foizini dala sinovlaridan oldin chiqarib tashlash imkonini beradi; MAS ni ikkinchi klon avlodida qo‘llash iqtisodiy jihatdan samarali.

3. Allel dozasini aniqlash ota-onalarni tanlash aniqligini oshiradi va genomik bashorat aniqligini o‘rtacha 0,13 ga yaxshilaydi.

4. Namangan ilmiy-tajriba stansiyasida MAS ni joriy etish genofondni genotiplash, markerlarni mahalliy materialda validatsiya qilish va urug‘ ko‘chatlarida multipleks PCR tahlilini qo‘llashdan boshlanishi maqsadga muvofiq.

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