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MORPHOLOGICAL DIVERSITY OF LOCAL RADISH (*RAPHANUS SATIVUS* L.) IN THE FERGANA VALLEY: THEORETICAL BASIS AND APPROACHES TO CHARACTERIZATION

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Abstract. Local radish forms of the «Margilan radish» type have been grown in the Fergana Valley for centuries, but their morphological diversity has not been described. This paper analyses published data on the morphological and genetic variation of cultivated radish, the UPOV descriptor system for radish and the evidence for a distinct Central Asian gene pool. It is shown that the morphological types of radish have a clear genetic and geographic basis, that root shape and size are the most variable traits, and that Central Asian accessions carry high genetic diversity. On this basis, working hypotheses and a framework for the morphological characterization of Fergana Valley radish landraces are proposed.

Keywords: radish, Raphanus sativus, landraces, Fergana Valley, morphological diversity, UPOV descriptors, root traits.

Introduction. Radish (*Raphanus sativus* L., 2n = 18) belongs to the family Brassicaceae and is grown as a vegetable crop worldwide. Different plant organs are consumed in different regions: small roots in Europe and the USA, large long roots in East Asia, and immature seed pods in South and Southeast Asia. Accordingly, cultivated radish is divided into several botanical varieties, including the small European radish (var. *sativus*),

black radish (var. *niger*), East Asian big radish (var. *hortensis*), rat-tailed radish (var. *caudatus*) and oilseed radish [1].

Vegetable growing is a leading branch of agriculture in Uzbekistan. In 2023, 11.55 million tonnes of vegetables were produced in the country, including 1.77 million tonnes in the Andijan region [2]. At the same time, more than 80% of the vegetable area is occupied by only ten crops, which shows that crop diversity is limited [3]. Local radish forms of the «Margilan radish» type are traditionally grown in the Fergana Valley, and their seeds are mostly reproduced by farmers themselves. A few such accessions are kept in foreign gene banks: a «Margalanskaja red’ka» landrace collected in Tashkent in 1995 (IPK, Germany), a landrace from Uzbekistan acquired in 2005 (World Vegetable Center) and a winter-type radish collected at the Osh market in 1999 (CGN, the Netherlands) [4–6].

Local research on radish has so far focused on agronomy and product quality. Khusanov et al. determined that the optimal germination temperature of daikon seed is 20–30 °C and that, in summer repeat sowing, the mean daily temperature should not exceed 30 °C [7]. Askarov and Atakulova studied the mineral, vitamin and polyphenol content of the leaves of the cultivar «Andijan-9» [8]. However, the morphological diversity of local radish forms in the Fergana Valley has not been described, and no standard approach to their characterization has been proposed.

The **aim** of this work was to analyse published data on the morphological diversity of cultivated radish and, on this basis, to substantiate working hypotheses and a framework for the morphological characterization of local radish forms of the Fergana Valley.

Materials and Methods. The study is theoretical. Scientific publications on the morphological and genetic diversity of radish were selected from PubMed Central, J-STAGE, SpringerLink, MDPI and AGRIS. The UPOV test guidelines for radish TG/63/7–TG/64/7, passport data of radish accessions from Uzbekistan and neighbouring areas in the Genesys and CGN gene bank databases, and statistical data of the National Statistics Committee were also analysed. Methods of comparative analysis, generalization and logical modelling were used.

Results and Discussion. Morphological types of radish and their genetic basis. The division of cultivated radish into morphological types is supported by molecular data. In a study of 510 accessions with genome-wide SNPs, cultivated radish formed four groups corresponding to Japan, East Asia, South and Southeast Asia, and the Occident and Near East. European small radish and black radish fell into the western group, most rat-tailed radishes into the South and Southeast Asian group, and most big East Asian radishes into the Japanese or East Asian groups [1]. Chloroplast SSR data indicate at least three independent domestication events of cultivated radish [9]. Thus, morphological type, geographic origin and genetic group are closely linked, and a local radish form should be described together with its origin.

Variation of root traits. Root traits are the most variable and most important for breeding. In Korea, genomic SSR markers revealed significant genetic differentiation between five market classes of radish cultivars (big, small, young, Altari and processing types), which differ mainly in root size and use [10]. In Pakistan, a study of 12 local and introduced genotypes found significant differences in all traits; the genotypic coefficient of variation exceeded 20% for all traits and was close to the phenotypic one, which indicates a mainly genetic origin of variation. Root shape and root base were the most variable qualitative traits, and plant fresh weight, root length, root weight, number of leaves and yield were positively correlated, so they can serve as selection criteria [11]. These data suggest that root shape, size and weight should be the core of any morphological description of radish landraces.

The UPOV descriptor system. Standardized descriptors make morphological data comparable between studies and with registered cultivars. The UPOV guidelines TG/63/7–TG/64/7 cover both small radish (S-type) and black and oriental radish (N-type), to which local Fergana forms belong. They list 29 characteristics of leaves, roots, maturity and quality (Table 1). Fourteen of them are recommended as grouping characteristics, including leaf length, number of leaf lobes, root length, diameter and shape, skin colour and time of harvest maturity. The guidelines require at least two independent growing cycles, and for N-type

varieties at least 60 plants divided between at least two replicates [12].

For breeding purposes, the UPOV characteristics should be supplemented with economically important traits that are not part of the distinctness test: root weight and yield per unit area, time of bolting and the proportion of bolted plants, and dry matter content. Bolting is especially important for the Fergana Valley, where radish is often sown as a repeat crop in summer under long days and high temperatures [7].

Table 1.

Groups of UPOV characteristics for radish relevant to N-type (black and oriental) forms

Group	Characteristics	Value for landrace study
Leaf	attitude; length; width; shape of apex; colour; number of lobes; depth of incisions; anthocyanin coloration of petiole; number of fully developed leaves	separation of forms with similar roots; vegetative vigour
Root: size and shape	length; diameter; shape; position in soil; shape of shoulder; shape of apex	main descriptors of type and productivity
Root: colour	number of skin colours; skin colour at stem end; colour of non-thickened root; red colour pattern; extent of white colour; main colour of flesh	identification of local types and consumer quality
Maturity and quality	time of harvest maturity; tendency to become pithy; ridging of surface	suitability for repeat sowing and storage

Fergana Valley radish as an object of study. Several facts suggest that local radish forms of the Fergana Valley may be highly diverse. First, in a genotyping-by-sequencing study of 152 accessions from eight geographic regions, Central Asian accessions showed the highest expected heterozygosity and many private alleles relative to their sample size, and one accession from Uzbekistan clearly differed from the general structure [13]. Second, radish is cross-pollinated, and in the same study 77.49% of genetic variation was found within individuals and only 6.51% among regions [13]. Third, seed of local forms is reproduced by farmers without formal selection and is exchanged between farms and markets. Under these conditions, both large differences between populations and considerable variation within each population are expected.

On this basis, three working hypotheses are formulated: (1) local radish forms of the Fergana Valley include several distinct morphological types that differ mainly in root shape, colour and size; (2) variation in root weight and size within and between populations is high (CV above 20%), as in other landrace collections [11]; (3) one local name may cover several morphological types, and similar types may be sold under different names, so local names alone are not reliable for identifying forms.

Framework for morphological characterization. To test these hypotheses, a stepwise framework is proposed (Table 2). It combines passport documentation, UPOV-based description, field evaluation according to UPOV test design and statistical methods suitable for both quantitative and qualitative traits.

Table 2.

Proposed framework for morphological characterization of Fergana Valley radish landraces

Stage	Content	Basis
1. Collection and passport	Samples from farmers’ markets and dehqan farms in the Andijan, Fergana and Namangan regions; local name, origin, GPS, seed source recorded by FAO/Bioversity multi-crop passport descriptors	gene bank standards [4–6]
2. Preliminary description	Root length, diameter, weight, shape and colour scored on harvested roots	UPOV root characteristics [12]
3. Field evaluation	Uniform field trial at the Andijan station, at least two growing cycles, replicated, at least 60 plants per accession; leaf, root, maturity, bolting and pithiness traits	UPOV test design [12]
4. Statistical analysis	Mean, SE, range, CV; Shannon–Weaver index $H' = -\Sigma\, p_i \ln p_i$ for qualitative traits; correlations; cluster analysis and principal component analysis	methods used for radish variability [11]
5. Integration with markers	Comparison of morphological groups with genetic distances from SSR markers	molecular grouping of radish [1, 10, 13]

In the statistical analysis, variation can be considered low at CV < 10%, medium at 10–20% and high at CV > 20%. The Shannon–Weaver index, standardized by dividing by ln n,

where n is the number of classes, allows the diversity of qualitative traits such as root shape and colour to be compared on one scale. Cluster analysis on standardized trait values and principal component analysis reveal groups of similar forms and the traits that separate them. The comparison of morphological groups with SSR-based genetic distances will show whether visible types reflect real genetic differences, which is the key question for using landraces in breeding.

Conclusions. 1. Morphological types of cultivated radish correspond closely to genetic groups and geographic origin, and root shape, size and weight are the most variable and breeding-relevant traits. This analysis shows that root traits should form the core of the description of local radish forms.

2. The UPOV system of 29 characteristics, supplemented with yield, bolting and dry matter traits and applied over at least two growing cycles, provides a standard basis for describing Fergana Valley landraces. Its use ensures that the data are comparable with registered cultivars and international studies.

3. High genetic diversity of Central Asian radish, cross-pollination and farmer-based seed reproduction give reason to expect considerable morphological variation among local forms. Therefore, a need for systematic collection, passport documentation and combined morphological and molecular evaluation of Fergana Valley radish is observed.

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