



VARIABILITY OF STEM AND PANICLE MORPHOLOGICAL AND BREEDING TRAITS OF INTRODUCED QUINOA (*Chenopodium quinoa* Willd) VARIETIES AND ACCESSIONS UNDER IRRIGATED CONDITIONS

Yuldasheva Ra'no Abdurashidovna

Professor, Tashkent State Agrarian University

yuldashevarano777@gmail.com

ORCID: 0000-0009-3311-0242

Allanov Xolik Keldiyorovich

Professor, Tashkent State Agrarian University

xoliq72@mail.ru ORCID: 0000-0003-2423-8913

Yigitayeva Mushtariy Farxodjon qizi

Master's Student, Tashkent State Agrarian University

yigitalievamushtariy@gmail.com

ORCID: 0009-0004-6974-3846

Normuradova Munajat Tog'ayevna

PhD, Tashkent State Agrarian University

E-mail: munojatnormurodova22@gmail.com

ORCID: 0009-0001-8692-8170

Abstract

This study was devoted to evaluating the variability of stem and panicle morphological and breeding traits of introduced quinoa (*Chenopodium quinoa* Willd.) varieties and accessions under irrigated conditions. Important morphological traits, including stem diameter, height of the first lateral branch,



number of panicles per plant, panicle width, panicle shape, and panicle density, were studied in different introduced quinoa varieties and accessions. Quantitative traits were analyzed based on the mean value, standard deviation, standard error of the mean, and coefficient of variation.

The results of the study demonstrated considerable differences in stem and panicle morphological traits among the studied varieties and accessions. Relatively strong stem development, as well as higher values for the number, width, and density of panicles, were recorded in some accessions. Three types of panicle shape—glomerulate, intermediate, and amaranthoid—were identified. Relatively low coefficients of variation for quantitative traits indicated stable expression of certain morphological traits.

The obtained results demonstrate that stem and panicle traits can be used for morphological characterization and comparative evaluation of introduced quinoa varieties and accessions, as well as for the selection of promising initial materials in breeding programs under irrigated conditions.

Keywords: *Chenopodium quinoa* Willd, quinoa, introduction, stem diameter, lateral branching, panicle, panicle width, panicle shape, panicle density, morphological traits, breeding traits, variability.

1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) is one of the promising crops distinguished by its diversity of morphological and agronomic traits. The introduction of quinoa materials originating from different ecological conditions into a new environment, assessment of their adaptability, and characterization of these materials as initial material for breeding represent an important scientific and practical research direction.

Stem development, branching characteristics, and panicle structure are important descriptive traits in the morphological evaluation of quinoa varieties and accessions. These traits are associated with the vegetative and generative development of the plant and make it possible to identify phenotypic differences



among introduced materials. Stem diameter is one of the quantitative morphological characteristics of the quinoa plant and is used to characterize the degree of stem development. The height of the first lateral branch from the soil surface is an important indicator for evaluating branching characteristics. The number of panicles per plant is considered a quantitative trait reflecting the degree of development of generative branches.

Panicle shape, width, and density are also important for morphologically distinguishing quinoa genotypes. In the studied materials, panicle shape was classified into glomerulate, intermediate, and amaranthoid types, while density was classified from sparse to dense. Therefore, comprehensive evaluation of these traits contributes to determining the differentiation and stability of initial materials intended for breeding.

The aim of the study was to determine the variability of stem and panicle morphological and breeding traits in quinoa varieties and accessions grown for two vegetation periods under irrigated conditions in Tashkent Region, to comparatively evaluate the differences among them, and to characterize combinations of traits important for breeding.

2. Materials and Methods

The study was conducted using introduced quinoa varieties and accessions. The experiment was established under irrigated conditions in Tashkent Region, and six materials were studied in three replications. In the first vegetation period, sowing was carried out on April 1. During the vegetation period, quantitative and qualitative traits of the stem and panicle were evaluated.

Table 1. Varieties and accessions studied

Code	Variety/accession
Check1	Ames-654
New 14	Ames-13761
New 21	BO-16
New 42	CHEN-298
New 170	PI433232
New 141	D-12229



2.2. Evaluation of Stem Morphological and Breeding Traits

Stem diameter was measured in millimeters using a digital caliper. Measurements were taken from the lower part of the stem. The height of the first lateral branch was determined in centimeters as the distance from the soil surface to the point where the first significant lateral branch was formed. These indicators were used for comparative evaluation of stem development and branching characteristics.

2.3. Evaluation of Panicle Morphological and Breeding Traits

The following traits were evaluated: number of panicles per plant, panicle width, panicle shape, and panicle density. Panicle shape was divided into three morphological groups: glomerulate, intermediate, and amaranthoid. Panicle density was evaluated according to the density level of the inflorescence as sparse, intermediate, and dense. These classifications were used in accordance with descriptions applied in quinoa phenotyping.

2.4. Statistical Analysis

For quantitative traits, the arithmetic mean (M), standard error of the mean (m), standard deviation (σ), and coefficient of variation (V%) were calculated.

The coefficient of variation was determined using the following formula:

$$V = (\sigma/M) \times 100$$

where M is the arithmetic mean and σ is the standard deviation. The obtained values were compared among the six materials and between the two vegetation periods.

3. Results and Discussion

3.1. Stem Diameter

The results demonstrated clear differences in stem diameter among the studied quinoa materials. The mean stem diameter ranged from 11.8 mm in the Check1 accession to 15.1 mm in the New 170 accession. In the New 42 accession, the value was 14.7 mm, while in New 21 and New 141 it was 13.9 and 13.2 mm, respectively.



In the second year of vegetation, the general trend was also maintained: stem diameter was 15.4 mm in New 170, 15.0 mm in New 42, and 12.1 mm in Check1. In both years, the coefficient of variation was below 5% for all materials. This indicates that stem diameter was expressed relatively uniformly within the experimental materials.

Table 2. Variability of stem diameter of varieties and accessions across years

Variety/accession	M±m, mm	σ	V, %	M±m, mm	σ	V, %
Check1	11,8±0,28	0,56	4,75	12,1±0,27	0,54	4,46
New 14	13,5±0,31	0,62	4,59	13,8±0,29	0,58	4,20
New 21	13,9±0,27	0,54	3,88	14,2±0,26	0,52	3,66
New 42	14,7±0,30	0,60	4,08	15,0±0,28	0,56	3,73
New 170	15,1±0,32	0,64	4,24	15,4±0,30	0,60	3,90
New 141	13,2±0,29	0,58	4,39	13,5±0,28	0,56	4,15

The higher stem diameter observed in New 170 and New 42 indicates relatively strong stem development. This trait can be used as an additional criterion for evaluating morphological differentiation of plants in the breeding process.

3.2. Height of the First Lateral Branch

The height of the first lateral branch differed among the studied materials. In the first year, the lowest mean value was observed in New 141, while the highest value was recorded in New 170. The same general trend was maintained in the following year.

Table 3. Variability in the height of the first lateral branch among varieties and accessions across years, cm

Variety/accession	M±m, cm	σ	V, %	M±m, cm	σ	V, %
Check1	36,8±0,74	1,48	4,02	37,5±0,70	1,40	3,73
New 14	41,2±0,69	1,38	3,35	42,0±0,67	1,34	3,19
New 21	39,6±0,71	1,42	3,59	40,4±0,68	1,36	3,37
New 42	44,3±0,76	1,52	3,43	45,1±0,73	1,46	3,24
New 170	46,1±0,81	1,62	3,51	47,0±0,77	1,54	3,28
New 141	34,9±0,65	1,30	3,72	35,6±0,63	1,26	3,54



New 170 and New 42 were characterized by a relatively higher position of the first lateral branch, whereas New 141 was characterized by a lower position. These differences indicate that branching traits were combined differently in the introduced materials.

3.3. Number of Panicles per Plant

The number of panicles per plant also differed among the introduced materials. Mean values ranged from 3.8 panicles in Check1 to 5.6 panicles in New 141. In the following year, this indicator ranged from 4.0 to 5.8 panicles.

Table 4. Variability in the number of panicles per plant among varieties and accessions across years

Variety/accession	M±m	σ	V, %	M±m	σ	V, %
Check1	3,8±0,18	0,36	9,47	4,0±0,17	0,34	8,50
New 14	4,5±0,20	0,40	8,89	4,7±0,19	0,38	8,09
New 21	4,8±0,21	0,42	8,75	5,0±0,20	0,40	8,00
New 42	5,3±0,22	0,44	8,30	5,5±0,21	0,42	7,64
New 170	5,1±0,23	0,46	9,02	5,3±0,21	0,42	7,92
New 141	5,6±0,24	0,48	8,57	5,8±0,22	0,44	7,59

The relatively higher number of panicles in New 141, New 42, and New 170 indicates stronger development of generative branches. The number of panicles per plant is a quantitative trait that can be taken into account when comparatively evaluating materials for breeding purposes.

3.4. Panicle Width

Panicle width demonstrated significant differences among the studied materials. It ranged from 5.8 cm in Check1 to 8.4 cm in New 42. Relatively wide panicles were also observed in New 141 and New 170. In the following year, the overall range was 6.0–8.7 cm.



Table 5. Variability in panicle width among varieties and accessions, cm

Variety/accession	M±m, cm	σ	V, %	M±m, cm	σ	V, %
Check1	5,8±0,17	0,34	5,86	6,0±0,16	0,32	5,33
New 14	6,7±0,19	0,38	5,67	6,9±0,18	0,36	5,22
New 21	7,1±0,18	0,36	5,07	7,3±0,17	0,34	4,66
New 42	8,4±0,21	0,42	5,00	8,7±0,20	0,40	4,60
New 170	7,8±0,20	0,40	5,13	8,1±0,19	0,38	4,69
New 141	8,1±0,22	0,44	5,42	8,4±0,20	0,40	4,76

New 42 demonstrated the greatest panicle width in both vegetation periods. Relatively wide panicles were also recorded in New 141 and New 170. The relatively low coefficient of variation indicates that this trait was expressed stably within the experimental materials.

3.5. Panicle Shape and Density

Considerable diversity was observed in the morphological structure of the panicle. The studied materials were classified into glomerulate, intermediate, and amaranthoid forms.

Table 6. Panicle shape and density of varieties and accessions

Variety/accession	Ro'vak shakli	Ro'vak zichligi
Check1	Glomerulyat	Oraliq
New 14	Oraliq	Oraliq
New 21	Glomerulyat	Oraliq
New 42	Amarantoid	Zich
New 170	Oraliq	Zich
New 141	Glomerulyat	Oraliq

New 42 demonstrated an amaranthoid panicle shape in both years. New 14 and New 170 were characterized by an intermediate shape, while Check1 and New 141 were characterized by a glomerulate shape. In New 21, a glomerulate shape was recorded in 2025, whereas an intermediate shape was observed in the following



year. This indicates that some qualitative traits may vary depending on vegetation conditions.

New 42 was characterized by a dense panicle in both vegetation periods. An increase in density level during the second vegetation period was observed in New 14 and New 141, while New 170 changed from an intermediate to a dense condition. Thus, joint evaluation of panicle shape and density is important for identifying morphological differences among introduced materials.

3.6. Comprehensive Breeding Evaluation of Stem and Panicle Traits

Comprehensive analysis of the studied traits demonstrated different combinations of stem and panicle traits among the six quinoa materials. New 170 was characterized by a relatively large stem diameter and a higher position of the first lateral branch. New 42 combined a large stem diameter with a wide and dense panicle and an amaranthoid panicle shape. New 141 was distinguished by a relatively high number of panicles per plant and wide panicles, although its first lateral branch was positioned lower than in the other materials.

New 21 demonstrated intermediate values for most stem and panicle traits, whereas Check1 was characterized by relatively low values for most quantitative traits. These differences indicate that vegetative and generative traits were combined differently in the introduced materials.

Comparison between the two years revealed similarity in the general trends among the materials. The relatively low coefficients of variation for quantitative traits, particularly stem diameter and panicle width, indicate their stable expression. However, because certain annual changes were observed in qualitative traits such as panicle shape and density, these traits should be evaluated through repeated observations during the breeding process.

Thus, evaluation of the studied traits not separately but in relation to one another makes it possible to identify initial materials possessing combinations of valuable traits for breeding. In this regard, New 170 demonstrated specific morphological characteristics associated with stem development and branching, New 42 with stem



development as well as panicle width and density, and New 141 with traits related to generative branching.

4. Conclusion

Evaluation of introduced quinoa varieties and accessions under irrigated conditions in Tashkent Region across years demonstrated considerable differences in the morphological and breeding traits of the stem and panicle. Stem diameter ranged from 11.8–15.1 mm and from 12.1–15.4 mm in 2026. Higher stem diameter was recorded in New 170 and New 42. The height of the first lateral branch also differed among the materials: in New 170 and New 42, the branching point was positioned relatively higher, whereas in New 141 it was positioned lower.

The number of panicles per plant ranged from 3.8–5.6, while in the following year it ranged from 4.0–5.8. This indicator was relatively high in New 141, New 42, and New 170. Panicle width ranged from 5.8–8.4 cm and from 6.0–8.7 cm in the following year, with New 42 demonstrating the greatest panicle width in both years. Morphological differences were also identified in terms of panicle shape and density. New 42 was consistently characterized by an amaranthoid and dense panicle during both years. Glomerulate or intermediate shapes and different density levels were recorded in the other materials.

Overall, stem diameter, height of the first lateral branch, number of panicles, panicle width, shape, and density were shown to be traits that can be used for the morphological characterization and preliminary breeding evaluation of introduced quinoa materials. Comprehensive and repeated evaluation of these traits may provide an additional scientific basis for selecting initial materials adapted to irrigated conditions.

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