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DYNAMICS OF LEAF NUMBER IN INTRODUCED QUINOA (*CHENOPODIUM QUINOA* WILLD.) VARIETY SAMPLES UNDER IRRIGATED CONDITIONS

Yigitayeva Mushtariy Farxodjon qizi

Master's Student, Tashkent State Agrarian University

yigitalievamushtariy@gmail.com

<https://orcid.org/0009-0004-6974-3846>

Normuradova Munajat Tog'ayevna

PhD, Tashkent State Agrarian University

E.mail: munojatnormurodova22@gmail.com

<https://orcid.org/0009-0001-8692-8170>

Yuldasheva Ra'no Abdurashidovna

Professor, Tashkent State Agrarian University

yuldashevarano77@gmail.com

<https://orcid.org/0009-0009-3311-0242>

Allanov Xolik Keldiyorovich

Professor, Tashkent State Agrarian University

xoliq72@mail.ru

<https://orcid.org/0000-0003-2423-8913>

Abstract. The study was conducted to evaluate the dynamics of leaf formation in introduced quinoa (*Chenopodium quinoa* Willd.) variety samples under irrigated conditions. Six quinoa materials, including Check1 (Ames-654), New 14 (Ames-13761), New 21 (BO-16), New 42 (CHEN-298), New 170 (PI433232), and New 141 (D-12229), were evaluated during the 2025 and 2026 growing seasons. Leaf number was determined at three successive developmental stages, and the mean value, standard deviation, and coefficient of variation were used to characterize the variability of the trait. In 2025, the mean number of leaves increased from 4.6–6.3 leaves at the first developmental stage to 20.9–28.8 leaves at the second stage and 38.1–49.8 leaves at the third stage. New 21 showed the highest leaf number at the first stage, while New 141 and New 42 demonstrated the highest values at the second and third stages, respectively. In 2026, the same general tendency of increasing leaf number was observed throughout plant development. New 21 maintained a high level of early leaf formation, whereas New 42 and New 141 demonstrated superior leaf formation during later developmental stages. The coefficient of variation was generally low at the second and third stages, indicating comparatively stable expression of the trait. The results demonstrate considerable differences among introduced quinoa materials in the dynamics of leaf formation and indicate that leaf number at different developmental



stages can be used as an informative biometric characteristic in the comparative evaluation and selection of quinoa materials.

Keywords: *Chenopodium quinoa* Willd., quinoa, leaf number, leaf formation, developmental stages, introduced variety samples, biometric traits, irrigated conditions.

Annotatsiya. *Tadqiqot sug'oriladigan sharoitda introduksiya qilingan quinoa (Chenopodium quinoa Willd.) nav namunalarida barglarning shakllanish dinamikasini baholash maqsadida olib borildi. 2025 va 2026-yillardagi vegetatsiya mavsumlarida oltita quinoa materiali, jumladan Check1 (Ames-654), New 14 (Ames-13761), New 21 (BO-16), New 42 (CHEN-298), New 170 (PI433232) va New 141 (D-12229) o'rganildi. Barglar soni o'simlik rivojlanishining ketma-ket uchta bosqichida aniqlandi hamda belgining o'zgaruvchanligini tavsiflash uchun o'rtacha qiymat, standart og'ish va variatsiya koeffitsientidan foydalanildi. 2025-yilda barglarning o'rtacha soni birinchi rivojlanish bosqichida 4,6–6,3 donadan ikkinchi bosqichda 20,9–28,8 donagacha, uchinchi bosqichda esa 38,1–49,8 donagacha oshdi. Birinchi bosqichda New 21 eng yuqori barg sonini ko'rsatgan bo'lsa, ikkinchi va uchinchi bosqichlarda mos ravishda New 141 va New 42 namunalarida eng yuqori qiymatlar qayd etildi. 2026-yilda ham o'simlik rivojlanishi davomida barglar sonining ortib borish tendensiyasi kuzatildi. New 21 dastlabki barg hosil bo'lishida yuqori ko'rsatkichni saqlab qolgan bo'lsa, keyingi rivojlanish bosqichlarida New 42 va New 141 namunalari yuqori barg hosil qilish ko'rsatkichlarini namoyon etdi. Variatsiya koeffitsienti, odatda, ikkinchi va uchinchi bosqichlarda past bo'lib, ushbu belgining nisbatan barqaror ifodalanishini ko'rsatdi. Olingan natijalar introduksiya qilingan quinoa materiallari o'rtasida barg hosil bo'lish dinamikasi bo'yicha sezilarli farqlar mavjudligini ko'rsatadi hamda turli rivojlanish bosqichlaridagi barglar sonidan quinoa namunalarini qiyosiy baholash va tanlashda informativ biometrik belgi sifatida foydalanish mumkinligini ko'rsatadi.*

Kalit so'zlar: *Chenopodium quinoa* Willd., quinoa, barglar soni, barg hosil bo'lishi, rivojlanish bosqichlari, introduksiya qilingan nav namunalari, biometrik belgilar, sug'oriladigan sharoit.

Аннотация. *Исследование проведено с целью оценки динамики формирования листьев у интродуцированных образцов сортов киноа (Chenopodium quinoa Willd.) в условиях орошения. В течение вегетационных сезонов 2025 и 2026 годов были изучены шесть образцов киноа, включая Check1 (Ames-654), New 14 (Ames-13761), New 21 (BO-16), New 42 (CHEN-298), New 170 (PI433232) и New 141 (D-12229). Количество листьев определяли на трёх последовательных этапах развития растений, а для характеристики вариабельности признака использовали среднее значение, стандартное отклонение и коэффициент вариации. В 2025 году среднее количество листьев увеличивалось с 4,6–6,3 листа на первом этапе развития до 20,9–28,8 листа на втором этапе и 38,1–49,8 листа на третьем этапе. На первом этапе наибольшее количество листьев отмечено у образца New 21, тогда как на втором и третьем этапах наиболее высокие значения зарегистрированы соответственно у New 141 и New 42. В 2026 году также наблюдалась общая*



тенденция увеличения количества листьев по мере развития растений. Образец New 21 сохранял высокий уровень раннего формирования листьев, тогда как на последующих этапах развития New 42 и New 141 характеризовались более высокими показателями формирования листьев. Коэффициент вариации, как правило, был низким на втором и третьем этапах, что свидетельствует о сравнительно стабильном проявлении данного признака. Полученные результаты демонстрируют наличие значительных различий между интродуцированными образцами киноа по динамике формирования листьев и показывают, что количество листьев на различных этапах развития может использоваться в качестве информативного биометрического признака при сравнительной оценке и отборе образцов киноа.

Ключевые слова: *Chenopodium quinoa* Willd., киноа, количество листьев, формирование листьев, этапы развития, интродуцированные образцы сортов, биометрические признаки, условия орошения.

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) is an important annual crop characterized by substantial diversity in morphological, physiological and agronomic traits. The introduction and evaluation of diverse quinoa materials under new environmental conditions are important steps in identifying plant materials with valuable characteristics for agricultural production and breeding.

Leaves are the principal organs responsible for photosynthetic activity, and the number of leaves formed during plant development reflects the intensity of vegetative growth. Consequently, quantitative assessment of leaf number can provide useful information when comparing varieties and introduced samples. The expression of morphological traits is not constant throughout plant development. The number of leaves increases progressively as plants pass through successive developmental stages, while the rate of leaf formation can differ among genetic materials. Therefore, observations conducted at several stages may provide a more complete characterization of vegetative development than measurements taken at a single stage.

The evaluation of quinoa materials under irrigated conditions is particularly relevant for regions where irrigation plays an important role in crop production. Differences in leaf formation among introduced materials may reflect their biological characteristics and their response to local growing conditions. The present study focused on six introduced quinoa variety samples and examined the dynamics of leaf number during three developmental stages over two growing seasons. The main objective was to determine differences in leaf formation among the studied materials and to identify samples characterized by a comparatively high and stable number of leaves during plant development.

MATERIALS AND METHODS.

The research was conducted under irrigated conditions using six introduced quinoa variety samples. The studied materials were:

Code	Variety/sample
Check1	Ames-654
New 14	Ames-13761
New 21	BO-16



Code	Variety/sample
New 42	CHEN-298
New 170	PI433232
New 141	D-12229

The experimental design consisted of six materials with three replications. The experimental plot was established under irrigated conditions, and sowing in the first experimental year was carried out on 1 April 2025. Observations were conducted during the growing season in order to characterize the formation of vegetative organs at successive stages of plant development.

Determination of leaf number. Leaf number was recorded at three developmental stages. At each stage, leaves were counted on the plants included in the observations, and the obtained values were used to determine the mean number of leaves for each variety/sample.

The following statistical parameters were calculated:

- $M \pm m$ — arithmetic mean and its error;
- σ — standard deviation;
- $V\%$ — coefficient of variation.

The coefficient of variation was calculated according to the equation:

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

where M represents the arithmetic mean and σ represents the standard deviation. The obtained values were compared among the studied materials and between developmental stages in order to determine the dynamics of leaf formation.

RESULTS AND DISCUSSION

3.1. Leaf number at the first developmental stage. The first developmental stage was characterized by relatively low leaf numbers in all studied quinoa materials. However, considerable differences among the samples were observed.

In 2025, the mean number of leaves ranged from 4.6 ± 0.34 in Check1 to 6.3 ± 0.41 in New 21. The highest value was recorded in New 21, followed by New 170 with 5.9 ± 0.36 leaves and New 42 with 5.8 ± 0.39 leaves. New 14 had 5.7 ± 0.33 leaves, while Check1 and New 141 recorded 4.6 ± 0.34 and 4.7 ± 0.33 leaves, respectively.

The coefficient of variation ranged from 11.80% to 15.20%. The lowest variability was observed in New 14, whereas Check1 showed the highest variation.

In 2026, the mean number of leaves ranged from 4.8 ± 0.32 in Check1 to 6.5 ± 0.39 in New 21. New 21 again demonstrated the highest value. New 170 recorded 6.1 ± 0.34 leaves, while New 42 had 6.0 ± 0.37 leaves. The lowest value after Check1 was observed in New 141. The first-stage results therefore demonstrate a relatively consistent pattern across the two years. New 21 was distinguished by a comparatively high number of leaves during the initial phase of development.

Table 1. Leaf number at the first developmental stage in introduced quinoa variety samples in 2025–2026

Variety/sample	2025 $M \pm m$	σ	V, %	2026 $M \pm m$	σ	V, %
Check1	4.6 ± 0.34	0.69	15.20	4.8 ± 0.32	0.64	13.33
New 14	5.7 ± 0.33	0.67	11.80	5.9 ± 0.31	0.62	10.51
New 21	6.3 ± 0.41	0.82	13.06	6.5 ± 0.39	0.78	12.00



Variety/sample	2025 M±m	σ	V, %	2026 M±m	σ	V, %
New 42	5.8±0.39	0.78	13.60	6.0±0.37	0.74	12.33
New 170	5.9±0.36	0.73	12.50	6.1±0.34	0.69	11.31
New 141	4.7±0.33	0.67	14.36	4.9±0.31	0.62	12.65

3.2. Leaf number at the second developmental stage. The second developmental stage was associated with a pronounced increase in leaf number. In 2025, the mean values ranged from 20.9 ± 0.55 leaves in Check1 to 28.8 ± 0.39 leaves in New 141.

New 141 showed the highest value, followed by New 42 with 27.2 ± 0.45 leaves. New 170 and New 21 recorded 25.7 ± 0.41 and 25.2 ± 0.39 leaves, respectively. New 14 had 22.4 ± 0.53 leaves, while Check1 had the lowest value.

The coefficient of variation ranged from 2.73% to 5.26%. Such relatively low values indicate that the expression of leaf number was comparatively uniform within the studied materials at this developmental stage. In 2026, a similar increase in leaf number was observed. Check1 reached 21.8 leaves, while New 14, New 21, New 42, New 170 and New 141 reached 23.2, 26.0, 28.0, 26.4 and 29.5 leaves, respectively. New 141 remained the material with the highest leaf number at the second developmental stage, followed by New 42. This consistency indicates a relatively strong capacity for leaf formation during the intermediate period of vegetative development.

Table 2. Leaf number at the second developmental stage in 2025–2026

Variety/sample	2025 M±m	σ	V, %	2026 M±m	σ	V, %
Check1	20.9±0.55	1.10	5.26	21.8±0.52	1.04	4.77
New 14	22.4±0.53	1.04	4.79	23.2±0.50	1.00	4.31
New 21	25.2±0.39	0.78	3.13	26.0±0.38	0.76	2.92
New 42	27.2±0.45	0.91	3.37	28.0±0.44	0.88	3.14
New 170	25.7±0.41	0.82	3.20	26.4±0.40	0.80	3.03
New 141	28.8±0.39	0.78	2.73	29.5±0.38	0.76	2.58

3.3. Leaf number at the third developmental stage. The third developmental stage was characterized by the highest leaf numbers in all studied materials.

In 2025, New 42 showed the highest mean value, reaching 49.8 ± 0.56 leaves. New 141 followed closely with 49.2 ± 0.84 leaves. New 170 recorded 45.1 ± 0.89 leaves, while New 14 and New 21 had 41.6 ± 0.82 and 40.0 ± 0.74 leaves, respectively. The lowest value was observed in Check1, at 38.1 ± 1.11 leaves.

The coefficient of variation ranged from 2.27% in New 42 to 5.86% in Check1. The combination of a high mean value and low coefficient of variation in New 42 is particularly noteworthy, indicating a relatively stable expression of high leaf number at the later developmental stage. In 2026, the number of leaves increased further in all studied materials. New 42 recorded the highest value of 51.0 leaves, followed by New 141 with 50.3 leaves. New 170 reached 46.2 leaves, whereas New 14 and New 21 recorded 43.0 and 41.2 leaves, respectively. Check1 had the lowest value of 39.5 leaves. The results indicate that New 42 and New 141 were characterized by the greatest accumulation of leaves during the later stage of plant development.



Table 3. Leaf number at the third developmental stage in 2025–2026

Variety/sample	2025 M±m	σ	V, %	2026 M±m	σ	V, %
Check1	38.1±1.11	2.23	5.86	39.5±1.04	2.08	5.27
New 14	41.6±0.82	1.64	3.95	43.0±0.80	1.60	3.72
New 21	40.0±0.74	1.49	3.72	41.2±0.72	1.44	3.50
New 42	49.8±0.56	1.13	2.27	51.0±0.55	1.10	2.16
New 170	45.1±0.89	1.79	3.97	46.2±0.86	1.72	3.72
New 141	49.2±0.84	1.68	3.42	50.3±0.81	1.62	3.22

3.4. Dynamics of leaf formation across developmental stages. The three-stage observations clearly demonstrate progressive leaf formation in all six quinoa materials. In 2025, Check1 increased from 4.6 leaves at the first stage to 20.9 leaves at the second stage and 38.1 leaves at the third stage. New 14 increased from 5.7 to 22.4 and subsequently to 41.6 leaves. New 21 increased from 6.3 to 25.2 and then to 40.0 leaves. New 42 increased from 5.8 leaves at the first stage to 27.2 at the second and 49.8 at the third stage. New 170 increased from 5.9 to 25.7 and subsequently to 45.1 leaves. New 141 showed an increase from 4.7 leaves at the first stage to 28.8 at the second and 49.2 leaves at the third stage.

A similar developmental pattern was observed in 2026. The number of leaves increased from the first stage to the second and third stages in all studied materials. New 42 reached the highest value at the third stage, while New 141 remained close to it.

Table 4. Dynamics of leaf number according to developmental stage in 2025–2026

Variety/sample	2025 Stage I	2025 Stage II	2025 Stage III	2026 Stage I	2026 Stage II	2026 Stage III
Check1	4.6	20.9	38.1	4.8	21.8	39.5
New 14	5.7	22.4	41.6	5.9	23.2	43.0
New 21	6.3	25.2	40.0	6.5	26.0	41.2
New 42	5.8	27.2	49.8	6.0	28.0	51.0
New 170	5.9	25.7	45.1	6.1	26.4	46.2
New 141	4.7	28.8	49.2	4.9	29.5	50.3

The dynamics indicate that the ranking of the studied materials changed during ontogenetic development. New 21 demonstrated the highest number of leaves at the initial stage, whereas New 141 became the leading material at the second stage. At the third stage, New 42 demonstrated the highest leaf number. This pattern suggests that early leaf formation and subsequent leaf accumulation represent related but not identical characteristics. Some materials may initiate leaf development more actively at the beginning of growth, while others may demonstrate stronger leaf accumulation during subsequent vegetative development.

The relatively high values observed in New 42 and New 141 during the later stages indicate a strong development of the leaf apparatus. This characteristic may be of interest in further comparative studies of vegetative productivity and plant architecture.



3.5. Interannual comparison. Comparison between the two growing seasons showed a generally similar pattern of leaf formation. The mean leaf number in 2026 was slightly higher than in 2025 for all six studied materials.

At the first stage, the increase ranged from 0.2 leaves in all materials. At the second stage, the increase ranged from 0.7 leaves in New 14 to 0.9 leaves in Check1 and New 141. At the third stage, differences between years ranged from 1.2 leaves in New 21 to 1.4 leaves in New 42 and New 170. The general consistency of the ranking of materials across years indicates that differences in leaf formation were not entirely random. New 21 maintained a high position during the first stage, while New 42 and New 141 showed superior performance during later stages.

From a breeding perspective, the stability of a morphological characteristic across developmental stages and growing seasons is an important consideration. Materials that combine a high mean value with comparatively low variability may be useful candidates for further evaluation.

CONCLUSION

The investigation of six introduced quinoa variety samples under irrigated conditions demonstrated clear differences in the dynamics of leaf formation during three developmental stages.

In the first developmental stage, New 21 recorded the highest mean leaf number in both years, with 6.3 leaves in 2025 and 6.5 leaves in 2026. At the second developmental stage, New 141 demonstrated the highest values, reaching 28.8 leaves in 2025 and 29.5 leaves in 2026. At the third developmental stage, New 42 had the highest leaf number, with 49.8 leaves in 2025 and 51.0 leaves in 2026. New 141 was also characterized by a high leaf number, reaching 49.2 and 50.3 leaves, respectively. The coefficient of variation was relatively low at the second and third developmental stages, particularly in New 42 and New 141. This indicates comparatively stable expression of leaf number during the later phases of plant development. The study demonstrates that assessment of leaf number at several developmental stages provides more informative characterization of quinoa vegetative development than a single measurement. The differences observed among the introduced materials indicate the presence of distinct patterns of leaf formation. New 42 and New 141 can be considered particularly noteworthy materials with regard to high leaf number during later developmental stages, while New 21 demonstrated comparatively strong early leaf formation.

Leaf number and its developmental dynamics may therefore be used as supplementary biometric characteristics in the comparative evaluation of introduced quinoa materials and in the identification of promising materials for further breeding studies.

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