

Phenotypic and Agronomic Evaluation of Isogenic and Introgressive Cotton Lines for Yield, Fiber Quality, and Growth Traits under Field Conditions in Uzbekistan

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ABSTRACT

The present study evaluated the phenotypic and agronomic variability of isogenic and introgressive cotton (*Gossypium hirsutum* L.) lines under field conditions in Uzbekistan. A total of ten cotton lines and two commercial cultivars were assessed for earliness, yield performance, fiber quality, and morphobiological traits using a randomized complete block design. Significant genotypic differences were observed for all evaluated parameters. Early-maturing lines L-608 and L-454 showed shorter periods from sowing to flowering, indicating their suitability for environments with limited growing seasons. Line L-452 exhibited the highest boll weight and cotton weight per plant, demonstrating superior yield potential. Regarding fiber quality, lines L-454, L-453, and L-452 showed higher fiber yield and fiber index, while L-4112 recorded the longest fiber length. Morphobiological assessment revealed vigorous vegetative growth in L-4112 and L-620, whereas L-608 showed a more compact growth habit associated with earliness. Overall, no single genotype was superior across all traits; instead, different lines expressed specific advantages in yield, earliness, and fiber quality. The results highlight the presence of valuable genetic diversity among the studied materials and their potential use in cotton breeding programs aimed at developing high-yielding, early-maturing, and high-quality fiber cultivars adapted to Uzbekistan agroecological conditions.

Keywords: *Gossypium hirsutum*, isogenic lines, introgressive lines, phenotypic variation, fiber quality, yield components, morphobiological traits.

INTRODUCTION

Cotton (*Gossypium* spp.) is one of the most important fiber and oilseed crops worldwide, playing a key role in the global textile industry and agricultural economy. In addition to fiber production, cottonseed is an important source of oil and protein, which increases its economic value. Therefore, improving both fiber and seed-related traits

remains a major objective in modern cotton breeding programs (Fang et al., 2013; Grover et al., 2020). Seed germination, viability, and early growth dynamics are critical indicators of plant performance, as they directly determine successful crop establishment and productivity. These traits are highly sensitive to genetic factors as well as external influences, including mutagenic treatments (Finch-Savage and Bassel, 2016). Recent

studies emphasize that early developmental traits such as germination rate, seedling vigor, and survival capacity are closely associated with yield stability and stress tolerance (Wi et al., 2007). Gamma irradiation is widely applied in plant breeding as a powerful mutagenic tool for inducing genetic variability. It causes structural and functional changes at the DNA level, leading to the emergence of new phenotypic variations. Depending on the dose, gamma radiation may stimulate physiological processes or inhibit growth due to oxidative stress and cellular damage (Oladosu et al., 2016; Raina et al., 2022; Riviello-Flores et al., 2022). This dual effect highlights the importance of optimizing irradiation conditions in breeding programs. Hybridization is another fundamental approach for cotton improvement. Intraspecific hybridization allows the exploitation of heterosis within species, while interspecific (distant) hybridization enables the transfer of valuable traits across species boundaries, including stress tolerance, disease resistance, and improved seed composition (Zhang et al., 2024). Studies on distant hybrids have shown that economically important traits can exhibit complex inheritance patterns influenced by gene interactions.

In particular, the inheritance of seed oil content in distant cotton hybrids has been investigated by Amanturdiev et al. (2021), who reported that in F_2 populations, the appearance of non-parental traits indicates additional gene effects, suggesting that oil content may not follow simple polygenic inheritance. This highlights the genetic complexity of economically important seed traits in hybrid populations.

Recent advances in cotton genetics further support the importance of integrating classical breeding with modern molecular approaches. For instance, marker-assisted selection (MAS) has proven effective in identifying genes associated with fiber quality, disease resistance, and abiotic stress tolerance. A recent study by Narkizilova et al.

(2025) demonstrated that specific molecular markers (e.g., BNL1604, Gh247, BNL3255) are strongly associated with fiber traits and Fusarium wilt resistance, emphasizing the role of genomics in accelerating cotton improvement.

Despite these advances, the combined effects of mutagenesis and hybridization - particularly their influence on seed germination, viability, and early growth dynamics - remain insufficiently studied. Most previous research has focused either on mutation breeding or hybrid performance separately, with limited attention given to their interaction across developmental stages.

Therefore, the present study aims to evaluate seed germination, viability, and growth dynamics of intra- and interspecific hybrid cotton plants derived from gamma-irradiated seeds. This research will contribute to a better understanding of the interaction between induced mutagenesis and hybrid genetic systems, and its potential application in developing high-yielding, stress-tolerant cotton varieties.

MATERIAL AND METHODS

Plant materials and experimental conditions

The study was conducted using a collection of cotton (*Gossypium hirsutum* L.) genetic resources, including isogenic and introgressive lines. The experimental materials consisted of the lines L-452, L-453, L-454, L-492, L-494, L-608, L-620, L-4112, L-34, and the commercial cultivars Farovon and Namangan-77. Representative morphobiological and phenological characteristics of selected cotton lines evaluated under field conditions are presented in Figure 1. Cotton is one of the most important fiber crops worldwide, and the evaluation of agronomic and fiber-quality traits plays a crucial role in breeding programs aimed at improving yield and technological characteristics (Smith and Cothren, 1999; Zhang et al., 2024).

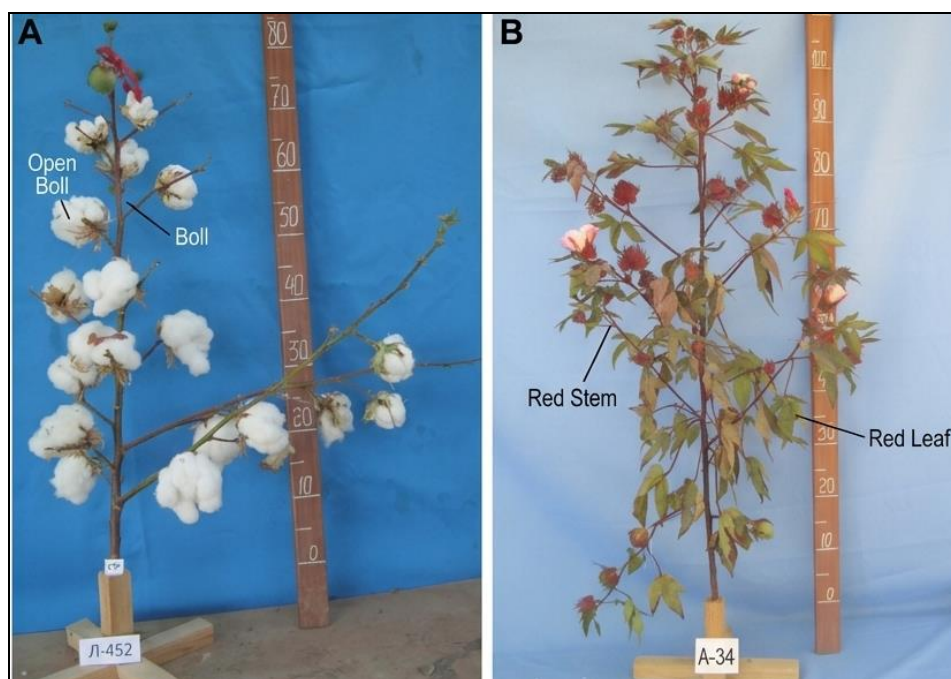


Figure 1. Representative morphobiological and phenological characteristics of cotton genetic collection lines used in the study. (A) Morphological characteristics of line L-452 showing boll development and open bolls; (B) Phenological variation observed in line L-34 characterized by red stem and red leaf pigmentation. Photographs were taken during the flowering and boll-opening stages under field conditions.

Field experiments were carried out under irrigated conditions during the growing season at an experimental research station in Uzbekistan. Standard agronomic practices, including irrigation, fertilization, weed management, and pest control, were uniformly applied according to regional cotton cultivation recommendations (Ritchie et al., 2004). Environmental and agronomic uniformity was maintained throughout the experiment to minimize non-genetic variation among the studied genotypes.

Experimental design and phenological observations

The experiment was established using a randomized complete block design (RCBD) with multiple replications, which is commonly applied in cotton breeding and field evaluation studies to reduce environmental error and improve statistical reliability (Gomez and Gomez, 1984). All genotypes were sown simultaneously under identical field conditions. Phenological observations were conducted during the principal developmental stages of cotton growth. The duration from sowing to 50%

flowering and from sowing to 50% boll opening was recorded to assess earliness and maturity characteristics. These developmental parameters are widely used as important indicators in cotton breeding programs because they directly influence adaptation and productivity under different environmental conditions (Oosterhuis, 1990; Bednarz and Nichols, 2005).

Evaluation of productivity traits

Productivity-related traits were evaluated at the maturity stage. Boll weight (g) was determined by weighing seed cotton obtained from mature bolls collected from representative plants. Cotton yield per plant (g) was measured based on the total harvested seed cotton from individual plants. Yield and boll characteristics are considered major agronomic traits influencing overall cotton productivity and are extensively used in genetic improvement studies (Meredith and Bridge, 1972; Preetha and Raveendran, 2007). Mean values and standard errors were calculated for all measured traits to evaluate the extent of variation among genotypes.

Fiber quality analysis

Fiber quality parameters were analyzed after ginning harvested seed cotton samples under laboratory conditions. Fiber yield (%) was calculated as the proportion of lint weight relative to total seed cotton weight. Fiber index (g), fiber length (mm), and 1000-seed weight (g) were determined according to standard cotton evaluation procedures widely adopted in cotton research and breeding programs (ASTM, 2012; USDA, 2019). Fiber length is considered one of the most important technological properties determining spinning quality and textile performance (Bradow and Davidonis, 2000). The 1000-seed weight was determined by weighing one thousand mature and healthy seeds from each genotype.

Morphobiological trait assessment

Morphobiological observations were conducted during the third phenological stage of plant development. Plant height (cm) was measured from the soil surface to the apex of the main stem, while the number of nodes on the main stem was counted manually for representative plants. Morphological and growth-related traits are widely used in cotton breeding studies for the characterization of genetic resources and the identification of promising parental forms (Ali et al., 2008; Song et al., 2012).

Assessment of boll formation traits

During the boll opening stage, the total number of bolls and the number of opened bolls per plant were recorded. These parameters are considered important indicators of reproductive efficiency and yield potential in cotton (Pettigrew and Meredith, 1994). Observations were conducted on representative plants selected from each experimental plot, and the obtained data were expressed as mean values with corresponding standard errors.

Statistical analysis

All experimental data were subjected to statistical analysis using standard biometric methods. Descriptive statistical parameters, including means and standard errors (mean $\pm$ SE), were calculated for each trait. Comparative analyses among cotton lines and cultivars were performed to identify genotypes with superior agronomic and fiber-quality characteristics. Statistical approaches described by Gomez and Gomez (1984) were followed for data evaluation.

RESULTS AND DISCUSSION

In this study, morphobiological and economically valuable traits of isogenic and introgressive cotton lines were evaluated. The obtained results demonstrated considerable variation among the studied genotypes in terms of vegetation period, productivity, fiber quality, and morphological characteristics.

Vegetation period and productivity traits

The shortest period from sowing to 50% flowering was observed in lines L-608 and L-454, accounting for 63.5 ± 0.86 and 64.3 ± 0.81 days, respectively. In contrast, the longest period was recorded in line L-4112, where flowering occurred after 68.0 ± 1.12 days. Regarding the period from sowing to 50% boll opening, lines L-608 (111.3 ± 0.84 days) and L-4112 (113.5 ± 0.88 days) exhibited relatively early maturity. Conversely, lines L-452 and L-453 were characterized by a comparatively longer vegetation period.

The highest boll cotton weight was observed in line L-452, reaching 9.0 ± 0.24 g. Similarly, the highest cotton weight per plant was also recorded in this line, amounting to 63.7 ± 0.42 g. High productivity indicators were also observed in line L-620 and the cultivar Farovon.

Table 1. Vegetation period and productivity characteristics of cotton genetic collection lines and cultivars

No	Lines/ Cultivars	Sowing-50% flowering (days)	Period until boll opening (days)	Cotton weight per boll (g)	Cotton weight per plant (g)
1	L-452	65.8±1.14	119.9±0.84	9.0±0.24	63.7±0.42
2	L-453	65.5±0.75	119.6±0.69	7.0±0.17	52.2±0.51
3	L-454	64.3±0.81	118.4±0.94	7.3±0.21	49.3±0.39
4	L-492	66.8±0.97	117.3±0.90	6.3±0.09	48.7±0.53
5	L-494	65.1±0.69	115.3±0.92	6.2±0.19	53.9±0.59
6	L-608	63.5±0.86	111.3±0.84	6.3±0.14	49.2±0.44
7	L-620	65.3±0.91	115.7±0.98	6.5±0.11	60.8±0.55
8	L-4112	64.0±1.12	113.5±0.88	6.6±0.16	47.7±0.67
9	L-34	66.3±0.85	118.2±0.79	6.7±0.26	53.9±0.51
10	Farovon	65.8±0.77	114.5±0.69	6.9±0.31	57.8±0.49
11	Namangan-77	67.0±0.81	118.0±1.07	6.8±0.18	53.9±0.63

Analysis of fiber quality traits

The highest fiber yield was observed in line L-454, accounting for 46.4±0.30%. High fiber yield was also recorded in lines L-453 (43.2±0.17%), L-452 (42.6±0.21%), and L-492 (41.4±0.19%) (Table 2). In contrast, the lowest value was observed in the Namangan-77 cultivar (36.2±0.20%).

Fiber index values were highest in lines L-454 (11.2±0.09 g), L-453 (10.9±0.06 g), and L-452 (10.6±0.12 g). The lowest fiber

index was recorded in line L-608. Regarding fiber length, line L-4112 showed the best result (35.4±0.3 mm). High fiber length values were also observed in line L-620 and the cultivar Farovon, reaching 34.2±0.1 mm and 33.5±0.1 mm, respectively. The highest 1000-seed weight was recorded in lines L-452 (149.3±0.89 g) and L-453 (140.7±0.59 g), whereas the lowest value was observed in line L-608.

Table 2. Fiber quality traits of cotton genetic collection lines and cultivars

No	Lines/ Cultivars	Fiber yield (%)	Fiber index (g)	Fiber length (mm)	1000-seed weight (g)
1	L-452	42.6±0.21	10.6±0.12	27.3±0.2	149.3±0.89
2	L-453	43.2±0.17	10.9±0.06	24.8±0.2	140.7±0.59
3	L-454	46.4±0.30	11.2±0.09	26.1±0.3	130.1±0.71
4	L-492	41.4±0.19	8.5±0.07	32.1±0.1	119.5±0.83
5	L-494	39.3±0.32	8.3±0.05	33.0±0.2	125.8±0.72
6	L-608	39.2±0.29	7.2±0.08	33.1±0.2	114.1±0.68
7	L-620	37.7±0.31	7.6±0.11	34.2±0.1	120.6±0.75
8	L-4112	38.8±0.34	7.4±0.06	35.4±0.3	125.3±0.62
9	Farovon	40.0±0.27	8.3±0.11	33.5±0.1	125.9±0.76
10	Namangan-77	36.2±0.20	7.8±0.09	32.1±0.2	130.1±0.74

Analysis of morphobiological traits

According to the results of the third phenological observations, the highest plant height was recorded in L-4112 (127.50±1.99 cm), L-492 (123.75±2.06 cm), L-494 (121.31±1.79 cm), and the cultivar Farovon (121.19±2.25 cm). In contrast, the lowest

plant height was observed in line L-608 (98.60±1.78 cm). The number of nodes on the main stem was comparatively higher in lines L-4112, L-492, and the cultivar Farovon, whereas Namangan-77 showed the lowest value.

Table 3. Morphobiological characteristics of cotton genetic collection lines and cultivars

Lines/ Cultivars	Plant height (cm)	Number of nodes
L-452	105.5±1.75	24.45±0.25
L-453	102.56±2.02	25.40±0.34
L-454	103.44±1.99	25.62±0.32
L-492	123.75±2.06	26.24±0.37
L-494	121.31±1.79	26.07±0.36
L-608	98.60±1.78	25.02±0.34
L-620	113.35±2.19	25.11±0.38
L-4112	127.50±1.99	25.67±0.29
Farovon	121.19±2.25	25.76±0.36
Namangan-77	115.45±2.19	24.20±0.34

Analysis of boll number traits

Phenological observations conducted during the boll opening stage showed that the highest total number of bolls was observed in lines L-620 (16.63±0.73) and

L-494 (15.27±0.64). Regarding the number of opened bolls, the highest values were recorded in L-494 (10.33±0.47), Namangan-77 (10.30±0.48), and L-620 (10.27±0.46).

Table 4. Phenological observation results during boll opening stage

Lines/ Cultivars	Total number of bolls	Number of opened bolls
L-452	11.07±0.46	6.16±0.60
L-453	11.80±0.44	7.96±0.56
L-454	12.13±0.50	7.13±0.67
L-492	14.61±0.66	8.02±0.62
L-494	15.27±0.64	10.33±0.47
L-608	13.92±0.28	7.89±0.46
L-620	16.63±0.73	10.27±0.46
L-4112	11.72±0.74	7.98±0.45
Farovon	13.64±0.47	8.88±0.52
Namangan-77	13.28±0.57	10.30±0.48

The present study revealed substantial variation among the investigated isogenic and introgressive cotton lines with respect to vegetation period, productivity, fiber quality, and morphobiological traits. Such variability is of considerable importance for cotton breeding programs because the identification of genotypes combining earliness, high productivity, and superior fiber quality remains one of the major objectives in modern cotton improvement (Smith and Cothren, 1999; Zhang et al., 2024).

Vegetation period and productivity traits

Earliness is considered an important adaptive and agronomic trait in cotton, particularly under regions characterized by limited water availability and shortened growing seasons (Bednarz and Nichols, 2005). In the present study, lines L-608 and L-454 exhibited the shortest period from

sowing to flowering, indicating their potential as early-maturing genotypes. Early maturity may contribute to efficient resource utilization and reduced exposure to late-season environmental stress (Oosterhuis, 1990). The comparatively early boll opening observed in lines L-608 and L-4112 further confirms their suitability for breeding programs focused on earliness. Similar relationships between shortened vegetation period and improved adaptation have been reported in previous cotton studies (Song et al., 2012). Among the studied genotypes, line L-452 demonstrated the highest boll weight and cotton weight per plant, suggesting strong yield potential. Yield components such as boll weight and boll number are recognized as key determinants of overall cotton productivity (Meredith and Bridge, 1972). In addition, line L-620 and the cultivar Farovon also showed relatively high productivity

indicators, which may indicate favorable genetic potential for yield-related traits. The observed differences among the genotypes confirm the existence of broad phenotypic diversity within the studied collection.

Fiber quality characteristics

Fiber quality traits are among the most economically important characteristics in cotton breeding because they directly affect spinning efficiency and textile quality (Bradov and Davidonis, 2000). The highest fiber yield and fiber index values recorded in lines L-454, L-453, and L-452 indicate the superiority of these genotypes in lint production efficiency. High fiber yield is considered a desirable breeding target because it increases the proportion of usable lint obtained from seed cotton. In contrast, the longest fiber length was observed in line L-4112, followed by L-620 and the cultivar Farovon. Fiber length is one of the principal technological properties determining yarn strength and processing quality (Smith and Cothren, 1999). Therefore, the superior fiber length detected in these genotypes suggests their potential value as parental materials in breeding programs aimed at improving textile performance. The variation observed in 1000-seed weight among the studied lines may reflect differences in seed development and assimilate accumulation. The relatively high seed weight in lines L-452 and L-453 may be associated with their increased boll productivity and overall biomass accumulation.

Morphobiological traits

Plant height and node number are important indicators of vegetative growth and adaptation capacity in cotton (Ali et al., 2008). In the current study, line L-4112 exhibited the highest plant height, while L-492, L-494, and the cultivar Farovon also demonstrated vigorous vegetative growth. Taller plants with increased node number may possess greater photosynthetic capacity and reproductive potential; however, excessive vegetative growth can sometimes negatively affect earliness and harvest efficiency. The comparatively lower plant height observed in

line L-608 may be associated with its earlier maturity. Similar negative relationships between earliness and vegetative growth duration have been reported in previous studies (Bednarz and Nichols, 2005).

Boll formation characteristics

The number of total and opened bolls is one of the principal yield-forming traits in cotton (Pettigrew and Meredith, 1994). In this study, lines L-620 and L-494 produced the highest total number of bolls, indicating enhanced reproductive efficiency. Moreover, the high number of opened bolls observed in L-494, L-620, and Namangan-77 suggests good boll maturation and field productivity. The combined evaluation of boll number, boll opening, and cotton weight per plant indicates that several studied genotypes possess valuable agronomic characteristics suitable for breeding applications. In particular, L-452 demonstrated superior productivity traits, whereas L-4112 and L-620 showed promising fiber quality performance.

Overall evaluation of cotton lines

The obtained results demonstrate that the investigated cotton collection contains genetically diverse material with significant variation in economically valuable traits. Different genotypes exhibited superiority for specific characteristics, indicating their potential utility as breeding resources. Lines L-452 and L-620 may be considered promising for productivity improvement, while L-4112 appears valuable for fiber length enhancement. Similarly, L-608 showed potential as an early-maturing genotype. Overall, the identified variability among isogenic and introgressive cotton lines provides an important basis for future breeding programs aimed at developing high-yielding, early-maturing, and high fiber-quality cotton cultivars adapted to the environmental conditions of Uzbekistan.

CONCLUSIONS

The present study demonstrated considerable phenotypic and agronomic

variation among the investigated isogenic and introgressive cotton lines, confirming the presence of valuable genetic diversity for cotton breeding. Significant differences were observed in vegetation period, yield components, fiber quality, and morphobiological traits, indicating that the studied genotypes possess distinct genetic potentials for specific agronomic characteristics. Among the evaluated lines, L-608 and L-454 were identified as early-maturing genotypes with shorter periods from sowing to flowering, making them particularly valuable for environments with limited growing seasons and water constraints. In contrast, L-452 showed superior performance in yield-related traits, including boll weight and cotton weight per plant, suggesting its strong potential for productivity improvement in breeding programs. Regarding fiber quality, lines L-454, L-453, and L-452 exhibited higher fiber yield and fiber index, while L-4112 demonstrated the longest fiber length, indicating its usefulness as a donor for improving textile-related traits. Morphobiological assessment further revealed that L-4112 and L-620 exhibited vigorous vegetative growth, whereas L-608 maintained a more compact and early-maturing growth habit.

Overall, the results highlight that no single genotype was superior across all traits; instead, different lines expressed excellence in specific characteristics. These findings emphasize the complementary value of the studied germplasm and support its utilization in breeding strategies aimed at developing cotton cultivars with improved earliness, productivity, and fiber quality, adapted to the agroecological conditions of Uzbekistan.

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