Journal of Wildlife and Biodiversity
Online ISSN: 2588-3526
Volume 7(Supplementary issue): 173-183 (2023) (http://www.wildlife-biodiversity.com/)

Research Article

Inheritance of morphological indicators of Cotton Bolls in geographically distant F_1 hybrids

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Received: 19 July 2023 / Revised: 11 October 2023 / Accepted: 19 October 2023/ Published online: 20 October 2023.
How to cite: Kahharov, I., Mutalova, M., Kodirova, M., Azimov, A., Yusupova, S. (2023). Inheritance of morphological indicators of Cotton Bolls in geographically distant F1 hybrids, Journal of Wildlife and Biodiversity, 7(Supplementary issue), 173-183. **DOI**: https://doi.org/10.5281/zenodo.10023408

Abstract

This article presents an analysis of Cotton Bolls' size and shape indicators in geographically distant hybrids F_1. It has been established that in hybrid plants obtained by crossing small-boll and large-boll forms, the dominance of the large-boll parent is observed. In the form of a boll in F_1 hybrid plants in, all types of inheritance are observed. Significant changes in the shape of the boll are observed in hybrid combinations, where geographically distant samples served as initial forms. It has been established that in F_1 plants the inheritance of morphological traits depends on the genetic structure and on the geographical distance of the crossed forms.

Keywords: *G. hirsutum* L, cotton, inheritance, dominance, boll, hybrid, line, variety

Introduction

Cotton (*Gossypium hirsutum* L.) — is an important economic crop, grown up all over the world as a source of fiber. (Constable & Bange, 2015; Shavkiev *et al.*, 2022, 2023). The main components of the economic yield of cotton are the number of bolls per plant and the mass of raw cotton (size) of one boll. (Karimov *et al.*, 2008; Shavkiev *et al.*, 2021). The number and location of cotton bolls, which are the fruit of cotton and an important component of fiber yield, are perhaps one of the most important phenotypic traits (Sun *et al.*, 2020; Shavkiev *et al.*, 2020). The boll is the rounded mature fruit of the cotton plant. It is made up of separate compartments which are called lobules, in which cotton seeds and lint grow. These open at harvest time. An average boll will contain nearly 500,000 cotton fibers.

The fruit is a 3-5 lobular boll, which in most varieties open when ripe. The shape of the boll is ovoid, ovoid-conical, round-oval, spherical, spherical-flattened. The surface of the boll is smooth or pitted, light green, pink, dark red in color. Cotton is one of the most important industrial crops in the world belongs to *Malvaceae* family of genus *Gossypium*; this genus is comprised of ~50 species. Among cultivated cotton species, *Gossypium hirsutum* and *Gossypium barbadense* are all tetraploid (2n = 52) while *Gossypium herbaceum* and *Gossypium arboreum* are diploid (2n = 26). (Abdul Rehman *et al.*, 2019) Cotton bolls located at different (FB) positions experience different climate conditions (Liu *et al.*, 2015) and boll weight and fiber quality differ at different fruiting branch (FB) positions (Zhao *et al.*, 2011; Zhao & Oosterhuis, 2000)

The main method for the analysis of heredity and variability of traits in living organisms is hybridological or genetic analysis. When analyzing the inheritance of alternative qualitative traits in peas, Mendel established the rule of dominance in $F_{1,}$ the rule of gamete purity and their free combination, and it was also shown that hybridization of plant forms with alternative expression of traits in a number of subsequent generations leads to regular decrease in heterozygotes. Usmanov and Abdiev (2012) showed that in fine-fiber hybrids of older generations- indicators of boll weight, lobule weight, weight of 1000 seeds were significantly lower than that of 4-5-lobular bolls. To increase the weight of one boll, which is one of the main elements of productivity, it was recommended to select 4-5-lobular bolls.

Umirova et al (2019) found that in the original sources and backcross-hybrids F_1, F_1B_1 in greenhouse and field conditions, the traits of the weight of per boll slightly differed from each other. It should be noted that under both conditions, the inheritance boll mass trait in F_1 plants dominance, incomplete dominance and overdominance was observed. Later, with the accumulation of data with deviations from the basic irregularities, the concepts of semi-dominance, polymorphism, allelism, etc., were introduced to explain these deviations. Omelchenko and Sadykov (1983) proved continuous gradations of the transition of alternative expressions of the gene for the anthacyanin color of the cotton leaf (to green). The presence of anthacyanin color genes in the recessive state in green-leafed cotton has been established. Long-term observations of plant objects, in particular cotton, and its qualitative features show that, along with the extreme forms of their expression, there is and constantly exists a multitude of the most diverse transitional forms (Sherimbetov *et al.*, 2020). The fact that genes can mutate from A to A and vice versa has been established, and the ability of genes to persist in altered states has been noted (Dubinin, 1979). A gene can also be in any fractional state (Gaisinovich, 1967), which naturally increases its mutational and potential possibilities almost to infinity.

Materials and methods

The experiments were carried out in 2016-2022 at the site of the Academy of Sciences of the Republic of Uzbekistan Institute of Genetics and Experimental Plant Biology zonal experimental base located in the Zangiata district of the Tashkent region. The soils of the experimental plot are typical serozems, non-saline, with deep groundwater (8.0 meters or more) naturally infected with verticillium wilt. Agricultural technology used is generally accepted for the experimental base. The work was carried out in the laboratory "Seed Science" of the Institute during the 2016-2022 period. Hybridization was carried out according to the generally accepted method with preliminary castration and subsequent isolation of flowers on the eve of their flowering according to the diallel scheme:

1. 146 x L-2777
2. L-2777 x 146
3. 146 x L-2689
4. L-2689 x 146
5. 146 x L-6161
6. L-6161 x 146
7. 146 x Yulduz
8. Yulduz x 146
9. 146 x 75007-3
10. 75007-3 x 146
11. L-2777 x 75007-3
12. 75007-3 x L-2777
13. L-2689 x 75007-3
14. 75007-3 x L-2689
15. L-6161 x 75007-3
16. 75007-3 x L-6161
17. Yulduz x 75005-3
18. 75007-3 x Yulduz
19. L-2777 x L-6161
20. L-6161 x L-2777
21. L-2777 x L-2689
22. L-2689 x L-2777
23. L-2777 x Yulduz
24. Yulduz x L-2777
25. L-2689 x Yulduz
26. Yulduz x L-2689
27. L-2689 x L-6161
28. L-6161 x L-2689
29. Yulduz x L-6161
30. L-6161 x Yulduz

Sowing of hybrids and parental forms was carried out according to the scheme 60x25x1 and 90x15x1, in compliance with the principle of randomization, next to each combination of crossing with seeding parental forms ($P_1P_2xF_1$ xP_1P_2).

In parental forms and hybrid populations of F_1. All plants are obtained from sowing seeds of self-pollinated bolls. The initial forms and their reciprocal hybrids were studied according to the following morphological habit of the bush, type of branching, size and shape of the box, pubescence of the bush. The morphological description was carried out twice: 1) in the flowering phase and in the fruiting phase (at the end of July), the habit of the bush, plant color, degree of pubescence of the stem, intensity of anthocyanin tan, leaf shape, length of the leaf petiole, type and depth of dissection of the leaf blade was described.

The shape of the flower, the color of the corolla and the anthers. 2) in the maturation phase (at the end of August and beginning of September), the size and shape of the boll, the boll surface nature, the boll opening degree, the color of the fiber, the lintedness of the seeds, and the color of the seed fuzz were described. The number of loculi in the boll, the number of seeds in the loculus. Statistical processing of field and laboratory data and calculation of correlation coefficients between features were carried out according to the method of Dospekhov (1985), using the Microsoft Excel 2020 software package. All the discussed features of the samples we studied have not been previously published.

Results

It should be noted that when creating new varieties of cotton, it is necessary to take into account the inheritance and variability of the morphological parameters of hybrid forms. Since the current stage of agricultural development requires the creation of cotton varieties, an intensive type of study of morphological traits reveals the potential for hybrid populations to obtain valuable biotypes. To determine the degree of inheritance of the morphological parameters of the bolls, we conducted studies in geographically distant hybrids F_1. Varieties 146 (Bulgaria), 75007-3 (Australia) and Yulduz, lines L-6161, L-2689 and L-2777 served as the material for the study. The size of the bolls was studied, subdividing them into the following groups: small, medium and large (Fig. 1).

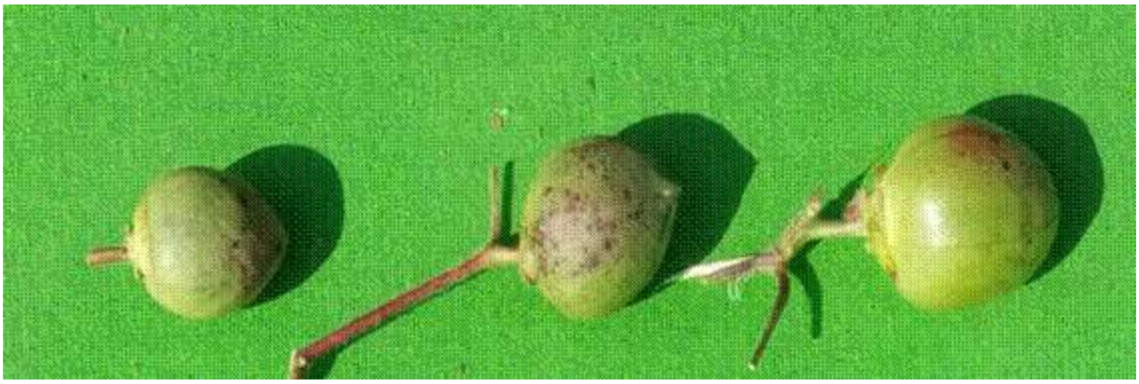

Figure 1. Boll sizes - small, medium and large

The forms used in crossing were mainly with an average boll size (with the exception of L-2777 with a small boll) (table-1).

Table 1. Boll sizes in initial parental forms and hybrids F_1

♀ \ ♂	146	L-2777	L-2689	L-6161	75007-3	Yulduz
146	**medium**	medium	medium	medium	medium	medium
L-2777	medium	**small**	large	medium	medium	large
L-2689	medium	large	**medium**	large	medium	large
L-6161	medium	medium	medium	**medium**	medium	large

75007-3	medium	medium	medium	medium	**medium**	medium
Yulduz	medium	medium	large	medium	medium	**medium**

Hybrid plants in most combinations, as well as parental forms, had an average size of bolls. In hybrid combinations, where one of the parental forms was L-2777 with a small boll, the dominance of parents with a larger boll was observed. It should be noted that in some hybrid combinations obtained by crossing L-2689 with other forms, the size of the boll turned out to be larger than that of the original parental forms.

So, from the above data, we can conclude that in hybrid plants obtained from crossing small-boll and larger-boll forms, the dominance of the large-boll parent is mainly observed. When crossing geographically distant forms in hybrid plants, the size of the boll increases.

Boll shape inheritance in geographically distant F_1 hybrids. The shape of the cotton boll is mainly divided into three groups: oval, ovoid and round. (Fig. 2).

Figure 2. Boll shape - oval, ovoid and round

Initial-parent varieties and lines used in boll form hybridization were divided into the following; oval in varieties 146, 75007-3 and lines L-2689, L-2777, ovoid in variety Yulduz and round in lines L-6161. Hybrid populations obtained as a result of crossing the above varieties and lines with each other, in the form of a boll, had a different degree of inheritance. Thus, the shape of the boll in hybrid plants obtained by crossing two forms with a round shape of the boll turned out to be the same as in the original parental forms (Table 2).

Table 2. Boll shape indicators in hybrids F_1

♂ / ♀	146	L-2777	L-2689	L-6161	75007-3	Yulduz
146	**round**	oval	round	ovoid	ovoid	round
L-2777	oval	**round**	ovoid	ovoid	ovoid	ovoid
L-2689	round	ovoid	**round**	ovoid	round	ovoid
L-6161	ovoid	ovoid	ovoid	**round**	ovoid	ovoid
75007-3	ovoid	oval	round	ovoid	**round**	ovoid
Yulduz	round	ovoid	ovoid	ovoid	ovoid	**ovoid**

The data showed that the hybrid plants obtained by hybridization of variety 146 with a round boll shape with the rest of the samples mainly had a round boll shape, i.e. variety 146 dominated. However, in one hybrid combination (146 x L-6161), the dominance of the parent with a round boll shape (L-6161) was observed. Hybrids obtained from crossing two forms with a round boll shape among themselves, in most combinations had round bolls. However, it is interesting to note that in some hybrid combinations, the hybrids had an oval (75007-3 x L-2689) and ovoid (146 x L-2777 and 75007-3 x L-2777) boll shape. Apparently, this is due to the geographical remoteness of the original forms.

Thus, the inheritance of morphological traits in F_1 hybrids depends on the genetic structure and on the geographical remoteness of the crossed forms; - in hybrid plants obtained by crossing small-boll and large-boll forms, the dominance of the large-boll parent is observed. In the form of a boll in hybrid plants in F_1, all types of inheritance are observed. In hybrid combinations obtained from crossing geographically close forms, there were no differences in this trait. Significant changes in the shape of the boll are observed in hybrid combinations, where geographically distant samples served as initial forms.

The data obtained showed that the original parental accessions differ in the shape of the beak of the bolls in the following way: bolls with a curved beak in variety 146 and Yulduz, lines L-6161 and L-2689 and an elongated beak in variety 75007-3 and line L-2777 (Fig.3).

Figure 3. Beakshape - curved, elongated and intermediate

Although the original forms had bolls both with a turned-up beak and with an elongated beak, the hybrid plants mostly had a boll with a turned-up beak, with the exception of the hybrid combination obtained by crossing variety 146 with a turned-up boll beak and line L-2777 with an elongated beak of the boll (Table 3).

Table 3. Beak bolls shape in hybrids F_1 (TU - turned-up, EL – elongated, IN – intermediate)

♂ / ♀	146	L-2777	L-2689	L-6161	75007-3	Yulduz
146	**TU**	EL	TU	TU	TU	IN
L-2777	EL	**EL**	TU	TU	TU	TU
L-2689	TU	TU	**TU**	TU	IN	TU

L-6161	TU	TU	IN	**TU**	TU	TU
75007-3	TU	TU	IN	TU	**EL**	IN
Yulduz	IN	TU	TU	TU	IN	**TU**

Inheritance bolls surface trait in geographically distant hybrids F_1. In variety 75007-3 and line L-2777 used in hybridization, the surface of the boll was smooth; rough - in grade 146; pitted - in variety Yulduz and lines L-6161 and L-2689. (Fig.4).

Figure 4. Boll surface trait: 1-rough, 2-pitted and 3-smooth

According to this trait, in hybrid combinations obtained from crossing the above forms, an ambiguous degree of inheritance was observed. So, when crossing forms with a smooth surface of the boll, in hybrid plants (75007-3 x L-2777) a pitted surface of the bolls was revealed. However, in hybrid combinations obtained by crossing L-2777 with a smooth surface of the bolls and samples with a pitted surface of the bolls, a regular dominance of L-2777 was observed, i.e. the surface of the capsules of hybrid plants turned out to be smooth (table 4).

Table 4. Boll surface in F_1 hybrids.

♂ / ♀	146	L-2777	L-2689	L-6161	75007-3	Yulduz
146	**R**	P	S	S	S	P
L-2777	P	**S**	S	S	P	S
L-2689	S	S	**P**	P	P	S
L-6161	S	S	S	**P**	P	S
75007-3	S	P	P	P	**S**	R
Yulduz	P	S	S	S	S	**P**

Note: R - rough; S -smooth; P - pitted.

It is interesting to note that the bolls of hybrid plants obtained by crossing rough boll surface variety 146 with smooth and pitted surface variety, in most cases had a smooth and pitted surface. We assume that the genes responsible for the roughness of the boll surface are recessive.

When crossing geographically close, but genotypically different pitted boll surface samples, the smooth surface of the bolls was observed in hybrid plants, which indicates the genotypic heterogeneity of the crossed forms. Thus, in terms of the boll surface trait, hybrid combinations obtained from crossing both geographically close and geographically distant ones show an ambiguous degree of inheritance. When crossing smooth boll surface forms, the hybrid plants show a pitted surface of the bolls. In hybrid combinations obtained by crossing forms with a smooth surface of the bolls and samples with a pitted surface of the bolls, a regular dominance of the sample with a smooth surface of the bolls is observed. Inheritance of boll opening degree in geographically distant F_1 hybrids. According to the boll opening degree, the studied initial parental forms were divided into strong L-6161, medium variety 146, 75007-3, Yulduz and line L-2689 and weak line L-2777 groups. (Fig. 5).

Figure 5. Boll opening degree: 1-strong, 2-medium and 3-weak

The data obtained indicate that in F_1 hybrid plants the indicators of boll opening degree are improved. So, in hybrids obtained by crossing the line L-2777 with a low boll opening degree with variety 146, 75007-3, Yulduz lines L-6161 and L-2689, which had a strong and medium degree of opening of bolls, respectively, the dominance of the latter was observed (table -5). In hybrid combinations obtained by crossing similar forms with an average degree of boll opening, hybrid plants had an average degree of boll opening as in the parents, and in some combinations a strong boll opening degree was observed.

Table 5. Boll opening degree in F_1 plants

♀ \ ♂	146	L-2777	L-2689	L-6161	75007-3	Yulduz
146	**medium**	medium	medium	strong	medium	strong
L-2777	medium	**weak**	strong	strong	medium	strong
L-2689	medium	strong	**medium**	strong	medium	strong
L-6161	strong	strong	strong	**strong**	strong	strong
75007-3	medium	medium	medium	strong	**medium**	weak
Yulduz	strong	strong	strong	strong	strong	**strong**

It is interesting to note that in hybrid combinations obtained from crossing geographically close varieties and lines with each other, an improvement in this trait was observed, i.e. a strong boll opening degree. Hybrid combinations, obtained by crossing geographically distant forms, basically had, like the original forms, an average boll opening degree. It should also be noted that when crossing L-6161, which has a strong boll opening degree with other forms, in hybrid plants F_1 , its dominance was naturally observed.

Thus, the study showed that the inheritance of morphological traits of F_1 hybrids depends on the genetic structure and the geographical remoteness of the crossed forms. It was found that when forms with a smooth boll surface were crossed, the hybrids showed a pitted boll surface. In hybrids from varieties with smooth surfaces and samples with pitted boll surfaces, the dominance of the sample with a smooth boll surface was observed. In hybrids from geographically distant forms, the boll opening degree generally improved. A strong boll opening degree was observed in hybrids, where one of the parents was a form with limited branching type and a strong boll opening degree.

Discussion

Several researchers have conducted research in this direction mainly on plant shape. Sanaev et al (2020) present an inheritance of the traits in F_1 and F_2 hybrids such as the number of sympodial branches, number of bolls, the yield per plant, and "plant shape" trait of the plants that are differentiated by branched, cone-shaped and cylindrical shapes in 6 introgressive lines obtained on the basis of interspecific hybridization of *G. hirsutum* L. species and the varieties Armugon-2, Navbahor-2 in artificial drought conditions and the analysis of their genotypic formation. According to genetic analyses, "plant shape" trait is inherited through 4 unrelated genes (S-s; S1-s1; S2-s2; S3-s3) in the polymer state. As a result, it was found that in drought conditions, the forms of cotton that are cone-shaped and have type I sympodial branches of a compact branching can be resistant and more productive than other forms of cotton. The line L-8 with such traits and characteristics was found to be related to genotype Sss1s1s2s2s3s3.

After pollination occurs the boll begins to develop. Under optimum conditions, it requires approximately 50 days for a boll to "open" after pollination occurs. Boll development can be characterized by three phases: enlargement, filling, and maturation. Several researchers have also worked on boll of cotton development. But research on the shape of the boll of cotton is just beginning.

The enlargement phase of boll development lasts approximately 3 weeks. During this time the fibers produced on the seed are elongating and the maximum volume of the boll and seeds contained therein are attained. Also, during this time, the fiber is basically a thin-walled tubular structure, similar to a straw. Each fiber develops from a single epidermal cell on the seed coat.

During the boll enlargement and fiber elongation phase, the development of the fiber is very sensitive to adverse environmental conditions (http://cotton.tamu.edu).

Within-boll yield components are the most basic determinants of seed cotton and/or lint yield in cotton (*Gossypium hirsutum* L.). Worley et al. (1974) revealed that the number of bolls on unit land area played a primary role in the total contribution to lint yield.

Conclusion

Trait heredity in F_1 hybrids depends on genetic structure and on geographical remoteness of the crossed forms. The dominance of the large-boll parent is observed in hybrid plants obtained by crossing small-boll and large-boll forms.

The differences in boll form are insignificant in hybrid combinations obtained from crossing geographically close samples. When forms with smooth boll surfaces are crossed, pitted boll surfaces appear in hybrid plants; when forms with smooth boll surfaces and samples with pitted boll surfaces are crossed, the sample with smooth boll surfaces is observed to dominate; When crossing geographically distant forms in hybrids, the boll opening degree improves as a whole. A strong boll opening degree is observed in plants obtained by crossing geographically distant forms, where one of the parents was a form with a limited branching type and a strong boll opening degree.

Acknowledgements

The authors are grateful to the Institute of Genetics and Plant Experimental Biology and to researchers in the Laboratory of Cotton Genetics, Selection and Seeding, Academy of Sciences of Uzbekistan.

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