Anabel – a new cotton variety

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Abstract
The aim of this research was to study the productive potential and to evaluate the technological fiber properties of the new cotton variety Anabel, compared to the standard varieties. The new variety was studied in competitive varietal trials conducted in 2014-2017 in the experimental field of the Field Crops Institute in Chirpan. In the IASAS system, the Anabel variety was tested in 2017-2018. It was approved for the new cotton variety in 2021. Anabel variety was obtained by intraspecific hybridization and belongs to the species *Gossypium hirsutum* L. Anabel is an early and productive variety. According to IASAS, in seed cotton yield - 2026 kg/ha, on average for two years, it was inferior by 3.1% to the cultivar Chirpan-539 - standard for productivity and was equal to the cultivar Avangard-264 - standard for fiber quality. In terms of fiber yield, it was equal to Chirpan-539 and was superior to Avangard-264, as a result of the higher lint percentage. This new variety showed a number of valuable fiber technological qualities and in some respects exceeded both standard cultivars or was equal to Avangard-264. Compared to the standard cultivars, the variety Annabel had a better fiber spinning (SCI) Index, longer fiber, lower micriner, greater strength and better spectroscopy with reflection of the RD difference. The obtained results define the new variety Anabel as a very good combination of earliness, productivity and fiber quality. This makes it very valuable for cotton production and selection programs with cotton.

Keywords: cotton; *G. hirsutum* L.; variety; productivity; fiber properties

INTRODUCTION

Genetic and breeding studies with cotton worldwide have made significant progress. Many new varieties with high productivity and high fiber quality, resistant to diseases, pests, drought, etc. have been created. A number of genetically modified varieties resistant to specific herbicides or bollworms have been developed and implemented in the production. Traditional breeding approaches for developing of new stress tolerance cotton varieties are being complemented by innovative approaches, utilizing molecular markers and transgenic technologies, or using genome editing techniques to obtain desired features (Mubarik et al., 2020; Sabev et al., 2020; Yang et al., 2020). Genetic technologies are widely used to identify genes (Islam et al., 2020; Liu et al., 2020) and to develop different breeding strategies to solve specific problems - breeding for disease resistance (Aini et al., 2022), breeding for herbicide resistance (Iqbal & Nazir, 2022), drought tolerance (Magwanga et al., 2020), heat tolerance (Majeed et al., 2021) and others.

At present, iproving productivitry and fiber quality is the main goal of cotton breeding in Bulgaria. Primary importance is given to earliness due to the short growing season of cotton. The yield and fiber quality is improved by applying the classical methods of selection. Intraspecific hybridization and experimental mutagenesis are the main breeding methods for improving earliness and productivity, interspecific hybridization of *G. hirsutum* L. × *G. barbadense* L. and its combination with intraspecific hybridization is used to improve fiber quality. By these methods a number of varieties have been created, of which especially valuable are Avangard-264, obtained by interspecific hybridization of *G. hirsutum* L. × *G. barbadense* L. (Koynov & Stoilova, 1996), Kolorit, Darmi, Natalia, Rumi and IPK Nelina obtained by combining the interspecific hybrid-

ization of *G. hirsutum* L. × *G. barbadense* L. with intraspecific hybridization (Stoilova & Saldzhiev, 2008a, 2008b, 2010; Stoilova & Meluca, 2013), Helius, Trakia, obtained by experimental mutagenesis (Valkova, 2009), Boyana, Denitsa, Philipopolis, obtained by intraspecific hybridization (Valkova & Bozhinov, 2010; Valkova, 2014a, 2014b).

In recent years, many new cotton varieties have been created at the Field Crops Institute in Chirpan. The variety Sirius, obtained by experimental mutagenesis, is a new achievement in the selection of earliness and productivity. This variety combines high productivity with a number of other valuable qualities for the production and textile industry (Valkova, 2017). In 2017, IASAS approved the Tsvetelina variety, and in 2019 approved the Pirin and Aida varieties. The Tsvetelina variety was also created by experimental mutagenesis and combines earliness, productivity and technological fiber qualities. This variety showed high stability and it is suitable for growing in different ecological conditions and technologies (Koleva & Valkova, 2019). The Aida variety was created by remote hybridization, by crossing the allothetraploid *Gossypium thurberi* Tod. × *G. raimondii* Ulbr. with Darmi variety - *G. hirsutum* L. and backcrossing of the triple hybrid (*G. thurberi* Tod. × *G. raimondii* Ulbr.) × Darmi with Darmi variety. In the state variety testing this variety showed high and stable productivity by years and a number of valuable fiber technological qualities (Dimitrova, 2022). In 2020 the variety Perun was approved, in 2021 four new varieties were recognized and these were Anabel (No. 535), Tiara (No. 550), Melani (No. 553) and Kristal (No. 710).

The aim of this research was to study the productive potential and to evaluate the technological fiber properties of the new cotton variety Anabel, compared to the standard cultivars.

MATERIAL AND METHODS

The variety Anabel was obtained by intraspecific hybridization from the crossing of the selection line No. 37 with the variety Dorina (No. 37 × Dorina). The pedigree of maternal form line No. 37 included the variety Progress of interspecific origin (*G. hirsutum* L. × *G. barbadense* L.). The father's form Dorina variety was of intraspecific origin, obtained through a selection in the Romanian line T-89/2. The initial plant was selected in F_2 (2008) and repeating negative selection was performed in the progeny by the economically most important traits for two years. In 2011, as line No. 535, it was included in a control testing. In 2012 line No. 535 was included in preliminary variety testing and since 2013 was test in competitive varietal trials.

The trials were conducted in the experimental field of the Field Crops Institute in Chirpan on leached vertisoil type and were plotted by the block method, in 4 replications, and a 20 m^2 harvest plot. The cultivar Chirpan-539 was used as a standard. This variety is very early, high yielding and is distinguished by high lint percentage, very good ecological plasticity and stability. Standard cotton growing technology was applied. 10 plants of each replicate were observed. To evaluate the economic qualities the following were taken into account: seed cotton yield (kg/ha); boll weight (g); lint percentage (%) and fiber length measured by the "butterfly" method (mm). A two-factor analysis of variance was performed on the results (Lidanski, 1998). The ANOVA 123 program was used.

Variety Anabel was included for testing in the IASAS (Exclusive Agency for Variety Testing, Approbation and Seed Control) system in 2017-2018. In 2017, it was tested in two locations - Radnevo and Burgas experimental stations of variety testing at the IASAS. In the next 2018, it was tested only in Radnevo experimental station, typical in climatic and soil conditions for cotton cultivation in southern Bulgaria. The main cotton areas are located in this region. The cultivar Chirpan-539 was the standard for earliness and productivity and the cultivar Avangard-264 was the standard for fiber quality. Usually, in the state variety testing, the new cotton varieties are also compared with an average standard - the average of the two standard cultivars.

In the IASAS system the new variety Anabel was tested under non-irrigated conditions, for biological and economic qualities, for homogeneity, distinctiveness and stability, and on an artificial infectious background for resistance to verticillium wilt (*Verticilium Dahliae*).

The years of the study were characterized as follows: in terms of temperature sum, 2015, 2016, 2017 and 2018 were warm (P=14.3-17.2%), 2014 was medium to medium cool (P=66.7%); in terms of rainfall, 2015 and 2017 were moderately wet (P=28.6-33.3%), 2014 and 2018 were wet (P=12.9-14.8%) and

2016 was dry (P=93.1%). The variability of years in terms of the rainfall was greater compared to their temperature sum.

P% is the coverage factor (coefficient of security) for the temperature sum in May-September and for the rainfall in May-August, respectively.

The years of the study were compared with the average long-term values of the base period of the last 30 years (1989-2018). This period was taken as a climatic norm (Alexandrov et al., 2010).

RESULTS AND DISCUSSION

The variety Anabel has a medium high with a conical shape shrub. The stem is green, with medium hairiness at the upper part and medium anthocyan color at maturity. The leaf mass is of medium density. The leaves are medium-sized, palm-shaped, 3-5 lobed, with medium hair on the underside and light green color. The fruiting branches are medium-long, with medium-long internodes. The variety sets the 1st fruiting branch at an average height of 19.9 cm, by 1.8 cm lower than the standard variety Chirpan-539, but it is suitable for machine harvesting. The flowers are cream, without anthocyanin spot at the base of petals. The bolls are medium-sized, oval-ovate in shape and have a slight protrusion at the top, and they open strongly when ripe. The seeds are medium-sized, covered with a medium dense whitish fuzz. The fiber is white, medium-long, medium-fine, of good strength and uniformity in length. The lint percentage is 40.6% on average.

The variety Anabel had a relatively high productivity for the conditions of our country. Cotton is grown in non-irrigated conditions, with insufficient temperature and rainfall. The testing results of the variety Anabel in the experimental field of Field Crops Institute in Chirpan showed that the yield of raw cotton by years varied from 1470 kg/ha in 2015 to 2329 kg/ha in 2014 (Table 1). In terms of temperature, sum and rainfall 2014 differed significantly from the other three years, during which the seed cotton yields of the variety Anabel and the standard cultivar Chirpan-539 were much lower. In warm years, such as 2015, 2016, 2017 and 2018, high temperatures in the summer months of July and August, the period of flowering and fruiting, have acted as a stress factor, especially in combination with prolonged and severe drought (in 2016).

The new variety Anabel surpassed the standard cultivar Chirpan-539 in seed cotton yield in three of the studied years, by 9.5% in dry 2016 to 25.5% in wet 2014, when seed cotton yields were highest, and it was inferior to the standard cultivar by 3.7% in 2015.

On average for four years (2014-2017), the variety Anabel yielded 1794 kg/ha, which was 11.1% more the standard cultivar Chirpan-539 (1615 kg/ha).

The results obtained characterize the variety Anabel as high yielding and responsive to medium warm years with sufficient rainfall during the summer months.

Anabel variety in fiber yield - 728 kg/ha was superior to the standard cultivar Chirpan-539 by 10.0% (Table 2). As for boll weight (5.2 g) it was equal to the standard cultivar. Anabel variety in fiber length - 26.6 mm surpassed by 0.7 mm the standard cultivar. In terms of lint percentage - 40.6% it was insignificantly inferior by 0.4% to the standard cultivar. Given that the variety Anabel in terms of lint percentage was almost equal to the standard

Table 1. Seed cotton yield resulting from the Anabel variety included in competitive variety trial, conducted at the Field Crops Institute in Chirpan, during 2014-2017

Cultivar Variety	Seed cotton yield, kg/ha					In % to Chirpan-539
	2014	2015	2016	2017	Mean	
Chirpan-539	1855	1527	1643	1437	1615	100.0
Anabel	2329^{+++}	1470	1799^{++}	1579^{+++}	1794	111.1
GD 5%	153	126	117	57	81	5.0
GD 1%	202	168	158	76	107	6.6
GD 0.1%	257	220	211	98	138	8.5

cultivar Chirpan-539, the realized higher fiber yield was due to the higher seed cotton yield.

Results obtained from the state variety testing (IASAS data) are presented in Table 3. The September harvest, cotton harvested before 30 September, is used as the main criterion for determining the varieties earliness. In 2017, on average from the two locations - Radnevo and Burgas, the variety Anabel in September yield - 1600 kg/ha was inferior to both standard cultivars, more strongly to Chirpan-539 and less to Avangard-264, to the average standard (the average of the two standards) it was lower by 3.5%. In 2018, in Radnevo, the variety Anabel in September yield - 1760 kg/ha was inferior to Chirpan-539 by 4.1%, and exceeded Avangard-264 by 3.8%, as a result it was aligned with the average standard.

On average for the two years of testing, the variety Anabel in September harvest - 1680 kg/ha was inferior to the cultivar Chirpan-539 by 4.1%, to the average standard - by 1.8%.

Table 2. Economic traits of the variety Anabel included in competitive variety trial, conducted at the Field Crops Institute in Chirpan, during 2014-2017 (Average data for four years)

Cultivar Variety	Fiber yield kg/ha	Boll weight g	Fiber length mm	Lint percentage %
Chirpan-539	662	5.2	25.9	41.0
Anabel	728	5.2	26.6^{+++}	40.6
GD 5%	-	0.2	0.3	0.5
GD 1%	-	0.3	0.5	0.7
GD 0.1%	-	0.4	0.6	0.9

Table 3. Test results obtained from Anabel variety in the IASAS system (state variety testing) in 2017-2018

Cultivar Variety	2017	2018	Mean	In % to average standard
		September harvest, kg/ha		
Average standard	1657	1765	1711	100.0
Chirpan-539	1669	1835	1752	102.4
Avangard-264	1645	1695	1670	97.6
Anabel	1600	1760	1680	98.2
		Seed cotton yield, kg/ha		
Average standard	2047	2073	2060	100.0
Chirpan-539	2070	2111	2091	101.5
Avangard-264	2024	2034	2029	98.5
Anabel	1995	2057	2026	98.3
		Fiber yield, kg/ha		
Average standard	778	740	759	100.0
Chirpan-539	798	779	789	103.9
Avangard-264	759	702	731	96.3
Anabel	813	772	793	104.5
		Lint percentage, %		
Average standard	37.9	35.7	36.8	100.0
Chirpan-539	38.4	36.9	37.7	102.4
Avangard-264	37.3	34.5	35.9	97.5
Anabel	40.8	37.5	39.1	106.3

In 2017, the variety Anabel in seed cotton yield - 1995 kg/ha was inferior to Chirpan-539 by 3.6%, to Avangard-264 it was inferior by 1.4%, to the average standard - by 2.5%. In 2018, the Anabel variety yielded 2057 kg/ha of raw cotton, yielding to Chirpan-539 by 2.6% and surpassing Avangard-264 by 1.1%.

On average for the two years of testing (2017-2018) a total seed cotton yield of 2026 kg/ha was obtained from the variety Anabel, by 1.7% below the average standard. The average test results showed that in seed cotton yield the variety Anabel was equal to Avangardd-264 and was inferior to Chirpan-539 (standard for productivity) by 3.1%, which characterizes it as a slightly lower productive variety than the standard cultivar Chirpan-539.

In Radnevo, average for the two years, mean yields of 2269 kg/ha and 2215 kg/ha were obtained from the standard cultivars Chirpan-539 and Avangard-264, average from the two standards 2242 kg/ha (average standard). Anabel variety in seed cotton yield of 2166 kg/ha was inferior to both standard cultivars, to Chirpan-539 - by 4.5%, to Avangard-264 - by 2.2%, to the average standard - by 3.4% (data are not given here).

At the Burgas experimental station the yields were lower compared to Radnevo, the region is less suitable for growing cotton. In 2017, seed cotton yields of 1714 kg/ha and 1653 kg/ha were obtained from the standard cultivars and of 1683 kg/ha average from the two standards. Anabel variety in seed cotton yield - 1715 kg/ha was leveled with Chirpan-539, outperforming Avangard-264 by 3.7%, and exceeding the average standard by 1.9%.

It could be assumed that the variety Anabel is more suitable for less productive environments or requires more specific cultivation technology, given that in the competitive variety trials conducted at the Field Crops Institute in Chirpan during 2014-2017 it was superior to the standard cultivar Chirpan-539.

Anabel variety, in fiber yield in 2017 - 813 kg/ha, on average from the two locations, exceeded both standard cultivars Chirpan-539 by 1.9%, Avangard-264 - by 7.1%, the average standard - by 4.5%. In 2018, in the Radnevo experimental station, the variety Anabel in fiber yield - 772 kg/ha was equal to Chirpan-539 and surpassed Avangard-264 by 10%, as a result of which it exceeded the average standard by 4.3%. The same trend was observed based on the average of the two years, the variety Anabel in fiber yield of 793 kg/ha was equal to Chirpan-539 and surpassed Avangard-264 by 8.5%, as a result of which it exceeded the average standard by 4.5%. The variety Anabel realized higher yield of fiber than the average standard due to its higher lint percentage. This variety showed a higher lint percentage than the standard cultivars and the average standard in both years of testing. In lint percentage - 39.1%, on average over the two years, the variety Anabel exceeded both standard cultivars and the average standard by 6.3%.

The results of the fiber technological properties are presented in Table. 4. Compared to the two standard cultivars (Chirpan-539 - standard for productivity and Avangard-264 - standard for fiber quality) Anabel variety had a higher index (SCI Index) (consistency) of spinning in both years of testing. On average for the two years, for the new variety this index was 124, for the standard cultivars it was much lower, for Chirpan-539 it was 114, for Avangard-264 - 118, for the average standard - 117.

During the two years of the study, the Anabel variety in fiber fineness was equal to the Avangard-264, which fiber was finer than that of the Chirpan-539, or had a lower microner than it. On average for the two years, Anabel variety had a lower microner - 4.44 Mic than Avangard-264 (4.62 Mic), which means that its fiber was a little finer. The Anabel variety had a finer fiber than that of Chirpan-539 (4.87 Mic).

The Anabel variety in fiber length - 26.86 mm in 2017 exceeded the standard cultivars by 1.73 mm and 1.32 mm, respectively. In 2018, it had a slightly shorter fiber and exceeded the standard cultivars by 0.49 mm and 0.42 mm. On average for the two years, the variety Anabel had a fiber length of 26.64 mm, exceeding both standards, Chirpan-539 - by 1.12 mm, Avangard-264 - by 0.46 mm, the average of the two standards - by 0.74 mm.

The Anabel variety had greater fiber strength than the standard cultivars in both years of study. The average fiber strength was 29.0 g/tex, at 27.9 g/tex for the standard cultivars and it showed better spectroscopy with reflection of RD difference.

The variety Anabel was equal to the standard cultivars in terms of maturity index, fiber uniformity and fiber elongation. It had a low content of short fibers - 8.8%, as the standard cultivars.

Table 4. Technological fiber properties according to IACAS data, 2017-2018

Year	Average standard	Chirpan-539	Avangard-264	Anabel
Spinning, consistency (SCI), Index				
2017	115	114	117	121
2018	117	114	119	126
Average 2017-2018	116	114	118	124
Deviation		-2	+2	+8
Micronaire (Mic)				
2017	4.57	4.74	4.41	4.42
2018	4.92	5.00	4.83	4.46
Average 2017-2018	4.75	4.87	4.62	4.44
Deviation		+0.12	-0.13	-0.31
Maturity(Mat) Index				
2017	0.86	0.87	0.86	0.86
2018	0.87	0.87	0.87	0.86
Average 2017-2018	0.87	0.87	0.87	0.86
Fiber mean length (UHML - Upper Half Mean Length), mm				
2017	25.33	25.13	25.54	26.86
2018	26.37	25.91	26.83	26.41
Average 2017-2018	25.85	25.52	26.18	26.64
Deviation		-0.33	+0.33	+0.79
Uniformity (UL) %				
2017	81.5	81.6	81.3	81.4
2018	82.4	82.3	82.5	82.5
Average 2017-2018	82.0	81.9	81.9	82.0
Short fibers (SFL), 12.7 *mm*				
2017	9.2	9.4	9.0	9.2
2018	8.4	8.6	8.1	8.4
Average 2017-2018	8.8	9.0	8.5	8.8
Strength (Str), g/tex				
2017	28.3	28.4	28.2	29.0
2018	27.5	27.3	27.7	29.0
Average 2017-2018	27.9	27.8	27.9	29.0
Deviation		-0.1	0.0	+1.1
Elongation (Elg), %				
2017	7.1	7.1	7.2	7.5
2018	7.1	7.3	6.9	7.0
Average 2017-2018	7.1	7.2	7.1	7.3
Spectroscopy with reflectance of the difference RD				
2017	81.1	80.4	81.9	82.1
2018	81.5	81.9	81.0	82.2
Average 2017-2018	81.3	81.2	81.5	82.2
Deviation		-0.1	+0.2	+0.9
Yellowness (+b)				
2017	8.9	8.9	8.9	8.8
2018	8.2	8.3	8.0	8.1
Average 2017-2018	8.5	8.6	8.5	8.5
Color Grade(C Grad) Upland				
2017 Radnevo	-	21-1	11-1	11-1
Burgas	-	11-2	11-2	11-1
2018 Radnevo	-	21-1	21-1	21-1

Summarized results of the analysis showed that the variety Annabel in productivity was slightly inferior to the cultivar Chirpan-539 - standard for productivity and was equal to the cultivar Avangard-264. In fiber yield, it was equal to the high yielding standard cultivar Chirpan-539 and surpassed Avangard-264, as a result of the higher lint percentage. In lint percentage, it exceeded both standard cultivars.

Compared to the standard cultivars, the Anabel variety possessed a better fiber consistency, spinning (SCI) Index, which means better spinning, longer fiber, lower microner, which means finer fiber, greater fiber strength, which is important for yarn strength and better spectroscopy with reflection of RD difference.

Along with a number of other breeding programs, the USA Pee Dee program documented that the negative relationship between agronomic performance and fiber quality was most often caused by genetic linkage. Several of these breeding programs have demonstrated that the negative genetic linkage can be overcome. Campbell (2021) tested the hypothesis that three Pee Dee germplasm lines previously identified as rare recombinants can generate populations with a decreased negative relationship between agronomic performance and fiber quality. The results suggested that two of the three Pee Dee germplasm lines generated populations with a decreased negative relationship and presumably transmit beneficial allelic combinations for lint percent and fiber quality traits in coupling phase linkage with one another or fixed in offspring.

The results obtained in this study give grounds to conclude that Anabel variety also showed a decreased negative relationship between agronomic performance and fiber quality.

There was no development of verticillium wilt and bacteriosis on a natural infectious background. The variety was susceptible to the verticillium wilt pathogens, as well as standard cultivars, on an artificial infectious background.

The Anabel variety was stable, sufficiently homogeneous and clearly distinguishable from all other varieties.

Anabel variety has been approved by the Expert commission of the IASAS as a new cotton variety in 2021 (Order No RD 12-5 of 19.03.2021 of the Minister of Agriculture) and it is in the process of certification from the Patent Office of the Republic of Bulgaria.

CONCLUSIONS

The new cotton variety Anabel has proven to be slightly less productive than the high yielding standard cultivar Chirpan-539, but in terms of fiber yield it was equal to it and surpassed the cultivar Avangard-264, as a result of the higher lint percentage.

Anabel variety possessed a number of valuable fiber technological qualities such as high lint percentage, better spinning consistency, lower microner and greater fiber strength, compared to both standard cultivars. The new variety had by 1.1 mm and 0.5 mm longer fiber than that of the standard cultivars Chirpan-539 and Avangard-264. Fiber strength was average 29.0 g/tex, compared to 27.8-27.9 g/tex for the standard cultivars. Its fiber was characterized by a high spinning index (SCI), an average of 124, at 114 and 118 for the standard cultivars.

The Anabel variety with its high technological fiber qualities is very valuable for the textile industry and for the cotton breeding, for inclusion in crosses to further improve the quality of modern cotton varieties.

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