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STUDY OF THE COTTON VARIETY IZABELL WITH NATURAL COLORED FIBER UNDER NITROGEN FERTILIZATION AND IRRIGATION

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Abstract

Optimizing nitrogen (N) fertilization in cotton is essential for balancing yield, fiber quality, and environmental sustainability. This study examines the response of the Bulgarian cotton cultivar Izabell to varying nitrogen rates (N0, N80, N160, and N240) under irrigated and non-irrigated conditions over a three-year period (2018-2020) in Central Southern Bulgaria. The results indicate that nitrogen application significantly affects plant height, boll number, and cotton yield, with the optimal rate determined at N160 level. Irrigation was the dominant factor influencing productivity, increasing cotton yield by 33.2% compared to non-irrigated conditions. Yield variation was strongly influenced by meteorological conditions, with drought stress during flowering leading to significant yield reductions. Excessive nitrogen fertilization (N240) resulted in delayed maturity and did not further improve yield. The findings highlight the importance of site-specific nitrogen management and irrigation practices in optimizing cotton production.

Key words*: cotton, fertilization, fiber, nitrogen, yield.*

INTRODUCTION

In many areas, both domestically and abroad, nitrogen fertilization with a positive balance is commonly applied. Excessive nitrogen doses promote excessive vegetative growth and delay maturity (Hodges, 2002). When high nitrogen rates are used, plants are unable to absorb the entire surplus of nitrogen in the soil. These additional nitrogen levels are gradually leached from the soil through water edema, resulting in the contamination of groundwater and drinking water with nitrates (Clawson, 2008; Stavrinos & Georgiev, 2006). In relation to improving nitrogen use efficiency in cotton cultivation, recent years have seen a critical reassessment of the application of high fertilizer rates.

Researchers (Silvertooth & Norton, 2011) have confirmed that nitrogen exerts a greater influence on cotton yield than any other nutrient element. Nitrogen deficiency limits plant growth and can lead to premature shedding of floral buds in cotton, ultimately resulting in reduced yields.

Managing nitrogen (N) fertilization in cotton is challenging due to issues with low or excessively high levels, the influence of other agronomic practices, and abiotic stress factors such as drought and salinity (Luo et al., 2019). Raphael et al. (2019) report that plant density and nitrogen fertilization ranging from 0 to 180 kg/ha strongly affect the yield of raw cotton and its earliness. At higher plant densities, the number of fertilized bolls in the early positions decreases by 33% and 40%, respectively, while earliness is reduced at higher nitrogen levels due to later-maturing fertilized bolls in the upper positions. Nitrogen deficiency during the growing season leads to inadequate vegetative growth, a reduction in the number of fertilized bolls, and premature aging (Zhang et al., 2017). Furthermore, nitrogen deficiency results in lower fiber quality (Hu et al., 2006; Mohsen & Rashidi, 2011; Zhang and Zhang, 2010).

According to Szilvay (2020), high nutrient application rates may lead to luxury consumption or delayed maturity, while too little nitrogen results in plant stress or suboptimal yields. Sawan et al. (2006) report that the maximum raw cotton yield (3,310 kg ha^{-1}) was achieved with the application of 160 kg N ha^{-1}, whereas the lowest yield (1,016 kg ha^{-1}) was observed in the control treatment. Gormus et al. (2016) indicate that among the tested nitrogen rates, the best results were obtained with 180 kg N ha^{-1} combined with 150 kg K ha^{-1}, leading to the highest raw cotton yield and the highest fiber turnout.

Varietal specificity in nutrient uptake has been established by Zhang et al. (2018) in an evaluation of 100 cotton genotypes based on total dry mass, total accumulated nitrogen, nitrogen uptake efficiency, and other parameters. The authors emphasize that the development of cotton varieties with higher nitrogen use efficiency, suitable for cultivation in low-nitrogen conditions, is crucial for sustainable production.

Under the influence of specific conditions and predominantly cultivation irrigation cotton in Bulgaria develops less biomass and has a shorter vegetation period compared to Greece and Spain (Saldjiev et al., 2008; Shah et al., 2021). Constable and Bange (2015) indicate that low water reserves and nitrogen concentrations in the soil are increasingly becoming a serious problem, especially in arid regions. The impact of meteorological conditions on yield, structural elements, and fiber quality is of utmost importance, as Bulgaria is at the northern limit for cotton cultivation.

The objective of this study was to determine the effect of drip irrigation and nitrogen fertilization at different rates on the productivity and quality of the Bulgarian cotton variety Izabell under the conditions of Central Southern Bulgaria.

MATERIALS AND METHODS

The cotton cultivar *Izabell* represents a significant achievement in Bulgarian cotton breeding, marking the beginning of a new generation of varieties with naturally colored brown fiber, offering both ecological and economic benefits. The fiber is short, medium-fine, with high uniformity, good elongation, and strength. In terms of fiber length and some related characteristics, *Izabell* falls slightly behind the standard cultivars *Chirpan-539* (recognized for earliness and yield potential) and *Avangard-264* (a benchmark for fiber quality).

The study examined the following parameters: meteorological conditions for the period 2018–2020; soil characteristics; plant height and dry matter accumulation rates at the stages of bud formation, flowering, and boll maturation; total yield of raw (un-ginned) cotton and fiber (t ha^{-1}); yield components, including the number of mature harvested bolls per plant and the mass of a single boll (g); fiber lint percentage, calculated as the ratio of fiber yield to total raw cotton yield (%); fiber length (mm); and the weight of 100 seeds (g).

Figure 1. A view from an experimental field with Bulgarian cotton variety *Isabell*

The study was conducted during the period 2018-2020 at Trakia University, Stara Zagora, under field conditions with both irrigated and non-irrigated treatments. The preceding crop was common wheat. The field experiment was arranged in a randomized block design with four replications, and the harvested plot size was 15 m^2 (1.80 × 8.34 m). Four nitrogen fertilization rates were tested: N0, N80, N160, and N240. Nitrogen in the form of NH_4NO_3 was applied as a single pre-sowing dose. Phosphorus in the form of triple superphosphate at a rate of P80 was applied post-harvest and incorporated into the soil through deep plowing. Drip irrigation was applied with an irrigation rate of 15 mm when soil moisture dropped below 75% of field capacity in the 0–50 cm soil layer.

The soil is well supplied with mineral nitrogen and experimental area is classified as a typical meadow-cinnamon soil. In terms of mechanical composition, it is a medium sandy-clay loam. The soil exhibits a slightly alkaline to alkaline reaction, with pH(H_2O) values averaging 7.7 in the plow layer and 7.9 in the subsoil layer.

Sowing was carried out between April 25 and April 30 at an inter-row spacing of 60 cm and an intra-row spacing of 5 cm, with a seeding depth of 3–5 cm. The plant density ranged between 120,000 and 160,000 plants per hectare. The experimental area was treated post-sowing but before emergence with the herbicide Stomp 33 EC (4 L ha^{-1}), which is effective against both grass and broadleaf weeds. Pest control measures were implemented in response to

aphid and thrips infestations at the early vegetative stage. The cotton harvest was performed manually.

RESULTS AND DISCUSSIONS

The average plant height of the *Isabell* cotton variety at the flower bud formation stage over the study period was 28.4 cm, with irrigation exerting a significant effect-increasing from 25.9 cm under non-irrigated conditions to 30.9 cm under irrigation (Table 1). As the nitrogen application rate increased, plant height also increased; however, under non-irrigated conditions, no significant differences were observed between N160 and N240.

The growth rate of cotton plants was considerably more intense during the flower bud formation–flowering period (0.46 cm day^{-1}) compared to the flowering–maturity period. At the flowering stage, the average plant height reached 42.7 cm, with both studied factors (irrigation and nitrogen application) having a similar effect.

Table 1. Plant height (cm) of the Isabell cotton cultivar at the square initiation and flowering stages (2018–2020)

Version			Buttoning phase				Flowering phase			
№	Irrigation method	N	2018	2019	2020	Averag	2018	2019	2020	Average
1.	Non-irrigation	N_0	28.2	21.4	18.5	22.7	51.4	24.0	28.0	34.5
2.		N_{80}	29.5	22.7	22.5*	24.9	55.0	27.1	34.0	38.7
3.		N_{160}	29.7	24.8*	28.0***	27.5	53.2	35.5*	40.0**	42.9
4.		N_{240}	29.5	27.1**	26.0**	27.5	58.7*	34.5*	41.0**	44.7
		Average	**29.2**	**24.0**	**23.8**	**25.9**	**54.1**	**30.3**	**35.8**	**40.1**
5.	Irrigation	N_0	33.9**	23.2	23.0*	26.7	47.7	29.7*	41.0**	39.5
6.		N_{80}	35.3***	24.6**	31.5***	30.5	54.8	28.6*	40.5**	41.3
7.		N_{160}	35.3***	26.9**	34.5***	32.2	59.4*	39.6***	45.5***	48.2
8.		N_{240}	35.2***	28.1***	39.0***	34.1	62.4**	38.8***	48.0***	49.7
		Average	**34.9**	**25.7**	**32.0**	**30.9**	**57.8**	**34.2**	**43.8**	**45.3**
Average			**32.05**	**24.85**	**27.9**	**28.4**	**55.95**	**32.25**	**39.8**	**42.7**

* - P≤0.05; ** - P≤0.01; *** - P≤0.001

In ripening with increasing nitrogen rate the average plant height over the study period increased from 51.2 cm in the unfertilized control to 67.7 cm under the highest nitrogen application rate (N240) (Table 2). Under non-irrigated conditions, the application of N240 resulted in a 19.4% increase in plant height compared to the unfertilized control, whereas, in combination with irrigation, this increase reached 44.8%. Irrigation led to an average increase in plant height of 13.0% compared to non-irrigated conditions. The meteorological conditions had a significant impact on plant height, with the most favorable year, 2018, producing the tallest plants an average of 74.2 cm representing an increase of 52.0% and 30.3% compared to years 2019 and 2020.

The average total yield of unginned cotton for the Isabella variety over the study period was notably high - 1.70 t ha^{-1} (Table 3). The combined effects of irrigation and nitrogen fertilization significantly increased total yield across all years, as well as the overall mean for the period. A well-documented interaction between nitrogen fertilization, irrigation, and meteorological conditions was observed throughout the three years of the study. A comparative analysis of cotton yield under irrigated and rainfed conditions revealed that the prevailing climatic conditions had the strongest impact on yield variability, accounting for 51.27% of the total factor influence under irrigated conditions and 85.33% under rainfed conditions.

In 2018, the highest mean yield was recorded - 1.89 t ha^{-1}, exceeding the yields of 2019 and 2020 by 14.5% and 22.2%, respectively. The substantial interannual variation in yield underscores the pronounced influence of environmental factors. The meteorological conditions of 2018 were particularly favorable for the full realization of the genetic potential and timely ripening of the variety, which incorporates germplasm from *Gossypium*

barbadense. The primary reason for the high yields in 2018 was the optimal combination of temperature and precipitation during the growing season. The rainfall during May–July 2018, totalizing 259.7 mm, facilitated timely germination, ensured good stand establishment, and stimulated the retention and development of a high number of fertile bolls.

Table 2. The height of cultivar cotton Izabell in ripening phase (cm), 2018-2020

Version			Year of experiment			Average		
№	Irrigation method	N	2018	2019	2020	cm	% into no-irrigation	% into N_0
1.	No-Irrigation	N_0	63.5	43.7	43.0	50.1	100.0	100.0
2.		N_{80}	74.5**	47.8	43.0	55.1	100.0	110.0
3.		N_{160}	80.0***	49.7*	51.0	60.2	100.0	120.2
4.		N_{240}	75.0**	50.3*	54.0*	59.8	100.0	119.4
Average no-irrigation			**73.3**	**47.9**	**47.8**	**56.3**	-	-
5.	Irrigation	N_0	61.5	42.2	53.0*	52.2	104.2	100.0
6.		N_{80}	63.5	46.5	62.5*	57.5	104.4	110.2
7.		N_{160}	84.5***	53.0**	70.0*	69.2**	115.0	132.6
8.		N_{240}	91.0***	56.8***	79.0*	75.6***	126.4	144.8
Average irrigation			**75.1**	**49.6**	**66.1**	**63.6**	-	-
Average			**74.2**	**48.75**	**56.95**	**59.95**	-	-

* - P≤0.05; ** - P≤0.01; *** - P≤0.001

In contrast, the lower yields in 2020 were attributed to elevated temperatures during the growing season and prolonged summer drought, which led to premature shedding of buds and flowers and hindered proper boll development. Khan et al. (2017) emphasize that nitrogen fertilization in cotton, particularly under water-deficit conditions, plays a crucial role in mitigating drought-induced stress and promoting growth and development.

The total yield reached its maximum value of 2.42 t ha^{-1} under N240 fertilization in irrigated conditions in 2020, representing an increase of 214.8% compared to the unfertilized control in the same year, with statistical significance at $p \leq 0.1\%$.

The results for the total yield of non-defoliated cotton under both irrigation regimes indicate high efficiency of the applied nitrogen fertilization rates. Nutrient deficiency or insufficient fertilizer supply fails to provide adequate assimilates, thereby limiting cotton plant development, reducing the number and size of bolls, and ultimately decreasing both total cotton yield and fiber yield. Yield increased from 1.52 t ha^{-1} under unfertilized conditions to 1.81 t ha^{-1} under N160, which represents a 19.3% increase compared to the control. However, at N240, a slight decline in yield was observed (by 2.8% compared to N160). On average over the study period, N160 proved to be the optimal nitrogen rate. The strong interaction between irrigation and nitrogen fertilization led to a significant increase in yield, confirmed across years and for the entire period. The results also demonstrate that the application of nitrogen at a rate of 80 kg ha^{-1} had a positive impact, increasing yield by 17.2% compared to the unfertilized control under non-irrigated conditions and by 8.3% under irrigation. No significant differences were detected between the yields obtained under N80 and N240. The high nitrogen rate was associated with delayed maturity due to excessive vegetative growth. Excessive nitrogen application can lead to a reduction in total yield, does not result in a proven increase in productivity, and is not an effective agronomic practice.

Our findings align with those of Karademir et al. (2006), who reported a decline in cotton yield at higher nitrogen application rates. Data from Saleem et al. (2010) on seed cotton yield under nitrogen fertilization indicate that nitrogen has a significant effect on cotton yield, with the highest yield (3002 kg ha^{-1}) recorded at a nitrogen rate of 120 kg ha^{-1}, while the lowest yield was obtained under the unfertilized control. Silvertooth and Norton (2011) confirmed that nitrogen deficiency reduces plant growth and can cause premature shedding of fruiting structures, leading to lower yields, whereas excessive nitrogen promotes excessive

vegetative growth, delays fruit development, prolongs maturity, complicates defoliation, and increases pest and disease susceptibility. Geng et al. (2015) also reported that high nitrogen rates during boll filling can negatively impact seed cotton yield by stimulating excessive vegetative growth. Szilvay (2020) noted that plant responses to environmental conditions vary considerably. Therefore, the optimal nitrogen rate for cotton must be determined on a case-by-case basis and adjusted according to environmental conditions and crop status.

Irrigation conditions tense the strongest influence on cotton productivity. The *Isabel* cultivar exhibited a highly positive response to irrigation, with an average yield of 1.94 t ha^{-1} under irrigated conditions, exceeding the yield under non-irrigated conditions by 33.2%. Yield variations across years were clearly expressed, ranging from 1.78 t ha^{-1} in 2019 to 2.21 t ha^{-1} in 2020. Under non-irrigated conditions, plant growth, development, and yield formation in 2020 were constrained by high temperatures and minimal summer precipitation, resulting in an average yield of 0.895 t ha^{-1}, ranging from 0.77 t ha^{-1} under N0 to 0.989 t ha^{-1} under N160.

Table 3. Effect of the interaction between irrigation and nitrogen fertilization on the total yield (t ha^{-1}) of cotton cultivar Izabell., 2018-2020

Irrigation method	N	Year of experiment			Average		
		2018	2019	2020	t ha^{-1}	% into non-irrigation	% into N_0
Non-irrigation	N_0	1.548	1.456	0.769	1.257	100,0	100.0
	N_{80}	2.030***	1.551	0.839	1.474	100.0	117.2
	N_{160}	2.127***	1.611**	0.989***	1.576	100.0	125.3
	N_{240}	2.115***	1.491	0.984***	1.530	100.0	121.7
	Average	**1.955**	**1.527**	**0.895**	**1.459**	-	-
Irrigation	N_0	1.741	1.686***	1.948***	1.792*	142.52	100.0
	N_{80}	1.888*	1.784***	2.150***	1.941**	131.72	108.3
	N_{160}	1.956**	1.880***	2.320***	2.052***	130.23	114.5
	N_{240}	1.764	1.784***	2.421***	1.990***	130.05	111.0
	Average	**1.837**	**1.784**	**2.210**	**1.944**	-	-
Average		**1.896**	**1.656**	**1.552**	**1.702**	-	-

* - P≤0.05; ** - P≤0.01; *** - P≤0.001

The average number of ripening bolls per plant is 4.42, reaching a maximum of 5.77 bolls per plant under N160 fertilization with irrigation (Table 4). Fertilization with 80, 160, and 240 kg N ha^{-1} increased the number of ripening bolls by 9.4%, 20.0%, and 19.3%, respectively, compared to the non-fertilized control (3.94 bolls per plant). The application of drip irrigation significantly increased the number of matured bolls by an average of 44.2% compared to non-irrigated conditions.

Table 4. The number of ripened bolls per plant under irrigation conditions and nitrogen fertilization in cotton cultivar Isabel, average for the 2018-2020

№	Irrigation method	N	2018	2019	2020	Average	% into non-irrigation	% into N_0
1.	Non-irrigation	N_0	3.75	3.10	2.70	3.18	100.0	100.0
2.		N_{80}	4.40***	3.53	2.95	3.63	100.0	114.2
3.		N_{160}	4.50***	3.42	3.16	3.69	100.0	116.0
4.		N_{240}	4.65***	3.93	3.40*	3.99	100.0	125.5
Average non-irrigation			**4.33**	**3.50**	**3.04**	**3.62**	-	-
5.	Irrigation	N_0	4.25***	4.03	5.83***	4.70	147.8	100.0
6.		N_{80}	4.6***	4.48	5.90***	4.99	137.5	106.2
7.		N_{160}	4.7***	6.60***	6.00***	5.77	156.4	122.8
8.		N_{240}	4.8***	4.93*	6.50***	5.41	135.6	115.1
Average irrigation			**4.59**	**5.01**	**6.06**	**5.22**	**144.2**	-
Average			**4.46**	**4.26**	**4.55**	**4.42**	-	-

* - P≤0.05; ** - P≤0.01; *** - P≤0.001

On average over the study period, the *Isabell* variety exhibited a trend towards a very good boll weight, reaching 4.68 g per boll. Without fertilization, the average boll weight was 4.47 g, whereas with the application of 80, 160, and 240 kg N ha^{-1}, it increased to 4.66, 4.72, and 4.86 g, respectively, representing a 4.2–8.7% increase compared to the unfertilized control (Table 5). Under irrigation, the average boll weight reached 4.78 g, which was 4.6% higher than under non-irrigated conditions.

Table 5. One of weight boll (g) under irrigation and nitrogen strategies, 2018-2020

№	Irrigation method	Fertilization	2018	2019	2020	Average	% into non-irrigated	% into N_0
1.	Non-irrigation	N_0	4.36	4.90	4.01	4.42	100.0	100.0
2.		N_{80}	4.62***	4.95	4.56*	4.71	100.0	106.6
3.		N_{160}	4.98***	4.97	4.35	4.77	100.0	107.9
4.		N_{240}	5.19***	4.53	4.23	4.37	100.0	98.9
Average non-irrigation			**4.79**	**4.84**	**4.29**	**4.57**	-	-
5.	Irrigation	N_0	4.58***	4.60	4.94***	4.71	106.6	100.0
6.		N_{80}	4.63***	4.63	5.02***	4.76	101.1	101.1
7.		N_{160}	4.65***	4.41	5.18***	4.75	99.6	100.8
8.		N_{240}	4.80***	4.73	5.21***	4.91*	112.4	104.2
Average irrigation			**4.67**	**4.59**	**5.09**	**4.78**	**104.6**	-
Average			**4.73**	**4.72**	**4.69**	**4.68**	-	-

* - P≤0.05; ** - P≤0.01; *** - P≤0.001

CONCLUSIONS

A pronounced effect of variable meteorological conditions on cotton yield and fiber quality has been substantiated, with drought stress during the flowering phase being particularly detrimental. A statistically significant interaction between nitrogen fertilization, irrigation, and meteorological factors has been established over the three-year study period.

The irrigation regime exerts the most significant influence on cotton productivity. The Isabel cultivar responds exceptionally well to irrigation, with an average yield under irrigated conditions of 1.94 t ha^{-1}, exceeding the yield under non-irrigated conditions by 33.2%.

The number of mature bolls averages 4.42 per plant, reaching a maximum of 5.77 bolls per plant with N160 fertilization under irrigation.

A strong impact of fluctuating meteorological conditions on cotton yield and quality has been confirmed, particularly the adverse effects of drought during the flowering phase. A well-established interaction between nitrogen fertilization, irrigation, and meteorological conditions has been observed over the three-year study period.

The characterization of the Isabel cultivar regarding productivity and nitrogen use efficiency has identified the effects of the studied factors - irrigation regime, nitrogen fertilization rates, and cultivar performance.

The evaluation of the Isabel cultivar in terms of productivity and nitrogen use efficiency has elucidated the effects of the examined factors - irrigation regime, nitrogen fertilization rates, and cultivar-specific characteristics.

The cultivation of the naturally pigmented brown cotton cultivar Isabel is strongly recommended. Given its potential to enhance environmental sustainability and minimize chemical inputs in the fabric manufacturing.

Considering the enhanced environmental benefits and the reduced use of chemicals in the textile industry, the cultivation of the naturally pigmented brown cotton cultivar Isabel is recommended.

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