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COTTON CULTIVAR M-5027 WITH AGROTECHNOLOGY AND ITS RELATIONSHIP WITH PRODUCTIVITY IN THE TURKESTAN REGION, KAZAKHSTAN

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SUMMARY

The cotton (*Gossypium hirsutum* L.) crop is a priority sector of agriculture in the Turkestan Region, Kazakhstan. An evaluation of the cotton cultivar Maktaaral-5027's response took place for nine variants comprising different doses of nitrogen, phosphorus, and potassium under two soil backgrounds (slightly saline and medium saline). The study occurred at the Agricultural Experimental Station of Cotton and Melon Growing, Turkestan, Kazakhstan. Fertilizers used included ammonium nitrate (34%), double superphosphate (45%), and potassium sulfate (51%), which were applied in one step before sowing the cotton crop for deep cultivation. The fertilizer application revealed some patterns in the formation of seed cotton yield. In the variant combining triple doses of nitrogen with double doses of phosphorus and potassium ($N_{150}P_{100}K_{80}$) under low soil salinity, the seed cotton yield was higher, reaching 6.49 t/ha of raw cotton. On a slightly saline background, nitrogen fertilizers increased the raw cotton yield to 18.3% and 28.8% in variants with double ($N_{100}P_{100}K_{80}$) and triple ($N_{150}P_{100}K_{80}$) doses compared with medium doses of phosphorus and potassium.

Keywords: Cotton (*G. hirsutum* L.), saline soil, fertilizer doses, seed cotton yield, fiber quality

Key findings: The upland cotton (*G. hirsutum* L.) cultivar Maktaaral-5027 with different doses of fertilizers allowed us to identify its higher seed cotton yield on the gray soil of the Turkestan Region, Kazakhstan.

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INTRODUCTION

The cotton (*Gossypium hirsutum* L.) is one of the strategically important crops in Kazakhstan. In previous years, the cotton crop area varied between 120,000 and 126,000 hectares. High salt content and the aridity of arable soils are the main limiting factors affecting cotton crop growth and productivity (Nazarova *et al.,* 2019; Makhmadjanov *et al.,* 2023). Moreover, past studies established the effect of mineral fertilizers and irrigation on the leaf surface manifested in the flowering and ripening phases, ultimately causing the accumulation of biological mass of cotton (Batkaev, 2000; Batkaev and Shotaeva, 2012).

Cotton research is an influential aspect of agricultural science in Kazakhstan, as the said crop plays a key role in the textile industry. In the Turkestan Region of Kazakhstan, it is crucial to study genotypes adapted to local climatic conditions to improve the efficiency of agricultural production (Makhmadjanov *et al.,* 2024). Cotton requires mineral nutrition at various stages of its growth and development, and the greatest need for nutrients appears during the formation of generative organs (Dzhumankulov, 1990; Batkaev *et al.,* 2013; Guseinov, 2017; Ashirbekov *et al.,* 2018). Furthermore, past research authenticated that soil fertility is a prime factor influencing the quality of cotton fiber (Madraimov, 1996; Umbetaev, 2004; Seyidaliev, 2010).

Under monoculture conditions in the southern part of Kazakhstan, long-term primary cultivation of irrigated lands has led to a sharp differentiation of the soil profile— into a less dense arable horizon with a bulk density of 1.15–1.30 g/cm^3 and a very dense horizon with a bulk density of 1.6–1.8 g/cm^3. The lower sub-arable dense horizon has low porosity, aeration, and filtration characteristics. It impedes the downward and upward flows of moisture along with nutrients, which considerably reduces the leaching efficiency, decreasing the productivity of cultivated crops (Raisov *et al.,* 2016). The application of mineral fertilizers in cotton monocultures increases the yield of raw cotton by an average of 4.61 kg/ha over 10 years. As a result, a relatively fertile background emerged for the content of nutrients in the soil (Aslanov and Novruzova, 2017). During the cotton growing season, the foliar nitrogen fertilization has become an essential technological solution for satisfying the plants' need for nitrogen nutrition (Thomas *et al.,* 1998).

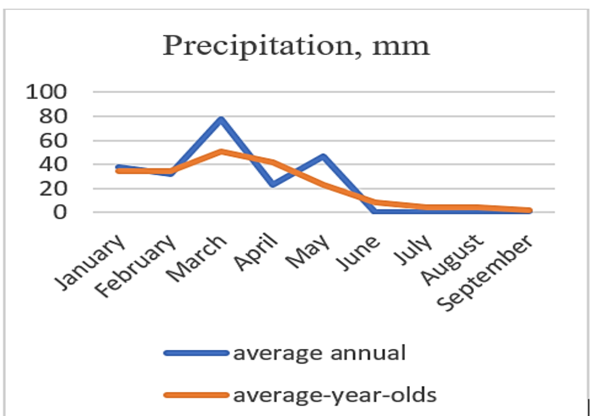
Nitrogen prolongs crop growth and enhances the number of main nodes of the stem and fruiting on the sympodial and monopodial branches. These resulted from the increased photosynthetic activity of plant leaves, which eventually reflected in forming more bolls and higher yield. Phosphorus plays an important role in the processes of energy transfer of plant cells and is also necessary for normal growth and development. Plants with accumulated potassium in the foliar mass in the first half of the growing season can avoid its deficiency during the fruiting and ripening phases. Low-water availability, extreme temperatures, and nutrient deficiencies, especially potassium, can reduce cotton fiber length (Tokareva, 2013).

According to Khairiddinov and other scientists, an increase in nitrogen to 300 kg/ha does not further boost the yield of raw cotton. The most effective joint application of mineral fertilizers at nitrogen 250, phosphorus 175, and potassium 100 kg/ha with fertilizers accelerates plant growth and development, raising crop yields (Khairiddinov *et al.,* 2018). If a lack of potassium happens during the budding period, the leaves fall off, the mass of the stem decreases, and the supply of sugars from the leaves to the organs is cut short. This slows down the formation of fibers and structural elements of the seed (Huseynov and Shirinova, 2022). The potential research aimed to develop an agrotechnology for better photosynthetic indices, cotton productivity, and cotton fiber quality traits by using mineral fertilizers on light gray soils with varied salinity in the Turkestan Region, Kazakhstan.

MATERIALS AND METHODS

For the cotton (*G. hirsutum* L.) field experiment on gray soils with low and medium salinity, the production sites selected comprised the LLP Agricultural Experimental Station for Cotton and Melon Growing, District Maktaaral, Turkestan, Kazakhstan. Spring (March-May) 2022–2024 seasons were distinct with the following features: March and April = air temperature was higher by -1.06 °C and -1.58 °C, and in May, the temperature shared the level of the long-term data, with a slight decrease of 0.45 °C compared with the long-term data (Figure 1). The weather data revealed warm springs and contributed to better cotton crop growth and development. In summer (June to August), the air temperature was higher than perennial (-3.07 °C, -1.0 °C, and -2.5 °C, respectively), with no precipitation in these three months. Climatic conditions in 2022–2024 showed the daytime air temperature reached 41.0 °C to 44.0 °C in June and July, which favorably affected the growth and maturation of cotton plants.

The experimental soil, as represented by light gray earth, was medium loamy in mechanical composition. In the upper half-meter layer, the humus content varies between 0.63% and 0.78% (Table 1). In the arable and sub-arable soil layers, the easily hydrolyzed nitrogen content varies within 39.2–61.6 mg/kg. For mobile phosphorus content, due to the annual unilateral use of phosphorus fertilizers, the soils appeared significantly enriched with mobile phosphorus and distinctly high (70–78 mg/kg) in the arable and sub-arable horizons. The reserves of exchangeable potassium were 280–380 mg/kg in these soils. The analysis of the aqueous extract of soil samples showed that selected areas, based on salt degradation, can have slightly and moderately saline classifications, with a salt content of 0.140%–0.150% and 0.450%–0.510%, respectively.



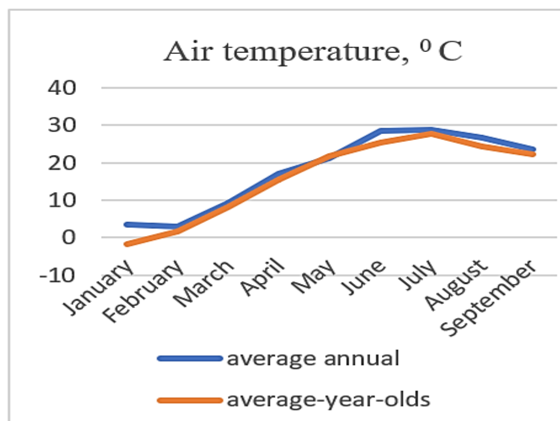


Figure 1. Main meteorological indicators of the vegetation period 2022–2024 in the conditions of the Maktaaral District, Turkestan Region.

Table 1. Agrochemical parameters of cotton plots during the spring of 2022–2024 at the Maktaaral District, Turkestan Region.

Sample depth (cm)	Humus (%)	Physical clay (0.01-0.001 mm) (%)	Mobile forms (mg/kg)			Gross forms (%)			pH	Total salts (%)
			N	P	K	N	P	K		
Slightly saline background										
0-25	0.78	35.7	61.6	78.0	350.0	0.10	0.32	2.38	8.8	0.140
25-50	0.70	30.9	47.6	70.0	280.0	0.07	0.30	2.38	8.8	0.150
Moderately saline background										
0-25	0.78	26.4	53.2	78.0	380.0	0.06	0.34	2.38	8.5	0.450
25-50	0.63	34.9	39.2	75.0	360.0	0.07	0.23	2.38	8.6	0.510

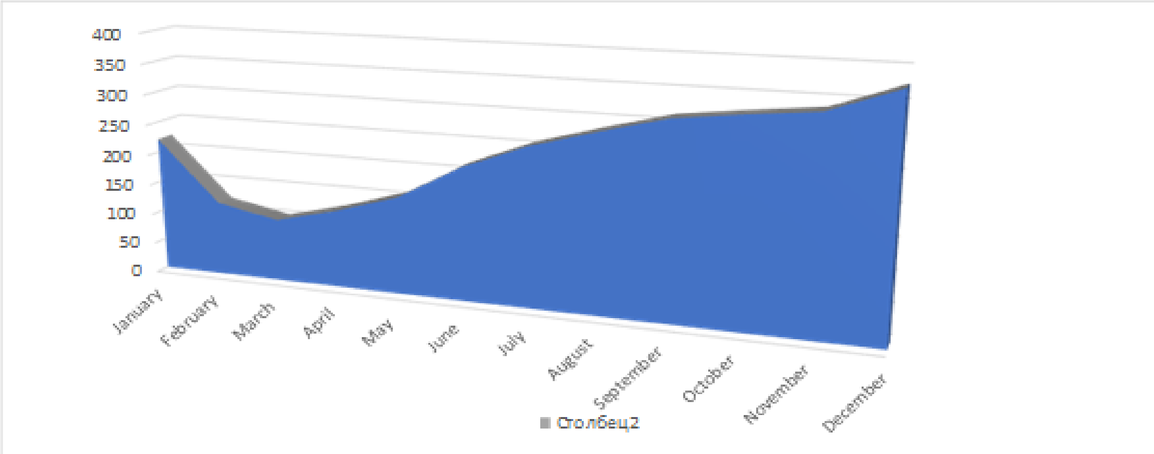


Figure 2. Dynamics of movement of the groundwater table in 2022–2024 (years and months average).

One should note that the depth of groundwater varies during the growing season, and in the spring months, this indicator rises to a depth of one meter, while in the winter months, it drops to 3.0–3.5 m. The depth of groundwater distribution occurred by month: in January = 321.2.0 cm; in February = 121.4 cm; in March = 102.1 cm; in April = 127.2 cm; in May = 158.5 cm; and in June = 215.4 cm. In July, groundwater dropped from the soil surface by 256.2 cm. In December, this mark was 375.5 cm. This was due to irrigation stops at this time and groundwater sinks (Figure 2). Based on the accepted standards, the soil sample analysis succeeded in the analytical laboratory of the U.U. Uspanov Kazakh Research Institute of Plant Protection and Agronomy, Kazakhstan.

The field experiments on cotton crops on both salinity backgrounds included nine variants with different doses and ratios of fertilizers, i.e., 1. Control (without fertilizers); 2. $N_{100}P_{100}$; 3. $N1_{00}K_{80}$; 4. $P_{100}K_{80}$; 5. $N_{100}P_{100}K_{80}$; 6. $N_{50}P_{100}K_{80}$; 7. $N_{150}P_{100}K_{80}$; 8. $N_{100}P_{150}K_{80}$; and 9. $N_{100}P_{100}K_{120}$. Ammonium nitrate (34%), double superphosphate (45%), and potassium sulfate (51%) served as fertilizers, with a one-time application before sowing for deep cultivation. The domestically bred variety 'M-5027 (Maktaaral-5027)' was the sample used in the experiments. Sowing commenced on May 2 using a row seeder on a row spacing of 90 cm, with an average plant density of 110,000–120,000 plants ha^{-1}. The area of the experimental plot was 54 m^2, with three replications.

During the main phases of cotton plants' growth and development, biometric studies and selection of plant samples progressed to study photosynthetic indices based on the different doses and ratios of fertilizers under two salinity backgrounds. Determining the accumulation of dry biomass, leaf surface area, photosynthetic potential, and photosynthetic productivity of cotton plants used the formula of Nichiporovich *et al.* (1961). In assessing the dependencies of photosynthetic indicators of cotton on the applied doses of mineral fertilizers and the degree of soil salinity, data analysis for a regression relationship considered their effects and interactions (Peregudov, 1978).

The experimental data underwent mathematical processing using the Excel software application, providing for a sequential assessment and exclusion of nonsignificant regression terms at a significance level of $P > 0.05$. The consistency of theoretical and actual data, as assessed, employed the determination coefficient (R^2). The factors' effect and their interactions under study became represented by a half-model in the form of a regression equation:

$$Y = a_0 + a_1N^{05} + a_2N + a_3P^{05} + a_4P + a_5K^{05} + a_6K + a_7S^{05} + a_8S + a_9(NP)^{05} + a_{10}(NK)^{05} + a_{11}(NS)^{05} + a_{12}(RK)^{05} + a_{13}(PS)^{05} + a_{14}(KS)^{05}$$

Where,
Y is the resulting (dependent) factor,
a_0 – free term reflecting the value of the resulting factor without application of mineral fertilizers, and
a_1, a_2, a_3 … an – regression coefficients reflecting the action and interaction of factors.
N, P, K, and S were independent factors studied in the experiment (N, P, and K stand for nitrogen, phosphorus, and potassium fertilizers, and S is the sum of salts).

The experiments proceeded as per the generally accepted methodology in breeding and seed production work, 'Genetics, selection, and seed production of cotton' (Simongulyan *et al.,* 1980). Phenological observations continued according to the Methodology of the State Variety Testing of Agricultural Crops (2015). The recalculation of the yield in tons per hectare succeeded in the following sequence (using the Maktaaral-5027 variety as an example):

The following indicators were:

Row spacing = 0.9 m; Length of plot = 6 m; Number of rows in the plot = 12; Number of plants in the plot = 434; and Yield per plant = 79.5 g

Plot area = $0.9 \text{ m} \times 6 \text{ m} \times 12 = 64.8 \text{ m}^2;$

Plant density = $\frac{10000 \text{ m}^2 * 434}{64.8 \text{m}^2} = 66.975 \text{ thousand/ha}$

Harvest ha^{-1} = $\frac{66.975 * 79.5}{1000} = 5.32 \; t/ha$

RESULTS AND DISCUSSION

In previous decades, the breeders at the LLP Agricultural Experimental Station of Cotton and Melon Growing, Turkestan, Kazakhstan, have created 13 varieties of medium-fiber cotton (*Gossypium hirsutum* L.), and one of them was Maktaaral-5027, the sample used in the presented study. In developing new varieties, factors such as precocity of 117–125 days, high yield of 40.0–45.0 t/ha, weight per boll at 6.0–6.3 g, and resistance to salinity, diseases, and pests were noted considerations (Makhmadjanov *et al.,* 2023).

In Uzbekistan, the studies revealed an increase in the degree of soil salinity shortens the fiber length by an average of 5.2 mm, negatively affecting all the fiber quality traits (Rakhmankulov, 2015). On the typical irrigated gray soils, the amount of potassium varies depending on soil properties and application of potash fertilizers. Soils with a moderate content of mobile phosphorus vary depending on the rate and proportion of application of nitric acid fertilizers (Sattarov *et al.,* 2023).

Early fertilization of the cotton crop with nitrogenous fertilizers is highly important. The cotton plant's resistance to wilting increases with foliar fertilization of plants with 1.5% urea solution at the 3–4 leaf stage and in the phase of mass budding. Nitrogen fertilizers, applied at 150 kg/ha in three doses of 50 kg each, ensued in the phases of budding, flowering, and fruiting. Phosphorus fertilizers (100 kg P_2O_5 ha^{-1}), given in two doses, continued at the budding and flowering phases. Cotton varieties should have good adaptability to changing environmental conditions and respond effectively to improved agricultural technology, in particular, to increased fertilizer doses (Makhmadjanov, 2023).

The use of mineral fertilizers raises the phytomass and seed cotton yield in cotton, which showed a positive correlation of phytomass with the yield of raw cotton, where an upsurge in phytomass, the yield of raw cotton increases (Mamashukurov *et al.,* 2024). In experiments with different doses of fertilizers, carried out with cotton crops on gray soils of the Turkestan Region, comparative results were evident on photosynthetic, productive indicators of cotton and on the fiber quality, allowing us to judge the effectiveness of using mineral fertilizers on soils with varying degrees of salinity.

The biometric parameters of cotton plants showed leaf areas (LA) vary adequately with variations in mineral nutrition conditions

Table 2. Gross cotton yield at different salinity levels based on fertilizers.

Fertilizer options	Gross yield (t/ha)	Yield increase (%)				Decrease in gross yield (%)
		Control (%)	From N (%)	From P (%)	From K (%)	
Slightly saline background						
1. Control	5.29	0,0	-	-	-	
2. N100P100	5.49	3.8	-	-	0.0	
3. N100K80	6.00	13.5	-	0.0	-	-
4. P100K80	5.04	-4.7	0,0	-	-	-
5. N100P100K80	5.96	12.7	18.3	-0.7	8.6	-
6. N50P100K80	5.75	8.8	14.1	-	-	-
7. N150P100K80	6.49	22.8	28.8	-	-	-
8. N100P150K80	5.95	12.6	-	-0.8	-	-
9. N100P100K120	6.14	16.2	-	-	12.0	-
Means	5.78	9.33	15.31	-0.48	6.86	-
$LSD_{0.05}$	0.77					
Moderately saline background						
1. Control	3.40	0,0	-	-	-	35.7
2. N100P100	4.83	42.0	-	-	0,0	12.0
3. N100K80	4.80	41.2	-	0,0	-	20.0
4. P100K80	3.87	13.8	0,0	-	-	23.3
5. N100P100K80	5.14	51.2	32.9	7.0	6.4	13.8
6. N50P100K80	4.64	36.5	20.0	-	-	19.3
7. N150P100K80	5.41	59.1	39.8	-	-	16.7
8. N100P150K80	4.72	39.0	-	-1.6	-	20.6
9. N100P100K120	5.30	55.8	-	-	9.7	13.8
Means	4.66	37.12	23.17	1.82	5.4	19.5
$LSD_{0.05}$	0.54					

(Table 2). A relatively large leaf surface of cotton plants increased by the fruiting phase on the slightly saline background, and it varied from 14,700 m^2/ha (control) to 36,300 m^2/ha ($N_{100}P_{100}K_{120}$) (Figure 3). However, on the moderately saline background, the leaf surface values were 7,900 m^2/ha (control) to 25,700 m^2/ha ($N_{100}P_{100}K_{120}$).

The effect and interaction of fertilizers and the salts in the soil on the leaf area (LA) in different phases of cotton were well described by the regression equation, as follows: In all the below equations, N, P, and K were the nitrogen, phosphorus, and potassium doses (kg active ingredient/ha), while S was the sum of salts (%) in the soil.

LA in the budding phase (Y) (thousand m^2/ha):

$$Y = 1.8045 - 1.738S - 0.876N^{0.5} + 32.341P^{0.5} - 35K^{0.5} - 3.129(NP)^{0.5} + 3.6122(NK)^{0.5} - 0.163(NS)^{0.5} - 0.111\,(PK)^{0.5} - 0.074(PS)^{0.5}$$

$$R^2 = 0.958$$

LA in the flowering phase (Y) (thousand m^2/ha):

$$Y = 6.5805 + 0.0243N - 5.341N^{0.5} + 184.56P^{0.5} - 0.046K - 199.1K^{0.5} - 17.84(NP)^{0.5} + 20.601(NK)^{0.5} - 0.814\,(NS)^{0.5} - 0.629(PK)^{0.5} - 0.674(PS)^{0.5}$$

$$R^2 = 0.957,$$

LA in the fruit formation phase (Y) (thousand m^2/ha):

$$Y = 18.209 - 0.122N - 8.87N^{0.5} + 297.57P^{0.5} + 0.2135K - 318.1K^{0.5} - 0.376P^{0.5} - 23.4S - 28.33(NP)^{0.5} + 32.935(NK)^{0.5} - 1.168\,(PK)^{0.5} + 0.7266(PS)^{0.5} - 1.585(KS)^{0.5}$$

$$R^2 = 0.972,$$

The effect and interaction of fertilizers and the salts in the soil on the formation of leaves in different phases of cotton gained quite an accurate description (R^2 = 0.957–0.972) by regression models. Simultaneously, the individual effects of nitrogen and potassium

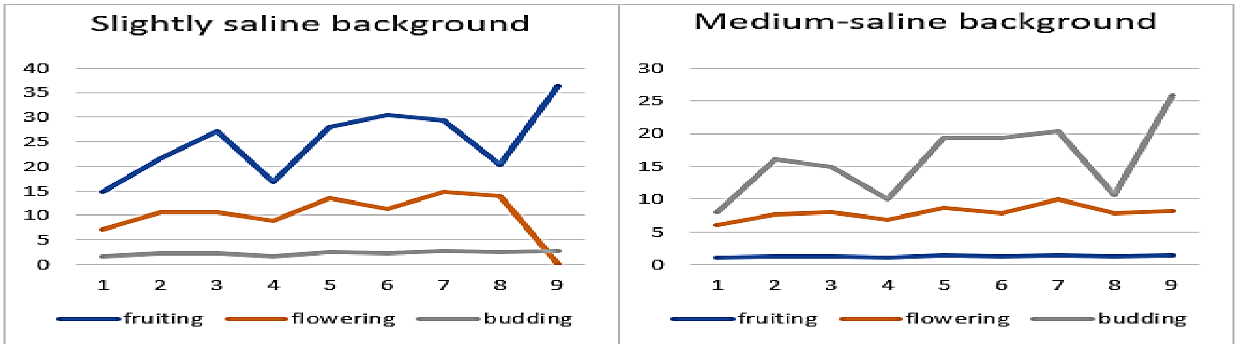


Figure 3. Dynamics of cotton leaf area (1000 m^2/ha) depending on fertilizers applied on gray soils of different salinity in 2022–2024. Fertilizer options: 1. Control; 2. N100P100; 3. N100K80; 4. P100K80; 5. N100P100K80; 6.N50P100K80; 7. N150P100K80; 8. N100P150K80; and 9. N100P100K120.

fertilizers were negative, and phosphorus was positive. On interaction, nitrogen with phosphorus and salt and phosphorus with potassium and salt adversely influenced the leaf area size of cotton plants. Soil salts, independently and in interaction with nitrogen, phosphorus, and potassium, negatively affected the leaf area size.

The size of dry biomass (DB) of cotton at the budding phase on a slightly saline background, depending on the mineral nutrition, ranged from 0.264 (control) to 0.499 t/ha ($N_{150}P_{100}K_{80}$), while on a moderately saline background, it varied from 0.182 (control) to 0.308 t/ha ($N_{150}P_{100}K_{80}$). In the fruit formation phase, the accumulated dry biomass on a slightly saline background, depending on the fertilizers, ranged from 8.638 (control) to 20.119 t/ha ($N_{150}P_{100}K_{80}$), and on a moderately saline background, these varied from 6.166 to 14.063 t/ha, respectively, in the same variants. The effect of fertilizers and salts in the soil on the accumulation of dry biomass of cotton in different phases of vegetation received an adequate description by the following regression models:

DB in the budding phase (Y) (t/ha):

$$Y = 0.2935 + 0.0011N - 0.214N^{0.5} - 0.002P + 7.1822P^{0.5} + 0.0012K - 7.768K^{0.5} - 0.693(NP)^{0.5} + 0.8001(NK)^{0.5} - 0.019\,(NS)^{0.5} + 0.024(PK)^{0.5} - 0.011(PS)^{0.5}$$

$$R^2 = 0.954,$$

DB in the flowering phase (Y) (t/ha):

$$Y = 1.3694 + 0.0043N - 1.289N^{0.5} - 0.008P + 44.286P^{0.5} - 0.017K - 47.63K^{0.5} - 4.279(NP)^{0.5} + 4.9434(NK)^{0.5} - 0.197\,(NS)^{0.5} - 0.155(PK)^{0.5} - 0.112(KS)^{0.5}$$

$$R^2 = 0.960,$$

DB in the fruit formation phase (Y) (t/ha):

$$Y = 9.3105 - 10.76N^{0.5} - 0.159P + 338.99P^{0.5} - 0.043K - 363.9K - 6.47S - 32.6(NP)^{0.5} + 37.22\,(NK)^{0.5} - 1.206(PK)^{0.5} - 0.581(PS)^{0.5} - 0.698(KS)^{0.5}$$

$$R^2 = 0.912,$$

The dynamics of cotton biomass accumulation also followed the actions and interactions of the studied factors. With the rise of nitrogen and potassium fertilizer doses, the biomass accumulation rate decreased, and phosphorus contributed to its growth. During the vegetation period, the combinations of studied factors, except for nitrogen with potassium, unfavorably altered the dynamics of cotton biomass accumulation.

An indicator of the efficient work of the plant foliage apparatus is the dry biomass produced per unit of leaf area over a certain period of time, expressed as the net productivity of photosynthesis (NPP). In the promising cotton experiments, NPP also significantly varied during the growing season—the most productive leaf apparatus of cotton plants worked in the period between budding and flowering. Similarly, on a slightly saline background, it changed from 19.5

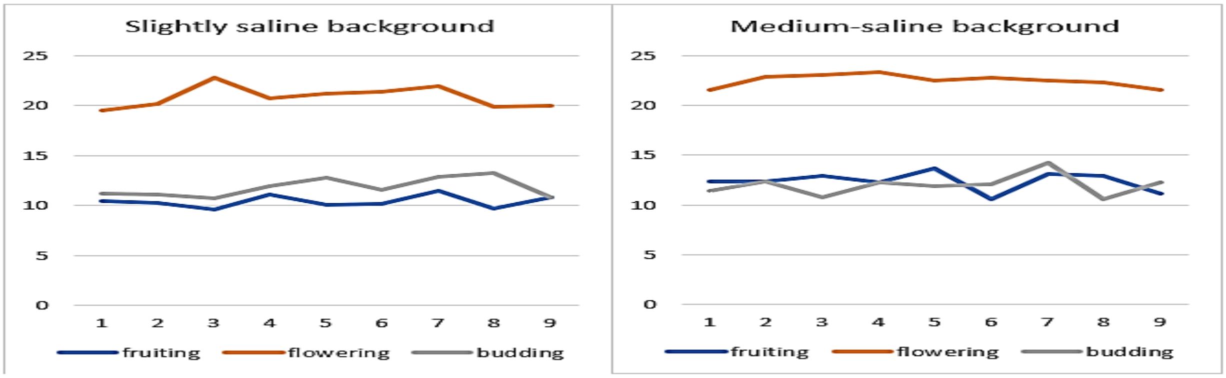


Figure 4. Dynamics of net productivity of cotton photosynthesis (g/m^2 per day) depending on fertilizers applied on gray soils of different salinity. Fertilizer options: 1. Control; 2. N100P100; 3. N100K80; 4. P100K80; 5. N100P100K80; 6.N50P100K80; 7. N150P100K80; 8. N100P150K80; and 9. N100P100K120.

(control) to 22.8 g/m^2 per day ($N_{100}K_{80}$), and on a moderately saline background, it ranged from 21.6 (control and $N_{100}P_{100}K_{120}$) to 23.3 g/m^2 per day ($N_{100}P_{80}$). By the end of the growing season (fruit formation), a slight decrease in the NPF (10.7–13.2 g/m^2 per day) was visible with the slightly saline background and 10.6–13.7 g/m^2 per day with the moderately saline background (Figure 4).

Variations in the NPP of cotton plants during the studied periods of growth and development were 71%–81% due to the action and interaction of mineral fertilizers and the salts found in the soil.

NPP in the budding phase (Y) (g/m^2 per day):

$$Y = 9.204 + 0.038N - 2.821N^{0.5} - 0.067P + 92.591P^{0.5} - 100.07K^{0.5} + 5.728S - 8.944(NP)^{0.5} + 10.272(NK)^{0.5} - 0.261(PK)^{0.5}$$

$$R^2 = 0.813$$

NPP in the flowering phase (Y) (g/m^2 per day):

$$Y = 18.484 - 0.028P + 12.199P^{0.5} - 0.062K - 12.263K^{0.5} + 7.132S - 1.187(NP)^{0.5} + 1.349(NK)^{0.5} - 0.364(NS)^{0.5} - 0.042(PK)^{0.5} + 0.465(PS)^{0.5} - 0.377(KS)^{0.5}$$

$$R^2 = 0.806$$

NPP in the fruit formation phase (Y) (g/m^2 per day):

$$Y = 10.097 + 0.029N - 3.897N^{0.5} + 116.32P^{0.5} - 0.088K - 125.05K^{0.5} + 5.772S - 11.249(NP)^{0.5} + 12.986(NK)^{0.5} - 0.388(PK)^{0.5} - 0.541(PS)^{0.5}$$

$$R^2 = 0.709$$

As can be seen from the presented equations, the effects of action and interaction of the studied types of fertilizers and the soil's salt content on the productivity of cotton photosynthesis in the vegetation phases were also complex. However, the same patterns of action and interaction of the studied factors were noticeable, recognized as the characteristic of the dynamics of accumulation of biomass of cotton plants.

The results of fertilizer application ultimately allowed us to identify some patterns in the seed cotton yield formation (Table 2). In the experiments with different backgrounds of soil salinity, the greatest increase in the raw cotton yield resulted in the variant with a combination of a triple dose of nitrogen with double doses of phosphorus and potassium ($N_{150}P_{100}K_{80}$). It obtained 6.49 t/ha of raw cotton. The next highest seed cotton yield (6.14 t/ha) was evident in the variant with double doses of nitrogen and phosphorus fertilizers in combination with a triple dose of potassium ($N_{100}P_{100}K_{120}$).

With the slightly saline background, the increase in raw cotton yield from nitrogen fertilizers varied from 14.1% (in the variant with its single dose [$N_{50}P_{100}K_{80}$]) to 18.3% and 28.8% (in the variants with double [$N_{100}P_{100}K_{80}$] and triple [$N_{150}P_{100}K_{80}$] doses of phosphorus and potassium). The phosphorus fertilizer used with double doses of nitrogen and potassium gave an undesirable effect—even a slight tendency toward a decrease in the yield (0.7%–0.8%) was apparent, which confirms the inefficiency of phosphorus fertilizers on soils highly supplied with phosphorus. The response of cotton plants to the double and triple doses of potassium with double doses of nitrogen and phosphorus ($N_{100}P_{100}K_{80}$ and $N_{100}P_{100}K_{120}$) was also noticeable, and the rise amounted to 8.6% and 12.0%, respectively.

The study of fertilizers on a moderately saline background exhibited the same picture for nitrogen, and here, the increasing doses of nitrogen provided an adequate boost in seed cotton yield by 20.0%, 32.9%, and 39.8%. However, an increase in the production from phosphorus was prominent only with its double dose, with further growth reduced by 1.6%. The rise from doubled and tripled doses of potash fertilizers was nonsignificant (6.4% and 9.7%, respectively). On average, the cotton productivity on a moderately saline background was 19.5% lower than on the slightly saline background. The effect of mineral fertilizers on the gross productivity of cotton after treatments and step-by-step exclusion of insignificant factors (*P* > 0.05) yielded an equation that fairly accurately reflects the level of gross cotton yield.

$$Y = 5{,}7723 - 0{,}7323N^{0.5} - 0.0115P + 21.79P^{0.5} - 23.44K^{0.5} - 4.847S - 2.0952(NP)^{0.5} + 2.4277(NK)^{0.5} + 0.1705(NS)^{0.5} - 0.0787\,(PK)^{0.5}$$

$$R^2 = 0.861$$

Notably from the equation, the gross cotton yield was 86%, determined by the combined effect of nitrogen, phosphorus, and potassium fertilizers and the degree of soil salinity. The research has established the correlation between the fiber quality characteristics, revealing that fiber length emerged positively associated with micronaire (*r* = 0.33) and negatively associated with fiber strength (*r* = -0.31). Such contradictory findings indicate the need to study the dependencies between the factors used and the quality of the fiber of the cultivated crop.

In this study, the indicators of cotton fiber quality, such as the instrument rendering in mm of water column, fiber strength, fiber metric number, TMTEX, fiber maturity coefficient, fiber breaking length, and micronaire, sustained scrutiny. The determinations proceeded at the Experimental Station of Cotton and Melon Growing, Turkestan, Kazakhstan, with Atakent, following existing standards on an automatic device for determining the micronaire indicator (TB310C Automatic Micronaire Meter) (State Standard of USSR, 1974; State Standard of the Republic of Kazakhstan, 2006).

The raw cotton samples collected from each fertilizer variant on two salinity backgrounds incurred analysis using an automatic micronaire meter. The correlation analysis showed a fairly high dependence existed between potassium nutrition and fiber quality indicators (*r* = 0.38-0.62) (Figure 5). However, with the improvement of potassium nutrition, the indicators, such as the reading of the water column device (*r* = -0.60), the metric fiber number (*r* = -0.60), and micronaire (*r* = -0.38), worsened. The fiber quality indicators, such as the fiber strength (*r* = 0.61), TMTEX (*r* = 0.59), the fiber maturity coefficient (*r* = 0.48), and the breaking length of the fiber (*r* = 0.62), reached adequate improvement with an increase in potassium doses. Variations in fiber quality parameters generally had a fairly considerable relationship with the salts in the arable soil layer (*r* = 0.51-0.61), except for the micronaire reading (*r* = 0.37).

In identifying the regression relationship between fertilizer doses, the degree of soil salinity, and the cotton fiber quality indicators, a series of statistical processing succeeded in obtaining the regression values.

For linear density (TEX) (g):

$$Y = 184.3 - 0.1295N + 1.2925N^{0.5} - 0.0665P - 26.722S + 0.0616(NP)^{0.5} + 1.6115(KS)^{0.5}$$

$$R^2 = 0.752$$

	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6	Tr7	Tr8	Tr9	Tr10	Tr11	Tr12	Tr13
Tr1	1,00												
Tr2	0,15	1,00											
Tr3	0,10	0,30	1,00										
Tr4	0,63	0,73	0,66	1,00									
Tr5	0,08	0,05	-0,08	0,03	1,00								
Tr6	0,49	0,15	0,50	0,55	-0,65	1,00							
Tr7	-0,14	-0,01	-0,60	-0,35	0,52	-0,71	1,00						
Tr8	0,13	0,03	0,61	0,36	-0,51	0,68	-0,99	1,00					
Tr9	-0,13	0,00	-0,60	-0,34	0,53	-0,71	1,00	-0,99	1,00				
Tr10	0,13	-0,02	0,59	0,33	-0,53	0,70	-1,00	0,99	-1,00	1,00			
Tr11	0,23	0,12	0,48	0,40	-0,61	0,75	-0,94	0,93	-0,94	0,93	1,00		
Tr12	0,12	0,05	0,62	0,37	-0,47	0,62	-0,95	0,98	-0,94	0,95	0,89	1,00	
Tr13	-0,14	-0,16	-0,38	-0,33	0,37	-0,51	0,79	-0,77	0,79	-0,79	-0,76	-0,69	1,00

Figure 5. Correlation matrix of paired dependencies of quality indicators of cotton fiber on the studied factors in 2022–2024. (Tr1 - N, Tr2 - P, Tr3 - K, Tr4 - NPK, Tr5 - Total salts [%], Tr6 - Gross yield [t/ha], Tr7 - Instrument readings in mm of water column, Tr8 - Fiber breaking load [in g.s.], Tr9 - Fiber metric number, Tr10 - TMTEX, Tr11 - Fiber maturity coefficient, Tr12 - Breaking length of fiber [in km], and Tr13 - Micronaire).

For the fiber maturity coefficient (micronaire):

$$Y = 2{,}0193 - 0.0006N - 0{,}002P + 0{,}025K^{0.5} - 0.2257S + 0.0037(NP)^{0.5} - 0.0025(NK)^{0.5} - 0.0228(PS)^{0.5} + 0.0206(KS)^{0.5}$$

$$R^2 = 0.763$$

For the breaking fiber length (km):

$$Y = 24.736 - 0.0182N - 0.153\,N^{0.5} - 0.013K + 0.242K^{0.5} + 0.01(NP)^{0.5} - 0.203(PS)^{0.5} - 0.0025(NK)^{0.5} - 0.0228(PS)^{0.5} + 0.0206(KS)^{0.5}$$

$$R^2 = 0.778$$

For fiber breaking load (g/s):

$$Y = 4.545 - 0.007N + 0.06\,N^{0.5} - 0.004P - 0.005K + 0.095K^{0.5} + 0.004(NP)^{0.5} - 0.677S$$

$$R^2 = 0.758$$

For the water column meter reading (mm):

$$Y = 223.4 + 0.363N - 3.632\,N^{0.5} + 0.303P - 3.499K^{0.5} + 55.005S - 0.472(NP)^{0.5} + 0.338(NK)^{0.5} + 3.155(PS)^{0.5} - 0.828(KS)^{0.5}$$

$$R^2 = 0.763$$

For the metric fiber number:

$$Y = 5515.6 + 3.832N - 38.84N^{0.5} + 3.261P - 34.85K^{0.5} + 628.64S - 5.002(NP)^{0.5} + 3.662(NK)^{0.5} + 32.844(PS)^{0.5} - 55.979(KS)^{0.5}$$

$$R^2 = 0.772$$

For micronaire (MIC):

$$Y = 5.158 - 0.0771\,N^{0.5} + 0.1242(NS)^{0.5} - 0.0456(KS)^{0.5}$$

$$R^2 = 0.347$$

CONCLUSIONS

The interaction effects of fertilizers and soil salinity on the formation of leaves in different phases of cotton (*G. hirsutum* L.) development received quite accurate description by regression equations (R^2 = 0.957–0.972). The individual effects of nitrogen and potassium fertilizers were negative, and phosphorus fertilizers were positive. The correlation analysis between potassium nutrition and fiber quality indicators showed a fairly high dependence (*r* = 0.38-0.62). However, with the improvement of potassium nutrition, the readings of the water column device (*r* = -0.60) and the metric number of fiber (*r* = -

0.60) worsened. In contrast, the fiber strength (r = 0.61), TMTEX (r = 0.59), the fiber maturity coefficient (r = 0.48), and the breaking length of fiber (r = 0.62) improved with an increase in potassium doses.

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