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EFFECT OF SOWING METHODS ON FIBER YIELD AND QUALITY PARAMETERS OF THE UPLAND COTTON (*GOSSYPIUM HIRSUTUM* L.)

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SUMMARY

The influences of different sowing methods on the seed cotton yield and fiber quality traits of upland cotton (*Gossypium hirsutum* L.) became this research's focus, carried out at the District Maktaaral, Turkestan Region, Kazakhstan. The results revealed the two-line sowing method with plant spacing (80×11×2×10×1) and plant density (200,000 ha^{-1}) contributed to an increase in the seed cotton yield (4.76 t/ha). The highest seed cotton yield could refer to the topmost plant density and the largest number of bolls per unit area, which were 32%–33% more than the traditional cotton sowing technology. In addition, with the two-line sowing method of cotton, higher values appeared for the sympodial branches per plant (16.0), bolls per plant (14.2), fiber yield (35.1%), and fiber length (33.1 mm). Experiments also showed the formation of longer branches with row width of 90 and 70 cm. Based on the findings, the study recommends the two-line sowing scheme (80×11×2×10×1) and plant spacing (45×12×1), with a plant density of 200,000 and 180,000 ha^{-1}, respectively, as superior for cotton sowing under the conditions of the Turkestan Region, Kazakhstan.

Keywords: Upland cotton (*Gossypium hirsutum* L.), sowing methods, growth and yield traits, seed cotton yield, fiber yield and quality

Key findings: In upland cotton (*Gossypium hirsutum* L.), the plant spacing scheme (45×12×1) and two-line sowing method (80×11×2×10×1), with a plant density of 180,000 and 200,000 ha^{-1}, respectively, were most effective in the irrigated zone of Turkestan region, Kazakhstan. These selected sowing methods have contributed to an increase in the seed cotton yield (4.56 to 4.76 t/ha), with a profitability range of 181.3% to 193.6%.

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INTRODUCTION

Upland cotton (Gossypium hirsutum L.) is one of the important cash and industrial crops, grown for its natural fiber. About 70 countries have around 200 million workers in cotton harvesting. Another 60 million people gain employment in various enterprises processing raw cotton into cotton fabric and in enterprises producing the cottonseed byproducts (seed oil and proteins used for edible purposes and in animal feed). The leading cotton producers are China, India, the USA, Pakistan, and Uzbekistan. These five countries combined produce 65% of the world's total cotton. The remaining 35% comes from other countries worldwide (Azhimetova, 2011).

In modern history, the official cultivation of cotton considerably began in the first decade of the 15th century in India, and later, by the end of the century, it spread to the most tropical regions of Asia and America (Mukhamedjanov, 1976). India was the cradle of cotton, from which it later spread to other countries globally. At that time, cotton has the common name of karpas in India. Later, this name passed onto many languages. Thus, its Persian name is kirpas, in Armenian is karpas, the Greek and Latin names are karpasos and carbasos, the Arabic name is qutun or kutun, while in Pakistan it is kapas, and the English name is cotton (Azhimetova, 2011).

The cotton-growing region is the main growing area under medium salinization and close groundwater table in Kazakhstan (Makhmadjanov et al., 2022). Around 115,000–125,000 hectares undergo with medium-staple cotton (Gossypium hirsutum L.) growing annually, with 80,000–85,000 hectares sown in the districts of Maktaaral and Zhetysay. The higher salt content in the arable soil horizon and the arid climate of the Turkestan Region are the main limiting factors of this region. Moreover, a wide cultivar of pests and diseases are other issues affecting the cotton crop (Makhmadjanov et al., 2023).

Cotton plants respond significantly to sowing methods, the uniformity of their distribution over the sowing area, considerably affecting the seed cotton yield and fiber quality traits (Ozpinar and Isik, 2004; Mert et al., 2006; Balkcom et al., 2010; Menefee et al., 2023). The population density, determined by a combination of row and intra-row spacing, also substantially influences the yield and fiber quality under different production systems. The effects of row spacing on cotton lint yield bore extensive scrutiny earlier in numerous studies (Aslanov and Quliyeva, 2021; Azimova, 1963; Danilenko, 1975; Tashmukhamedova, 1984).

Based on cotton growing conditions, the sowing methods showed varied responses and effectiveness in production. Therefore, it is crucial to establish the soil and climatic conditions suitable to what type of sowing method to ensure the optimum seed cotton yield. The genotypes genetic potential, environmental conditions, and growing and production technologies considerably affect the cotton crop yield and its fiber quality parameters (Baloch et al., 2015; Yuksekkaya, 2002). In addition to the genetic potential for yield-related traits of the genotype, it is essential to determine if the said cultivar is stable for quality variables (Gul et al., 2016).

In the present era, the main task of cotton growing is to enhance the productivity with desirable fiber quality. For this purpose, it is necessary to study the different aspects of crop rotation, the correct approach for cultivation of this crop, the compliance with varietal agrotechnology, which had insufficient studies. The presented research sought to study the influence of various sowing methods and row spacing on seed cotton yield and fiber quality traits under the conditions of the Turkestan Region, Kazakhstan.

MATERIALS AND METHODS

The research commenced during the crop seasons 2021 to 2023 on sierozemic soil at the Maktaaral Agricultural Experimental Station of Cotton and Melon Growing, Turkestan Region, Kazakhstan (43°17′50.3″ North latitude, 68°15′6.1″ East longitude, and an altitude of 214 masl). The object of research was the regional cotton cultivar 'Maktaaral-5027,' bred at the Agricultural Experimental Station of Cotton and Melon Growing. The said cultivar is early maturing and takes 117 to 119 days from sprouting to the opening of the first boll. For fiber yield, it prevails over the check cultivar by 2.2% and on fiber length, by 0.5 mm. The cultivar has a conical bush shape, not a spreading type, with a plant height of 120–125 cm, and a first type of branching. Sympodial branches formed at 4–5 nodes. The leaves are large, five-lobed, colored green, and the flowers have no anthocyanin spots. The boll is 4–5 valve, round, slightly rough, and bursts well, not falling off when ripe. The seeds are medium-sized and egg-shaped, with linters of light gray. The 1000-seed weight was 122.5–124.2 g, and the fiber is white. The said cotton cultivar also proved resistant to bollworm and beet borer pests, which makes it possible to increase the planting density.

Experimental design

Field experimental studies used generally accepted classical methods, i.e., experiments and observations. Field experiments proceeded according to the field-plot technique in cotton (Imamaliev, 1977).

The cotton seed sowing comprised different plant spacing as per the following schemes:

a) 90×9×1, with a plant density of 120,000 ha^{-1}, a traditional sowing (rows and plant spacings of 90 cm and 9 cm, respectively;
b) 70×10×1, with a plant density of 134,000 ha^{-1}, with 70 cm and 10 cm rows and plant spacings, respectively;
c) 45×12×1, with a plant density of 180,000 ha^{-1}, with 45 cm and 12 cm rows and plant spacings, respectively;
d) 80×11×2×10×1, with a plant density of 200,000 ha^{-1}, two-line sowing (80 cm - row spacing, space between two rows [11 cm], and plant spacing [10 cm]) (Figure 1).

The total area of the experiment was 2,592 m^2. The plot size was 7.2 m (width) × 30 m (length) = 216 m^2, 216 m^2 × 4 variants = 864 m^2, 864 m^2 × 3 replications = 2,592 m^2.

Record maintenance in each variant on registration rows occurred. Each subplot has eight rows, with the middle four rows registered in each plot. All the observations about the cotton growth and development continued according to the recommended methodology (Peregudov, 1978; Dospekhov, 1985; Simongulyan and Kurepin, 1985). Records of cotton seedlings maintained in all variants were in two-fold replication on two sites, on a plot of 4 m^2 (180 cm × 222 cm). The phenological observations of cotton growth and development progressed on 25 plants in each plot. Seed cotton yield's recording transpired manually on a plot-by-plot basis. The ginning and technological parameters of cotton fiber (micronaire, grade, yield, length, and fiber maturity) incurred analysis using the laboratory equipment, LD-10, LPS-4, and KH-730, at the Agricultural Experimental Station of Cotton and Melon Growing, Atakent, Kazakhstan.

Meteorological conditions

According to natural and climatic conditions, the research area belongs to the semidesert zone, characterized by low atmospheric precipitation, and high summer and low winter air temperatures. Agrochemical characteristics of the experimental soil are available in Table 1. The soil reaction was medium alkaline (pH 8.0), with absorption capacity (9–10 mEq), nitrogen (0.072%), phosphorus (0.129%), the C:N ratio (5–7), the mobile phosphorus (25.7 mg/kg), and exchangeable potassium (400 mg/kg), with characteristics as average and highly affluent.

The climate pattern characteristics of the sierozemic zone include low precipitation, uneven precipitation over the year in seasons, high temperatures in summer and low temperatures in winter, high air dryness in warm season, and strong soil evaporation. In the research area, the meteorological conditions for the period 2021 to 2023 appear in Table 2. The research zone's climatic factors, in general, and during the research years, in particular, required regulating conditions for cultivating cotton plants regarding complying with the optimal nutrient status and the conditions of water availability. In the Turkestan Region, with cotton plantings, the groundwater level was very close (Figure 2).

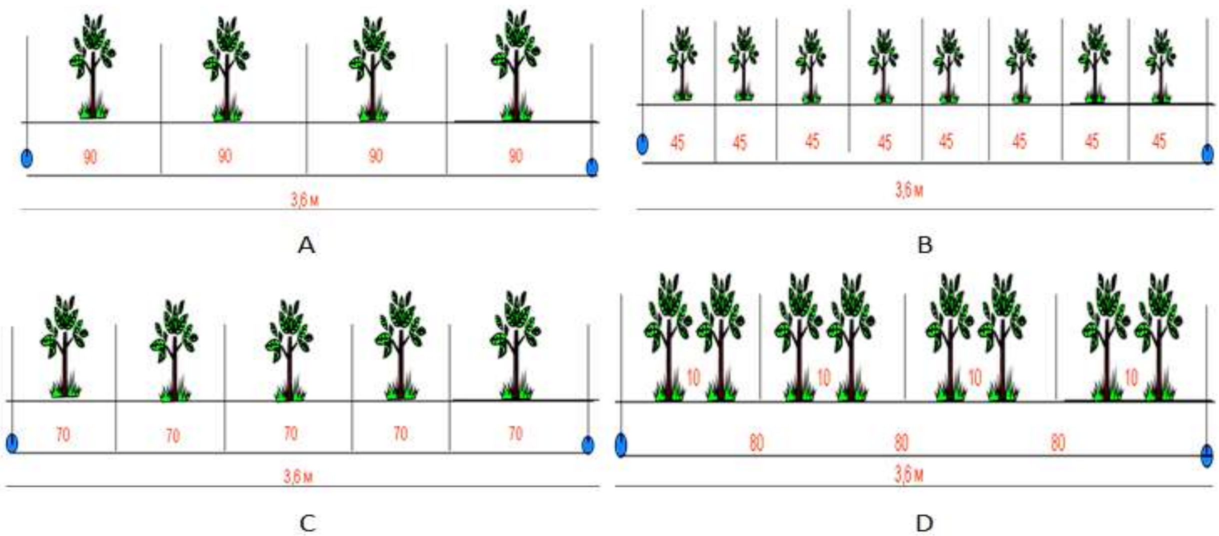

Figure 1. Scheme of sowing cotton seeds (A - Traditional cotton sowing; B - Sowing cotton with row spacing of 70 cm; C - Sowing cotton with row spacing of 45 cm - narrowed seeding; D - Two-line sowing of cotton).

Table 1. Agrochemical characteristics of the soil of the experimental plot.

Depth (cm)	Humus (%)	Gross forms (%)		Mobile forms (mg/kg)		Carbonates (%)	pH
		nitrogen	phosphorus	P_2O_5	K_2O		
0-30	0.806	0.072	0.129	25.7	400	6.2	7.0
30-40	0.654	0.064	0.103	18.4	350	7.9	7.5
40-60	0.495	0.060	0.101	13.2	230	10.3	8.0

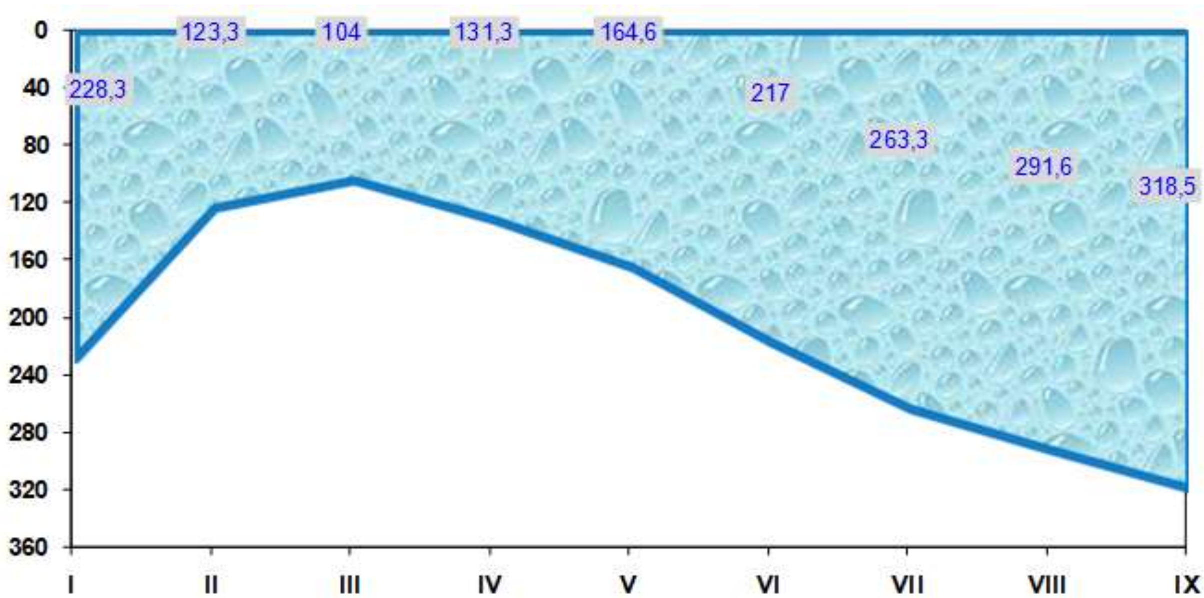

Figure 2. Dynamics of groundwater level movement by month.

Table 2. Meteorological indices of the growing period 2021–2023 in the conditions of the District Maktaaral, Kazakhstan.

Months	Air temperature (°C)			Precipitation (mm)			Air humidity (%)		
	2021	2022	2023	2021	2022	2023	2021	2022	2023
I	-0.2	- 2.7	2.7	48.6	46.8	62.5	86.4	87.2	77.8
II	4.3	4.5	3.0	60.4	34.1	39.5	86.6	79.5	73.4
III	6.9	8.1	8.3	36.0	86.3	20.1	77.8	82.9	67.6
IV	16.9	14.6	13.3	19.8	24.6	0.9	57.4	49.2	37.4
V	21.6	21.2	22.4	26.4	22.6	0.0	51.6	67.1	55.1
VI	26.3	25.5	25.2	1.2	11.0	0.4	39.4	55.2	44.8
VII	26.8	26.4	26.1	0.2	3.0	0.005	45.7	54.7	48.7
VIII	23.1	24.6	25.0	2.2	0.0	20.0	51.1	51.4	65.0
IX	17.7	20.8	20.2	0.8	0.8	22.0	53.3	44.3	63.2
Average	16.0	15.8	16.2	195.6	229.2	165.4	61.0	63.5	59.2

RESULTS AND DISCUSSION

Numerous researchers have argued reduction in plant abundance is one of the possible ways of managing the decline of drought stress and save crops' life. According to Bange et al. (2005), yields often remain the same even if decreasing plant population because crop plants with lower density produce more yields. Gwathmey et al. (2008) reported the reduced planting density had minimal effect on yield under rainfed conditions.

The analysis of cotton growth on June 1 showed particularly no effects of the plant density on plant development. An explanation is by their smaller growth results in the absence of plant oppression. Moreover, according to sowing methods and in the beginning period of ontogenesis, nonsignificant differences were evident in the growth of the cotton main stem. On average, over three years, phenological observations of the growth and development of cotton on July 1 revealed cotton plants manifested mass budding and flowering in all the variants. On average, the plants' height ranged from 46.0 to 47.0 cm, while the number of sympodial branches was 6.9 per plant. However, in the sowing with row spacing of 45 cm and two-line sowing of cotton, growth retardation and fruit accumulation was prevalent. Additionally, the plant's development in the two-line sowing displayed noticeable lagging after the control, with less number of sympodial branches and buds observed on the cotton plants.

During the period of plant development on August 1, the cotton plants' progress differed for growth in all variants. However, the height of the main stem was 98.3 cm in the traditional sowing scheme with row spacing of 90 cm, the number of sympodia was 12.7, and the number of bolls was within 8.1 per plant. The cotton main stem height was 92.7 cm, on average, with the sowing scheme of 70 cm row spacing, the number of sympodial branches was 12.2, and the number of bolls was 8.0 per plant. In cotton sowing with 45 cm row spacing, and, on average, the main stem height was 91.1 cm, the number of sympodia was 11.1, and the number of bolls was 6.4 per plant. In the two-line sowing of cotton, the main stem height averaged 89.7 cm, the number of sympodia was 12.3, and the number of bolls was 10.0 per plant. For the two-line sowing of cotton with dense population, the main stem height decreased by an average (13.7 cm) compared with the control variant (Table 3).

During the growth and development period on September 1, on average, the phenological observations over three years showed in the two-line sowing method (80×11×2×10×1), with a plant density of 200,000 ha^{-1}, the number of sympodial branches provided 16.0. Furthermore, the number of bolls was 14.2 per plant, and the bolls per plant were 34.5% more than the traditional method of cotton sowing (Figure 3).

The results further revealed by cultivating cotton with traditional sowing

Table 3. Growth, development, and yield-related traits of the different cotton sowing schemes for 2021–2023.

Sowing Schemes	Years	July 1		August 1			September 1	
		Growth (cm)	Number of sympodia (#)	Plant height (cm)	Number of sympodia (#)	Bolls plant^{-1}	Number of sympodia (#)	Bolls plant^{-1}
Control: Traditional sowing scheme with 90 cm row spacing 90×9×1 – 120,000 pcs/ha	2021	43.7	7.0	103.4	13.0	8.2	16.6	9.6
	2022	40.5	6.8	100.2	12.4	8.0	13.5	9.2
	2023	54.3	7.0	91.4	12.9	8.0	13.8	9.0
	average	46.1	6.9	98.3	12.7	8.1	14.6	9.3
Sowing scheme with 70 cm row spacing 70×10×1 – 144,000 pcs/ha	2021	42.4	6.4	96.2	12.6	8.0	16.0	9.4
	2022	39.7	6.2	94.0	12.1	7.8	13.0	8.6
	2023	53.6	6.6	88.0	12.0	8.2	13.4	8.2
	average	45.2	6.4	92.7	12.2	8.0	14.1	8.7
Sowing scheme with 45 cm row spacing 45×12×1 – 180,000 pcs/ha	2021	41.8	6.0	94.8	11.4	6.1	14.6	8.2
	2022	39.6	5.8	91.7	11.0	6.0	10.2	7.0
	2023	51.6	6.1	86.7	11.8	7.3	10.4	7.6
	average	44.3	5.9	91.1	11.1	6.4	12.7	7.6
Two-line sowing of cotton 80×11×2×10-1 – 200,000 pcs/ha	2021	42.0	6.2	95.7	12.3	10.0	15.4	14.6
	2022	38.4	6.0	90.2	12.0	9.8	16.2	14.2
	2023	5.1	5.8	83.4	12.7	10.2	16.4	14.0
	average	43.5	6.0	89.7	12.3	10.0	16.0	14.2
$LSD_{0.05}$							0.7	1.2

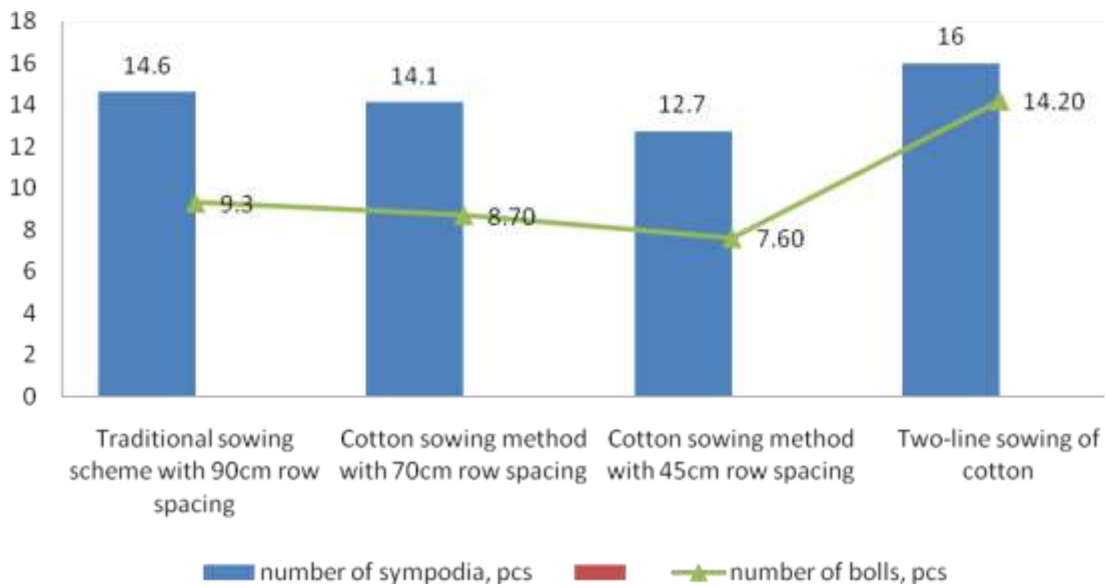

Figure 3. Number of sympodial branches and bolls based on different cotton-sowing technology on September 1.

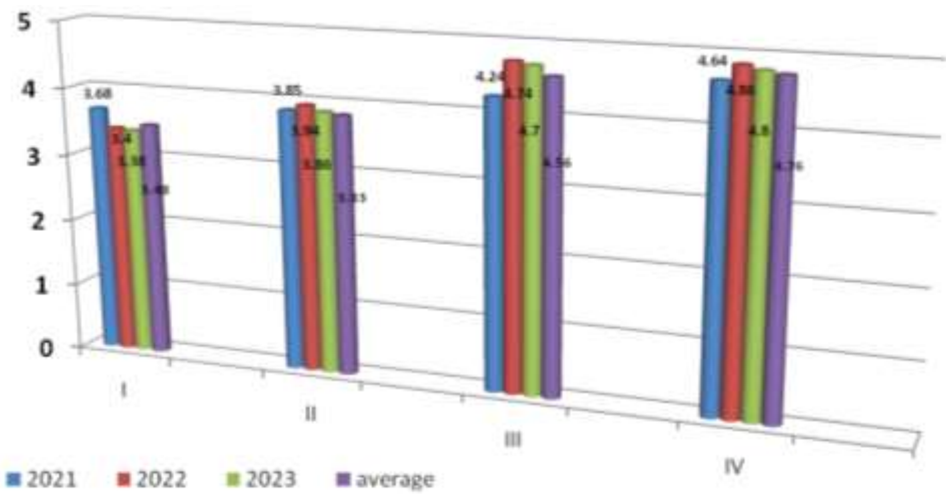

Figure 4. Cotton yield depending on different cotton sowing schemes for 2021–2023.
(*Note:* I - Traditional sowing method 90×9×1 – 120,000 pcs/ha; II - 70×10×1 – 144,000 pcs/ha; III - 45×12×1 – 180,000 pcs/ha; IV – Two-line sowing method 80×11×2×10-1 – 200,000 pcs/ha, LSD_{05} – 0.54 t/ha).

scheme (90 cm row spacing), with a plant density of 120,000 ha^{-1} and application of mineral fertilizers (N_{120}:P_{70}), and averaged over three years, the seed cotton yield was 3.48 t/ha. Mineral fertilizers noticeably increased the accumulation of bolls per plant, and the effectiveness of fertilizers was significantly higher in wide-row spacing and in two-line sowing of cotton (Figure 4).

In the cotton sowing with 70 cm row spacing and a plant density of 144,000 ha^{-1} using mineral fertilizers (N_{120}:P_{70}), the average seed cotton yield was 3.83 t/ha, which was 0.35 t/ha higher than the yield obtained with the traditional cotton sowing method. This may be because cotton plants' density per unit area was 24,000 ha^{-1} more than the traditional cotton sowing technology; therefore, the largest harvest has resulted due to the higher cotton plant density. One can also see in Figure 2, the cotton sowing scheme with 45 cm row spacing, with increased plant density (180,000 ha^{-1}s), using mineral fertilizers (N_{120}:P_{70}), the domestic cotton cultivar Maktaaral-4011 gave the seed cotton yield of 4.56 t/ha and produced 0.11 t/ha more yield than the control variant.

In the two-line sowing method with increased plant density (200,000 ha^{-1}) and mineral fertilizers (N_{120}:P_{70}), the total seed cotton yield was 4.76 t/ha, which was 0.13 t/ha (27.0%) more than the yield obtained with the traditional cotton sowing method. This may also be due to the cotton sowing scheme with 45 cm row spacing and the two-line cotton sowing, the seed cotton yield enhanced because of the plant density, given the plant density was 33%–40% greater than the control. Parajulee et al. (2011) reported while skipping two rows reduced yield, skipping one row did not, and the skip-row cotton had higher quality grades for fiber length and strength. Numerous studies authenticated the skip-row reduced plant population tend to improve the fiber quality as decreasing water stress help in better fiber development in cotton (Jones and Wells, 1998; Bange et al., 2005; Darawsheh et al., 2007).

Thus, the two-line cotton sowing method proves to achieve an increased plant density (200,000 ha^{-1}) compared with traditional sowing methods, showing 20% more seed cotton yield. Specifically, one can consider the high density of cotton plants and the relatively smaller number of bolls per plant with the two-line sowing technology the bolls per unit area was 35% more than with the traditional cotton sowing technology. Therefore, it can be apparent that the seed cotton yield was still better with a higher plant density than with a relatively low plant population. Chhabra and Bishnoi (1993) reported similar findings and mentioned increasing plant density implied an elevated seed cotton yield. According to Cheema et al. (2008), the greater number of bolls was evident with increased plant density. The raising plant density provided large monopodial and sympodial branches per plant, which were notable with more number of bolls on the plant (Ali et al., 2009; Makamov et al., 2023; Makhmadjanov et al., 2023).

The influence of different sowing technologies on fiber quality parameters of cotton also gained probing. The technological properties of cotton fiber were distinctive of the following main indicators, i.e., fiber length and yield. However, the fiber length of cultivated cotton species varies from 20 to 60 mm. The longer the fiber, the higher the strength of the yarn obtained from it. In improving the technological properties of cotton fiber and increasing cotton lint yield, agrotechnical practices play an essential role, particularly the mineral fertilizers and cotton sowing methods. The research has shown in the cultivar Maktaaral - 5027 the highest cotton fiber yield emerged with the traditional sowing method (90 cm row spacing) and amounted to be 36.0%, with a fiber length of 33.6 mm. The fiber quality parameters of raw cotton depended on the sowing technology and plant spacing schemes with the use of mineral fertilizers (Table 4).

The results further revealed relatively high fiber yield resulted in the cotton sowing scheme with 70 cm row spacing and amounted to be 35.2%, with a fiber length of 32.3 mm (Table 4). However, the lowest fiber yield appeared in the cotton sowing scheme with 45 cm row spacing, where the average fiber yield was 34.3%, with a fiber length of 31.7 mm. Based on the observed quality parameters of cotton fiber, the two-line sowing of cotton gave the optimal yield of cotton fiber (35.1%), with a fiber length of 33.1 mm. Thus, under the conditions of medium saline sierozemic soils, the two-line sowing method with an increased plant density (200,000–220,000 ha^{-1}) proved effective and most appropriate in the medium-fiber cotton cultivar Maktaaral-5027. Shahzad et al. (2017) also reported the highest raw cotton yield (2,944.5 kg/ha) with enhanced planting density in a sowing scheme with a row spacing of 25 cm.

Economic efficiency

By economically assessing the effectiveness of the sowing technology used, the key indicator was the net income (profit) received from one hectare. The main indicators were the size and quality of raw cotton and its cost and return on additional production expenses. Determining the net income received in cotton growing was by comparing the cost of production and the price of additional harvest of raw cotton. By identifying the economic efficiency of cotton cultivation, we proceeded from the indicators of raw cotton yield from one hectare, additional costs for its harvesting and transportation, the assortment of raw cotton, direct costs of cotton cultivation, and revenue obtained by sale of the crop. According to Larson et al. (2009), for improved lint quality and reduced production costs, row-skipped configurations can increase the profitability of cotton cultivation and production. The three-year average data showing the level of economic efficiency of the presented research is available in Table 5.

The results enunciated with a plant density of 180,000 ha^{-1} and the cotton sowing scheme with 45 cm row spacing, the net profit was USD 959.86/ha, with a profitability of 181.3% (Table 5). However, in the traditional sowing scheme, with 90 cm row spacing and a plant density of 120,000 ha^{-1}, the net profit was USD 675.23 /ha, with a profitability of 146.3%. However, in the cotton sowing scheme with 70 cm row spacing and a plant density of 144,000 ha^{-1}, the net profit was only USD 742.3 /ha.

The economic efficiency showed the highest net income resulted in the two-line sowing of cotton (USD 1,025.18/ha with a profitability level of 193.6%). This may be

Table 4. Fiber quality parameters of cotton based on different sowing schemes for 2021–2023.

Sowing schemes	Plant spacing scheme and plant density (ha)	Years	Boll weight (g)	Fiber length (mm)	Fiber yield (%)
Traditional sowing scheme with 90 cm row spacing	90×9×1 120,000 pcs. N_{120} P_{70}	2021	4.8	33.6	36,0
		2022	4.2	33.6	36,2
		2023	4.4	33.8	35.8
		average	4.4	33.6	36.0
Cotton sowing scheme with 70 cm row spacing	70×10×1 144,000 pcs. N_{120} P_{70}	2021	4.6	33.4	35.4
		2022	4.0	33.4	35.6
		2023	4.2	33.0	35.0
		average	4.3	32.3	35,3
Cotton sowing scheme with 45 cm row spacing	45×12×1 180,000 pcs. N_{120} P_{70}	2021	4.0	31.6	34.0
		2022	3.8	31.6	34.2
		2023	4.0	31.8	34.6
		average	3.9	31.7	34.3
Two-line sowing of cotton	80×11×2×10-1 200,000 pcs.	2021	4.5	33.0	35.2
		2022	3.7	33.0	35.4
		2023	3.6	33.4	34.8
		average	3.9	33.1	35.1
$LSD_{0.05}$			0.6	1.1	1.7

Table 5. Comparative economic efficiency of the different cotton sowing schemes.

Sowing Scheme	Plant spacing scheme and plant density (ha)	Annual rate (kg/ha)		Average yield (t/ha)	Purchase price (dollar/kg)	Sales profit (dollar/ha)	Total expense (dollar/ha)	Net profit (dollar/ha)	Profitability (%)
		N	P						
Traditional sowing scheme with 90 cm row spacing	90×9×1 120,000 pcs.	120	70	3.48	0.326	1 136.53	461.29	675.23	146.3
Cotton sowing scheme with 70 cm row spacing	70×10×1 144,000 pcs.	120	70	3.83	0.326	1 250.83	508.54	742.3	146.0
Cotton sowing scheme with 45 cm row spacing	45×12×1 180,000 pcs.	120	70	4.56	0.326	1 489.24	529.38	959.86	181.3
Two-line sowing of cotton	80×11×2×10-1 200,000 pcs.	120	70	4.76	0.326	1 554.56	529.38	1 025.18	193.6

because in cotton sowing scheme with 45 cm row spacing and in the two-line sowing of cotton, the plant density was two times greater. This variant was more cost-effective than other sowing schemes. Shahzad's et al. (2017) economic analysis revealed the maximum net profit was successful with a denser planting method (25 and 50 cm apart).

CONCLUSIONS

Based on the results of harvesting raw cotton, higher seed cotton yield (4.56–4.76 t/ha) emerged in the variants with the sowing scheme of 45×12×1, with a plant density of 180,000 ha^{-1}, and the two-line sowing method (80×11×2×10×1), with a plant density of

200,000 ha^{-1}, despite the low boll weight (3.9 g). The seed cotton yield increased due to the higher plant density (180,000–200,000 plants) and bolls setting on the plants.

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