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THE RESPONSE OF THE MEDIUM FIBER COTTON VARIETY PIDOZERSKY 4 TO THE SEEDING RATE AND ROW WIDTH UNDER DIFFERENT CONDITIONS OF SOIL MOISTURE IN THE SOUTHERN STEPPE OF UKRAINE

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Abstract

The article presents the results of studying the reaction of the early maturing medium-fiber cotton variety Pidozerskyi 4 to the sowing rate and row width under different conditions of moisture supply in the Southern Steppe of Ukraine. The scheme of the experiment included soil moisture conditions: natural moisture and watering at 70% of the lowest moisture content (LM); row width 30, 60, 90 cm; sowing rate of 250, 300 and 350 thousand pieces/ha. Studies have shown that the formation of the number of pods on a plant that opened before harvesting was significantly influenced by the rate of seed sowing, with an increase in which the indicators of the number of pods decreased on average by 43.9% in the experiment, and regardless of the conditions of soil moisture and width row spacing. The variability of the effective signs of the mass formation of the boll of pre-freeze raw cotton depended by 25.0% on the humidification conditions, by 15.0% - on the width of the rows, and by 16.0% - on the seeding rate; yield of domestic raw cotton - by 66.0% from the conditions of wet supply, by 3.0% - from the width of the rows and by 9.0% - from the sowing rate. The significant influence of irrigation on the yield formation of frozen raw cotton was determined. The increase in yield on irrigated plots at the seeding rate of 300,000 units/ha was: for row widths of 30 cm – 17%, for 60 cm – 18%, for 90 cm – 22%, compared to non-irrigated options. Raw cotton production is highly effective, the profitability level is 63-69%.

Key words: *precocious, medium-fiber, cotton variety, seeding rate, row width, moisture supply conditions*

INTRODUCTION

Cotton is widely cultivated in more than 80 countries worldwide due to its great socio-economic benefits and is the most important industrial fiber crop [9, 26, 36].

The shortage of water resources poses serious threats to the sustainable development of agriculture and causes the need for water-saving technologies. One of the potential strategies to overcome reduced irrigation opportunities is to plant crops such as cotton (*Gossypium hirsutum* L.) or sorghum (*Sorghum bicolor* L.), which are characterized by drought resistance [7].

Since this plant is able to withstand drought well, undemanding to growing conditions, it can become an alternative to traditional crops in the area of risky agriculture [41].

Climate change towards warming creates favorable conditions for crop cultivation in the Southern Steppe of Ukraine [39, 47]. Therefore, the greatest achievement of the Ukrainian breeders of the Institute of Irrigated Agriculture of the NAAS (now the Institute of Climate-Smart Agriculture of the NAAS) was the creation of two precocious, medium-fiber cotton varieties of a new generation for this zone.

For effective, scientifically based cotton production, the question arises of the need to improve its varietal agrotechnics of growing. The study of the reaction of the production features of cotton varieties with the optimization of the main parameters of technological elements is relevant and important. Solving this problem will contribute to the increase of high yields of raw cotton and the effective implementation of the culture in production in the conditions of the Southern Steppe of Ukraine.

Scientists from all over the world paid attention to the issue of improving cotton growing technology [11, 19, 20, 27].

In the conditions of climate change, agriculture is the key to human survival, and water is an indispensable factor for ensuring crop production. Approximately 70% of the world's water consumption is used for crop production [46], 60–80% – for irrigation [1, 15].

It has been proven that even crops which are not very picky about moisture - also need water during critical periods of development. The greatest need for vegetation irrigation of cotton arises during the flowering of plants and the formation of bolls, which in the conditions of the Kherson region take place in July.

Studies have shown that a water deficit during the flowering of this crop can lead to a significant reduction in yield [33, 35, 16].

A number of scientists emphasize the need for conducting field studies to assess the response of cotton under different soil moisture conditions [5, 12, 37]. Water use varies greatly depending on location, climate, irrigation method, and cotton variety [6].

The study of the cotton irrigation regime in Bulgaria (Chirpan) at the Institute of Cotton and Durum Wheat showed that the optimal irrigation regime is watering at the irrigation rate 1,130 m^3/ha and one rational watering with rate 418 m^3/ha, which ensured a 64.4% yield increase [31].

When studying the regime of cotton irrigation in the south of Ukraine Shtoyko D.A. recommends applying irrigation with an irrigation rate of 2,000 m^3 to obtain a cotton crop of 2.0 t/ha [34]. To obtain high yields of cotton in Uzbekistan, Azerbaijan and the former republics of Central Asia, it is necessary to carry out from 3 - 4 to 8 - 10 irrigations, depending on the type of soil [45].

However, cotton can withstand severe droughts. It forms a crop without irrigation in areas with an annual amount of precipitation up to 350 mm. At the same time, the main importance is not the total amount of precipitation, but its distribution. Heavy rains harm cotton, if there is a lack of light and a drop in temperature. The amount of precipitation in the cotton regions of southern Ukraine is much lower than in South America, and the annual amount of heat is lower than in the republics of Central Asia, located in the dry zone, where cotton culture is possible only with irrigation [24]. In this regard, a number of authors recommend reducing the use of water on cotton crops to 25% of the recommended irrigation rate [29, 30].

The results of research carried out by scientists of the Institute of Irrigated Agriculture proved that the optimal irrigation rate of Dniprovskyi 5 cotton variety in the conditions of the Southern Steppe of Ukraine should be considered 1,250 m^3/ha at 70% of the LM [31].

Plant density is an important abiotic factor affecting cotton production [44], optimal indicators of which increase crop yield [2, 3, 13, 21, 38, 43].

When the plant density of 15,000, 33,000, 51,000, 69,000, 87,000 and 105,000 per hectare was studied in the Henan province of China, it was established that cotton grown at a lower density formed taller plants and a large number of leaves on them, while at a high one, a larger the number of branches, fruit nodes and a large number of pods per unit of sown area. The highest yield of raw cotton 4.55 t/ha and fiber 1.68 t/ha was obtained at a density of 87,000 plants per hectare [24]. Other authors also followed this opinion [12, 22].

Increasing the density from 10 to 15 plants per m^2 led to an extension of the cotton vegetation period.

It has been proven that raw cotton yields increase with plant density up to a certain value, which is called optimal, while low yields are obtained at very high or very low planting densities. Cotton plants react especially sharply to increased plant density during flowering [8].

It has been established that the optimal plant density depends on many factors, such as climate, genotype, irrigation method, and type of ground cover. Therefore, to determine the optimal density of cotton plants, in order to obtain the maximum yield, it is important to conduct research in each geographical area [10, 23, 24, 28]. With the introduction of modern varieties of cotton, interest in its narrow-row production has revived, primarily due to the reduction of weed control problems. Narrow-row spacing proved to be a viable agronomic practice for cotton production compared to traditional crop cultivation [18]. To determine the effect of row spacing on precocity, three row spacings of 60, 75 and 90 cm were studied in Pakistan. It was found that precocity index was highest (50.9%) with 60 cm row spacing, productivity index (55.9 g/day) - with a row spacing of 90 cm, and the yield of raw cotton is the highest (2.6 t/ha) - with a row spacing of 75 cm [32].

For machine cultivation of cotton, a number of scientists recommend an optimal row spacing of 76 cm [17, 25]. Thus, an important issue in the technology of growing new varieties of cotton is their reaction to the area of plant nutrition depending on the width of the rows and the density of the stand under different conditions of moisture supply. Optimizing the feeding area and moisture supply is important for the maximum use of natural factors and the formation of high yields of raw cotton. The study of these parameters is also necessary to determine the technological requirements for the purchase or creation of new equipment. The purpose of our research was to determine the reaction of the early ripening medium-fiber cotton variety Pidozerskyi 4 to the density and width of sowing under different conditions of soil moisture in the Southern Steppe of Ukraine.

MATERIALS AND METHODS

Determining the method of seeding and the density of plants under different conditions of moisture supply was carried out by conducting a field experiment. Factor A – soil moisture conditions: natural moisture and watering at 70% of the LM; Factor B – row width 30, 60, 90 cm; Factor C - seeding rate of 250, 300 and 350 thousand units/ha.

Experiments on the study of the method of seeding in conditions of moisture supply and on crops of the early ripening cotton variety Pidozerskyi 4 were carried out on the fields of the Institute of Irrigated Agriculture of the NAAS during 2012-2013, 2018 according to the Methodology of field and laboratory research on irrigated lands [40]. Soils are typical for the southern part of Ukraine - dark chestnut, medium loamy, medium saline. The depth of the humus horizon is 30-45 cm. The content of humus in the soil layer is 0-25 cm - 2.15%. The reaction of the soil solution in the upper horizons is close to neutral (PH = 7.0). The object of research is the cotton culture, the subject is the irrigation regime, the new variety is Pidozersky 4. The predecessor is winter wheat. Plowing was carried out to a depth of 25-26 cm, the experimental plot was marked with a RPL-6 seeder to a width of 0.7 m. Cotton is a heat-loving crop and is very responsive to soil temperature conditions. Cotton seeding was carried out when the soil temperature at the depth of seed wrapping reached 13-14°C using a nest method with a manual seeder on May 5-8, equipped with a brush seeding mechanism with different hole diameters. Seeds were sown exposed to concentrated sulfuric acid. Laboratory seed germination was 92.0% in 2012, 91.5% in 2013, and 92.1% in 2018. After seeding, the herbicide "Stomp" was used at the rate of 5-6 l/ha for harrowing. The plot, depending on the size of the row spacing, had 12 rows (row spacing 30 cm), 6 rows (row spacing 60 cm) and 4 rows (row spacing 90 cm). In the variant with a row spacing of 30 cm, 8 rows were counted, with a row spacing of 60 cm – 4 rows, and with a row spacing of 90 cm – 3 rows. The registered area was 24 m^2. The direction of seeding is south-north. The recurrence is five times, the placement of plots is five-tiered by the method of randomization of plots of the third order.

During the growing season, two inter-row treatments were carried out with a cultivator KRN-4.2, chemical stamping of plants - with the retardant Pix at the rate of 1 l/ha in the

first decade of August. Fertilizers were applied manually, watered with a DDA100MA sprinkler.
Research methods - field, laboratory, statistical.

RESULTS AND DISCUSSIONS

Determining the date of onset of phases of growth and development of cotton plants allowed to calculate the duration of its interphase periods [42]. The results of the observations showed that this indicator was influenced by hydrothermal conditions, soil moisture, and plant density. Depending on the specified factors, the vegetation period of cotton plants lasted from 110 to 122 days (Table 1).

Table 1. Duration of phases of growth and development of cotton plants (average for 2012-2013, 2018), days

Soil moisture conditions, Factor A	Row width, cm Factor B	Seeding rate, thousand units/ha Factor C	Growth and development phases		
			"seeding - seedling"	"seedling-blooming phase"	"seedling phase - full maturity" (on the date of collecting the boxes)
Without irrigation	30	250	14	49	116
		350	14	49	114
		450	14	48	114
	60	250	14	51	114
		350	14	50	110
		450	14	50	112
	90	250	14	51	116
		350	14	50	113
		450	14	48	114
Irrigation at 70% of the LM	30	250	14	51	122
		350	14	50	120
		450	14	49	119
	60	250	14	51	118
		350	14	52	115
		450	14	49	114
	90	250	14	54	121
		350	14	52	119
		450	14	52	118
LSD_{05} Partial differences	Factor A				6.6
	Factor B				1.9
	Factor C				3.3
LSD_{05} The average (main) effects	Factor A				2.2
	Factor B				0.8
	Factor C				0.8

Source: Own calculation.

The results of the observations showed that the duration of the "seeding-seedling" period was the same for all variants of the experiment and amounted to 14 days on average over the years of research.
One of the most important indicators of the rate of growth and development of plants is the duration of the "seedling-blooming" period. In this period, slight differences were observed between the options of irrigation and natural soil moistening, which was 1–3 days.

The duration of the "seedlings-full maturity" phase was characterized by lower indicators in the variants without irrigation – 110 - 116 days, than in the case of watering, where the vegetation period was extended by 3.6 - 5.2% and was within 114 - 122 days. It should be noted that, regardless of moisture conditions and plant density, the vegetation period in the variants of the experiment with a row spacing of 30 cm was somewhat shorter – by 1 - 2 days, compared to the width of the row spacing of 60 and 90 cm (Fig. 1).

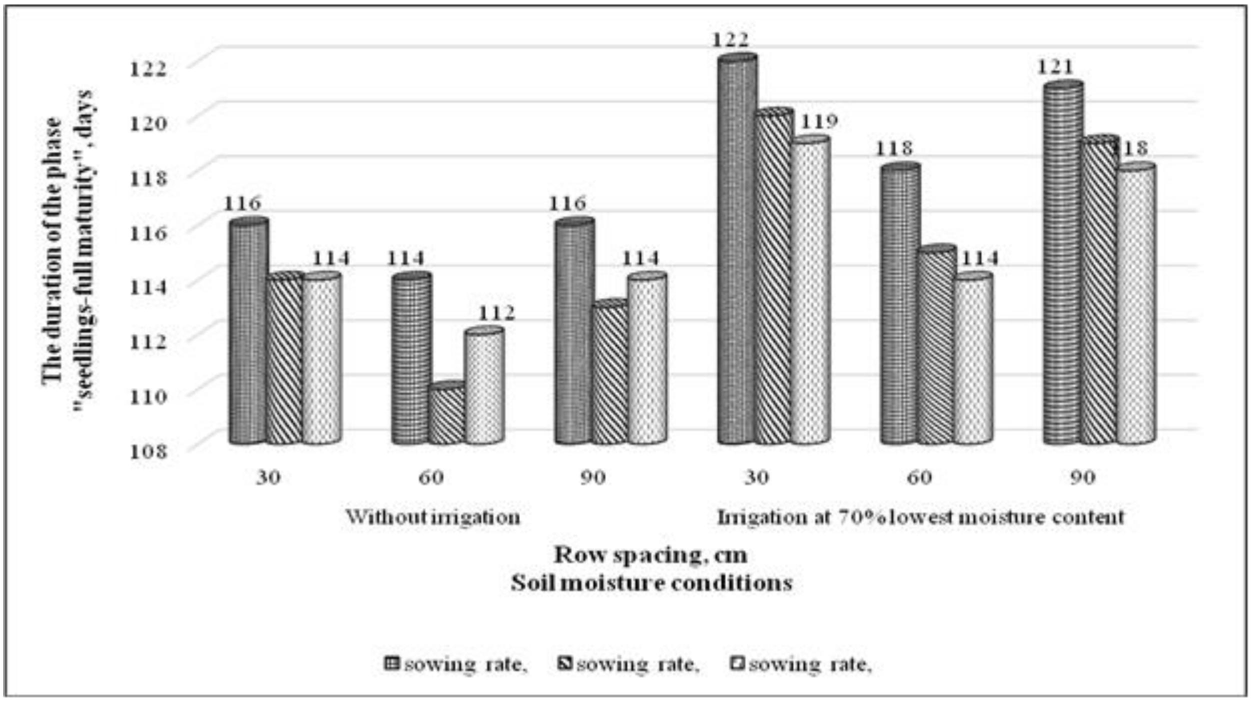

Fig. 1. The reaction of cotton plants of the Pidozerskyi 4 variety to duration of growth and development phases depending on the width of the rows and sowing rates under different conditions of moisture supply, days (average for 2012-2013, 2018)
Source: Own calculation.

As can be seen from Figure 2, the variability of the duration of the growing season depended significantly on soil moisture conditions (36.0%): with irrigation, the ripening period of the pods was extended by 4-6 days.

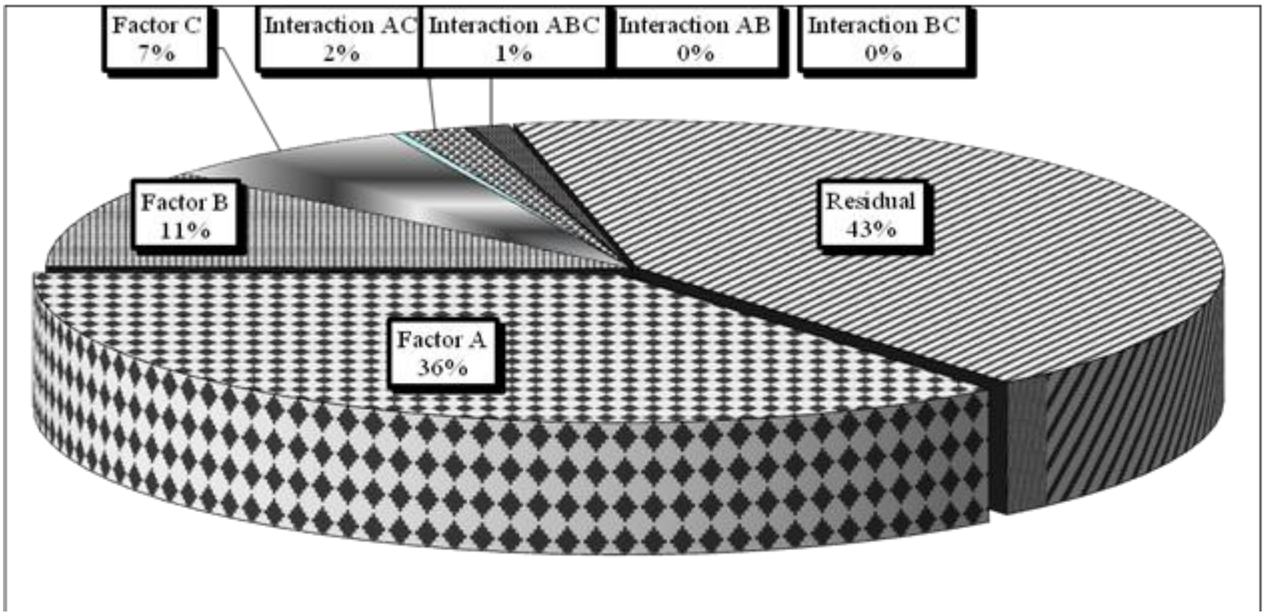

Fig. 2. Variability of the effective signs of the duration of the phases of growth and development of cotton plants of the Pidozerskyi 4 variety depending on the width of the rows and sowing rates under different conditions of moisture supply, days (average for 2012-2013, 2018)
Source: Own calculation.

Somewhat smaller variability of the vegetation period was observed depending on the width of the rows (11.0%) and even smaller - on the sowing rate (7.0%).

The main task in selecting a system of agrotechnical techniques for growing cotton varieties is to create such conditions that would best comply the requirements of the plants. In order to justify agrotechnical recommendations for growing high cotton yields, the dynamics of linear plant growth and their biometric parameters were studied in the conducted research. Biometric measurements on 10 medium plants from each plot were carried out in the phases of budding, blooming and full maturity on the date of collection of pods. As a result, the dynamic response of the Pidozerskii 4 cotton variety to soil moisture conditions, row spacing and sowing rates was determined based on the characteristics of "plant height" and "height of attachment of the first sympodial branch".

The height of the plants, depending on the investigated factors, varied from 52 to 72 cm. In the budding phase, according to this feature, the difference of these indicators by variants was insignificant. During the blooming phase in the areas with natural moisture, the height of the plants, depending on the studied row spacing and density, ranged from 52 to 62 cm (Fig. 3).

The highest values of 62 cm for this feature were observed with a row spacing of 90 cm and a seeding rate of 250,000 units/ha. Depending on these factors of influence, the most intensive growth of plants in height occurred before the flowering phase and reached its maximum in the phase of full maturity – 56 - 62 cm.

The lowest value of the indicator was observed at the seeding rate of 350,000 units/ha, regardless of the width of the rows.

In the irrigated areas during the blooming period, the height of the plants, depending on the studied row width and density, ranged from 62 to 72 cm, which was 10 cm higher than the variants with natural soil moisture and was the highest at 72 cm with a row width of 90 cm and sowing rates 250 thousand units/ha.

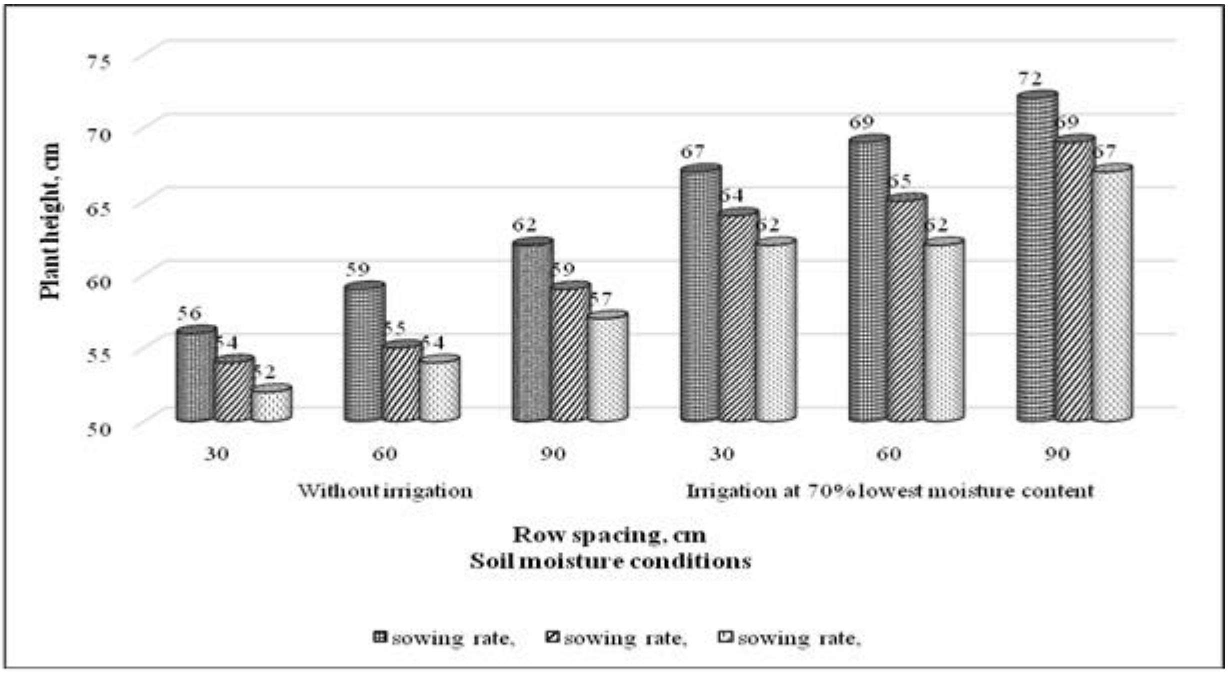

Fig. 3. The reaction of cotton plants of the Pidozerskyi 4 variety to duration of growth and development phases depending on the width of the rows and sowing rates under different conditions of moisture supply, days (average for 2012-2013, 2018)
Source: Own calculation.

A similar dependence was observed in the phase of full ripeness. Fluctuations of indicators for the "plant height" feature were within 52-72 cm. Research results show that irrigation turned out to be a significant factor influencing the height of cotton plants, therefore, higher values of indicators for this feature were obtained on these variants, compared to non-irrigated areas.

Variability of the formation of plant height depending on irrigation was 53.0%, the width of the rows and the density of plant stands – 10.0% each (Fig. 4).

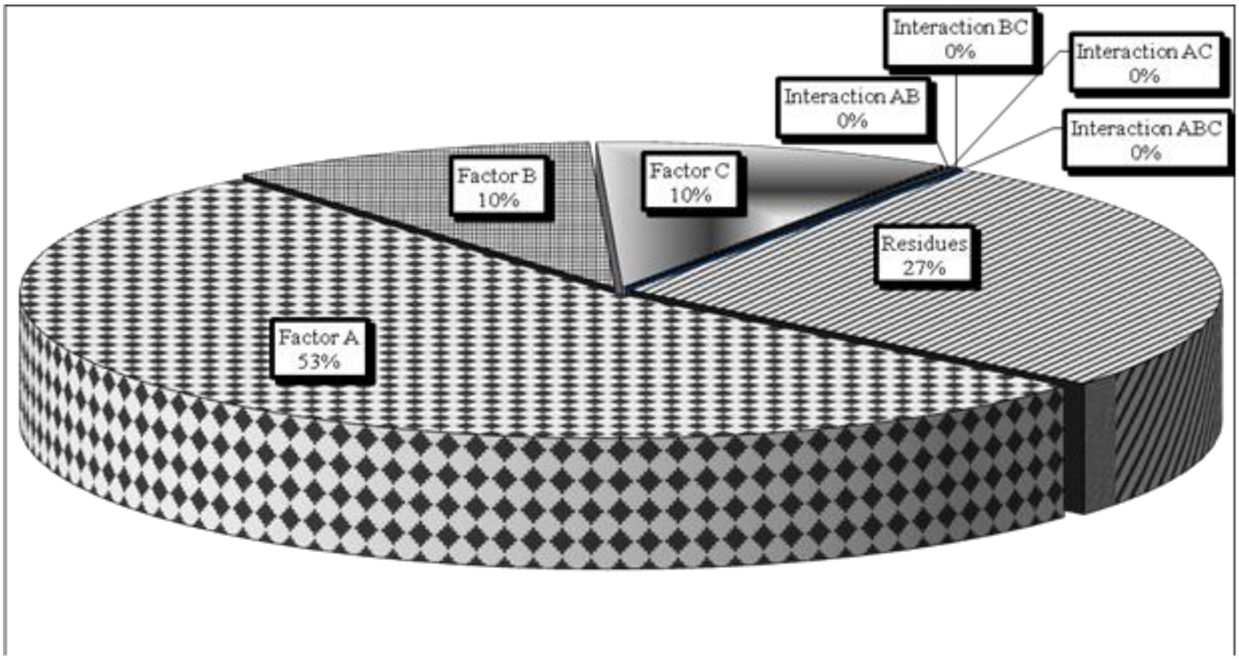

Fig. 4. Variability of the effective signs of the formation of the height of cotton plants of the Pidozerskyi 4 variety under different conditions of soil moisture, row width and sowing rate, cm (average for 2012–2013, 2018)
Source: Own calculation.

Determining the height of the first sympodia of the studied cotton variety Pidozerskyi 4 is important, as it determines its suitability for mechanized harvesting.

The height of attachment of the first sympodia of cotton plants on average over the years of research was affected by soil moisture conditions, row spacing and sowing rates.

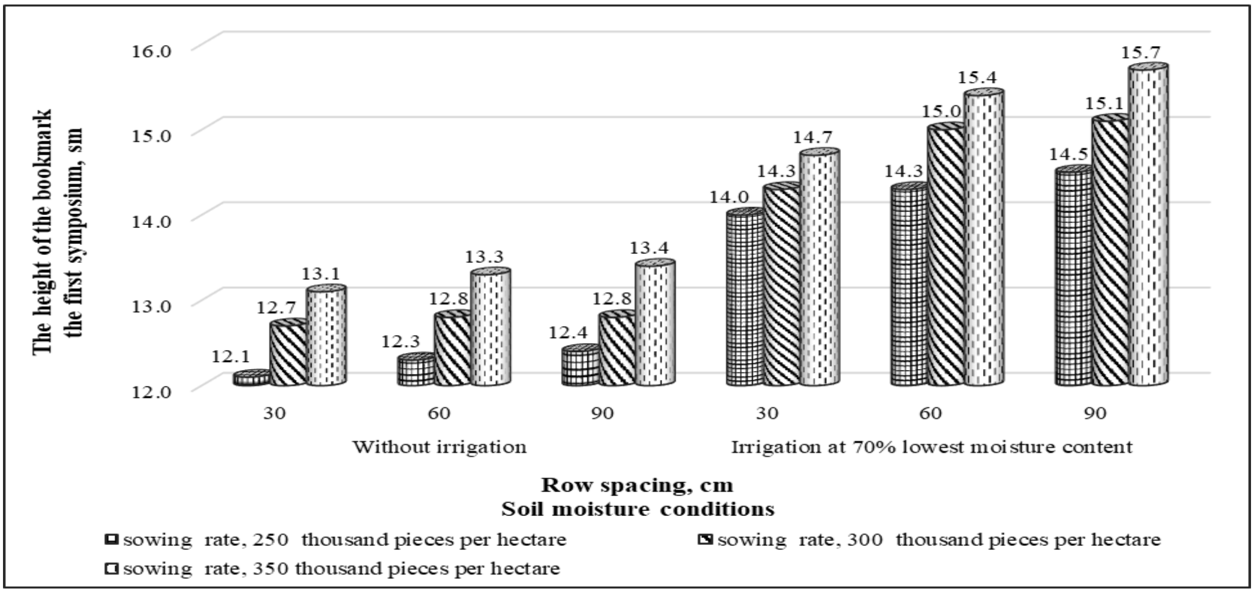

Fig. 5. The reaction of cotton plants of the Pidozerskii 4 variety to the height of the attachment of the first sympodia depending on the conditions of soil moisture, the width of the rows and the rate of sowing, cm (average for 2012-2013, 2018)
Source: Own calculation.

Depending on the investigated factors, for cultivation without irrigation, this indicator varied between 10.5 and 13.4 cm, and was the highest at 13.4 cm for the row width of 30 cm and the seeding rate of 350 thousand units/ha (Fig. 5).

When growing cotton under irrigation, the indicators of the height of attachment of the first sympodia were significantly higher – by 6.0 - 8.0% or by 0.8 cm (according to LSD_{05} = 0.1), compared to the options without irrigation, and ranged within 11.3 – 14.2 cm. The variant with a row width of 30 cm and a plant density of 350,000 units/ha stood out for the maximum height of the attachment of the first sympodia of 14.2 cm, as well as in non-irrigated conditions.

Therefore, the variability of the effective signs of attachment of the first sympodia depended to a large extent on the irrigation conditions and amounted to 62.0% (Fig. 6). A very small percentage of the influence on the formation of the height of attachment of the lower bean was exerted by the width of the interrows of 2.0% and the density of the plants standing at 8.0%.

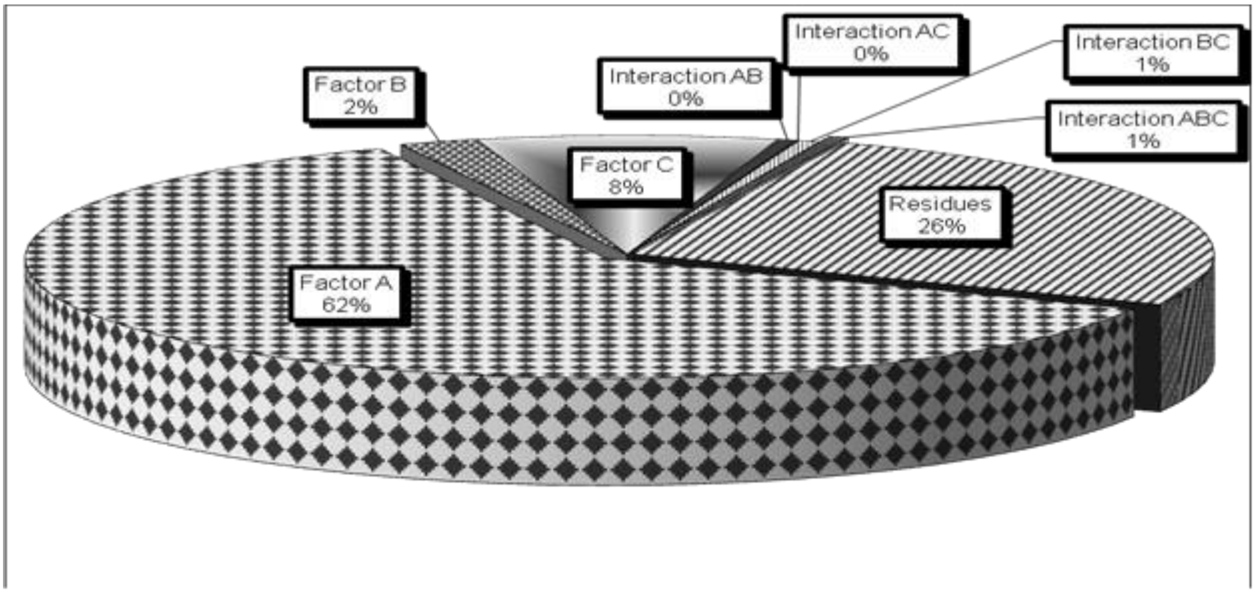

Fig. 6. Variability of the effective signs of the attachment of the first sympodia under different conditions of soil moisture, row width and sowing rate in cotton plants of the Pidozersky 4 variety, cm (average for 2012–2013, 2018)
Source: Own calculation.

For specific soil and climatic conditions, the optimal seeding rate for each variety is the one that ensures the formation of the maximum yield of raw cotton [14]. The calculation of plant stand density depending on the seeding rates indicated in the studies shows that this indicator in the phase of full maturity on the date of harvesting the pods decreased by 1.35-1.93 times, compared to the number of sown seeds, depending on the conditions of moisture and width row spacing. The death of plants before the harvest period can be explained by the fact that in the initial period of growth, before the appearance of the first 2 true leaves, cotton plants have a very delicate structure, as a result of which they are easily damaged under the influence of various external factors, including during mechanical processing crops. Thus, the average density of standing cotton plants at a seeding rate of 250 thousand units/ha was 96 thousand units/ha, at a seeding rate of 300 thousand units/ha – 168, and at 350 thousand units/ha – 240 thousand units/ha of plants, respectively (Table 2).

The data in Table 2 show that the density of cotton plants decreased with an increase in the width of the rows both in non-irrigated options and under irrigation conditions. For example, with a row width of 30 cm, the density of plants in the areas without irrigation was 112, 182, and 260 thousand units/ha, and at 90 cm – 88, 156, 218 thousand units/ha; on irrigated areas, respectively – 112, 182, 262 thousand units/ha and 83, 156 and 218 thousand units/ha.

Table 2. The reaction of cotton of the Pidozerskyi 4 variety to the density of plant stands depending on the width of the rows and sowing rates under different conditions of moisture supply, thousand units/ha (average for 2012 - 2013, 2018)

Soil moisture conditions (factor A)	Row spacing, cm (factor B)	Density of standing plants in the phase of "full maturity", thousand per ha (factor C)			The average factor of A, thousand pieces per hectare	The average factor of B, thousand pieces per hectare
		sowing rate, 150 thousand pieces per hectare	sowing rate, 300 thousand pieces per hectare	sowing rate, 450 thousand pieces per hectare		
Without irrigation	30	112	182	260	168.2	185.0
	60	90	172	236		166.0
	90	88	156	218		153.2
Irrigation at 70% lowest moisture content	30	112	182	262	167.9	
	60	92	166	240		
	90	83	156	218		
The average factor of C, thousand pieces per hectare		96.2	169.0	239.0		

Source: Own calculation.

As a result of the research, it was established that the rate of seed sowing had a significant influence on the formation of the number of pods on the plant that opened before harvesting [4], as it increased, the indicators of the number of boxes decreased, and regardless of the conditions of soil moisture and the width of the rows. The reduction of these indicators occurred, on average, by 43.9% (Fig. 7).

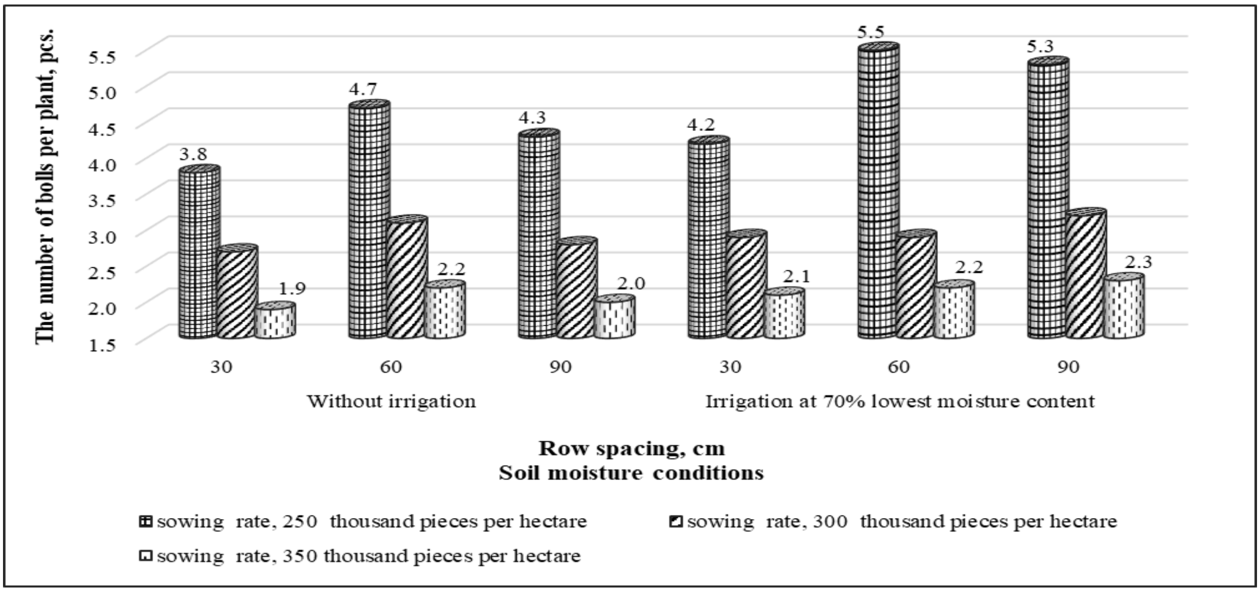

Fig. 7. The reaction of cotton of the Pidozerskiy 4 variety to the formation of the number of bolls per plant depending on the conditions of soil moisture, the width of the rows and the rate of sowing, pcs. (average for 2012-2013, 2018)
Source: Own calculation.

The variability of the effective signs of the formation of the number of bolls per plant in cotton of the Pidozerskyi 4 variety depended most, by 86.0%, on the seeding rate.

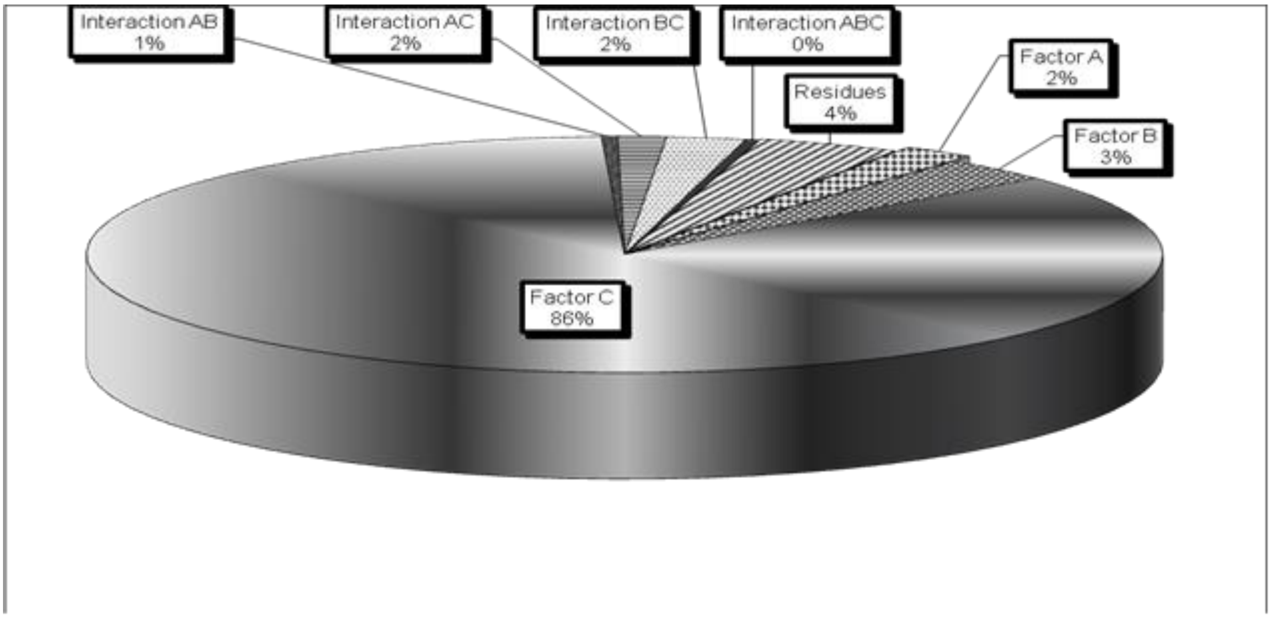

Fig. 8. Variability of the effective signs on the formation of the number of bolls per plant in cotton of the Pidozerskyi 4 variety depending on the conditions of soil moisture, the width of the rows and the rate of sowing, pcs. (average for 2012-2013, 2018)
Source: Own calculation.

A completely different pattern was observed in relation to the reaction of cotton plants to the formation of boll mass, depending on the studied Factors: larger bolls were observed in areas with a lower density of plant stands. Also, the formation of the mass of the box was influenced by the conditions of wet provision of sowing and the width of the rows (Fig. 9).

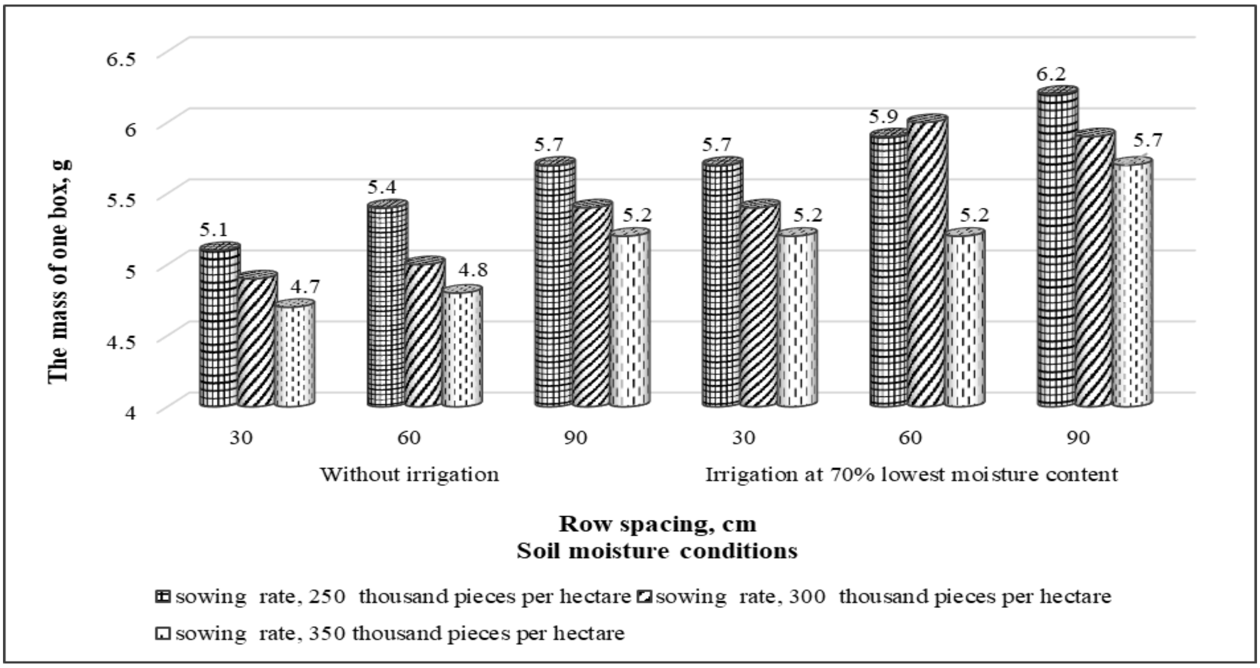

Fig. 9. Reaction of cotton of the Pidozersky 4 variety to the formation of the mass of one box depending on the conditions of soil moisture, the width of the rows and the rate of sowing, g (average for 2012-2013, 2018)
Source: Own calculation.

If in the variants without irrigation, the parameters of the mass of the box were in the range of 4.7 - 5.7 g, then in the irrigated areas - 5.2 - 6.2 g. The maximum value of the weight of the box of 5.6 g was observed in the areas with natural soil moisture in variants with a row spacing of 60 cm and a seeding rate of 300 thousand units/ha and 5.7 g with a row spacing of 90 cm and a sowing rate of 250 thousand units/ha and 6.0 and 6.1 thousand units/ha, respectively, on areas with irrigation. An increase in the width of the rows and the rate of sowing or a decrease, in relation to the above parameters, led to a decrease in the weight of the box.

Variability of the effective signs of boll mass formation of pre-freezing raw cotton depended by 25.0% on the conditions of wet supply, by 15.0% - on the width of the rows, and by 16.0% - on the seeding rate.

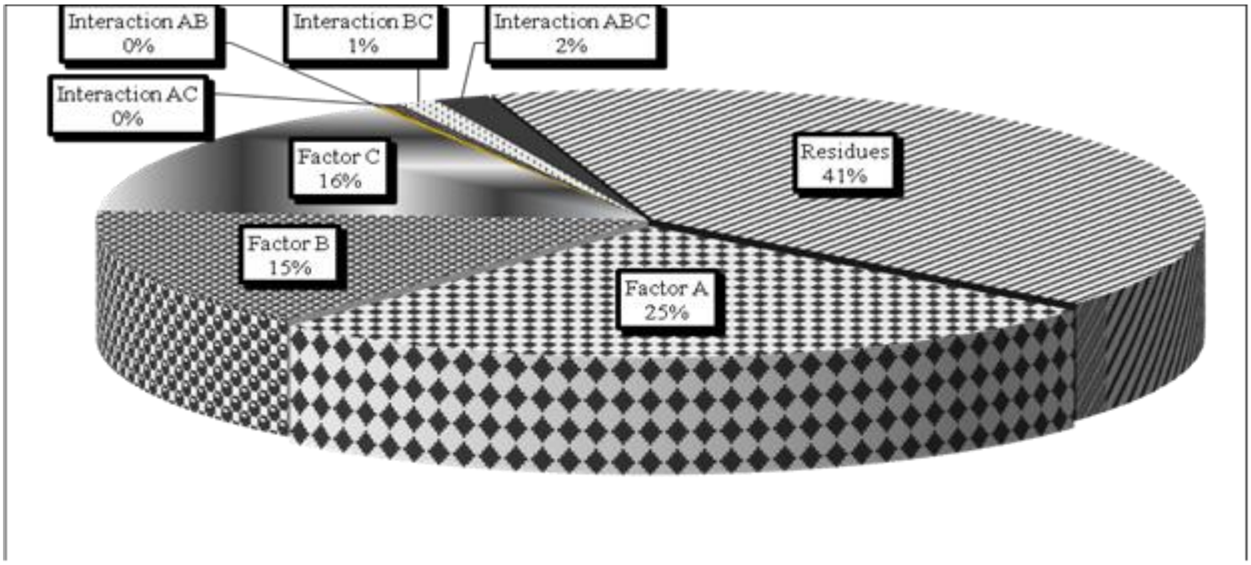

Fig. 10. Variability of the effective signs of the formation of the mass of one boll in cotton of the Pidozersky 4 variety depending on the conditions of soil moisture, the width of the rows and the rate of sowing, g (average for 2012-2013, 2018)
Source: Own calculation.

The competition of plants for material growth factors regulated by different conditions of soil moisture, the method and seeding rate - had a significant impact on the formation of the yield of cotton plants.

Based on the results of the research, it was established that the maximum indicators of yield to frost raw were obtained with a row width of 60 cm, regardless of the moisture conditions: 2.56 t/ha with natural soil moisture and 3.02 t/ha on irrigated plots (Fig. 11).

Further narrowing of the row spacing to 30 cm at the sowing rate of 300 thousand units/ha led to a decrease in pre-freeze raw material collection by 0.2 t/ha [4].

Despite the drought resistance of cotton plants, a significant influence of irrigation on the formation of the yield of raw cotton was determined. The increase in yield on irrigated plots at the seeding rate of 300,000 units/ha was: for row widths of 30 cm – 17%, for 60 cm – 18%, for 90 cm – 22%, compared to non-irrigated options.

Correlation-regression analysis of the obtained data of the research results shows that there is a direct relationship between the formation of the crop and the number and weight of the box under natural moisture supply (Fig. 12).

The correlation coefficient is 0.623 – 0.644, respectively.

The mathematical model has the form

$y=23.248x^2-112.45x+138.78$,

where y - productivity ratio;

x – number of boxes on the plant;

and

$y=3.5209x^2-17.977x+27.863$,

where y - productivity ratio;

x – the weight of one box.

The variability of the effective signs of yield formation of pre-frost raw cotton depended by 66.0% on the conditions of moisture supply, by 3.0% - on the width of the rows, and by 9.0% - on the seeding rate (Fig. 13).

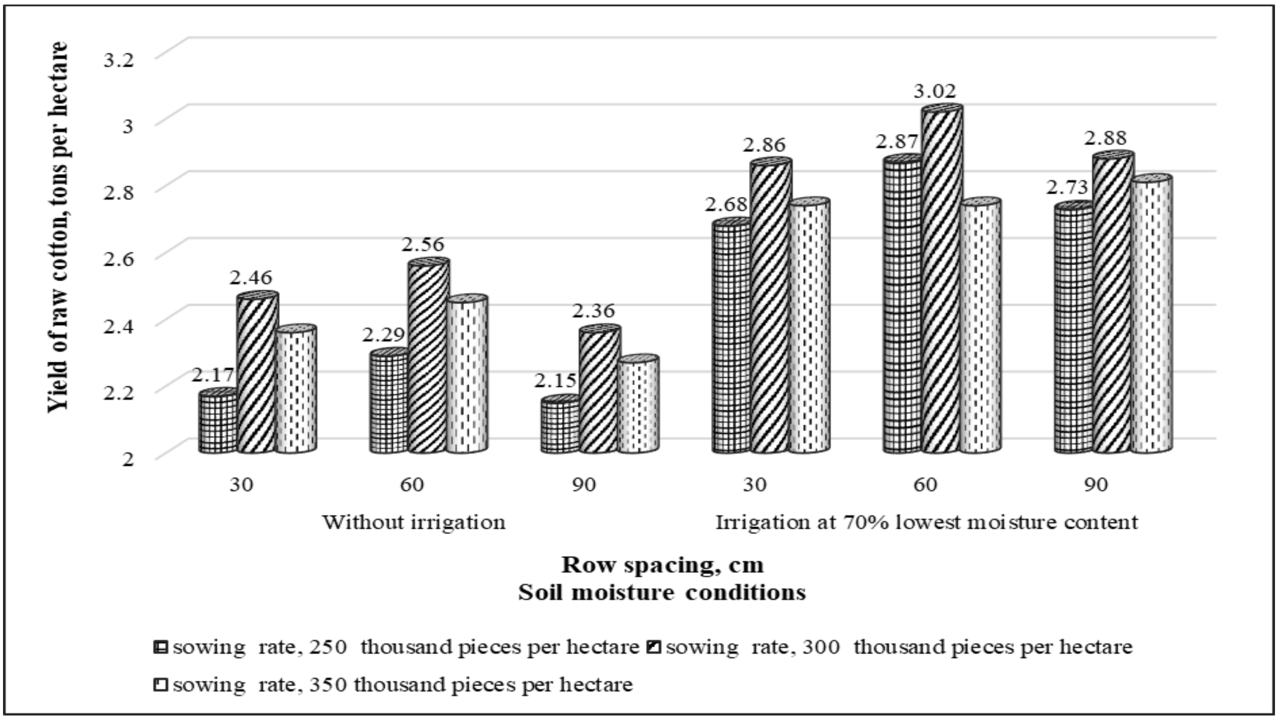

Fig. 11. Yield of pre-freeze raw cotton in the Pidozerskyi 4 variety depending on soil moisture conditions, row width and sowing rate, t/ha

Source: Own calculation.

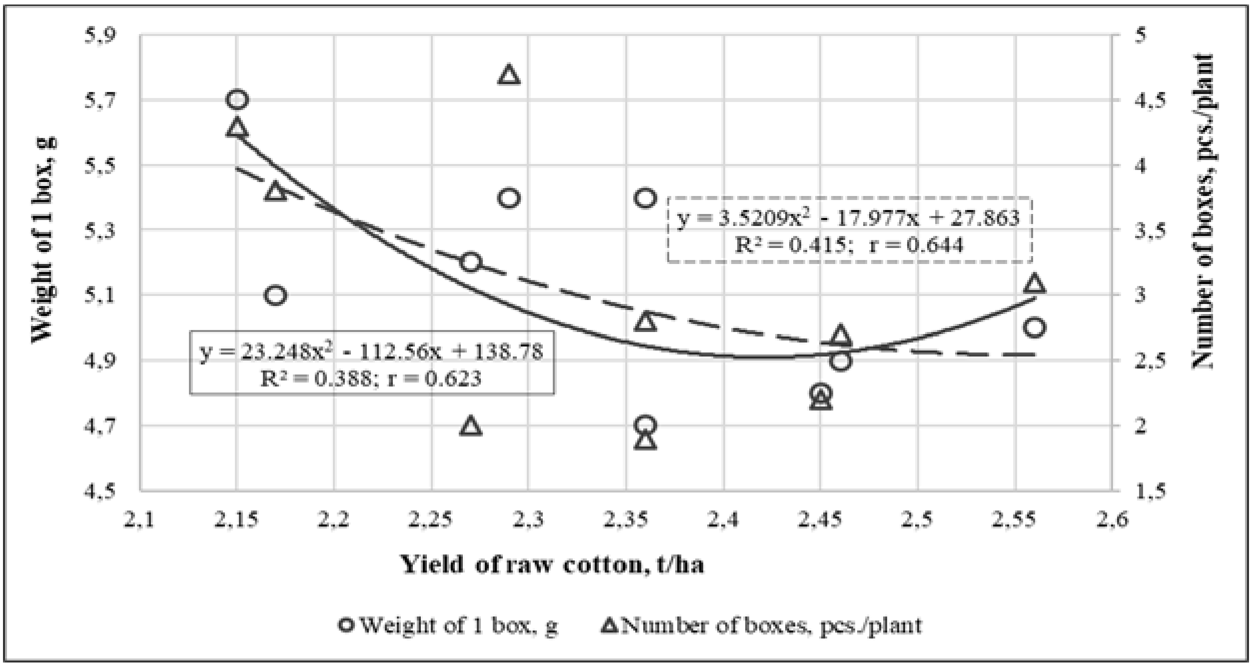

Fig. 12. Correlation-regression model of yield formation depending on the number and weight of the box under the conditions of natural moisture supply (average for 2012-2013, 2018)

Source: Own calculation.

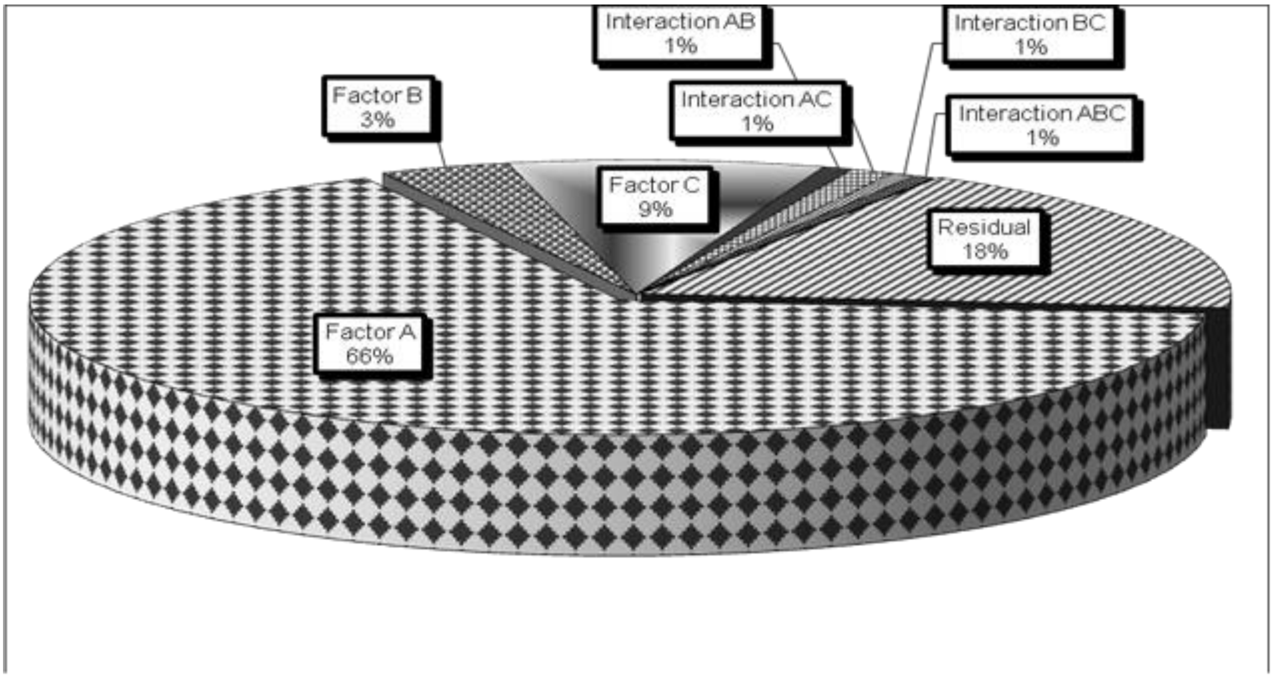

Fig. 13. Variability of the effective signs of the formation of the yield of pre-freeze raw cotton in the Pidozerskyi 4 cotton variety depending on the conditions of soil moisture, the width of the rows and seeding rate, t/ha (average for 2012-2013, 2018)
Source: Own calculation.

Table 3. Economic efficiency of raw cotton growing depending on technological support (average for 2012-2013, 2018)

Soil moisture conditions Factor A	The width of the row, cm Factor B	Sowing rate, thousand pcs/ha Factor C	Yield, t/ha	Conditionally net profit, USD/ha	Cost, USD/t	Profitability level, %
Without irrigaring	30	250	2.27	1,239	306	64.00
		300	2.52	1,447	277	68.00
		350	2.38	1,327	294	66.00
	60	250	2.33	1,289	298	65.00
		300	2.65	1,558	264	69.00
		350	2.48	1,412	282	67.00
	90	250	2.18	1,161	319	63.00
		300	2.40	1,345	291	66.00
		350	2.31	1,268	303	65.00
Irrigation at 70% of the LM	30	250	2.72	1,480	307	64.00
		300	2.82	1,562	297	65.00
		350	2.77	1,518	303	65.00
	60	250	2.90	1,634	289	67.00
		300	3.07	1,775	273	68.00
		350	2.77	1,518	303	65.00
	90	250	2.84	1,582	292	66.00
		300	2.91	1,639	288	67.00
		350	2.90	1,629	290	66.00

Source: Own calculation.

According to calculations, the production of raw cotton is quite efficient and profitable. In all presented areas, it provided high indicators of net profit and profitability. Conditionally net profit was 1,239-1,775 USD/ha, and the level of profitability was 63-69%.

For the width of the rows of 60 cm, in areas with irrigation where the highest yield of raw cotton was formed – 3.07 t/ha, the maximum conditionally net profit of 1,775 USD/ha was obtained (Table 3).

And although the maximum yield was obtained under irrigation conditions, the highest profitability of 69.00% and the lowest cost of funds per hectare of 264 USD/ha were observed on the plots without irrigation.

So, the results of the research show that for irrigation on a plot with a row width of 60 cm. a high yield of 3.07 t/ha of raw cotton of the early ripening medium-fiber cotton variety Pidozerskyi 4 is ensured at the lowest cost of 273 USD/ha and the highest profitability of 68.00%. On non-irrigated areas. the maximum yield of 2.65 t/ha was obtained at an even lower cost of 264 USD/ha than on irrigation. and at the highest profitability of 69.00% in the conditions of the Southern Steppe of Ukraine. which makes it possible to use this agrotechnical technique as on non-irrigated areas as well as on irrigated lands.

CONCLUSIONS

The formation of the number of pods on the plant that opened before harvesting was significantly influenced by the rate of seed sowing. with an increase in which the indicators of the number of pods decreased by 43.9% on average in the experiment. regardless of the conditions of soil moisture and the width of the rows.

The variability of the effective signs of the mass formation of the boll of pre-freeze raw cotton depended by 25.0% on the conditions of moisture supply. by 15.0% - on the width of the rows. and by 16.0% - on the seeding rate; the yield of domestic raw cotton depended by 66.0% on the conditions of moisture supply. by 3.0% - on the width of the rows. and by 9.0% - on the seeding rate.

The significant impact of irrigation on the formation of the yield of frozen raw cotton was determined. The increase in yield on irrigated plots at the seeding rate of 300 thousand units/ha was: for row widths of 30 cm – 17%. for 60 cm – 18%. for 90 cm – 22%. compared to non-irrigated options.

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REFERENCES

[1]Ballesteros, R., Ortega, J. F., Moreno, M. A., 2016, New software for reference evapotranspiration forecasting. Journal of Arid Environments. 124:128-141. DOI:10.1016/j.jaridenv.2015.08.006.

[2]Bednarz, C.W., Bridges, D. C. Brown, S. M., 2000, Analysis of cotton yield stability across population densities. Agronomy Journal. Vol. 92(1), 128-135. https://doi.org/10.2134/agronj2000.921128x

[3]Bednarz, C.W., Nichols, R. L.., Brown, S. M., 2006, Plant density modifications of cotton within-boll yield components. Crop Science. Vol. 46(5), 2076-2080. https://doi.org/10.2135/cropsci2005.12.0493.

[4]Borovyk, V. O., Stepanov, Yu. O., Fedchenko. S. O., 2008, The influence of row width and sowing rate on the density of productive plants and cotton yield under different conditions of moisture availability in the southern region of Ukraine. Irrigated agriculture: Between. topics of science coll. Kherson: Ailant. Vol. 49. pp.40-46.

[5]Chen, X., Qi, Z., Gui, D., Sima, M. W., Zeng, F., Li, L., Xiangyi, L., Gu, Z., 2020, Evaluation of a new irrigation decision support system in improving cotton yield and water productivity in an arid climate. Agricultural Water Management. Vol. 234. 106139. https://doi.org/10.1016/j. agwat.2020.106139.

[6]DeTar, W., 2007, Yield and growth characteristics for cotton under various irrigation regimes on sandy

soil. Agricultural Water Management. Vol. 95(1), 69-76, January 2008, doi: https://doi.org/10.1016/j.agwat.2007.08.009.

[7]De Laune, P. B., Mubvumba, P., Ale, S., Kimura, E., 2020, Impact of no-till. cover crop. and irrigation on Cotton yield. Agricultural Water Management V. 232. 106038. https://doi.org/10.1016/j.agwat.2020.106038.

[8]Eche, R. F. R., Rosolem, C. A., 2015, Cotton yield and fiber quality affected by row spacing and shading at different growth stages. European Journal of Agronomy. V. 65. 18-26. https://doi.org/10.1016/j.eja.2015.01.001.

[9] El-Yazied, M.A. E., Soliman, Y., El-Mansy, Y. M., 2014, Effectiveness of recurrent selection for improvement of some economic characters in Egyptian cotton. Egyptian Journal of Agricultural Research. 92(1):135-151. 2014. DOI:10.21608/ejar.2014.154473.

[10]Dai, J., Tian, L., Zhang, H., 2017, Review of the technology for high-yielding and efficient cotton cultivation in the northwest inland cotton-growing region of China. Field Crops Research. Vol. 208. DOI:10.1016/j.fcr.2017.03.008.

[11]Fox, J. W., Khalilian, A., Han, Y.J., Williams, P. B., Nafchi, A.M., Maja, J.M., Marshall M. W., Barnes E. M., 2017, Real-Time. Variable-Depth Tillage for Managing Soil Compaction in Cotton Production. Open Journal of Soil Science. 08(06):147-161 DOI: 10.4236/ojss.2018.86012.

[12]Geerts, S., Raes, D., 2009, Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. Agricultural Water Management. Vol. 96(9). 1275–1284. https://doi.org/10. 1016/j.agwat.2009.04.009.

[13]Guzman, M., Vilain, L., Rondon, T., Sanchez, J., 2019, Sowing density effects in cotton yields and its components. Agronomy. Vol. 9. 349. https://doi.org/10.3390/agronomy9070349.

[14]Gwiranenzara, C., Chapepa, B., Mubvekeri, W., Kutywayo, D., 2018, Effect of seed rate on upland cotton (*Gossypium hirsutum*) seedling emergence. African Journal of Agricultural. Vol. 13(24), 1243-1247. DOI: 10.5897/AJAR2016.11470.

[15]Hake, K., Grimes, D., 2010, Crop water management to optimize growth and yield. Physiology of cotton. p. 255– 264. doi: https://doi.org/10.1007/978-90-481-3195-2_23.

[16]Howell, T., Evett, S., Tolk, J., Schneider, A., 2004, Evapotranspiration of full-. deficit-irrigated. and dryland cotton on the Northern Texas High Plains. Journal of irrigation and drainage engineering. Vol. 130(4): 277– 285. doi: https://doi.org/10.1061/(ASCE)0733-9437(2004)130:4(277).

[17]Hu, L., Pan, X., Wang, X., Hu, Q., Wang, X., Zhang, H., Xue, Q., Song, M., 2021, Cotton photosynthetic productivity enhancement through uniform row-spacing with optimal plant density in Xinjiang. China. Crop Science. 61(4): 2745–2758. 12. doi: 10.1002/csc2.20535.

[18] Jahedi, M.B., Vazin, F., Ramezani, M.R., 2013, Effect of row spacing on the yield of cotton cultivars. Agronomic research in Moldavia. 46(4). DOI:10.2478/v10298-012-0101-y.

[19]Khalilian, A., Marshall, M. W., Williams, P. B., Greene, J. K., Porter, P. M., 2018, Cotton Production Systems for Soil and Energy Conservation in Coastal Plain Soils Porter American Journal of Plant Sciences. 09(07):1500-1513. DOI: 10.4236/ajps.2018.97110.

[20]Khalilian, A., Jones, M. A., Bauer, P.,J., Marshall, M.W., 2017, Comparison of Five Tillage Systems in Coastal Plain Soils for Cotton Production. Open Journal of Soil Science. Vol. 07 No. 10. Article ID:79228.14 p. 10.4236/ojss.2017.710018. DOI: 10.4236/ojss.2017.710018.

[21]Kerby, T. A., Cassman, K. G., Keeley, M., 1990, Genotypes and plant densities for narrow-row cotton systems. I. Height. nodes. earliness. and location of yield. Crop Science. 30. V. 649-653(3). https://doi.org/10.2135/cropsci1990.0011183X003000030035x.

[22]Khan, A., Ullah, N., Wang, L., 2017, Planting density and sowing date strongly influence growth and lint yield of cotton crops. Field Crops Research. 209:129-135. DOI:10.1016/j.fcr.2017.04.019.

[23]Khan, A., Kong, X., Najeeb, U., Zheng, J., Yuen Tan, D. K., Akhta, K., Munsif , F., Zhou, R., 2019, Planting Density Induced Changes in Cotton Biomass Yield. Fiber Quality. and Phosphorus Distribution under Beta Growth Model. Agronomy. 9(9). 500; https://doi.org/10.3390/agronomy9090500.

[24]Khan, N., Han, Y., Xing, F., Feng, L., Wang, Z., Wang , G., Yang, B., Fan, Z., Lei, Y., Xiong, S., Li, X., Li, Y., 2020, Plant Density Influences Reproductive Growth. Lint Yield and Boll Spatial Distribution of Cotton. Agronomy. 10(1). 14; https://doi.org/10.3390/agronomy10010014.

[25]Ling, L., Helin, D., Yunzhen, M., Pengcheng, L., Chunmei, L., Na, Z., Sumei, W., Wenxiu, X., 2020, Effects of Row Spacing Patterns on the Growth. Yield and Quality of Machine-picked Cotton. Xinjiang Agricultural Sciences. Vol. 57(4): 713-721.DOI: 10.6048/j.issn.1001-4330.2020.04.017.

[26]Maiti, R., Satya, P., Rajkumar, D., Ramaswamy, A., 2012, Crop Plant Anatomy; CABI: Wallingford. UK. Vol. 42.

[27]McCarty, J. C., Jenkins, J., Johnie, N., Hayes, R.W., 2017, Effects of Plant Density on Boll Retention and Yield of Cotton in the Mid-South. American Journal of Plant Sciences. V. 8 pp. 891-906. DOI: 10.4236/ajps.2017.84060.

[28]Nei, M., 1972, Genetic Distance between Populations. The American Naturalist. V. 106(949). https://doi.org/10.1086/282771.

[29]Onder, D., Akiscan, Y., Onder, S., Mer, M., 2009, Effect of different irrigation water level on cotton yield and yield components. African Journal of Biotechnology. 8(8), 1536–1544.

[30]Pettigrew, W. T., 2004, Moisture deficit effects on cotton lint yield. yield components. and boll distribution. Agronomy Journal. 96(2). 377–383. https://doi.org/10.2134/agronj2004.3770.

[31]Pisarenko, V. A., Nemolovskaya, T. B., Stepanov, Yu. A., 1995, Prospects for growing cotton in the south of Ukraine. In the book: Problems on moisture-supplying grain bread crops. Sofia. Chirpan. P. 65-69.
[32]Salim, M. F., Anjum, S.A., Shakil, A., Ashraf, M.Y., 2009, Effect of row spacing on earliness and yield in cotton. Pakistan Journal of Botany. 41(5): 2179-2188.
[33]Simao, F. R., Ritchie, G. L., Bednarz, C. W., 2013, Cotton physiological parameters affected by episodic irrigation interruption. Applied Engineering in Agriculture. 31(6):883-897DOI:10.13031/aea.31.10953
[34]Shtoyko, D. A., 1956, Irrigation of cotton. Technical cultures. Under the editorship Demidenko T.T. Kyiv. pp. 258-263.
[35]Snowden, M. C., Ritchie, G. L., Simao, G. L., Bordovsky, J. P., 2014, Timing of episodic drought can be critical in cotton. Agronomy Journal. Vol.106: 452–458. doi: https://doi.org/10.2134/agronj2013.0325.
[36]Ullah, N., Aziz, K. A., Khan, N.U., Baloch, M.S., 2018, Effect of Irrigation Intervals on the Yield and Fibre Characteristics of Cotton Genotypes. Sarhad Journal of Agriculture. Vol.34(2), 342-348. DOI:10.17582/journal.sja/2018/34.2.342.348
[37]Ünlü, M., Kanber, R., Koç, D. L., Tekin, S., Kapur, B., 2011, Effects of deficit irrigation on the yield and yield components of drip irrigated cotton in a Mediterranean environment. Agricultural Water Management. 98(4). 597–605. https://doi.org/10.1016/j.agwat.2010. 10.020
[38]Venugopalan, M.V., Kranthi, K.R., Blaise, D., Lakde, S., 2013, Shankaranarayanan K. High density planting system in cotton—The Brazil experience and Indian initiatives. Cotton Res. J. 5(2). 172–185.
[39]Vozhehova, R., Borovik, V., Kokovikhin, S., Biliaieva, I., Kokovikhina, O., Boiarkina, L., Shkoda, O., 2022, Evaluation of cotton gene pool samples in different years of heat supply in the conditions of the southern steppe of Ukraine. To be cited: Book of Abstracts. International Conference "Agriculture for Life. Life for Agriculture". Section 1: Agronomy. P. 158. https://agricultureforlife.usamv.ro/images/2022/BookOfAbstracts/01-Book_of_Abstracts_-_Agronomy_A4LIFE_2022.pdf.
[40]Vozhegova, R. A., 2014, Methods of field and laboratory research on irrigated lands. Kherson: Hrin' D.S. 286 p.
[41]Vozhegova, R.A., Marchenko, T.Yu., Borovyk, V. O., Klubuk, V.V.., Boitseniuk, K. I., 2022, Peculiarities of the duration of the growing season of specimens of the cotton gene pool Gossypium hirsutum L. in the conditions of the southern Steppe of Ukraine. Agrarian innovations. № 12. DOI https://doi.org/10.32848/agrar.innov.2022.12.13.
[42]Vozhegova, R. A., Ryabchun, V. K., Borovyk, V. O., Stepanov, Y. O., Malyarchuk, M. P., Lavrynenko, Y.O., Bidnina, I. O., Bilyaeva, I.M., 2015, A broad unified classifier-handbook of the genus *Gossypium hirsutum* (L.). Kherson. 49 p.
[43]Wei, H., Meili, C., Wenqing, Z., Binglin, C., Youhua, W., Shan-shan, W., Yali, M., Zhiguo, Z., 2017, The effects of sowing date on cottonseed properties at different fruiting-branch positions. Journal of Integrative Agriculture » 2017. Vol. 16(06): 1322-1330 DOI: 10.1016/S2095-3119(16)61537-X
[44]Yang, G.-Z., Zhou, M.Y., 2010, Multi-location investigation of optimum planting density and boll distribution of high-yielding cotton (G. hirsutum L.) in Hubei Province. China. Agricultural Sciences in China. Vol. 9(12). P. 1749-1757. doi: https://doi.org/10.1016/S1671-2927(09)60273-X
[45]Yawson, D.O., Armah, F. A., Adu, M.O., 2020, Exploring the impacts of climate change and mitigation policies on UK feed barley supply and implications for national and transnational food security. SN Applied Sciencesю. Vol. 2:666. https://doi.org/10.1007/s42452-020-2444-6
[46]Yawson, D.O., Mohan, S., Armah, F.A., Ball, T., Mulholland, B., Adu, M.O., White, P.J., 2020, Virtual water flows under projected climate. Land use and population change: The case of UK feed barley and meat. Heliyon. Vol. 6(1), E03127.http://DOI.ORG/10/1016/J.Heliyon.2019.E03127.
[47]Zakaria, M. Sawan, 2013, Applied methods for studying the relationship between climatic factors and cotton production. Agricultural Sciences. Vol.4 No.11A. pp. 37-54. DOI: 10.4236/as.2013.411A005є.
[48]Zhang, N., Tian, L., Feng, L., Xu, W., Li, Y., Xing, F., Fan, Z., Xiong, S., Tang, J., Li, C., Li, L., Ma, Y., Wang, F., 2021, Boll characteristics and yield of cotton in relation to the canopy microclimate under varying plant densities in an arid area. Plant biology. 9:e12111 http://doi.org/10.7717/peerj.12111.