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SCIENTIFIC BASIS OF COTTON SEED GERMINATION IN THE CENTRAL REGION OF UZBEKISTAN

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SUMMARY

The responses of cotton (*Gossypium hirsutum* L.) seeds to germination depend upon the point in the germination-through-emergence sequence at which seed environmental conditions conclude to promote germination and seedling development. Temperature and genotype can influence seedling vigor in upland cotton and help identify promising genotypes that could perform well under different temperature extremes. In the presented research, the nature of the development of cotton seeds largely depends on temperature conditions and the growing seasons, which provide information that determines their uniformity based on the thermal regime of germination. The physical and biological diversity of cotton seeds has close relations to the pattern of plant development and the influence of certain environmental factors on them. In the presented study, sowing seeds of three local cotton cultivars, AN-Bayaut-2, Tashkent-6, and Armugon-2, transpired on two dates (April 17 and May 10). The nature of cotton seeds' development, largely dependent on temperature and growing season and on the thermal regime of their germination, showed different indicators. A discovery revealed that the germination of seeds decreased in areas with later-sown kernels. In terms of germination energy and other physiological functions, the best results were notable in seeds at the lower and middle stages of plant development. The cultivar AN-Bayaut-2 is adaptable to various environmental factors according to seed germination and vegetation period compared with other local cotton varieties, i.e., Tashkent-6 and Armugon-2.

Keywords: Upland cotton (*Gossypium hirsutum* L.), cottonseeds, seed germination, respiration intensity, productivity

Key findings: The nature of the development of cotton seeds largely depends on temperature and the growing season. According to germination vigor and other physiological functions, the best plants resulted from the grains of the bolls at the lower and middle stages of the harvest. The research has also established that the variety AN-Bayaut-2 proved superior to the other two cultivars based on seed germination and adaptation to various environmental factors during the growing season.

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INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is the most valuable industrial and commercial crop globally. Its fiber is the chief reason for its wide cultivation use in more than 80 countries with irrigation systems and seasonal conditions (Sanaev *et al.,* 2021; Matniyazova *et al.,* 2022). International cotton agribusiness is among the most pertinent groups from a social and economic point of view, generating more than USD 300 billion a year. Currently planted on 30 million ha, cotton is one of the crops that provides labor employment in the rural sector and distributes income (Project African Integration, https://www.wto.org). Cotton fiber quality and yield determine its cultivars' value (Shavkiev *et al.,* 2021; Makamov *et al.,* 2022, 2023). As in various regions worldwide, the leading type of agricultural crop in Central Asia, especially in Uzbekistan, and the created cotton cultivars are of higher value, having the highest rates of economic characteristics and resistance to adverse environmental conditions. At the same time, one of the imperative tasks is to know whether the physiological attributes of cotton cultivars adapted to various external factors depend on the genotype.

The President of the Republic of Uzbekistan Decree No. PD-60 dated January 28, 2022, "On the Development Strategy of New Uzbekistan for 2022–2026," provided for the "Creation and introduction of new breeding cultivars of agricultural crops adapted to local soils, climate, and environmental conditions." These objectives need adaptation to abiotic factors in addition to productivity and high fiber quality (lex.uz/uz/docs/-5841063).

Cotton is one of the topmost plantation crops in the Republic of Uzbekistan, and its importance in the national economy is incomparable (FAO, https://agris.fao.org/). About 200 byproducts are obtainable from it and widely utilized in industry, medicine, and other fields. Cotton, the chief product, makes yarn, gauze, and other products. Yarn and textile industry products produced by the Republic are for export to enrich the country's foreign exchange reserves (Chorshanbiev *et al.,* 2022, 2023). Nowadays, the cotton industry of Uzbekistan faces the task of creating new varieties with high fiber quantity and quality, early ripening, high yield, and resistance to abiotic (drought, salinity, and high and low temperatures) and biotic factors (Khamdullaev *et al*., 2021; Shavkiev *et al*., 2022, 2023; Ashiralieva *et al*., 2023).

The present era requires more to obtain high-yielding, healthy, full-ripened, dark-kernelled, well-preserved, and well-prepared seed material for planting (Gulyaev *et al.,* 2016, 2017). The Uzbekistan cotton collection has around 12,800 samples (Abdurakhmonov *et al.,* 2006). The renewal of seed material of these cotton samples takes 8–10 years, achieved by maintaining the seed's fertility. Notably, the more seed renewal, the more the primary indicators of their morphological and economic traits change to a certain extent (Abdullaev *et al.,* 2013). Several studies have ensued on the variations in cotton sample features during seed storage, such as germination, fertility, and seed maturation (Narimanov, 2000; Narimanov and Gaibullaev, 2006; Makhmadjanov *et al*., 2023). Therefore, a laboratory warehouse needs further studies to determine the most optimal terms for maintaining and renewing breeding samples and to develop new cotton cultivars.

The latest main problems cotton faces, especially under seasonal conditions, are seed germination and crop establishment (Santhy *et al.,* 2014). According to Asl and Taheri (2012), genotypes with larger seeds and significant genetic potential are now available; however, genetic improvement has limited sufficiency to increase seed vigor, as low vigor is a common feature of various crops and a problem. In cotton's case, the productivity is low, and it is the first quality component of the seed to disappear after harvesting since it begins to deteriorate, followed by low germination and viability.

In understanding the biological properties of the cotton crop, knowing the causes of differences in cotton seeds is of great magnitude. The existing physiological heterogeneity of kernels within the same plant and even in a pod has gained validity in past studies (Rashidova and Shilevski, 2017). Previous work has also established that the distinctiveness of cotton development, in combination with complex external and internal factors, leads to the appearance of seeds of different quality (Rashidova and Shilevski, 2017). Therefore, it is of vast economic importance to study the effect of buds on the productivity of cotton grain production. An observation also indicated that seed formation in the lower and middle parts of plants, closer to the main stem, brings more economic efficiency (Rozmetov, 2013).

Dry matter accumulation in the embryo of cotton seeds occurs extra slowly with the late formation of bolls in cotton (Simongulyan *et al.*, 1987; Narimanov *et al*., 2020). During this period, determination of the level of viability dependent on the age and time of formation of the embryos materialized. Vigorous early-season growth is a highly desirable trait in cotton because the plant is known to have poor seedling vigor relative to other major row crop species (Pilon *et al.,* 2016). Higher seedling stamina can result in superior early-season crop growth (Virk *et al.,* 2021), which also enhances competitiveness with weeds, improves resource acquisition, increases canopy light interception, and decreases susceptibility to early-season biotic stresses (Liu *et al.,* 2015; Snider and Oosterhuis, 2015).

The optimum temperature for a wide range of processes and growth stages in cotton is 28 °C ± 3 °C (Burke and Wanjura, 2010). Low, non-chilling temperatures (less than 25 °C but higher than 10 °C) limit leaf area development and slow the node formation rate on the main stem (Guthrie, 1991; Snider *et al*., 2009; Singh *et al*., 2018). In addition to the harmful effects on growth, low temperatures considerably reduce the photosynthetic rates (Labate and Leegood, 1988; Hendrickson *et al.,* 2003). Cold-induced declines in photosynthesis are often in parallel with decreases in stomatal conductance; however, low temperatures also strongly inhibit the primary photochemical processes (Snider *et al.,* 2016).

Significant differences occurred in the differentiated seed material of cotton according to germination energy, seedling emergence rate, and sowing qualities (Snider *et al.,* 2011; Wojtyla *et al.,* 2016). The seeds capable of germinating under adverse conditions are of immense value since their genetic nature is characteristic of maintaining high viability under certain conditions. Therefore, the biological spirit that determines the formation of the ability of cotton seeds to germinate at relatively low temperatures depends on environmental conditions. A feature of cotton is that plants entering the reproductive stage in early June continue the formation of generative organs until autumn frosts. Thus, the studies revealed that boll formation could occur under various environmental conditions (Govindaraj *et al.,* 2017).

Thus, the changes in environmental conditions contribute to the appropriate physiological preparation and development of plants in each period. However, in the plant itself, at different stages of its development, the process of assimilation proceeds in different ways. A discovery of the influence of environmental conditions on cotton plants in their seed germination at relatively low temperatures has taken place (Singh *et al.,* 2018).

The cottonseed immersion treatments have advanced in different substances to evaluate their germination and obtain information on the beginning of germination and enhancement in the germination percentage (Bange *et al.,* 2016). The prime substances used for pre-germination treatments of cotton seeds to cause an increase in germination percentage are C_2H_2OH, proline, water, homeopathic preparations of both Baryta Carbonica and Abrotanum, KCl, KH_2PO_2 (Asl and Taheri, 2012), polyethylene glycol, H.O. (Santhy *et al.,* 2014; Wojtyla *et al.,* 2016), and KNO_3 (Shafiq *et al.,* 2015). Recently, a test on the exposure of the seeds to plasma lights has also surfaced (Bange *et al.,* 2016).

Considering that improvement in seed germination under different environmental conditions is of massive worth for the sustainability of the cotton industry, various treatments have arisen on seeds to improve the germination and survival of the seedlings. In general, remedies used to increase seed germination in crops and varied techniques, including biological, physical, and chemical agents, need application to obtain and improve healthy and uniform seedlings. These include magnetic fields, gamma radiation, electric fields, laser radiation, healing energies, sounds, light, and heat (Govindaraj *et al*., 2017). The presented study sought to determine the scientific basis of the cottonseeds' germination and heterogeneity of seeds in local cotton cultivars in the Central regions of Uzbekistan.

MATERIALS AND METHODS

Genetic material, experimental site, and irrigation conditions

The pertinent research ran for two years (2018–2019) at the Institute of Genetics and Experimental Plant Biology, Tashkent Region, Uzbekistan (41.389°N and 69.465°E). This region experiences cold winters and long, hot, and dry summers. The annual photoperiod is 16/8 h. This study sought to determine the genetic potential and aspects of three upland varieties, i.e., AN-Bayaut-2, Tashkent-6, and Armugan-2, based on the growth and development of cotton from the germination phase to their maturation. The original seed material for planting came from Oz DST 1080:2005 and Oz DST 1128:2006 sections. The initial study of the inoculum in a thermostat had a temperature of +12 °C - +14 °C until the completion of the process. The seed germination carried out in Petri dishes (diameter 12.5 cm) was under humid conditions for 24 h on moistened filter paper until totally saturated. The experiment consisted of four replications with 25 seeds each.

In the experiment, sowing the seeds of the cotton cultivars had two different dates, i.e., April 17 and May 10. Phenological observations commenced at 50% of the flowering and boll maturation periods. Notably, the temperature during flowering and bud ripening was much higher than in the period before flowering. Planting the cotton genotypes came about in plant and row spacings of 10 and 60 cm in 50 m long furrows (Shavkiev *et al.,* 2019). The temperature increases in April and May during the cotton sowing season and decreases in late September before harvest. The information on maximum and minimum temperatures, air humidity, and total rainfall during the study period appears in Table 1. Sunny days were between 180–185 days. Rainfall varied from 0 to 45 mm during the dry season for 5–6 months.

Table 1. Maximum and minimum temperatures, air humidity, and total rainfall during the study period (https://weather.com/uz).

Months	Maximum temperature (°C)		Minimum temperature (°C)		Average relative humidity (%)		Total rainfall (mm)	
	2018	2019	2018	2019	2018	2019	2018	2019
April	+31°	+28°	+3°	+5°	34%	+35°	4.87	42.38
May	+36°	+36°	+9°	+10°	26%	+38°	1.79	11.25
June	+37°	+36°	+14°	+16°	19%	+39°	1.00	6.90
July	+42°	+42°	+19°	+20°	15%	+39°	0.00	2.43
August	+39°	+40°	+15°	+17°	14%	+38°	0.00	0.08
September	+32°	+36°	+12°	+10°	15%	+33°	0.16	1.05
October	+31°	+28°	+1°	+6°	29%	+24°	2.6	2.78

The seasonal application of fertilizers continued during tillage and before irrigation per annum with a ratio of 250:180:115 NPK kg/hm^2. The crop requires intensive irrigation throughout the vegetative period. Cotton crop irrigation followed a 1–2–1 (pre-flowering – flowering – boll opening) sequence before the boll-opening phase (Xamidov and Matyakubov, 2019). This sequence was an optimal irrigation protocol widely used in cotton production in Uzbekistan. Soil moisture also contributed to water during seed germination. For crop protection purposes, application of the insecticides Bi-58 (BASF, Germany) and Hexachloran ensued to control sucking (aphids) and chewing (bollworm) insects, respectively. By October 17, the counting of bolls began, with raw cotton harvested.

Data recorded and statistical analysis

Data recording on randomly selected plants in all the cotton genotypes for morphophysiological and yield attributes progressed. The data also underwent the analysis of variance (Steel *et al*., 1997).

RESULTS AND DISCUSSION

Laboratory studies have shown that the seeds of the first sowing period have higher germination energy at +12 °C - +14 °C than the seeds of the second sowing period (Figure 1). According to observations, cotton cultivar AN-Bayaut-2 has a higher germination rate than the other two cultivars. During the study to determine the intensity of respiration in cotton plants, some seed parts germinated at a temperature of +30 °C, noting the data on respiration one and two days after the start of seed germination. Numerous studies have demonstrated that high temperatures during planting can result in poor emergence and increased seedling mortality (Singh *et al*., 2017).

The cottonseeds sown in May showed a decrease in germination energy and respiration intensity, which confirms that having more time for fruiting bodies to form, depends on the influence of temperature. The obtainable data revealed that during the boll development obtained from plants sown on May 10, bolls ripened even at low temperatures during the last 30 days (Figure 2). High-temperature stress tends to negatively affect reproductive development than vegetative development in cotton (Snider and Oosterhuis, 2015). It is practically a concern because expected heat wave events become more frequent and intense due to climate change (Meehl and Tebaldi, 2004; Tian *et al*., 2023).

The change in temperature from flowering to ripening increased by 13 days in plants of the second sowing compared with the first. Considering that the lower temperature limit required for plants to pass through the flowering-ripening phase in the studied cultivars is within +12 °C - +13 °C, then the sum of effective temperatures for plants is 13.6 °C - 14.7 °C, which is lower than in the first sowing period. The boll opening at low temperatures is a consequence of factors associated with low temperatures, which adversely affects the seed quality based on the thermal regime of their germination. The cotton cultivar, AN-Bayaut-2, sown on April 17, in the flowering phase of the plant, exhibited that the formation of bolls was under the influence of the effective temperature. During the growing season, accounting for the number of flower buds that appeared during the flowering period and the opening time of the bolls remaining during the ripening period ensued (Table 2). For each of them, flowering measurements had two to three days' intervals. Calculating the number of days from flowering to maturation followed, as well as the sum of average daily and effective temperatures for the same period.

The duration of the interphase period from flowering to maturation, depending on the time and place of bud formation, showed that the later flowers appear on the plant, the longer their interphase budding period (flowering-ripening) (Figure 1). However, despite the lengthening of the flowering-ripening phase, the sum of the average daily effective temperatures naturally shifted down in later bolls. With the change in the development of the bolls, one can observe definite dynamics of seed germination from

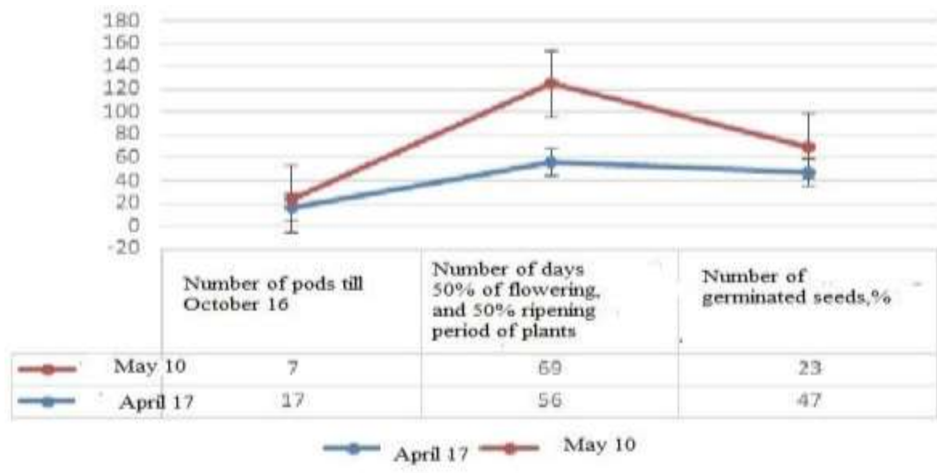

Figure 1. Influence of time on the germination of cotton cultivar seeds.

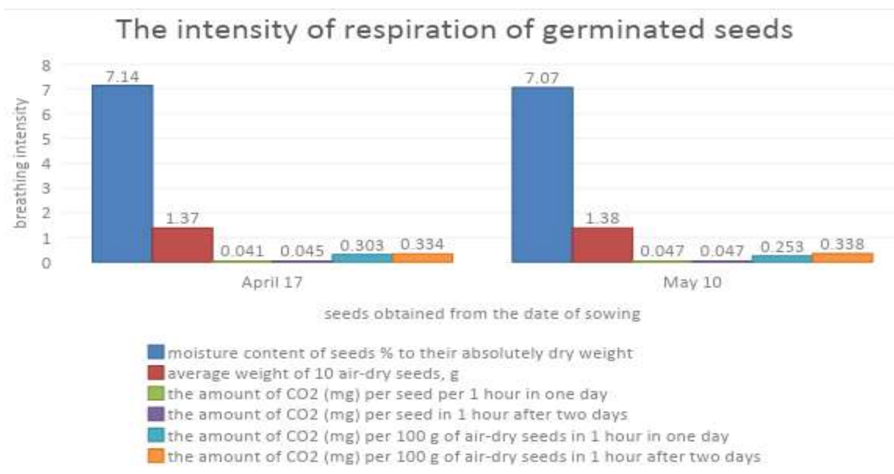

Figure 2. Influence of sowing time on the intensity of respiration of germinated cotton cultivar seeds.

Table 2. Phenological indicators of cottonseeds during the growing season.

Number of counted cells	Flowering date	Average ripening time	Number of days from flowering to ripening?	Summation of effective temperatures during flowering and ripening	Optimal limits of the sum of effective temperatures for the "flowering-ripening" period
10	7.VII	1.IX	56	1479	807-751
12	9.VII	4.IX	57	1498	814-757
26	11.VI	7.IX	58	1511	815-757
31	14.VI	11.IX	59	1495	787-728
29	16.VI	13.IX	59	1468	760-701
27	18.VI	16.IX	60	1450	731-673
27	20.VI	20.IX	62	1466	723-663
21	23.VI	28.IX	67	1509	706-641
18	26.VI	4.IX	70	1526	687-619
17	29.VI	10.IX	73	1521	645-572
8	1.VII	17.IX	77	1539	615-538

flowering to ripening. Thus, it revealed that the germination of cultivar AN-Bayaut-2 seeds was higher than the other two cultivars.

The results further enunciated that the seeds of cotton cultivar AN-Bayaut-2 germinate very slowly at low temperatures. For example, after 10–11 days at a temperature of +14 °C, germination occurred mainly in the seeds of the 2nd, 3rd, and 4th branches of crops harvested and then in a few grains of other boughs. Figures 3–4 present the results of the general physiological characteristics of cotton cultivar seeds to justify the several levels of quality for seed germination vigor.

The changes occurring in the seeds inside the bolls of crop branch plants appear in Figures 3 and 4. For example, in high sympodia, the average weight of raw cotton in one boll and the number of seeds in each boll also increased, which is the leading cause for their increase in size. An increase in the kernel number per boll also correlates with favorable conditions. In this case, a contradiction also arises, with the plant unable to provide sufficient nutrition with many seeds in the boll, and as a result, they do not reach absolute weight in the lower layers.

The higher sympodia included the smaller seeds formed, and their weakness can easily be visible in the field observation. An increase in the seed number in one boll reduces absolute mass, depending on the plant height, which is closely associated with seed germination characteristics and the intensity of seed respiration. During this period, rapid germination of seeds from the bolls at the lower level of the pharyngeal branch is characteristic, and it was notable that the intensity of seed respiration from the upper bolls significantly rises in the following days. The boll seeds on low-yielding branches retain high germination in the early period of development (seedlings and root growth). The study has established that the diversity of cotton seeds, as well as the development of the plant under the influence of changing environmental conditions, interlinked with the location of cotton bolls on the plants. Figures 5 and 6 present the data on seed germination and their impact on seed cotton yield in the laboratory.

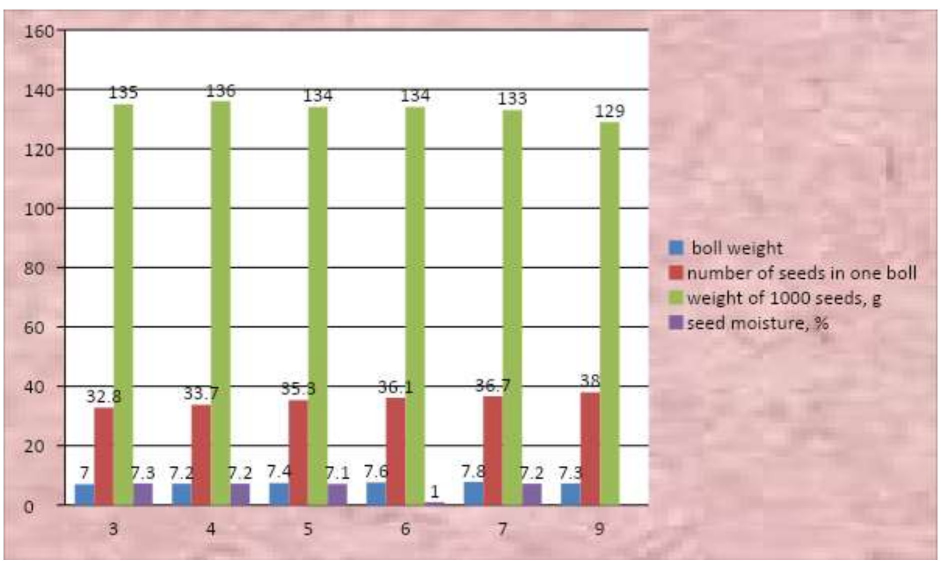

Figure 3. Economic values of germinated seeds of local cotton cultivars.

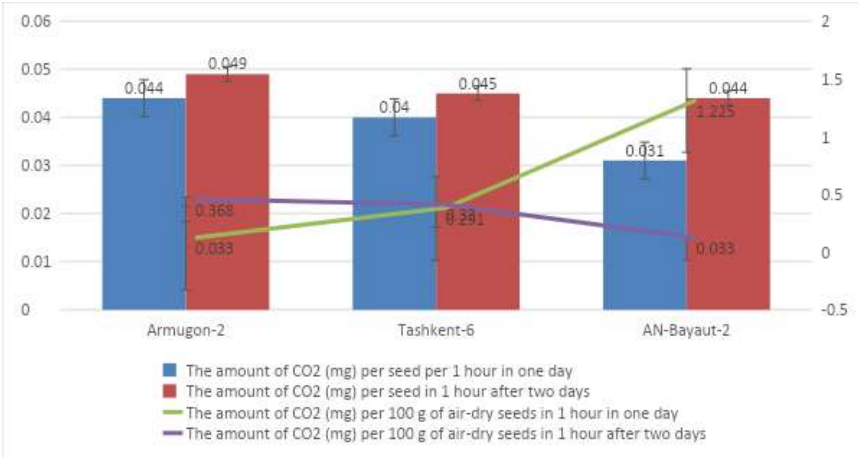

Figure 4. Physiological characteristics of the seeds of local cotton cultivars.

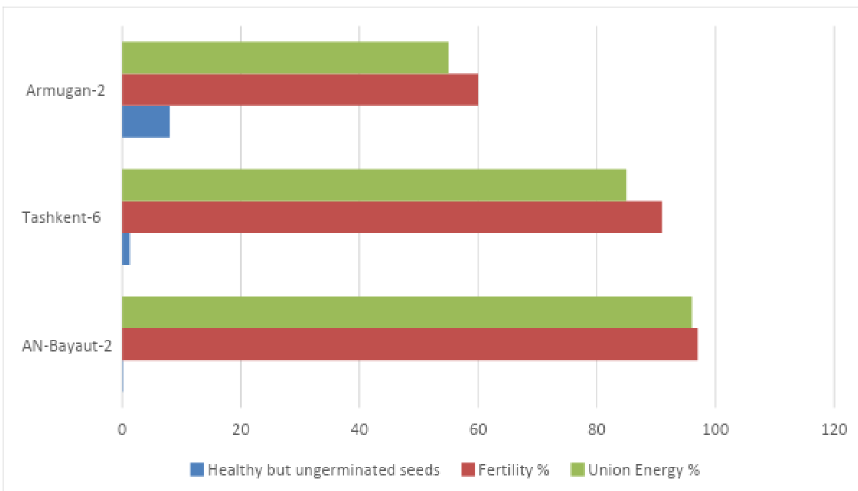

Figure 5. Germination of local cotton cultivar seeds.

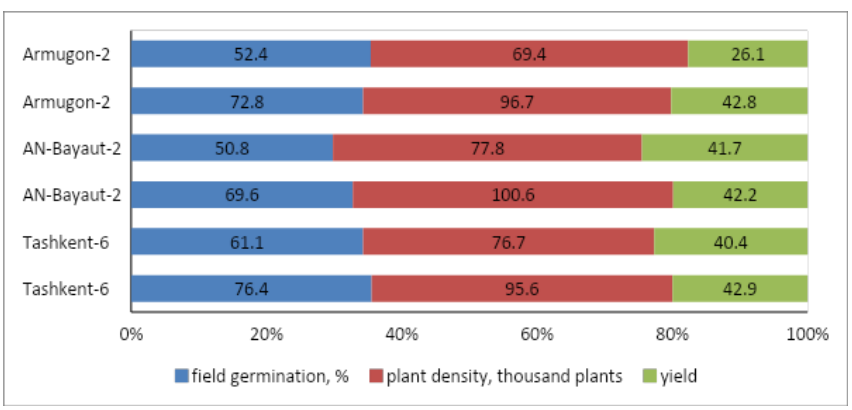

Figure 6. Yield of various cotton cultivars, percentage of field germination, and the plant density per thousand plants.

One of the core characteristics of seeds is their germination rate, which refers to what percentage of a planted seed will germinate. This indicator also determines how many seeds need to be sown per hectare to obtain the required number of seedlings. Artificially defined fertility under favorable conditions is called laboratory fertility. Under natural conditions, the number of seedlings germinated within 30 days after sowing in the field determines field fertility. Ground fertility ranges from 57% to 62% and 85% to 95% in laboratory conditions since sowing and germination depend on soil and climatic conditions, which are always optimal (Rashidova and Shilevski, 2017). Bolek (2010) evaluated the germination response to temperature for 106 cotton cultivars across three different cotton species and observed significant differences among the genotypes in seed germination percentage under cooler temperature conditions (18 °C) for *G. hirsutum* L. and *G. barbadense* L.

Importantly, seed vigor assessments at 18 °C show correlations with percent emergence in the field, and *G. barbadense* L. cultivars revealed that they were more cold-tolerant than most *G. hirsutum* L. genotypes. However, seed vigor does not necessarily predict seedling stamina under field conditions. At a minimum temperature, having high emergence rates could potentially contribute to sizable early-season crop growth rates. According to researchers, the sowing of hairy seeds can begin when the soil temperature reaches 12 °C, and the sowing of hairless seeds can start when the soil temperature reaches 14 °C. Light soil warms up quickly; therefore, plant the kernel to a depth of 4–5 cm and, for slowly warming heavy ground, to a depth of 3–4 cm. The cotton seeds planted in insufficiently warmed soil will rot, and cotton bushes will become rarer. In addition, cotton grows stunted and prone to disease. After the optimal period, the natural moisture content of the soil decreases, and some of the planted seeds do not even germinate (Kochkharov *et al.,* 2009).

Based on this study's experience, the factors studied do not eliminate the heterogeneity of cotton seeds; on the contrary, the plant organism largely depends on individual environmental factors (water regime and mineral nutrition) and the interaction system of the entire complex. Therefore, the nature of the development of cotton seeds largely depends on the temperature of the growing season, which indicates varied indicators of the thermal regime of their germination. Results have also established that the seeds' physical and biological diversity correlate closely with the plant's development and influences of some environmental factors. A discovery indicated that seed germination decreased in areas where later-sown seeds occur. The most important in terms of germination energy and other physiological functions are boll seeds of the lower and middle stages of the plant.

Rapid and uniform stand establishment with vigorous seedling growth are desirable characteristics of cotton. The cotton seedlings with high stamina are generally less affected by early-season insect herbivores and plant pathogens and more competitive with weedy plant species, which lessens the potential for early-season crop loss. This review emphasizes the significance of seed characteristics in determining seedling vigor. High planting seed mass and total nutritive reserves (oil and protein) positively impact early seedling vitality. Genotypes can also influence seed mass and nutrient composition. However, it is vital to note that production and postharvest storage environments can have a pronounced impact on these seed characteristics.

The practices, such as, irrigation, fertility, and planting date, appeared to influence the seed oil and protein content. Long periods of seed storage at high temperatures have shown a close association with decreased oil, protein, and seed viability. With various factors fast affecting seed quality, the study suggests that seed mass and composition could be beneficial as broadly applicable predictors of seedling vigor that integrate many variables. It could also help the growers position high-vigor seeds in locations where production conditions are challenging during the early season. Breeding has produced cotton genotypes with high lint percentages but smaller seeds, which could negatively affect seedling vigor. Future research should focus on opportunities to increase yield by manipulating yield components other than lint percent. Therefore, due to significant differences among the cotton cultivars, it is crucial to consider germination percentage (Snider *et al*., 2014).

CONCLUSIONS

Results revealed that cotton covered the extensive period from the flowering to the maturation phase under high-temperature influences, which showed the highest percentage of bolls with high seed quality. The seed germination decreased in areas where the sowing of seeds was late. According to germination vigor and other physiological functions, the best plants were obtainable from the boll seeds at the lower and middle stages of the harvest. Results also established that the local cotton variety, AN-Bayaut-2, proved superior to the other two cultivars, Tashkent-6 and Armugon-2, based on seed germination and adaptation to various environmental factors during the growing season. Therefore, it is necessary to further study the influence of environmental factors on the qualitative characteristics of the cottonseed sowing period, including the appearance of buds, flowering, and precocity of plants.

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