

Cotton Production, Breeding and Biotechnology Research in Kazakhstan

Nazira Bishimbayeva, Aigul Amirova, Islam Guseinov*, Ibadulla

Umbetayev*, Izbasar Rakhimbayev

(Institute of Plant Biology and Biotechnology, National Center of Biotechnology, Ministry of Education and Science of the Republic of Kazakhstan 45, Timiryazeva str, Almaty, 500040, KAZAKHSTAN;

Kazakh Cotton-growing Research Institute, Ministry of Agriculture of the Republic of Kazakhstan, South-West Department, Atakent, South Kazakhstan Region, KAZAKHSTAN

1 Cotton production in Kazakhstan

Cotton is one of the major agricultural crops in Kazakhstan that has an export importance. In addition, the cotton is a basis for the development of the own cotton-textile industry, which has become the one of seven major clusters of Kazakhstan economic development. The total amount of cotton fiber production takes the next place after oil, grain and nonferrous metals, which are main export products in Kazakhstan economy (Umbetayev, 2005).

In Kazakhstan cotton is growing in South Kazakhstan Region, where the appropriate soil-climatic conditions, warmth and sunlight abundance, frost-free period duration, and the availability of fertile irrigated lands allow growing middle-fiber cotton varieties (Umbetayev, 2005).

Kazakhstan is not taking leading positions in the cotton production worldwide because of its geographic location and soil-climatic conditions. The share of Kazakhstan in the world cotton fiber production is equal to 0,65 - 0,75 % (2003, 2005, respectively). Despite, during the period of time from 2002 to 2005, volumes of cotton raw material and fiber production had been increasing (Fig. 1) (Baktybayev, 2005).

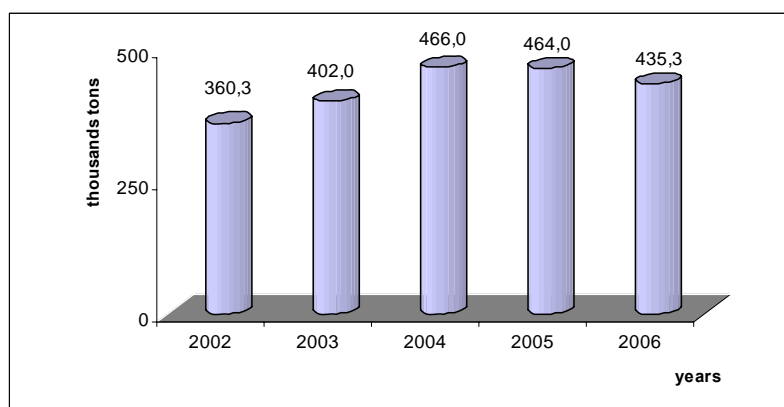


Figure 1 – Total amount of cotton raw material

At the same time, in 2006 and 2007 this parameter have the tendency to decrease (464,0; 435,0 tons, respectively) because of the water deficit problems, the absence and deficit of the important mineral nutrition salts and the predominance of priorities in Kazakhstan agriculture to the food crops. However, it is possible, that cotton growing and fiber production in Kazakhstan could be increased in next years because of world prices on the cotton fiber production have the tendency to grow every year. Since 1999,

the total cotton sowing crop areas have grown up to 80%, from 116000 to 205000 hectares in 2005. Quantitative characteristics of cotton sowing crop areas in South Kazakhstan and of cotton crop yield in 2002—2007 have the same tendencies as the total amount of cotton raw material. Crop areas increased from 170400 to 194000 hectares in this period of time with the highest value of 222900 hectares in 2005 (Fig. 2). The average crop yield has grown from 21,6 c/hc to 22,4 c/hc with the maximum value in 2005 of 23,5 c/hc (Fig. 3).

Advanced collective farms and industrial cooperatives obtain 32-47 centners from each hectare on the cotton fields.

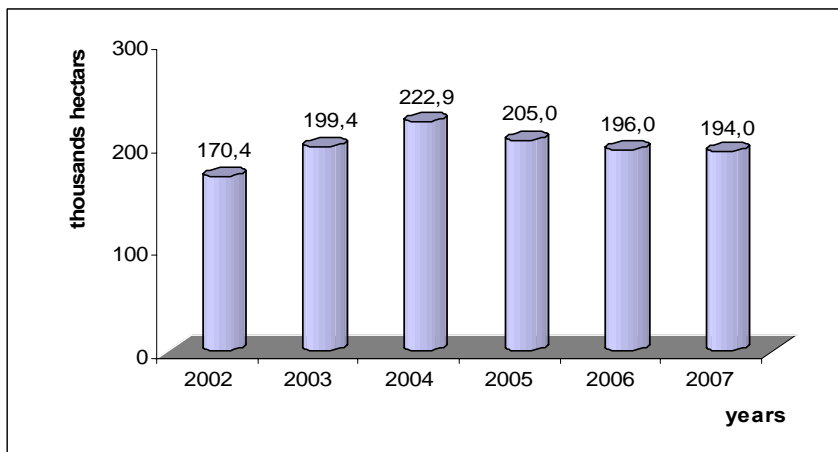


Fig.2 Crop areas in South Kazakhstan (2002—2007 years)

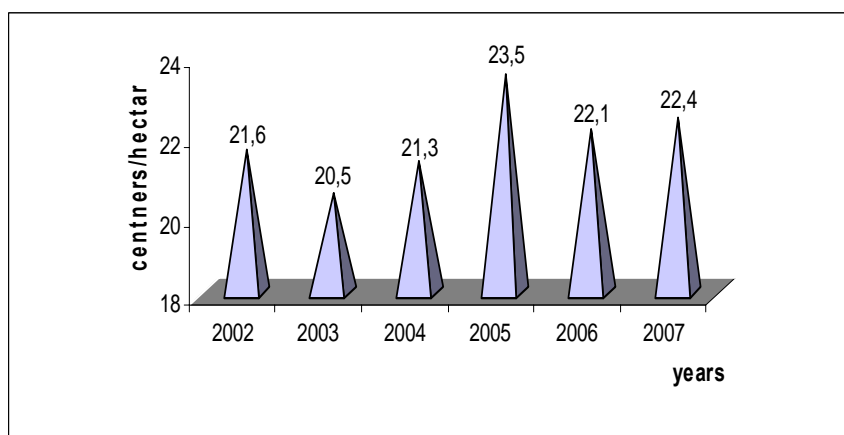


Fig.3 Crop yield of cotton (2002—2007 years)

Cotton producing region of Kazakhstan is situated in the most northern zone of world cotton sowing and characterized by the deficit of warm days in spring and autumn periods, water deficit, the significant spread of verticillium and phuzarium wilt, hommoz, black root rot and other diseases and insects, which complicates the ecological situation in the region for cotton growing and fiber production (Umbetayev et. al., 2005).

Therefore the main task of cotton breeding in Kazakhstan is the creation of new local varieties which exceed standard regioned cultivars (C-4727, 108-F, Kyrgyz-3) on the complex of economically important traits: fast ripening, productivity, adaptive capacity and fiber quality (Umbetayev et. al., 2005).

2 Cotton breeding in Kazakhstan

Genetic-breeding investigations of cotton is carried out in Kazakh Cotton-growing Research Institute (KCRI), recently founded on the base of Makhtaaral breeding station (Mirzakent, South Kazakhstan).

By the use of statistic programs of overall combinative capacity (OCC) and specific combinative capacity (SCC) positive results have been received on the creation of new cotton varieties resistant to the complex of diseases: verticillium wilt, black root rot and hommoz. Overall, 7 new varieties has been created in Makhtaaral breeding station, four of them has been regioned. On their main valuable characteristics they exceed traditionally growing regioned cultivar C-4727, which was considered as ethalone for middle-fibered cotton for the long time.

One of the main valuable traits of newly developed cotton varieties is a fast ripening with the period of vegetation 119 -125 days. For the comparison: in the fields of world leader cotton producers – India, Brazil and Chili – this period is equal to 180-185 days. Moreover, new local varieties are more resistant to insects, have high technologic fiber parameters and productivity (approximately, 40 c/hc).

In a whole, the series of new fast ripening cotton varieties has been created and regioned in the last years, as well as agrotechnic skills of their growing has been elaborated.

Gene fund of Kazakhstan elite cottons has been enriched by the following varieties of Makhtaaral breeding: Pakhtaaral-3031, Pakhtaaral-3044, Makhtaaral-4005, Makhtaaral-4007. These new varieties are tolerant to the complex of diseases (verticillium wilt, black root rot, hommoz), high productive (higher then 40%). Additionally, they have improved technologic traits, which satisfy the requirements of cotton sowing farms and textile industry: high fiber strength, high breaking boad and breaking length, microneir in accordance with generally accepted world standards (4,5 -4,7) (Umbetayev et. al., 2005).

Three perspective forms Makhtaaral-4011, Makhtaaral -3047 and Bereke-07 are in the process of screening and have received positive feedback in governmental competitive strain's tests (GCST). One perspective form Makhtaaral-4016 is in the process of examination in GCST.

New varieties have valuable agricultural traits in comparison with other regioned cotton varieties. These cultivars are more fruitful, have high fiber quality and yield, big pods. For example, average crop yield of Makhtaaral-3044 is equal to 45 c/hc, of Makhtaaral-4005 – 53 c/hc in the optimal soil-climatic conditions (Turkestan). Makhtaaral-3044 gave yield of 50-60 c/hc after growing in the checks after rice (Chardara).

Makhtaaral-3044 exceeds regioned cotton cultivar C-4727 more than to 3-4 centners in yield, 1,0 g in pod size, 0,2 g in fiber strength, 0,5 mm in fiber length, 16% in fiber yield, 15,5% in verticillium-resistance. This cultivar exceeds the regioned cultivar more than for 2-3 days in time of ripening. This new Kazakhstan's cultivar showed it's more tolerant to salinity and water deficiency because of its powerfull root system (Umbetayev, 2005).

The share of crop areas sowed by newly developed elite cotton varieties of Kazakhstan have a tendency to grow from year to year. It has increased from 30% to 44% during the period of 2005 -2007 (Fig. 4).

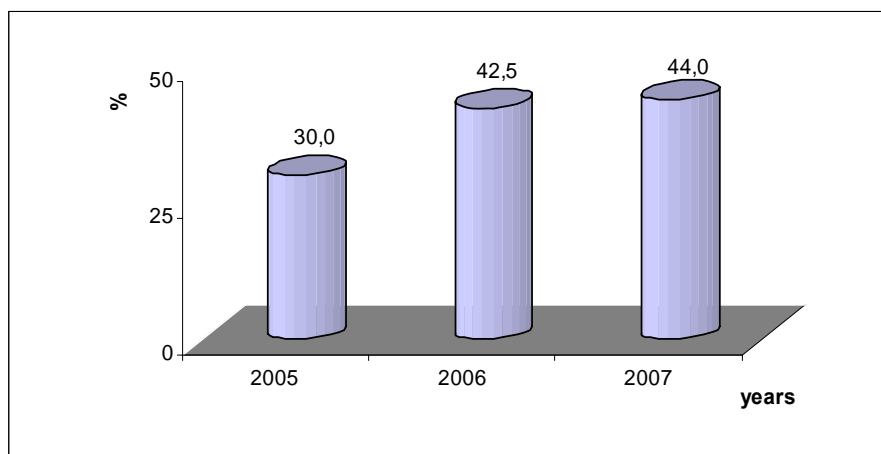


Fig. 4 Percent of crop areas of new Kazakh cotton varieties in the total cotton sowing areas

Thus, the use of modern breeding-genetic methods– statistic programs of OCC and SCC, allowed to Kazakhstan breeders successfully decide the problem of the creation of new varieties with traits of fast-ripening, high-yielding, high fiber quality, resistance to the complex of diseases (verticillium wilt, hommoz, black root rot) and tolerance to salinity and water deficit.

Unfortunately, the question of the creation of cultivars with heritable tolerance to pests – bollworm, karadrin, aphid, arachnoidal tick, are still poorly investigated. This question has become very important on the last decade because of 40% and higher yield loss in some years (1998, 2002) caused by cotton bollworm, karadrin and others.

Also, in Kazakhstan the lack of attention is given to the elaboration of approaches to the creation of carlic varieties, which is necessary for fast gathering of yield by machine technique and for the increasing of cotton productivity.

In addition, the search of ways for increasing the oil content in cotton seed is need to be conducted.

The important problem which is needed to be decided for cotton improvement in Kazakhstan is the widening of genetic basis for cotton breeding by including new donors of economically important traits – wild cotton relatives, foreign cotton species and varieties.

To solve these problems of cotton breeding in Kazakhstan it is necessary to increase international interdisciplinary collaboration and efforts of geneticists, breeders, plant physiologists, molecular biologists and biotechnologists.

3 Investigations in cotton biotechnology

One of the most effective and modern purposefull method of plant genotype change is a genetic engineering. Development and wide application of genetic transformation for cotton improvement is restrained by the unsolved problem of strong genotype dependence in regeneration in vitro (Trolinder and Xhixian, 1988).

High embryogenic and regenerative potential have been obtained for the limited number of Coker type genotypes which often had no commercial importance (Wilkins et al., 2004). Leelavathi et al. (2004) have elaborated efficient transformation protocol for model Coker 310 variety by the use of long-term embryogenic callus as a recipient system. However, a high level of genotype and cytogenetic variations in plants regenerated from callus culture has been established for cotton (Stelly et al., 1989). Therefore, it has become important to reduce the time in vitro to minimize somaclonal variation (Smith, Park, 2004). Different approaches to avoid genotype limitation and somaclonal variations have been used including shoot meristem transformation (Zapata et al., 1999) and pollen transformation (Li et al., 2004); however,

the efficiency of transformation was significantly low in comparison with the use of embryogenic lines. Thus, each of the above mentioned transformation systems has positive and negative features. For this reason we in the Laboratory of cell biology of the Institute of Plant Biology and Biotechnology (Almaty) have used various recipient systems and approaches for transformation of Kazakh cotton varieties.

In this investigation we have used approaches and experience in the elaboration of genotype independent regeneration systems for cereals - wheat, barley and wild grasses.

In order to overcome genotype dependence we have used the strategy of revealing the morphological type of primary calli which is common for various local genotypes and perspective from the point of morphogenesis (Maktaaral-4003, Maktaaral-4005, Maktaaral-4006, Maktaaral-4007, Maktaaral-4011, Maktaaral-4019, Pakhtaaral -3044). From three types of primary tissues type I - grayish-white callus, was found as most typical for all seven investigated genotypes and two type of explants (hypocotyls, cotyledons). This common tissue type was very responsive on the changing of media composition and used as a source for the induction of long-term friable embryogenic calli for two cultivars (Maktaaral-4005, Maktaaral-4006). This approach is in process and embryogenic callus lines are being induced from other local genotypes in the same conditions.

Long-term embryogenic calli of Maktaaral-4005 were bombarded by plasmid pAHC25 containing reporter gene β -glucuronidase (GUS) and selective marker gene, Bar, for phosphinotricin resistance. GUS-gene expression in callus cells has got during the optimization of ballistic transformation.

Pollen transformation was carried out according the protocol of Li et. al. (2004) for. Maktaaral-4005. Pollen was transformed by *Agrobacterium* strain containing plasmid with reporter gene GUS and selective marker gene, nptII, for resistance to kanamycin. The treated cotton bolls were produced from flowers that had been emasculated the previous day and pollinated by transformed pollens. Seedlings produced from these treated bolls were tested on the GUS-gene expression. From 140 pollinated flowers 19 bolls were produced; 600 seeds were obtained from these bolls and 25 of them gave rise to plantlets with positive reaction to histochemical GUS-assay. At the present time progeny of these plants (T_1) are investigated on the resistance to kanamycin, GUS-gene expression and on the obtaining of molecular biology evidence of foreign gene insertion.

Cotton biotechnology in Kazakhstan is in the first steps of development. It is necessary to direct efforts to the in vitro plant regeneration problem and on the development of international collaboration on the genetic transformation and molecular-genetic investigation of cotton genome.

References:

- [1] UMBETAYEV I I. Condition and prospects of cotton-growing development in Kazakhstan /In. Scientific basis to development of cotton production. Republic of Kazakhstan. Ministry of Agricultural Industry. Kazakhstan, Atakent, 2005,99 -103.
- [2] BAKTYBAYEV S R. Perspectives of cotton production and marketing in Kazakhstan. www.icac.org/meetings/uzbek_2005/papers/russian/r_conference.pdf
- [3] UMBETAYEV I I , Guseinov I R, Bigarayev O. Main direction of cotton selection /In. Scientific basis to development of cotton production. Republic of Kazakhstan. Ministry of Agricultural Industry. Kazakhstan, Atakent, 2005:257-262.
- [4] TROLINDER, N L, Xhixian, C. (1988). Genotype specificity of somatic embryogenic response in cotton. Plant Cell Rep, 8: 133-136.
- [5] Wilkins T A , Mishra R , Trolinder N. (2004). *Agrobacterium*-mediated transformation and regeneration of cotton. Food, agriculture and environment, 2 (1): 179-187.
- [6] LEELAVATHI, S , Sunnichan, V G, Kumria, et al. (2004). A simple and rapid *Agrobacterium*-mediated transformation protocol for cotton (*Gossypium hirsutum* L.): embryogenic calli as a source to generate large numbers of transgenic plants. Plant Cell Rep, 22 (7): 465-470.

- [7] STELLY D M , Altman D W , Kohel R ,et al. (1989). Cytogenetic abnormalities of cotton somaclones from callus cultures. *Genome*, 32: 762-770.
- [8] SMITH,R H, Smith, J W, Park,S H. (2004). Cotton Transformation: Successes and Challenges /Liang G H, Skinner D Z. Genetically modified crops. Their development, uses, and risks // Food Products Press, New York, 247-257.
- [9] ZAPATA C, Park S H, El-Zik K M,et al. (1999). Transformation of a Texas cotton cultivar by using *Agrobacterium* and the shoot apex. *Theoretical and Applied Genetics*, 98: 252-256.
- [10] LI X, WANG X D, ZHAO X,et al. Improvement of cotton fiber quality by transforming the *acsA* and *acsB* genes into *Gossypium hirsutum* L. by means of vacuum infiltration. *Plant Cell Report*,(2004). 22: 691-697.