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# THE USE OF INTROGRESSIVE HYBRIDS IN THE SELECTION OF *KOCHIA PROSTRATA* (L.) SCHRAD

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**Abstract**

In the territory of Kazakhstan, introgressive hybridisation is documented in many species of forage plants of the North Turan. Regarding *Kochia prostrata*, the facts of introgression at the subspecies level become known, therefore, it indicates the existence of spontaneous hybrids. It showed the morphological similarity of the so-called "rocky ecotypes" with natural hybrid populations. In the second stage (2000-2005), more in-depth studies based on the theory of introgressive hybridisation clarified the origin of rocky ecotypes as a result of the evolutionary incompleteness of the subspecies stage. Subsequently, the analysis of the species area of *K. prostrata,* conducted by the authors based on the results of expeditionary studies, allowed identifying 5 foci (microcentres) of localisation of introgressive hybrids in the territory of Kazakhstan and Central Asia. The applied use of these natural hybrids served as a theoretical justification for the deployment of large-scale selection work. Based on the results of many years of research (2005-2015), the authors have successfully developed the main methods of the selection of *K. prostrata*. The creation of hay-type varieties using rocky (introgressive) populations was a new area in selection practice. This study presents the materials of the completed process of selection from collection nurseries to the final stage of the State Testing of the Isken variety, covering a period of more than 15 years.

**Key words:** Area, Intergradation zones, Introgression, Natural hybrids, Selection, Haying variety, Variety testing.

## Introduction

Introgression is one of the factors of the evolutionary settlement of the plants, it is widely known in the plant world as a special type of natural hybridisation in nature, resulting from the overlapping in of the domain of genera, species, and subspecies. A study by Ivanov *et al*., (1986) notes that subspecific introgression is a rarer phenomenon than interspecific and in relation to arid plants, this phenomenon has not actually been investigated. The existence of introgressive hybridisation in higher plants was first shown by Anderson (1949). The study of Anderson (1940), which proved the existence of introgression, was of great importance for the theory of evolution. In addition, the long-known practice of overcoming the sterility of the first and subsequent generations with distant hybridisation (Tsitsin, 1960) in selection was essentially a typical introgression, which, along with amphiploidy, played a substantial role in the origin of cultivated plants (Zhukovsky, 1970; Čertner *et al*., 2020). In nature, there are facts of fertile hybrids during mass hybridisation between subspecies of the same species during their migration towards sympatric area or after the disappearance of the barriers separating them earlier (Skliar *et al*., 2019; Churilov *et al*., 2023; Shahini *et al*., 2023).

*K. prostrata* ("izen" in Kazakh) was cultivated for the first time in the Commonwealth of Independent States (CIS) in 1936, and more than 10 varieties had been created. According to the results of the expeditions of Institute of Plant Industry (Russia, 1986) and Kazakh Research Institute of Animal Husbandry and Forage Production (Kazakhstan, 1990), intergradation zones were identified on the territory of Kazakhstan – places of concentration of natural hybrid populations of this plant. Currently, *K. prostrata* is known to have an area of 5 (five) foci of intergradation zones of natural hybrids. These foci were empirically used at the initial stages of species introduction when creating artificial pastures, later these wild hybrid populations were used for selection practice as source material. Notably, after the collapse of the Union of Soviet Socialist Republics (USSR) (1990), theoretical studies were suspended. However, they were resumed in disparate scientific institutions of the independent republics of the CIS in 2000. Among the wide variety of arid plant species, *K. prostrata* has become one of the leading plants in arid forage production over eighty years of cultivation (Shokatayeva *et al*., 2019). Such great success of the introduction of this crop in the CIS countries and abroad (United States of America, Iran) was primarily conditioned due to its considerable ecological and biological plasticity, drought resistance, high yield, combined with high nutritional value and digestibility, resistance to grazing, and longevity on pastures (Tyliszczak *et al*., 2019; Kravchenko *et al*., 2023).

A multifaceted purpose was set to clarify the nature of the origin of "rocky ecotypes" and their classification in the species system.

## Material and Methods

The long-term research consisted of two stages; different methods were used in each of them. In the first stage (1990-1995), intraspecific systematics and classification were developed to solve the problems of intraspecific systematisation of a wide variety of genetic material based on morphological descriptions, which showed the similarity of

the morphology of rocky ecotypes (North Turanian rocky – NTR, Aral sandy loam – ASL, Fergana rocky – FR) with natural hybrid populations. In the second stage (2000-2005), more in-depth studies based on the generally accepted theory of introgressive hybridisation allowed identifying 5 foci of localisation of natural hybrids in the territory of Kazakhstan and Central Asia, the use of which subsequently formed the theoretical basis for applied selection.

Since 2005, a selection program has been developed to create a haying variety *K. prostrata*, using generally accepted methods and guidelines. The collected samples were examined according to the "Methodological guidelines for the mobilisation of plant resources and the introduction of arid forage plants" (Shamsutdinov, 2000) and "Methodological guidelines for conducting research in the selection of perennial grasses" (Smurygin, 1986). Field experiments were conducted according to the "Methodology of field experiments with forage crops" (Dospekhov, 1985). The study was carried out at the experimental base "Zhainak" in the Kazakh Research Institute of Animal Husbandry and Forage Production (Almaty region, Kazakhstan). Sixty samples of wild populations collected from the territory of Russia, Kazakhstan, Uzbekistan, and Kyrgyzstan were analysed in the collection nursery of the initial material of 2005. Nurseries were laid in a wide-row way (with a row spacing of 60 cm) with a plot area of 25 $m^2$, in 3-fold repetition. The selected 20 high-potential samples of *K. prostrata* were examined in breeding nurseries of the selection of 2010-2012 years of study to create varieties of haying use. The nurseries were laid in a square-nesting way (60cm x 60cm) with a plot area of 25 $m^2$, in 3-fold repetition. Agricultural equipment in all experiments met the requirements adopted for this zone.

The examination of the entire variety of samples and numbers at nurseries during the whole selection process was conducted in 2 areas: according to economic assessment (phenological observations, plant height, plant bushiness, leafiness, resistance to drought, pests and diseases, yield of pasture, haying fodder and seeds, crude protein content); according to morphobiological characteristics and properties (bush shape, thickness, pubescence, the colour of shoots; fruit morphology and inflorescence shape).

## Results

**The evolutionary emergence of introgressive (rocky) hybrids:** At the initial introduction and selection stage, the most important practical purpose was to clarify the evolutionary settlement of *K. prostrata* across various regions. According to the results of the expeditions of the Institute of Plant Industry (Russia, 1973-1981) and Kazakh Research Institute of Animal Husbandry and Forage Production (Kazakhstan, 1981-1983), the facts of the regular settlement of two subspecies (greenish and grey) of *K prostrata* over the area (Fig. 1) are from the foothill steppes of the Tian Shan-Tarbagatai to the sandy deserts of the Balkhash-Moinkum and further in the latitudinal direction from the northern desert of Kazakhstan to the European part of southern Russia (Ivanov *et al*., 1986). According to the intraspecific taxonomy developed by the Institute of Plant Industry, the species *K. prostrata* (L.) Schrad has the following taxa: subsp. *prostrata* – a group of clay ecotypes (Tianshan clay – TSC, Dzungarian clay – DC, Sevroturpnsky solonetzic – STS) of a greenish subspecies distributed in the dry-steppe zone along uplands, low mountains, and small hills from the southeastern and eastern regions of Kazakhstan to the dry-steppe zone of the Eurasian continent, in the west within the Sarpinsk lowland and Ergeninsk uplands of Kalmykia, Rostov region of Russia. Subsp. *grisea* – sandy (South Kazakhstan sandy – SKS, Aral sandy – AS, Kazakhstan sandy – KS) grey subspecies which are distributed throughout the northern desert of Turan from the eastern part of the Balkhash – Alakol depression, through the Southern Balkhash – Moinkum – Aral sands to the western part of the Northern Caspian Sea within the European part of Russia. Considering the intraspecific taxonomy of the group of rocky ecotypes (*convarietas canescens*), botanists have always had questions about their subspecies. Based on the provisions of the modern theory of introgressive hybridisation, their origin is explained as a result of overlapping of the distribution areas of two subspecies.

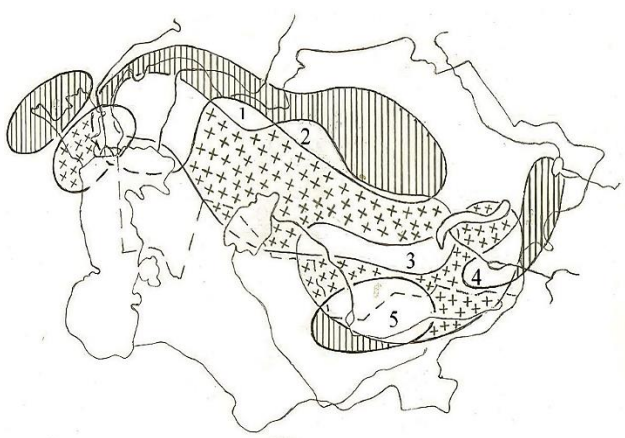


Fig. 1. Zones of intergradation in the area of *K. prostrata.*

According to the scientific provisions of historical geography, the spontaneous emergence of interspecific hybrid populations in nature exists as a natural evolutionary process and indicates the origin of rocky populations as a result of the transition of the subspecific stage of evolution (Lyubchik *et al*., 2004). The authors examined the areas of subspecies of *K. prostrata* based on the materials of expeditions of the Institute of Plant Industry and Kazakh Research Institute of Animal Husbandry and Forage Production. The results of schematic and are presented below (Table 1).

**Table 1. Subspecies areas of *K. prostrata***

| Introgression | Note |
|---|---|
| AS x STS<br>ASL (hybrid populations) | (AS) Aral sandy<br>(STS) Sevroturpnsky solonetzic<br>(ASL) Aral sandy loam |
| SKS x DC<br>NTR (hybrid populations) | (SKS) South Kazakhstan sandy<br>(DC) Dzungarian clay<br>(NTR) North Turanian rocky |
| SKS x TSC<br>FR (hybrid populations) | (TSC) Tianshan clay<br>(FR) Fergana rocky |

Note: \\\ – subsp. prostrata (greenish subspecies: TSC; DC; STS; KC); +++ – subsp. grisea (subspecies grey: SKS; AS; KS)

The results of studies of subspecific areas indicate the areas of overlapping, observed throughout the species area (they are indicated by white contours with digital indications in Fig. 1), which eventually allowed determining the intergradation zone on the species area of K. *prostrata*. From the standpoint of evolutionary theory, these zones are essentially natural local microcentres of microevolution and are organically connected with the centre of species origin.

Note: 1 – Mugodzhar low mountain (NTR); 2 – Torgai hollow (ASL); 3 – Betpak–Dalinsk plateau (NTR); 4 – Malai-Sarin low mountain (NTR); 5 – Fergana foothills (FR). The intergradation zones that are shown in Figure 1: Mugodzhar low mountains (NTR, 1); Torgai hollow (ASL, 2); Betpak–Dalinsk plateau (NTR, 3); Malai–Sarin low mountains (NTR, 4), and Fergana foothills (FR, 5) actually exist on the territory of Kazakhstan and are marked on geographical contour maps as foci: Mugodzharsk, Torgaysk, Betpakdalinsk, Malaysarinsk, and Fergana.

**Rocky ecotypes are a new type of source material for the selection:** In reality, at the initial stages of the selection study (1990-2000), the existence of natural hybrids was not yet known, breeders in various regions of the CIS desert (Kazakhstan, Uzbekistan, Russia) empirically researched natural hybrid populations in collection nurseries as source material for selection. Taxonomists put the so-called rocky ecotypes (NTR, ASL, FR) into a separate transitional group, which already at the initial stages of the study showed signs of hybrid origin according to a large number of morphological descriptions since they were distinguished by the rate of growth and development. In the conditions of the Southern Balkhash region (Kazakhstan), the study of more than 170 samples in the collection nurseries of the Kazakh Research Institute of Animal Husbandry and Forage Production showed the largest number among the high-potential ones were from Volgograd (k-210, 211, 215, NTR) and Aktobe regions (k-4, 262, 263, NTR); (k-252, 255, ASL). Soskov (1974) and Ivanov & Bukhteeva (1985) noted a considerable distribution of populations of hybrid origin based on the results of the expedition of the Institute of Plant Industry in the Aktobe region of Kazakhstan, where it was indicated that samples k-243, k-252, k-255 (Institute of Plant Industry) showed intermediate signs in phenotype (hybrid forms) under natural growth conditions between sandy and clay subspecies. Subsequently, extensive ecological testing of samples of wild populations of the North Turanian rocky ecotype k-207, 210, 211, 213 from the Volgograd region (Russia) in the conditions of the northern desert of the Almaty region (Aidarly, Kazakhstan) showed the best results as high-potential cultivars (k-210, 211) in terms of stability and productivity with yield pasture mass of 26.5-28.6 dt/ha (Yusumbaev & Kapyshev, 1982; Amirkhanov & Alimov, 1980).

At the same time (1990), a study was conducted in large scientific breeding centres for arid crops (Research Institute of Forage Production, Samarkand; Kazakh Research Institute of Animal Husbandry and Forage Production, Almaty) to determine the resistance of expedition material to naturally occurring diseases and pests that affected and damaged the growth and development of plants of *K. prostrata*. According to the results of the study (Kazakh Research Institute of Animal Husbandry and Forage Production, Almaty, 2002), it was determined that populations of rocky ecotypes having an introgressive nature of origin showed the highest resistance to diseases (52-76%) and pests (68%), thereby representing a valuable source material for the creation of immune varieties, while the resistance of remaining ecotypes did not exceed from 5-8% to 17-19% (Ismailov & Kenzhegaliev, 2002). The area of the North Turanian rocky extends along the dry-steppe zone from eastern Kazakhstan up to the west, then through Mugodzhary to the Volgograd region (Russia as the periphery of the area) but absent in Kalmykia. According to the studies of the Kazakh Research Institute of Animal Husbandry and Forage Production, k-262 (Institute of Plant Industry) was selected among the high-potential varieties for pasture use in the Almaty region (Kazakhstan) with a yield of 26.0 dt/ha of dry weight, leafiness – 67%.

Similar studies of rocky populations of the Fergana ecotype in the foothill zones of Uzbekistan, Kyrgyzstan, and southern Kazakhstan (South Kazakhstan region) identified considerable prospects for yield and adaptation and highly productive varieties Karnabchulsky (Uzbekistan) and Baktolen (Kazakhstan) were created based on them in subsequent stages (Shamsutdinov *et al*., 1986). The Fergana rocky (FR) ecotype is highly promising, has a narrow-locality area, and grows on the foothill plains of the Talas (Kyrgyzstan) and Fergana valleys (Uzbekistan). This ecotype has a geographically distribution in the southern subzone of the desert along the transition strip (ecotone) from the steppe to the desert, i.e. it forms saltwort-sagebrush communities similar to the North Turanian. In its area, the FR occupies a transitional ecological niche from foothill habitats to plain-sandy, in its ecotypic range it is thick-stalked, late-ripening, upright bush shape, tallness, drought resistance, high yield, resistance to powdery mildew, is tetra- and hexaploid (2n = 36.54). In the south of Kazakhstan and Central Asia, high-yielding selection varieties Karnabchulsky (Uzbekistan) and Baktolen (Kazakhstan) have become widespread in the artificial agrophytocenoses in the southern desert but in the conditions of the Northern Aral Sea region of Kazakhstan do not have prospects due to low winter hardiness (20-40%) and a long growing season. Therefore, the promotion of this highly productive ecotype in the northern regions of Kazakhstan based on hybridisation is advisable (Abdraimov & Seitkarimov, 1981).

The above material demonstrated that the widely analysed hybrid (introgressive) populations as the initial selection material in various regions of the CIS desert showed their applied perspective as a new type of source material. Therewith, these first varieties did not differ in their intended purpose as haying or pasture varieties but had general economic use, mostly for pastures.

**Fergana ecotype as a perspective for the selection of haying varieties:** In 2005, the Kazakh Research Institute of Animal Husbandry and Forage Production developed a long-term project to create a variety of *K. prostrata* for targeted haymaking use. In this regard, a collection of 60

wild specimens of various geographical origins (Russia, Kazakhstan, Kyrgyzstan, Uzbekistan) were established in nurseries (2005-2008). At the initial collection stage of the study, the best indicators were noted in rocky ecotypes (FR, NTR), distinguished by tallness, upright bushes, and good bushiness (5 points), which had an advantage over other ecotypes in yield (28-30 dt/ha), height (70-72 cm), and foliage (54-57%).

The second plan was the samples of sandy ecotypes (SKS) from Almaty (Kazakhstan) and (KS) from Kalmykia and Astrakhan region (Russia), with a yield of 21-25 dt/ha of dry weight but was slightly lesser in height (60-68 cm) and foliage (52-53%). In the subsequent stages, after a rigorous selection from the collection nursery, the 10 best numbers of the above high-potential ecotypes (FR, NTR, SKS, KS) were identified, which were transferred to the haying breeding selection nurseries (2010-2012) (Table 2). The main selection characteristics and properties were upright bush shape, tallness, bushiness, foliage, high yield, and resistance to pests, diseases, and drought. In the conditions of the South-East of Kazakhstan, during the peak of the growth of the haying mass (mid-July), the extreme factor is the summer heat. Therefore, during this critical period, among the above signs, drought resistance was the determining characteristics of the future variety. Studies established that the shape of the bush and its correlation with height played a decisive role in the development of the haying variety. According to this feature, samples of the Fergana rocky ecotype from Kyrgyzstan (numbers k-513 and k-517), distinguished by tallness (82-86 cm), leafiness (56-58%), high protein content (13.2-13.4%), and dry weight yield (30-32 dt/ha), were considered as promising from the whole variety of ecotypes.

**Table 2. Characteristics of high-potential selection samples of hay-type *K. prostrata* in the Southern Balkhash region (2010-2012).**

| Catalogue numbers according to the Institute of Plant Industry | Origin | Ecotype | Height, cm | Foliage, % | Yield of dry weight, dt/ha | Protein, % | In % to St by dry weight |
|---|---|---|---|---|---|---|---|
| Standard | Almaty sandy variety | SKS | 70.2 | 50 | 25.0 | 11.05 | 100.0 |
| K-513 | Kirghizia | FR | 86.8 | 56 | 32.6 | 13.45 | 130.4 |
| K-517 | Kirghizia | FR | 82.3 | 58 | 30.8 | 13.24 | 123.2 |
| K -210 | Volgograd | NTR | 72.4 | 57 | 30.1 | 14.13 | 120.4 |
| K -510 | Almaty | NTR | 71.8 | 56 | 29.6 | 14.28 | 118.4 |
| K -731 | Kalmykia | KS | 71.5 | 56 | 27.1 | 14.37 | 108.4 |
| K -728 | Astrakhan | KS | 70.3 | 54 | 26.5 | 12.78 | 106.0 |
| K -518 | Almaty | NTR | 72.0 | 54 | 28.0 | 11.67 | 112.0 |
| K -521 | Almaty | SKS | 70.7 | 53 | 26.7 | 12.02 | 106.8 |
| K -262 | Aktobe | AS | 69.6 | 52 | 25.6 | 11.86 | 102.4 |
| K -444 | Zhambylsk | TSC | 70.9 | 46 | 26.6 | 10.91 | 106.4 |
| HCP05 | | | | | 0.28 | | |

According to the results of the selection study, the best 6 numbers were selected: k-513; 517 (Kyrgyzstan); k-518; k-510 (Almaty region, Kazakhstan); k-731 (Kalmykia), k-210 (Volgograd region, Russia), which were transferred to the next stage of the selection process in the control nurseries of preliminary variety testing.

**Control variety testing:** 6 numbers (k-513; 517; 518; k-731; k-210; k-510) of *K. prostrata* were tested in control nurseries in comparison with the standard Almaty sandy variety (Table 3).

During the years (2011-2013), all the numbers under study in control nurseries underwent a comprehensive assessment of the most important economically valuable signs and properties. Table 3 presents the main indicators for plant height and yield. The yield of the dry mass of the standard averaged 25.8 dt/ha of hay with a height of 71.1 ± 0.81 cm of grass. The high yield of hay was distinguished by numbers K-513 and k-517 (33.8 and 33.0 dt/ha), which exceeded the standard by 31.0% and 27.9%, the other numbers exceeded the standard by dry weight of hay at the level of 4-24% (Table 3). Highly proven numbers in control nurseries k-513; 517 (FR, Kyrgyzstan); k-210 (NTR, Russia), and k-510 (NTR, Kazakhstan) were transferred to competitive nurseries in 2014 for further testing (Table 4).

**Competition variety testing:** In competition nurseries, 4 varieties of prostrate summer cypress were tested: k-513; k-517; k-210 and k-510 in comparison with the standard variety (Almaty sandy).

**Table 3. The yield of the fodder mass of the haying type *K. prostrata* in the control nursery (average for 2011-2013).**

| Number | Plant height, cm | Hay yield, dt/ha | In % to the standard |
|---|---|---|---|
| Standard | 71.1 | 25.8 | 100.0 |
| K-513 | 89.8 | 33.8 | 131.0 |
| K-517 | 85.6 | 33.0 | 127.9 |
| K-210 | 73.8 | 32.2 | 124.8 |
| K-510 | 73.3 | 31.1 | 120.5 |
| K-518 | 72.9 | 29.5 | 114.3 |
| K-731 | 72.6 | 26.9 | 104.2 |
| $HCP_{05}$ | 0.81 | 0.22 | |

**Table 4. The yield of fodder mass of hay-type varieties of *K. prostrata* in a competition nursery (average for 2014-2016)**

| Variety | Plant height, cm | Hay yield, dt/ha | In % to the standard |
|---|---|---|---|
| Standard | 72.4 | 27.6 | 100.0 |
| K -513 | 92.7 | 36.4 | 131.8 |
| K -517 | 89.6 | 35.1 | 127.1 |
| K -210 | 74.9 | 33.0 | 119.5 |
| K -510 | 74.2 | 32.7 | 118.5 |
| $HCP_{05}$ | | 0.28 | |

Varieties k-513 and k-517 were distinguished by high yields over the years of study (2014-2016), which averaged 36.4 dt/ha and 35.1 dt/ha, while the excess of the standard for haying weight was at the level of 27-31%. These varieties were distinguished by tallness with upright bush forms, high foliage (54-58%), the height of the plant stand was 92.7 and 89.6 cm against the standard – 72.4 cm (Table

4). The number k-513 allocated in the competitive test, which substantially exceeded the standard variety in 2017, was transferred under the name "Isken" to the State Variety Testing for further study with a base yield of 36.4 dt/ha of hay, with good indicators for foliage and protein (Shamsutdinov & Kenzhegaliev, 2020).

During the years of State Variety Testing (2017-2020), this variety was characterised as a semi-shrub, with a summer-autumn rhythm of development, a powerful root system, and the pronounced main root. The bush is upright, the stems are rough with grey-green pubescence, the leaves are widely lanceolate, the inflorescence is paniculate, loose, the seeds are wide (5-6 mm), orbicular, the weight of 1000 seeds is 2.3-2.4 g. Average bushiness (41-60 pcs./plant). Life expectancy is more than 10 years. The period from the beginning of spring vegetation to flowering is 131-138 days until the full ripeness of seeds – 208-215 days. The height of the plant stands of the 3rd year plants of the Isken variety reached an average of 91-98 cm. The yield of green mass for an average of 3 years was 95.2 dt/ha, dry hay 37.7 dt/ha, seeds 1.4-1.6 dt/ha. The content of crude protein is 13.5-13.7%, fibre is 26.6-30.4%. The Isken variety is recommended for creating summer-autumn haying on sandy loam and loamy soils of the dry-steppe and semi-desert zones of the Almaty region of Kazakhstan.

**Discussion**

The creation of the theory of introgression was facilitated by the ideas of distant hybridisation used in the domestication (introduction) of wild species and plant selection by the great breeders of the last century, these ideas subsequently received theoretical justification in the fundamental sciences, called introgressive hybridisation (Zhukovsky, 1970; Anwar *et al*., 2022; Tsvelev, 1972). In relation to cultivated plants, the theory of introgressive hybridisation has been widely developed by Zhukovsky (1970), where it is indicated that spontaneous introgression is a natural evolutionary process in populations, as a result of which the majority of cultivated plants of the world importance have arisen (highly ploidic species of wheat, corn, cotton).

Among recent papers, the study of introgressive hybridization (Hao *et al*., 2022) is interesting, which is a powerful method for expanding the germplasm base by transferring alien genes into wheat populations, with considerable implications for advancing wheat heterosis. In this way, it is possible to move forward in solving the problem of starvation of the growing population of the planet. The authors (Urfusová *et al*., 2021) investigated hybridization, polyploidization, and crop-to-wild gene transfer. Having examined the cross ability of Elymus hispidus with *Triticum aestivum* (bread wheat), it was identified that the extent of introgressive hybridization has implications for assessing the potential risk of gene flow between crops and troublesome weeds.

Researchers (Jiao *et al*., 2020) chose tree estimation as the subject of research. The authors examined the levels of gene flow needed to mislead species tree estimation with three species and either episodic introgressive hybridization or continuous migration between an outgroup and one ingroup species. Comparison of the continuous migration model with the episodic introgression model suggests that a small amount of gene flow per generation can cause drastic changes to the genetic history of the species and mislead species tree methods, especially if the species diverged through radiative speciation events (Zhantlessova *et al*., 2022; Bidolakh, 2023.). The authors make an attempt to identify genetic diversity in wheat and barley for resistance to biotic and abiotic stressors. On the example of sunflowers, the significance of seed storage proteins for solving problems of domestication and introgressive hybridizations is demonstrated.

In the study (Forsythe *et al*., 2020), it was hypothesized that biased gene retention in the face of introgression obscures species relationships. The authors applied phylogenomic techniques and several complementary statistical tests to show that introgressive hybridization appears to have occurred between close relatives of Arabidopsis, resulting in cytonuclear discordance and impacting our understanding of species relationships in the group. The composition of introgressed and retained genes indicates that selection against incompatible cytonuclear and nuclear–nuclear interactions likely acted during introgression, whereas linkage also contributed to genome composition through the retention of ancient haplotype blocks (Tykhonova *et al*., 2021).

Studies specifically related to *Kochia prostrata* are also interesting. Thus, the authors (Shamsudinov *et al*., 2021) based on examining the ecological and biological characteristics of wild populations of the fodder draft semishrub *Kochia prostrata* conducted the selection of more productive and environmentally sustainable forms of it to introduce it to the culture in the arid regions of the North-Western Circum-Caspian region. The paper (Djapova *et al*., 2020) presents data on the improvement of natural plant communities through revegetation, including adaptation of revegetative species in buffer zones, tops accumulation depending on the type and age of revegetative species, the effect of fires, etc. Nidyulin *et al*. (2020) compared the feed and seed productivity of three ecotypes of the xerogalophytic fodder half-shrub of *Kochia prostrata* (*Kochia prostrata* (L.) Schrad). In recent studies, attention is also focused on the biological activity and inhibitory potential of new cytotoxic kochiosides from *K. prostrata* (Irfan *et al*., 2020); the effect of Soil Conditions on *K. prostrata* (Shuyskaya *et al*., 2020); influence on establishment and growth of *Bassia prostrata* (L.) (Lauriault & Waldron, 2020). In contrast to them, this study presents research materials on the creation of the Isken variety.

**Conclusions**

According to the generally accepted theory of introgressive hybridisation and the results of the expeditions of the Institute of Plant Industry (Russia) and Kazakh Research Institute of Animal Husbandry and Forage Production, the places (foci) of concentration of natural hybrid populations were identified: Mugodzhar, Torgai, Betpakdalinsk, Malaysarinsk, and Fergana, passing along the border of Kazakhstan.

These introgressive hybrids, which arose as a result of the overlap of the ranges of two subspecies of *K. prostrata* in the process of the evolutionary settlement are of particular interest from the standpoint of applied selection as a new type of source material. Consequently, the discovery of these foci of natural introgression and the knowledge of the processes occurring in them substantially enriched the understanding not only in the field of evolution of the species of *K. prostrata* but also in the field of speciation theory of other important arid plants of Central Asia and Kazakhstan. Based on the theoretical provisions of introgressive hybridisation, the authors launched the studies on the creation of the Isken variety, the materials of which were presented in this study (Kazniizhik, Almaty, Kazakhstan).

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