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Gramineous fraction of the invasive flora of the Caucasus

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Abstract
Aim. Questions about the invasive flora of the Caucasus regions are a most important issue under discussion. The aim of the research is to identify the species composition of the family Poaceae, which are alien to the Western Caucasus, and their distribution over the floristic regions of the Caucasus.
Material and Methods. Material: Disturbed communities. Methods: analysis of herbarium collections, route reconnaissance studies of the territory of the Western and Eastern Caucasus, detailed geobotanical route studies with photography, population mapping and analysis of literary sources.
Results. 96 invasive cereal species in the territory of the Western Caucasus and the Ciscaucasia were identified and their current geographical distribution shown. 5 levels of danger have been established in terms of the amount of invasive cereal flora in the floristic regions of the Caucasus. An ecological analysis is given for 96 species of cereals in the Caucasus.
Conclusion. 96 invasive cereal species were identified and their current geographical distribution in the territory of the Western Caucasus and the Ciscaucasia shown. 5 levels of danger have been established in terms of the amount of such invasive flora in the Caucasus' floristic regions. An ecological analysis is given for these 96 invasive species of cereals.

Key Words
Caucasus, Western and Eastern Caucasus, invasive plants, family Poaceae, natural and disturbed communities, geographical distribution, level of invasive danger, species status.

Злаковая фракция инвазионной флоры Кавказа

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Резюме
Цель. Вопросы об инвазионной флоре регионов Кавказа – важнейший обсуждаемый вопрос. Цель исследований – выявление видового состава семейства Poaceae, являющихся чужеродными для Западного Кавказа и их распространение по флористическим районам Кавказа.
Материал и методы. Материал. Нарушенные сообщества. Методы: анализ гербарных коллекций, маршрутные рекогносцировочные исследования территории Западного и Восточного Кавказа, детально-маршрутные геоботанические исследования с фотографированием, картированием популяций; анализ литературных источников.
Результаты. Выявлено 96 инвазионных видов злаков. Показано современное географическое распространение инвазионных видов злаков по территории Западного Кавказа и Предкавказья. Установлено 5 уровней опасности по количеству инвазионной злаковой флоры по флористическим районам Кавказа. Дан экологический анализ 96 видам злаков Кавказа.
Заключение. На территории Западного Кавказа и Западного Предкавказья виды инвазионной злаковой флоры имеют широкое распространение по всем флористическим округам Кавказа. Родиной большинства видов являются древние центры земледелия. К регионам самого высокого первого уровня опасности относится Черноморское побережье. Уровень второй опасности характерен для Западного Предкавказья, Восточного Закавказья и Талыша.

Ключевые слова
Кавказ, Западный и Восточный Кавказ, инвазионные растения, семейство Poaceae, природные и нарушенные сообщества, географическое распространение, уровень инвазионной опасности, статус видов.

INTRODUCTION

In the conservation of biological ecosystem diversity, the problem of invasions of alien species is of great importance [1]. The process of flora enrichment with alien species can be catastrophically fast and the problem has become urgent in many countries [2; 3]. In the flora of Eastern Europe, 1148 adventive species have already been recorded [4]. For the Caucasian ecoregion, the problem of invasive interference in the structure of the vegetation cover is extremely important. The problem of coastal adventisation was raised in the 1980s [5]. There is information on the number of recorded invasions in individual territories: 252 adventive vascular species are given for the North-West Caucasus [6], 140 species for the Black Sea coast [7], 44 species for the urban forests of Sochi [8], 39 species have penetrated in the middle and upper mountain belts of the Western Caucasus [9], 33 species for the coastal Azov zone (Verbyanaya spit) [10], 28 species for the basin of the Mzymta River [11], 32 species for the Caucasian Biosphere Reserve [12] and 102 species for the Central Caucasus (Kabardino-Balkaria) [13]. For the Eastern Caucasus (Azerbaijan), 18 introduced species of cereals are represented (*Arthraxon centrasiaticus* (Griseb.) Gamajun.(=*A. hispidus* (Thunb.), *Arundo donax* L., *Beckmannia syzigachne* (Steud.) Fernald, *Bromus hordeaceus* L., *Ceratochloa carinata* (Hokk.et Arn.) Tutin (=*Bromus carinatus*, *C. cathartica* (Vahl) Herter (= *Bromus catharticus*), *Chloris virgata* Sw., *Digitaria ciliaris* (Retz.) Koeler, D. *horizontalis* Willd., *D. violascens* Link, *Echinochloa crus-galli* (L.) P. Beauv., *Eleusine indica* (L.) Gaertn., *E. tristachya* (Lam.) Lam, *Elymus canadensis* L., *Paspalum dilatatum* Poir., *P. thunbergii* Kunth ex Steud., *Pennisetum alopecuroides* (L.) Pers, *Sorghum halepense* (L.) Pers., *S. technicum* (Koern.) Batt.et Trab.) [14]. In 2020, during expeditionary trips to the Kura-Araz lowland, *Bromus secalinus* L. was found as a single species, which is commented on as "Weed species introduced to the Caucasus from the north with a possible finding in Azerbaijan" [15, p. 299]. It is possible that this is not the total number of invasive cereals in the region. The main part of the above species is concentrated in the areas of cotton, tea, rice, tobacco cultivation on well-irrigated and wet plantations (Greater Caucasus western botanical-geographical region, Kura-Araz lowland and Talysh). Their introduction is most likely associated with the long-standing cultivation of the above crops. It should be noted that introduced cereal in Azerbaijan are not as aggressive as in other regions of the Caucasus, with the exception of representatives of the genera *Paspalum* L. and *Digitaria* Hall.

For the regions of the Caucasus, where a high concentration of phytoinvasions is noted, a high level of the introduction process is characteristic, which is recognized as one of the main reasons for the disturbance of biodiversity [16]. For the Sochi region of the Black Sea coast, 167 invasive species are indicated, of which 30 species belong to the family Poaceae [17]. According to A. Kolakovsky, 36 species of alien cereals grow in Abkhazia [18].

According to the latest summary of the cereal flora within the territory of Krasnodar Territory (WC, WC, NWT, part of WT) [19], the growth of 96 (79 according to WFO) species of the family Poaceae considered to be invasive was established. Strict control and management of the spread of introduced species and the adoption of precautionary measures in all regions of the Caucasus are necessary.

MATERIAL AND METHODS

The material investigated was disturbed communities. The following methods were employed: analysis was carried out of herbarium collections of the Botanical Institute of the Russian Academy of Sciences (LE), the Caucasian Biosphere Reserve, the I.S Kosenko Herbarium named (KBAI), the Herbarium of the Institute of Botany of the Azerbaijan National Academy of Sciences (BAK) in order to establish the geographical distribution and the time of the first fixation of species; route reconnaissance studies in the territory of the Western and Eastern Caucasus, detailed route (territorial) geobotanical studies with photography, population mapping and analysis of literary sources. The levels of danger by the number of invasive cereal species in the flora of the regions were highlighted as follows: the first level – more than 90 species, the second level of danger – 50-60 species; the third -40-50, the fourth – 30-40 alien species, the fifth (the lowest) – up to 20 species. The aggressiveness status of the species was established according to O.G. Baranova [20]: biocoenosis transformers, phytocenosis transformers and ruderal cenosis formers.

RESULTS

Information on invasive species of the family Poaceae is somewhat contradictory. According to the latest monographic summary on Russia, 96 species of Poaceae growing in the Western Caucasus and Western Ciscaucasia [19] can be classified as invasive, according to the Conspectus of the Flora of Caucasus – 83 species in the North-Western Caucasus (in total about 110 species for the Caucasus) [21], according to the WCVP taxonomic database [World Checklist of Vascular Plants, version 2.0] – 80 species [22] (Table 1).

Invasive cereal flora were recorded in all floristic regions of the Caucasus (Table 2).

The first finds of alien cereals on the Black Sea coast date back to the end of the 19th century and the beginning of the 20th century. The species *Vulpia bromoides* (L.) Gray (*Festuca bromoides* L.) was first recorded in 1888, *Andropogon virginicus* (L.) was introduced to Abkhazia (Lake Bebsyr) in 1947 [18], *Briza maxima* L. (*Macrobriza maxima* (L.) Tzvelev) was first collected in 1935 and the first finds of *Echinochloa crus-galli* (L.) P. Beauv. date back to 1909. *Polypogon monspeliensis* (L.) Desf.was registered in 1911 on the outskirts of the Markotkh Range above Gelendzhik Bay [6.VI.1911, Palibin, Vorobiev, LE], *Sorghum dochna* (Forssk.) Snowden (*Sorghum bícolor* (L.) Moench) in 1908 – near Maikop near the Kurdzhips River [24.VIII.1908, Shestunov, LE]. *Setaria pumila* (Poir.) Roem. et Schult was registered in the Achiskho Range [4.VIII.1915, Аблецов, LE], st. Grigoropolisskaya [12.VII.1918, Shteyp, LE], in urban settlements of Kabardino-Balkaria [30.VII.1923, Poyarkova, LE] and in the Chernorechenskaya guard house in an opening on the right bank of the Black Brook [20.VII.1928, Leskov, LE].

Table 1. Generic spectrum of invasive taxa of the family Poaceae in the Western Caucasus and Western Ciscaucasia
Таблица 1. Родовой спектр инвазивных таксонов семейства Poaceae на Западном Кавказе и Западном Предкавказье

Taxon Таксон	**Quantity** Количество	**Taxon** Таксон	**Quantity** Количество	**Taxon** Таксон	**Quantity** Количество
Sasa	2 (2)	*Polypògon*	2(2)	*Erióchloa*	1(1)
Pseudosasa	1(1)	*Lolium*	1(1)	*Páspalum*	4(4)
Pleioblastus	2(2)	*Echinochloa*	6(2)	*Digitaria*	5(4)
Phyllostachys	3(3)	*Microstégium*	2(2)	*Setaria*	6(4)
Trachinia (*Brachypodium*)	1(1)	*Phalaroides* (*Phalaris*)	1(1)	*Pennisétum* (*Cenchrus*)	3(2)
Zizania	2(2)	*Phalaris*	2(2)	*Cenchrus*	1(1)
Triticum	2(2)	*Cortadéria*	1(1)	*Miscanthus*	2(1)
Ceratochloa (*Bromus*)	2(2)	*Macrobriza* (*Briza)*	1(1)	*Vúlpia* (*Festuca*)	2(2)
Bromus	1(1)	*Sieglingia* (*Danthonia*)	1(1)	*Sorghum*	6(3)
Secale	1(1)	*Eleusine*	2(2)	*Andropógon*	1(1)
Hordeum	6(6)	*Muhlenbergia*	1(1)	*Arthráxon*	3(1)
Avena	9(6)	*Sporobolus*	1(1)	*Zea*	1(1)
Avena (*Ventenata*)	(1)	*Oplismenus*	1(1)	*Coix*	1(1)
Anthoxánthum	1(1)	*Pánicum*	6(4)	*Oryza*	1(1)

Note: numbers in brackets – WCVP data, numbers without brackets – data of N. Tsvelev and N. Probatova [19]
Примечание: цифры в скобках – данные WCVP, цифры без скобок – данные Н. Цвелева, Н. Пробатовой [19]

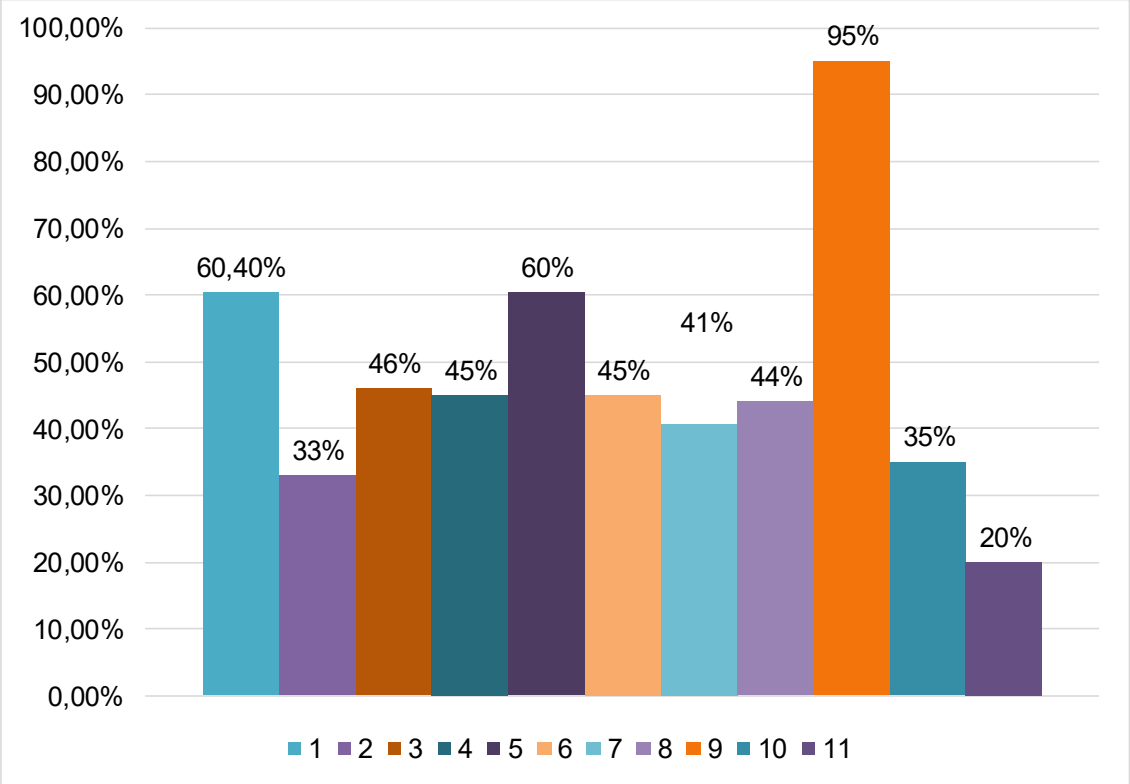
Table 2. Distribution of the cereal fraction of invasive species of the Western Caucasus and Western Ciscaucasia in the floristic regions of the Caucasus [22; 23]
Таблица 2. Распределение злаковой фракции инвазивных видов Западного Кавказа и Западного Предкавказья по флористическим районам Кавказа [22; 23]

Floristic region of the Caucasus Флористический район Кавказа	**Number of species** Количество видов	**Floristic region of the Caucasus** Флористический район Кавказа	**Number of species** Количество видов
WC (**Western Ciscaucasia**) ЗП (Западное Предкавказье)	58/60,4%	**NWT** (**Northwest Transcaucasia**) СЗЗ (Северо-Западное Закавказье)	42/44%
Az.-Kub. (Azov-Kuban) Аз.-Куб. (Азово-Кубанский)	48	**Anap.-Gel. (Anapa-Gelendzhik)** Анап.-Гел. (Анапа-Геленджикский)	28
EC (**Eastern Ciscaucasia**) ВП (Восточное Предкавказье)	32/33%	**Pshad.- Dzhubg. (Pshada-Dzhubga)** Пшад.-Джубг. (Пшадско-Джубгский)	7
WC (**Western Caucasus**) ЗК (Западный Кавказ)	44/46%	**WT (Western Transcaucasia)** ЗЗ (Западное Закавказье)	91/95%
Adag.-Pshish. (Adagum-Pshishskiy) Адаг.-Пшиш. (Адагум-Пшишский)	15	**Tuap.-Adl. (Tuapse-Adlersky)** Туап.-Адл. (Туапсе-Адлерский)	76
Belo.-Lab. (Belo-Labinsky) Бело.-Лаб. (Бело-Лабинский)	32	**Abkh. (Abkhazian)** Абх. (Абхазский)	61
Urup-Teb. (Urup-Teberda) Уруп.-Теб. (Уруп-Тебердинский)	6	**Adzh. (Adzhar)** Адж. (Аджарский)	32
EC (Eastern Caucasus) ВК (Восточный Кавказ)	43/45%	**T (Talysh)** Т (Талыш)	53/55%
ET (Eastern Transcaucasia) ВЗ (Восточное Закавказье)	58/60,4%	**CT (Central Transcaucasia)** ЦЗ (Центральное Закавказье)	34/35%
ST (South Transcaucasia) ЮЗ (Южное Закавказье)	43/45%	**SWT (Southwest Transcaucasia)** ЮЗЗ (Юго-Западное Закавказье)	19/20%
CC (Central Caucasus) ЦК (Центральный Кавказ)	39/40,6%		

Quantitative indicators of an invasive complex depend on natural (climate, relief and soil) and anthropogenic factors (duration of historical development, population density and economic development). The main centres of invasions are the coastal regions of the Black Sea and Caspian coasts of the Caucasus. The first is Western Transcaucasia, the second Talysh (58 species) and the third Eastern Transcaucasia (Absheron Peninsula – 61 species) (Fig. 1).

A number of species have a localised distribution and are confined only to the Abkhazian (*Aristida longespica* Poir.) and Adjara floristic regions (*Hemarthria altissima* (Poir.) Stapf et C.E. Hybb, *Arrhenatherum bulbosum* (Willd.) C. Presl, *Eragrostis nigra* Nees ex Steud., *E. frankii* C.A. Mey. ex Steud., *Oplismenus burmannii* (Retz.) Beauv.), Absheron Peninsula (*Aegilops uniaristata* Vis., *Elymus canadensis* L., *Stipagrostis pennata* (Trin.) De Winter) or Talysh floristic region (*Hordeum brevisubuatum* (Trin.)

Link., *Bromus hordeaceus* (L.), *Beckmannia syzigochne* (Steud.) Fern., *Eragrostis curvula* (Schrad.) Nees, *Oplismenus compositus* (L.) Beauv. But the invasions of cereals do not recognize the borders of states and rapidly expand their areas, quite calmly spreading along the coastal zones from Abkhazia to the territory of Russia, from Dagestan to Azerbaijan and vice versa. From Abkhazia to the Sochi region of Russia is the usual route of a number of invasive species. The species *Vulpia bromoides* (L.) Gray in 1888 was found by Tatarinov in the vicinity of Sukhumi [LE] and six years later in Sochi and Uch-Dere [17.V.1895, Lipsky, LE; 29.V.1895, Lipsky, LE], in 1901 – Kuchuk-Dere [1.V.1901, Hryniewiecki, LE]. *Andropogon virginicus* L. was introduced to Abkhazia (Lake Bebsyr) in 1947 [18], in 1955 it was registered in Sochi (park of the Belorussia sanatorium) [29.V.1955, Kotov? LE] and in 1962 was found on a steep slope to the sea and the slopes of railroad lines to the west of the Dagomys station [25.IX.1962, Tsvelev, LE]. By 1996 it was already in Novomikhailovskoe (USSR Orlyonok Pioneer Camp) [15.IV.1996, Chernovol].



Symbols: 1. WC; 2. EC; 3. WC; 4. EC; 5. ET; 6. ST; 7. CC; 8. NWT; 9. WT; 10. CT; 11. SWT
Условные обозначения 1. ЗП; 2. ВП; 3. ЗК; 4. ВК; 5. ВЗ; 6. ЮЗ; 7. ЦК; 8. СЗЗ; 9. ЗЗ; 10. ЦЗ; 11. ЮЗЗ
Figure 1. Quantitative indicators of invasive cereal flora in the floristic regions of the Caucasus
Рисунок 1. Количественные показатели инвазивной злаковой флоры во флористических районах Кавказа

The Black Sea coast has been used by humans as a migration route since before the 3rd millennium BC. The Cimmerians and Scythians moved along the Maeotis-Colchis route to South Transcaucasia, which was mastered by the Greeks from the 7th century BC, which contributed to the spread of European and Mediterranean species. Later there was Roman and Turkish colonization. The boom of introduction of the 18th-20th centuries expanded the geography of invasions. At present on the Black Sea coast of the Caucasus the maximum number of invasive cereal species has been recorded in Abkhazia – 62 species, Adzhar – 37, Anapa-Gelendzhik region – 28, Pshada-Dzhubga – 8, Tuapse-Adler – 76 (Fig. 2).

Analysis of the growth of 96 invasive species of the family Poaceae in the floristic regions of the Caucasus showed that a species can grow in 5-6 floristic regions or have a limited distribution. Most invasive cereal species are widespread: 44 species (45%) grow in more than 5 regions – group 6,4% – in 5. It was revealed that only 15% of species are confined to one floristic region (group 1), 14% – to 2 regions, 12% – to 3 regions and 8% (4 species) – to 4 regions (Fig. 3).

The determination of the number of alien species of cereals in each floristic region of the Caucasus [20] made it possible to assess the degree of invasive danger. The regions of the first and highest level of danger include the Black Sea coast (WT), where more than 90 species of invasive cereals have been recorded (Tuap.-Adl. – 76, Abkh. – 61, Adzh. – 32). This is a region where natural and climatic conditions favor the invasive process. The second danger level is typical for Western Ciscaucasia (WC), Eastern Transcaucasia (ET) and Talysh and the third for South Transcaucasia (ST), North-West Transcaucasia (NWT) and Western and Eastern Caucasus (WC, EC). The low level is typical for Eastern Ciscaucasia, the mountainous regions of the Central Caucasus (CC) and Central Transcaucasia (CT) and the lowest is noted for the Southwest Transcaucasia (SWT) (Fig. 4).

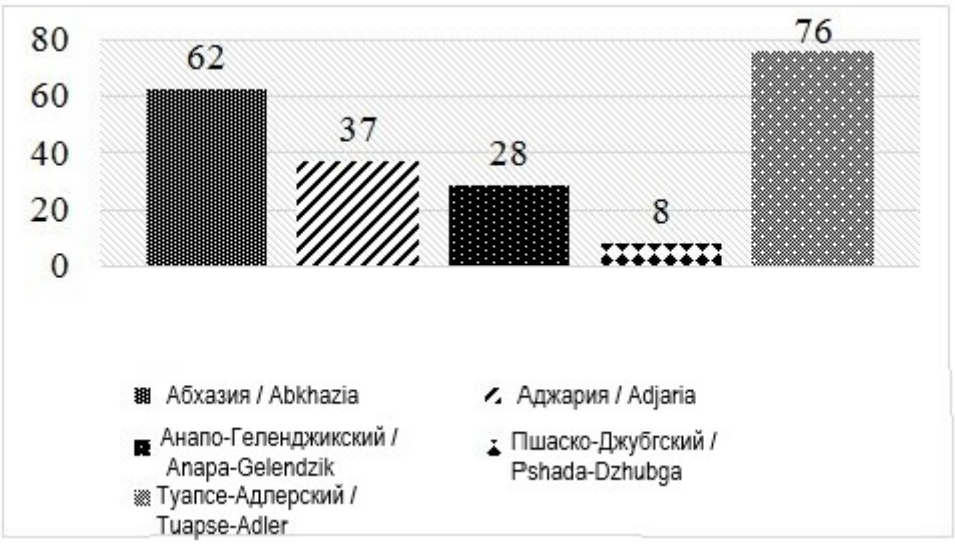
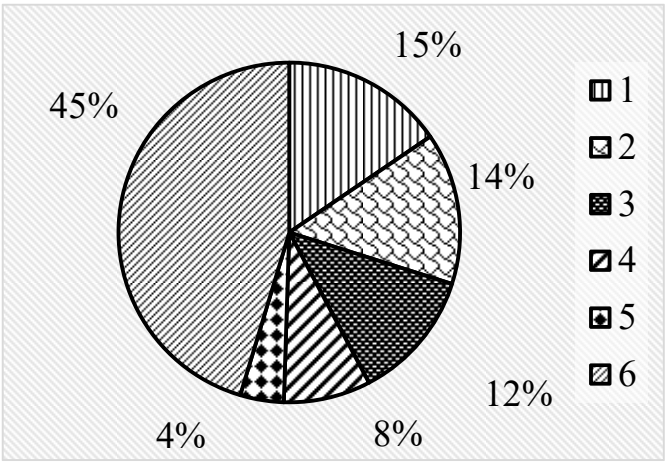


Figure 2. Quantitative indicators of invasive cereal flora in the floristic regions of the Black Sea coast of the Caucasus
Рисунок 2. Количественные показатели инвазионной злаковой флоры во флористических районах Черноморского побережья Кавказа



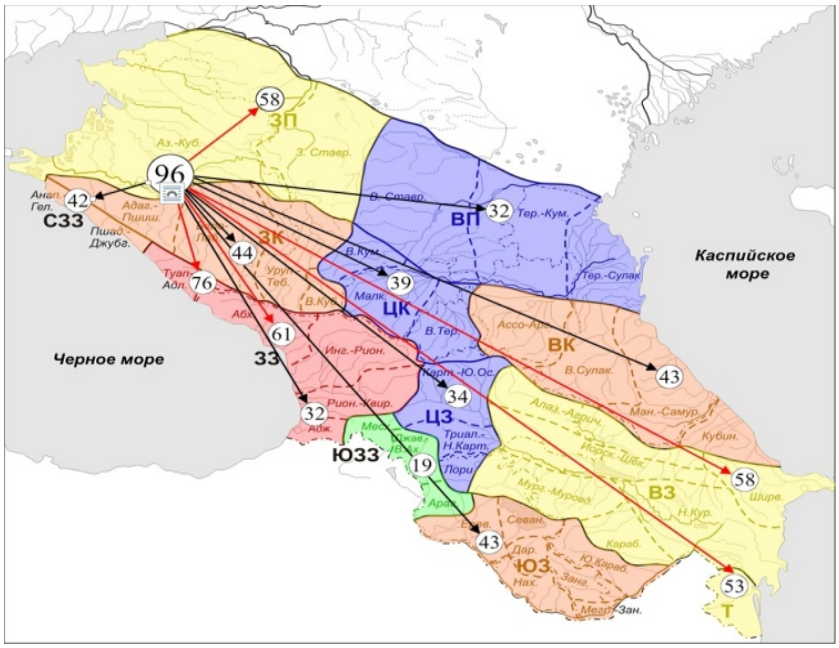
Symbols: 1. The species is noted in 1 district; 2. in 2 districts; 3. in 3; 4. in 4; 5. in 5 and 6. in more than 5 districts
Условные обозначения: 1. Вид отмечен в 1-м районе; 2. В 2-х районах; 3. В 3-х; 4. В 4-х; 5. В 5-ти; 6. Более 5-ти районов
Figure 3. Number of cereal species associated with an individual floristic region
Рисунок 3. Количество видов злаков, приуроченных к одному флористическому району

There are also species for which natural and climatic conditions play a decisive role in the development of biotopes. These are mainly introduced from subtropical regions (*Phyllostachys aurea* Rivière et C. Rivière, *Phyllostachys bambusoides* Siebold et Zucc. (*P. reticulata* Rupr.) K. Koch), *Pleioblastus fortune* (Van Houtte) Nakai and cereals of accidental drift, which are native to Southeast Asia, Japan, China (*Oplismenus undulatifólius* Ard.) P. Beauv., *Pennisetum alopecuroides* (L.) Spreng. (L.) Spreng. (*Cenchrus setosus Sw.* subsp. *setosus*), *Sorghum dochna* (Forssk.) Snowden and *Miscanthus sinensis* Andersson, and less commonly from North America (*Andropogon virginicus* L.) (Fig. 5).

Some species are characterized by high occurrence in the territories of the floristic regions, but there are few of them. Maps of the geographical distribution of the six most common invasive cereals in the Western Caucasus and Western Ciscaucasia were compiled. It was established that they are not confined to a certain type of vegetation or to natural and climatic indicators and belong to therophytes. Their distribution is diffuse (Fig. 6).

Analysis of the place of the initial range of invasive cereals showed that most species are native to ancient centres of agriculture in South, South East, East and Central Asia (*Pleioblastus fortunei, Phyllostachys aurea*, *P. bambusoides* (China), *P. viridiglaucescens* (Carrière) Rivière et C. Rivière (China), *Oryza sativa* L., *Triticum aestivum* L., *Phalaris minor* Retz., *Eleusine indica* (L.) Gaertn., *Sporobolus fertilis* (Steud.) Clayton, *Oplismenus undulatifolius*, *Echinochloa crus-gálli* **(**trop. Asia), *Panicum miliaceum* L. (India or China), *P. ruderale* (Kitag.) D.M. Chang (India or China), *P. sumatrensis* Roth (trop. Asia), *Echinochloa crus-galli* (trop. Asia), *E. oryzicola* (Vasinger) Vasinger (trop. Asia), *E. oryzoides* (Ard.) Fritsch (trop. Asia), *E. tzvelevii* Mosyakin ex Mavrodievet H. Scholz (trop. Asia), *Paspalum thunbergii* Kunth ex Steud. (Japan-China), *Digitaria asiatica* Tzvelev, *D. Ciliaris* (Retz.) Koeler (trop. Asia), *D. violascens* Link, *Setaria faberi* R.A.W. Herrm. (Japan, China), *S. germanica* (Mill.) P. Beauv., *S. italica* (L.) P. Beauv. (India), *S. pachystachys* (Franch. et Sav.) Matsum. (Japan, China), *Pennisetum alopecuroides*, *P. Glaucum* (L.) R. Br. (trop. Asia), *Miscanthus sinensis* (Japan, China), *M. purpurascens* Andersson (Japan, China), *Sorghum dochna* (trop. Asia, India), *Sorghum technicum* (Körn.) Trab. (Central Asia) and East Asia (*Zizania latifolia*(Griseb.) Turcz. ex Stapf, *Polypogon fúgax* Nees ex Steud., *Echinochlo*

acaudáta Roshev, *Eriochloa villosa* (Thunb.) Kunth (Far East), *Microstegium japonicum* (Miq.) Koidz. (Japan), *Microstegium vimineum* (Trin.) A. Camus (South Asia), *Sasa palmata* (Burb.) E. G. Camus (Hokkaido, northern Honshu), *S. veitchii* (Carrière) Rehder (Japan), *Pseudosasa japonica* (Siebold et Zucc. ex Steud.) Makino ex Nakai, *Pleioblastus distichus* (Mitford) Nakai, *Phalaroides japonica* (Steud.) Czerep., *Arthráxon hispidus* (Thunb.) Makino (Japan).

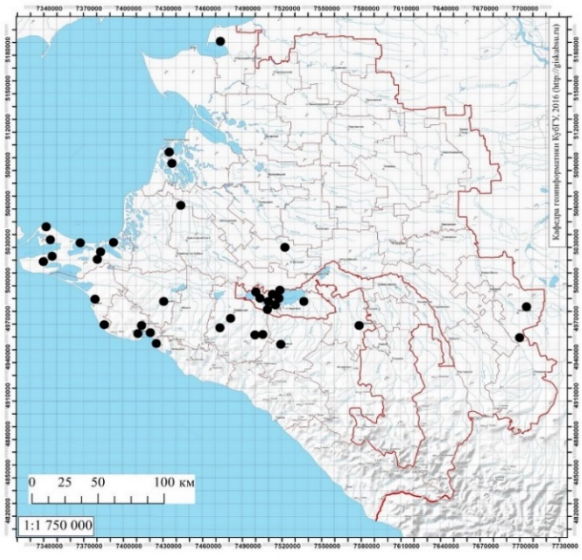


Level of danger: level 1/ level 2 / level 3/ level 4/ level 5/
Уровни опасности: уровень 1 уровень 2 уровень 3 уровень 4 уровень 5

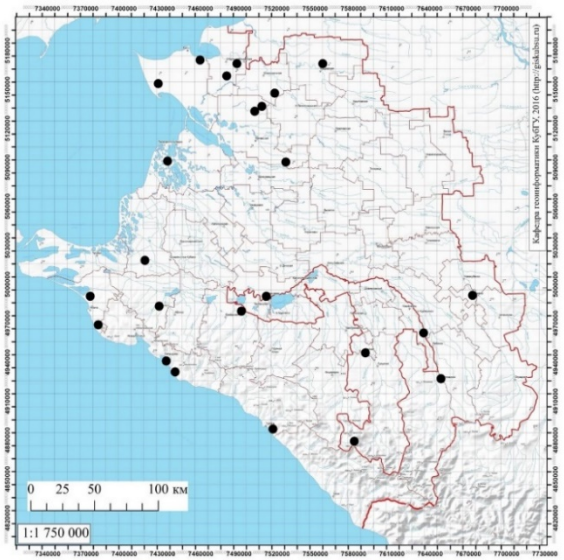
Figure 4. Floristic regions of the Caucasus according to the level of invasive cereal danger
Рисунок 4. Флористические районы Кавказа по уровню инвазионной злаковой опасности

Figure 5. Geographic distribution of *Andropogon virginicus,* Adler, 17.04.2010
Рисунок 5. Географическое распространение *Andropogon virginicus* Адлер, 17.04.2010

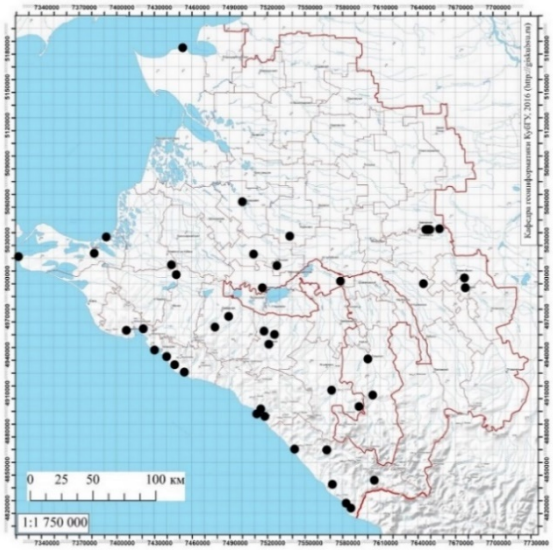
Invasions from America take second place: from North America (*Zizania palustris* L., *Hordeum jubatum* L., *Ceratochloa carinata* (Hook. et Arn.) Tutin (*Bromus carinatus* Hook. et Arn.), *Muhlenbergia schreberi* J. F. Gmel., *Panicum barbipulvinatum* Nash ex Rydb., *Panicum capilláre* L., *Panicum dichotomiflórum* Michx., *Paspalum distichum* (L.), *P. setaceum* Michx., *Digitaria ischaemum* (Schreb.) Muhl., *Cenchrus longispinus* (Hack.) Fernald, *Andropogon virgínicus*) and from South America: (*Ceratochloa cathartica* (Vahl) Herter (*Bromus catharticus* Vahl), *Cortaderia selloana* (Schult. et Schult. F.) Asch. et Graebn., *Eleusine tristachya* (Lam.) Lam., *Paspalum dilatatum* Poir., *Zea mays* L., *Ceratochloa cathartica* (Vahl) Herter, *Cortaderia selloana* (Schult. et Schult. f.) Asch. et Graebn. The Mediterranean is also home to certain invasive species (*Sorghum halepense* L. Pers. – North Africa, Mediterranean (*Hordeum geniculatum, H. glaucum*, *Avena barbata* Pott ex Link, *Avena byzantina* K. Koch, *Avena sterilis* L., *Anthoxanthum amarum* Brot., *Lolium multiflorum* Lam., *Vulpia bromoides*, *V. ciliata* Dumort., *Briza maxima* L., *Phalaris canariensi* L., *Sorghum cernuum* (Ard.) Host) and Southwest Asia (*Secale cereale* L.). The largest number of invasive cereal species on the Black Sea coast is associated with America, the East and Southeast Asian regions (50) and the Mediterranean (20).



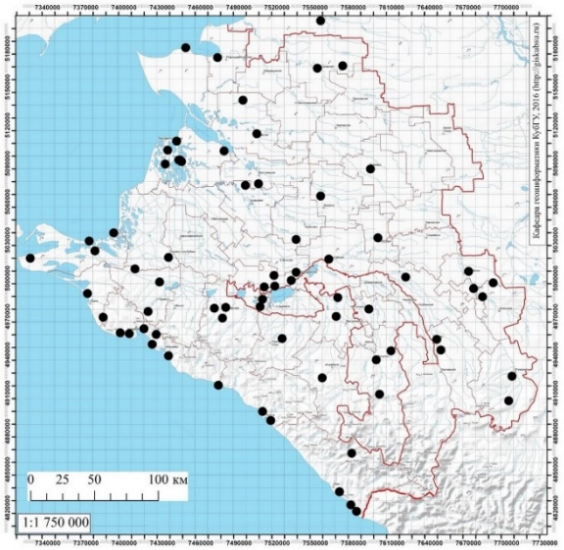
Hordeum geniculatum All.



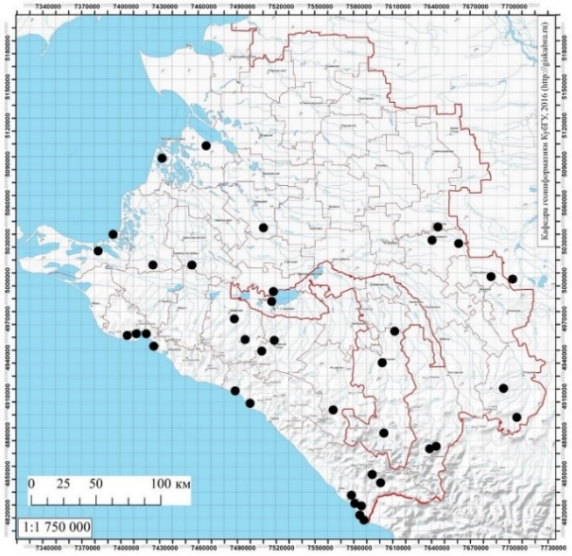
Avena fatua L.



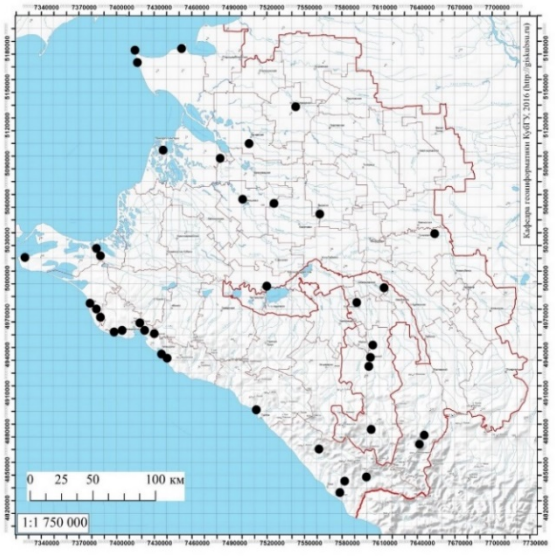
Digitaria sanguinális (L.) Scop.



Echinochloa crus-gali (L.) P. Beauv.



Setaria pumila (Poir.) Roem. et Schult.



Setaria viridis (L.) P. Beauv.

Figure 6. Geographic distribution of annual invasive species
Рисунок 6. Географическое распространение однолетних инвазивных видов

To understand the strategy of alien species, ecological characterization is of great importance. The ecological analysis of 96 invasive cereals of the Caucasus showed that more than 70% belong to the therophytes life form (Fig. 7).

Water and light are essential factors in the spread of invasive species. In hydromorphic terms the invasive cereal flora is mesophilic (Fig. 8), and photophilous in heliomorphic terms (Fig. 9). In other words, the main places that alien species develop are fairly humid and open biotopes.

Invasive species of family Poaceae mainly belong to the "soft invasive species" of the ruderal and segetal flora. Many of them were deliberately moved outside their natural range. The introduction was carried out for a specific economic purpose such as: decorative (*Coix lacryma-jóbi* L., *Briza maxima*), fodder (*Ceratochloa cathartica*, *Hordeum distichon*, *Avena sativa*) and food. Some of them became wild and naturalised into plant communities and, having overcome ecological, geographic and coenotic barriers, passed into the category of invasive plants. There are more than 40 naturalised invasive species, including *Zizania latifolia, Zizania palustris, Eleusine indica, Sporobolus fertilis*, *Panicum capillare* and *Cenchrus longispinus*. Western Transcaucasia is a centre for the deliberate introduction of aesthetically important ornamental plants. The process of creating arboretums and household collections began from the moment of the colonisation of the Black Sea coast in the 18th century. Currently, there are many decorative wild species in Western Transcaucasia (*Sasa palmata, Sasa veitchii*, *Pseudosasa japonica*, *Pleioblastus fortunei*, *Phyllostachys aurea*, *P. bambusoides*, *P. viridiglaucescens* and *Cortaderia selloana*).

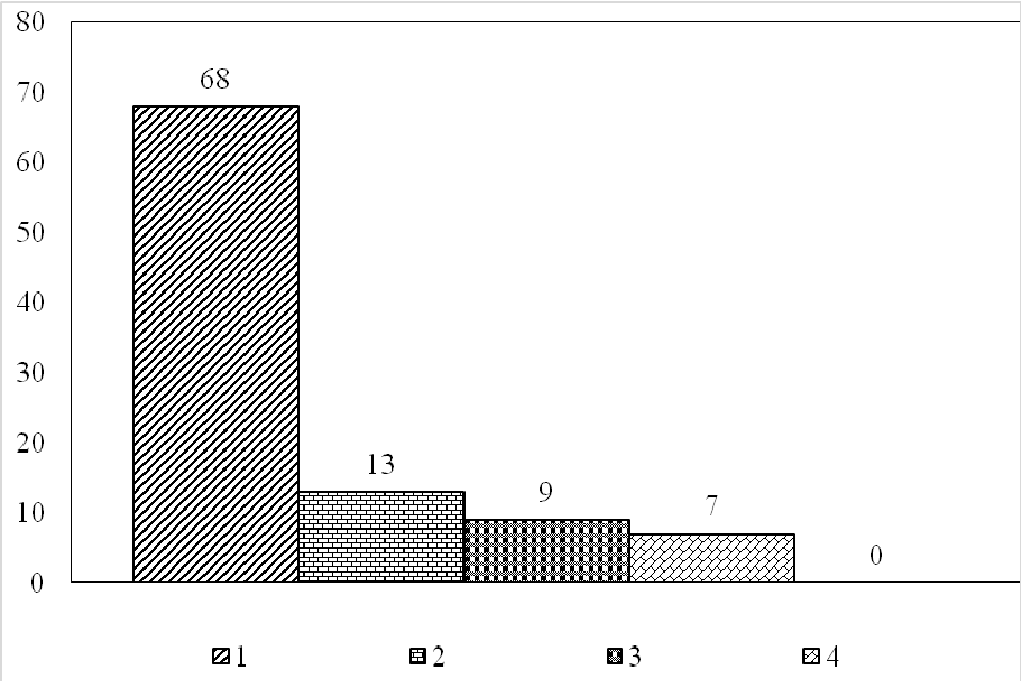


Figure 7. Distribution of invasive cereals by life forms (according to Raunkier C. [24])
Symbols: 1 – Therophytes, 2 – Hemicryptophytes, 3 – Geophytes, 4 – Cryptophytes
Рисунок 7. Распределение инвазивных злаков по жизненным формам (по К. Раункиеру [24])
Условные обозначения: 1 – Терофиты, 2 – Гемикриптофиты, 3 – Геофиты,4 – Криптофиты

We have identified several types of anthropogenic and natural habitats to which the invasive cereal flora is confined: 1. Segetal: a) gardens, parks, plantations of subtropical crops, b) crops, fields, vineyards, vegetable gardens, c) rice crops; 2. Ruderal: a) roadsides, pastures, vacant lots, b) settlements.

The following natural biotopes have been identified: 1. Riverside and coastal sands and pebbles; 2. Wet meadows, wetlands and waterlogged places; 3. Post-forest open stony and fine-earth slopes, sparse shrubs, forest edges; 4. Coastal sand and shell spits; 5. shibliak, dry steppes; 6. Saline biotopes (salt marshes); 7. Forest communities.

The maximum amount of invasive cereal flora is associated with ruderal and segetal communities. 27 species grow in gardens, parks, on plantations of subtropical crops: *Arthraxon langsdorffii*, *A. hispidus*, *Andropogon virginicus*, *Sorghum halepense*, *Microstegium imberbe*, *M. japonicum*, *Miscanthus purpurascens*, *Pennisetum alopecuroides*, *Setaria pumila*, *S. pachystachys*, *S. faberi*, *Digitaria violascens*, *D. horizontalis*, *Paspalum thunbergii*, *P. setaceum*, *P. distichum*, *Echinochloa crus-galli*, *Anthoxanthum amarum*, *Lolium multiflorum*, *Vulpia bromoides*, *Phalaris minor*, *Eleusine indica*, *Muhlenbergia schreberi*, *Sporobolus fertilis*, *Oplismenus undulatifolius*, *Panicum dichotomiflorum*, *P. sumatrense*.

23 species have been registered in agricultural landscapes (crops, fields, vineyards and vegetable gardens) (*Sorghum technicum*, *S. dochna*, *Setaria pachystachys*, *S. germanica*, *S. faberi*, *Digitaria ischaemum*, *D. asiatica*, *Paspalum thunbergii*, *P. distichum*, *Eriochloa villosa*, *Echinochloa crus-galli*, *Hordeum vulgare*, *Ceratochloa cathartica, Avena barbata*, *A. cultiformis*, *A. fatua*, *A. orientalis*, *A. sativa*, *Lolium multiflorum*, *Phalaris canariensis*, *P. minor*, *Panicum capillare, P. ruderale*). Species growing on paddy fields (7 species) were identified separately: *Eriochloa villosa*, *Echinochloa minor, E. oryzoides*, *E. caudata*, *E. oryzicola*, *Oryza sativa*, *Panicum sumatrense*. They appeared in the 1930s in the first wave of rice cultivation. Growing in agrocoenoses and forming segetal communities, they do not significantly affect the productivity of agrocoenoses. Most often, in disturbed

biotopes, they form one-season monodominant communities. Two groups were identified in ruderal communities, associated with ecotopes of roadsides, pastures, wastelands and within settlements. First recorded was the growth of 55 species (*Arthraxon langsdorffii*, *A. centrasiaticus*, *Andropogon virginicus, Sorghum technicum*, *S. halepense*, *Microstegium imberbe*, *M. japonicum*, *Miscanthus sinensis*, *Cenchrus longispinus*, *Pennisetum alopecuroides*, *Setaria verticillata*, *Setaria pumila*, *S. italica*, *S. faberi*, *Digitaria violascens*, *D. ischaemum*, *D. horizontalis*., *D. ciliaris*, *Paspalum thunbergii*, *P. setaceum*, *P. distichum*, *P. dilatatum*, *Trachinia distachia*, *Triticum aestivum*, *T. durum*, *Secale cereale*, *Hordeum distichon*, *H. jubatum*, *H. glaucum*, *H. vulgare*, *Ceratochloa carinata*, *C. cathartica*, *Avenabarbáta*, *A. fatua*, *A. intermedia*, *A. orientalis*., *A. sativa*, *A. sterilis*, *Polypògon fúgax*, *P. monspeliénsis*, *Vúlpia bromoídes*, *V. ciliáta*, *Briza maxima*, *Phalaris canariensis, Cortaderia selloana*, *Eleusine indica*, *E. tristachya*, *Muhlenbergia schreberi*, *Sporobolus fertilis*, *Panicum capilláre*, *P. miliaceum* and *P. ruderale*).

On the territory of settlements are noted: *Sorghum halepense*, *Pennisetum alopecuroides*, *Setaria pachystachys*, *S. italica*, *S. germanica*, *S. faberi*, *Digitaria ischaemum*, *D. asiatica*, *Eriochloa villosa*, *Echinochloa spiralis*, *E. crus-galli*, *Triticum aestivum*, *T. durum*, *Secale cereale*, *Hordeum jubatum*, *H. glaucum*, *H. murinum*, *Ceratochloa cathartica, Avena barbata*, *A. cultiformis*, *A. georgica*, *A. intermedia*, *A. sterilis*, *Vulpia bromoides*, *V. ciliata*, *Phalaris canariensis*, *Eleusine indica*, *Muhlenbergia schreberi*, *Sporobolus fertilis*, *Panicum dichotomiflorum*, *P. miliaceum*, *Panicum ruderale* – 32 species (Fig. 10).

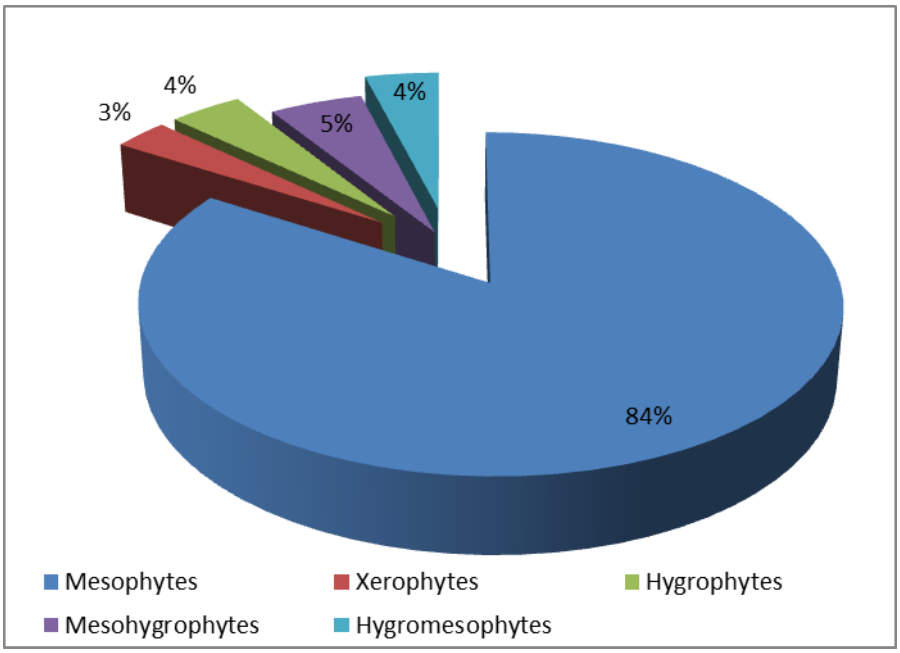


Figure 8. Distribution of invasive cereal species in relation to water
Рисунок 8. Распределение инвазивных видов злаков по отношению к воде

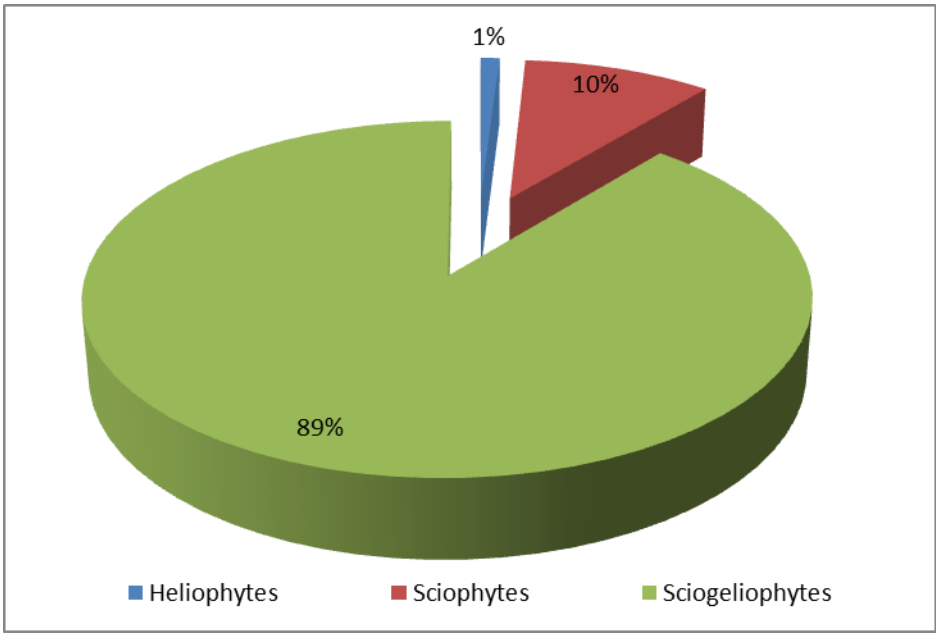


Figure 9. Distribution of invasive cereal species in relation to light
Рисунок 9. Распределение инвазивных видов злаков по отношению к свету

Pennisétum alopecuroides (L.) Spreng. *Eleusine indica* (L.) Gaertn.

Figure 10. Species growing in settlements
Рисунок 10. Виды, произрастающие в населенных пунктах

There are species that are characterized by the "universality" of the development of their living space. Thus, *Echinochloa crus-galli* has a wide range of syntaxonomic and ecological confinement: weedy places, yew-boxwood groves, wet places, river valleys, vegetable gardens, roadsides, settlements, crops, arboretums, tea plantations, gardens, steppes, riverbanks, littoral, coastal sands and pebbled areas from lowlands to the upper mountain belt, which is facilitated by the widespread use of agents that contribute to the spread: anemochory, barochory, exo-endozoochory. In the area of the Verbyanaya Spit, an interesting, tiled type of growth of the species was noted after the complete destruction of vegetation and cementation of the territory (Fig. 11).

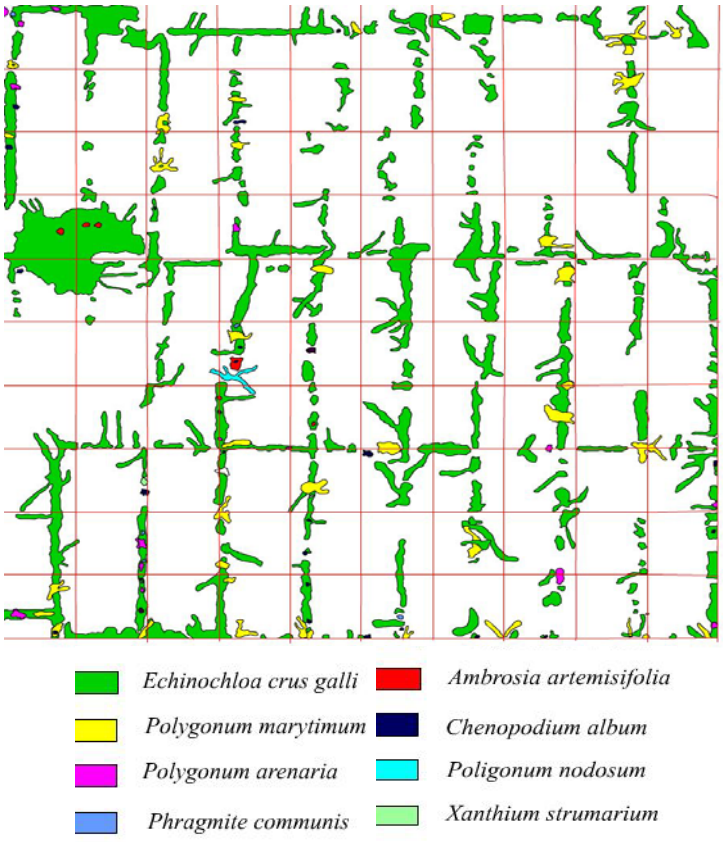


Figure 11. Projective cover of the community dominated by *Echinochloa crus-galli* on the ground of a drilling rig (2008) [10]
Рисунок 11. Проективное покрытие сообщества с доминированием *Echinochloa crus-galli* на полигоне буровой вышки (2008 г.) [10]

Littoral species, with mostly powerful root systems, could not grow in the conditions of a substrate covered with cement blocks. In the community dominated by *Echinochloa crus-galli*, 10 species were recorded, of which

there were no species from natural littoral communities. As part of the community, it was recorded once with an abundance of sol *Eryngium maritimum*. After 2 years, C*orispermum nitidum* Kit. ex Schult. and *Cenchrus longispinus* began to play the role of dominants. Sandbur is an invasive annual species of the family *Poaceae*. It is spread with the help of prickly multiple fruit, containing 1-3 spikelets with fruits – caryopsis. Compound fruits easily adhere to wool and skin of animals, clothing, footwear and skin of people, wheels of cars and are carried over long distances from the mother plant. The type of the Azov coast was introduced during the construction of a road with transport and quickly spread and began to dominate tiled communities.

Alien cereals expand their ranges by introducing them into natural communities. *Setaria pumila, Digitaria ischaemum*, *Hordeum geniculatum*, *Avena sterilis*, *Vulpia ciliata*, *Eleusine tristachya* grow on the sandy-shell seaside spurs of the Azov coast. *Zizania latifolia* and *Zizania palustris* were recorded in wet meadows, swampy biotopes, and *Hordeum geniculatum*, *H. glaucum*, *H. vulgare*, *Polypogon monspeliensis* on salt marshes.The following are distributed along the riverside and coastal sands and gravels of river valleys*: Arthraxon langsdorffii*, *A. hispidus*, *Microstegium japonicum*, *Miscanthus sinensis*, *Cenchrus longispinus*, *Setaria verticillata*, *S. pumila*, *S. germanica*, *Digitaria ischaemum*, *D. ciliaris*, *D. asiatica*, *Paspalum distichum*, *Echinochloa tzvelevii*, *E. crus-gálli*, *Phyllostachys bambusoides*, *Hordeum geniculatum*, *Avena barbata*, *Polypogon monspeliensis*, *Lolium multiflorum*, *Vulpia ciliata*, *Eleusine indica*, *E. tristachya*, *Oplismenus undulatifolius*, *Panicum ruderale*.

Invasions of cereals are noted in shrub communities, on forest edges, clearings, on open stony and fine-earth slopes and sometimes dominate, forming dense groups, but their role in the transformation of natural cenoses is not so significant. It all depends on the degree of disturbance of the vegetation cover. In the disturbed communities of the coastal zone of the Sochi coast there are the already common invasive feral species *Cortaderia selloana*, *Sasa palmata, Pseudosasa japonica*, *Pleioblastus distichus*, *P. fortunei*, *Phyllostachys aurea*, *P. reticulata*, *Echinochloa crus-galli* grows in the reserved Tiso-Samshitovaya Roshcha.

Typically favourable places for new penetration are linear objects of natural and anthropogenic character.Most importantly they are favourable for methods of distribution of fruits by anechory, zoochory, ornitochory and hydrochory. *Hordeum distichon*, *Hordeum jubatum*, *Panicum capillare Eleusine indica*, *Sporobolus fertilis*, *Polypogon fugax*, *Phalaris canariensis*, *Triticum aestivum* and others move along the roads and railroad embankments, *Arthraxon hispidus*, *Oplismenus undulatifolius*, *Digitaria ischaemum*, *Setaria verticillata* along river valleys.

Invasive species behave differently in the environment of developed regions. We have established the status of an alien cereal by its role in phytocenoses [20].

Status 1 includes those actively naturalized in natural cenoses, changing the character, conditions, physiognomy, or nature of ecosystems and disrupting successional relationships (biocenosis transformers [20], agriophytes): *Oplismenus undulatifolius*, *Phyllostachis aurea*, *P. bambusoides*, *P. viridiglaucescens* (4.1%).

Status 2 includes species that are currently actively spreading and naturalizing in disturbed biotopes, partially changing natural, semi-natural cenoses, but not leading to a complete change in their composition, i.e., moderately aggressive species (phytocenoses transformers [20]). Their transition to Status 1 is possible under favourable conditions. These are plants that have penetrated to natural or semi-natural cenoses and continue to actively spread (epectophytes). Of the cereal flora, 34.4% of species have this status: *Sasa palmata*, *Pseudosasa japonica*, *Zizania latifolia*, *Z. palustris*, *Brachypodium distachyon* (*Trachinia distachia*), *Hordeum distichon*, *H. jubatum*, *H. geniculatum*, *H. murinum* L. subsp. *glaucum* (Steud.) Tzvelev. (*H. glaucum*), *H. murinum*, *H. vulgare*, *Avena fatua*, *A. sativa*, *Anthoxanthum amarum*, *Polypogon monspeliensis*, *Lolium multiflorum*, *Vulpia ciliata*, *Phalaris minor*, *Cortaderia selloana*, *Eleusine indica*, *Panicum miliaceum*, *Echinochloa crus-galli* (*Echinochloa caudata)*, *E. crus-gálli*, *Setaria pumila*, *S.verticillata*, *Paspalum dilatatum*, *P. distichum*, *P. thunbergii*, *Digitaria ischaemum*, *Cenchrus longispinus*, *Miscanthus sinensis* Andersson (*M. purpurascens*), *M. sinensis*, *Sorghum halepense and Andropogon virginicus.*

Status 3 species are those that partially change only disturbed phytocenoses (ruderal, segetal, etc.), entering singly into natural and semi-natural cenoses, but do not have a negative effect (ruderal transformers [20]). The species of this group, in the course of further naturalisation, can penetrate into semi-natural and natural communities and change their aggressiveness status to a higher level. This is typical for 61.5% of species: *Sasa veitchii*, *Pleioblastus distichus*, *Phyllostachys fortunei*, *Oryzasativa*, *Triticum aestivum*, *T. durum*, *Secale cereale*, *Bromus carinatus* Hook. et Arn. (*Ceratochloa carinata*), *Bromus catharticus* Vahl (*C. cathartica*), *Bromus hordeaceus* var. *glabratus* Lindgr. ex Lindm. (*Bromus glabratus)*, *Avena barbata*, *A. byzantina*, *A. cultiformis*, *A. georgica*, *A. intermedia*, *A. orientalis*, *A. sterilis*, *Polypogon fugax*, *Vulpia bromoides*, *Briza maxima*, *Phalaris arundinacea* L. (*Phalaroides japonica*), *P. canariensis*, *Danthonia decumbens* (L.) DC. (*Sieglingia decumbens*), *Eleusine tristachya*, *Muhlenbergia schreberi*, *Sporobolus fertilis*, *Panicum capillare*, *P. dichotomiflorum*, *P. ruderale*, *P. sumatrense*, *Echinochloa oryzicola*, *E. oryzoides*, *E. spiralis, E. tzvelevii, Eriochloa villosa*, *Paspalum setaceum*, *Digitaria asiatica*, *D. ciliaris*, *D. horizontalis*, *D. violascens*, *Setaria faberi*, *S. germanica*, *S. italica*, *S. pachystachys*, *Pennisetum alopecuroides*, *P. americanum*, *P. glaucum*, *Microstegium japonicum*, *M. imberbe*, *Sorghum bicolor*, *S. cernuu)*, *S. dochna*, *S. drummondii*, *S. technicum*, *Arthraxon centrasiaticus*, *A. hispidus*, *A. langsdorffii*, *Zea may* and *Coix lacryma-jóbi.*

The main threat to natural vegetation cover is represented by the species of the first two statuses (41.7%). As one can see, the largest number of invasive species considered here belong to Status 3-59 species (61.4%), which partially enter natural communities, but can increase their aggressiveness status in the future. At present, they make a minimal contribution to the destruction of natural ecosystems and are common in segetal and ruderal communities. But, if we take into account the speed at which the natural biogeocenotical cover of certain regions of the Caucasus is transformed, then the strengthening of the positions of aggressive alien species is inevitable. Four species belong to the category of transformers. The most aggressive invasive cereal for the

southeastern part of the Black Sea coast is *Oplismenus undulatifólius*, which dominates in the herbaceous layer of broad-leaved Colchian forests and disrupts natural successional processes. *Oplismenus undulatifolius* successfully forms generative individuals, forms monodominant communities in natural Colchis Forest communities and has a significant distribution area. The successful invasion of the species is facilitated by a combination of seed and vegetative propagation (polycarpic above-ground rhizomatous grass), the efficiency of seed propagation (by anemochory, hydrochory and zoochory). The coenoareal is clearly confined to the communities of Colchis (Fig. 12).

Figure 12. Geographical distribution of *Oplismenus undulatifolius*
Рисунок 12. Географическое распространение *Oplismenus undulatifolius*

CONCLUSION

On the territory of the Western Caucasus and Western Ciscaucasia, 96 species of invasive cereal flora are recorded, which are widespread throughout all floristic districts of the Caucasus. The analysis showed that most of the species are native to ancient centres of agriculture (such a Southeast Asia). Ecological analysis showed that more than 70% belong to the therophytes life form. Water and light are essential factors in the spread of invasive species. The regions of the highest first level of danger include the Black Sea coast (WT), in which natural and climatic conditions contribute to the invasive process. Species of the second danger level are typical for Western Ciscaucasia (WC), Eastern Transcaucasia (ET) and Talysh. The status of alien species of cereals was established by their role in phytocenoses. The status of species was established according to their level of aggressiveness: biogeotransformers (4.1%), phytocenosis transformers (34.4%) and ruderal transformers (62.5%). The main threat to the natural vegetation cover is represented by species of the first two statuses (41.7%).

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AUTHOR CONTRIBUTIONS

Rena T. Abdyeva provided written content on the invasive cereal flora of Azerbaijan. Svetlana A. Lytvinskaya provided: information on 96 invasive species of the family Poaceae; distribution of the cereal fraction of invasive species of the Western Caucasus and Western Ciscaucasia in the floristic regions of the Caucasus; quantitative indicators of invasive cereal flora in the floristic regions of the Caucasus; assessment of floristic regions of the Caucasus according to the level of invasive cereal danger; geographic distribution of annual invasive species; analysis on site of the initial range of invasive cereals; ecological analysis of 96 invasive cereals of the Caucasus; confinement of invasive cereal flora to the place of growth and the status of an alien cereal by its role in phytocenoses. Both authors are equally responsible for plagiarism, self-plagiarism and other ethical transgressions.

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Рена Т. Абдыева предоставила материал по инвазивной злаковой флоре Азербайджана. Светлана А. Литвинская предоставила материал по следующим вопросам: сведения по 96 инвазионным видам сем. Poaceae; распределение злаковой фракции инвазивных видов Западного Кавказа и Западного Предкавказья по флористическим районам Кавказа; уровень инвазионной злаковой опасности флористических районов Кавказа; географическое распространение однолетних инвазивных видов»; анализ по месту первоначального ареала инвазионных злаков; экологический анализ 96 инвазивных злаков Кавказа; приуроченность инвазивной злаковой флоры к месту произрастания и статус чужеродного злака по его роли в фитоценозах. Оба автора в равной степени несут ответственность при обнаружении плагиата, самоплагиата или других неэтических проблем.

NO CONFLICT OF INTEREST DECLARATION

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