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The Use of Computer Technologies for Plants Introduction Value Diagnostics in the Arid Conditions of the Mangystau Desert

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Abstract

The paper describes a complex scale for determining the introduction value of plants in the arid conditions of the Mangystau Desert, including 24 diagnostic features, divided into 4 sections (groups): 1) biopersistence, 2) decorative-habitual properties, 3) reproductive capacity and 4) economic, biological, and scientific significance. The results of its approbation by the example of 155 species and forms of native and foreign flora are presented. A specialized computer program DInCeR is offered, which, along with diagnosing the introduction perspective, allows entering into the computer memory a variety of registration information about plants, forming lists by families and genera, preparing a seed catalogue (Delectus seminum), selecting an assortment according to particular bioecological, decorative, reproductive and greenery properties. All the information about taxa stored in the database can be printed, saved on a server, sent by e-mail or exported to external editors in various graphics and text formats. DInCeR also has an opportunity of program output of the geographical location of plants on the interactive Yandex map on the Internet according to the predetermined coordinates in GPS or decimal degrees. Currently, the electronic database of the program contains records for 1,002 collection introduced species from 3 botanical gardens, 6 taxonomic divisions, 9 classes, 14 underclasses, 29 superorders, 56 orders, 9 suborders, 58 families, and 146 botanical genera. This program has a Certificate of State Registration of the Rights to the Copyright Object No. 2339 of December 14, 2015, received in the Ministry of Justice of the Republic of Kazakhstan

Keywords: *Computer Program, Databases, Introduction Value, Perspective, Approbation, Scale*

INTRODUCTION

The problem of diagnosing the perspective of plants for introduction has been very acute from the very beginning of the botanical development of Mangystau due to the extremely harsh natural and climatic conditions of the desert zone, characterized by the extra aridity of the climate, salinity, shallow profile and poverty of soils and the intensity of the wind regime. The developments on this issue, existing in the practice of introduction studies, are mainly intended for forest and forest-steppe natural areas [1-5] and most of them include a fairly narrow list of diagnostic parameters (mainly without decorative qualities of introduced species); a very high priority is given to the indicator of "winter hardiness", which cannot be considered the main one in a desert habitat. Taking into account this fact, the task of drawing up a regional scale for determining the introduction value of plants, which would take into account the maximum possible number of factors and properties associated with the growth, development, and use of introduced species, was assigned in the Mangyshlak Experimental Botanical Garden.

MATERIALS AND METHODS

The character of the natural conditions of the Mangystau Desert, the 45-year experience of introduction research in the region, the results of the analysis of the long-term average annual bioecological properties of collection species and testing of the most common in other botanical centers methods for determining the viability and perspectives of plants [1-5] were taken into account simultaneously during the creation of this scale.

To transfer the scale into a specialized computer program, 4 programming languages were used: Microsoft Visual FoxPro 9 SP2, Visual Basic For Applications 7.0, HTML 4.0 and JavaScript API 2. Simplification of taxonomic units input was carried out in the program by means of the database created on the list of genera by Brummitt [6]. The basis of taxonomy was based on the phylogenetic system by Takhtajan [7].

RESULTS AND DISCUSSION

The structurally developed regional scale includes 24 diagnostic features (Table 1) divided into 4 sections (groups): 1) biopersistence (6); 2) decorative-habitual properties (8); 3) reproductive capacity (3) and 4) economic, biological, and scientific significance (7).

The tolerance of introduced species to the environment is calculated as the total of their points of drought, salt and winter hardiness, the demands to soil fertility, phytophage and gas resistance. The growth shape, the overall decorativeness of the vegetative part, defoliation, the abundance, duration, and aesthetics of the flowering and fruiting periods were taken into account for evaluation of decorative-habitual properties. Reproductive capacity is diagnosed on the basis of the account of plants' renewal success in the conditions of culture by the seed and vegetative methods. The opportunity of plants' use for landscaping, phytomeliorative, food, feed, medicinal and technical purposes, as well as the phytoprotection status are taken into account at determining the economic, biological and scientific value (Table 1). A 100-point scale, ranked into 10 classes (groups) of introduced species values, was used (Table 2).

Table 1: Complex diagnostics scale of plants' introduction value in the arid conditions of the Mangystau Desert

Feature No.	Indicator, feature	Evaluative variants and conditions	Numerical score
I. BIOPERSISTENCE			
1.1	Drought hardiness	very low value	0
		low value	3
		middle value	7
		high value	12
		very high value	15
1.2	Salt resistance	non-salt-resistant	0
		very low salt-resistant	1
		low salt-resistant	2
		salt-resistant	5
		the most salt-resistant	7
		salt-proof	9
		super salt-proof (halophytes)	10
1.3	Winter hardiness	highly winter-hardy	8
		winter-hardy	6
		middle winter-hardy	3
		little winter-hardy	1
		non-winter-hardy	0
1.4	Exactingness to soil fertility	non-exacting	6
		middle-exacting	4
		exacting	2
		very exacting	0

Feature No.	Indicator, feature	Evaluative variants and conditions	Numerical score
1.5	Phytophage resistance	high value	6
		middle value	3
		low value	1
		very low value	0
1.6	Gas resistance	gas-resistant	5
		relatively gas-resistant	3
		low gas-resistant	1
		non-gas-resistant	0
		TOTAL:	50
II. DECORATIVE-HABITUAL PROPERTIES			
2.1	Growth shape and life duration	trees	4
		bushes, lianas	3
		subshrubs, low bushes, dwarf low bushes	2
		perennial and biennial herbage plants, ephemeroids	1
		annual herbage plants, ephemeris	0
2.2	Originality of the growth shape	expressed	1
		not expressed	0
2.3	General decorativeness of the vegetative part during the vegetation period	very high value	3
		high value	2
		middle value	1
		low value	0
		very low value	0
2.4	Defoliation	spruce evergreen	3
		spruce deciduous	2
		leafed evergreen	2
		leafed half evergreen	1
		leafed deciduous	0
2.5	Flowering intensity (abundance)	highly expressed	1
		low expressed or not expressed	0
2.6	Flowering duration (days)	less than 10	0
		10-25	1
		more than 25	2
2.7	Flowering aesthetics	very high value	4
		high value	3
		middle value	2
		low value	1
		very low value	0
2.8	Fruiting decorativeness	very high value	2
		high value	1
		middle value	1
		low value	0
		very low value	0
		TOTAL:	20
III. REPRODUCTIVE CAPACITY			
3.1	Propagate by seeds	good	6
		satisfactory	4
		bad	1
		do not propagate	0
3.2	Propagate vegetatively	good	4
		satisfactory	3
		bad	1
		do not propagate	0
3.3	Propagate in special conditions or by other methods	good	2
		satisfactory	1
		bad	0
		TOTAL:	10
IV. ECONOMIC, BIOLOGICAL, AND SCIENTIFIC SIGNIFICANCE			
	Possible to use:		
4.1	- as decorative during creation	tree woods and groves	1
		lines of trees and shrubs	1
		spot planting	3
		single planting	5
		living fences	4
		vertical compositions	8
		cover-ground compositions	7
		aquatic plants' compositions	7
		lawns	9
		flower beds	12
		rosaries	14
		not used	0
4.2	for phytomelioration	sands	5
		technogenic-contaminated lands	4
		soil bodies defected by wind and water erosions or human economic activities	2
		not used	0
4.3	- as food	very valuable	9
		valuable	4
		low valuable	1
		not used	0
4.4	- as fodder	very valuable	8
		valuable	4
		low valuable	1
		not used	0
4.5	- as medicinal	very valuable	7
		valuable	4
		low valuable	2
		not used	0
4.6	- as technical	very valuable	5
		valuable	3
		low valuable	1
		not used	0
4.7	Phytoprotection status	endangered	11
		rare	7
		endemic	4
		relict	3
		reducing but not endangered (reducing)	2
		unclassified	1
		safety (non-run-down)	0
		TOTAL (no more than)	20
		TOTAL:	100

Table 2: Classes, total score, and indices of introduced species value

Class	Total score	Value indices
I	0-10	nonvaluable
II	11-20	extremely low value
III	21-30	very low value
IV	31-40	low value
V	41-50	decreased value
VI	51-60	middle value
VII	61-70	increased value
VIII	71-80	high value
IX	81-90	very high value
X	91-100	maximal (model) value

Explanations of some evaluation features of section 1 are given below.

Biopersistence.

Drought hardiness. In the conditions of the Mangystau Desert, all cultivated plants need watering, and dry air is observed annually during the entire period of vegetation, especially in the summer months. Therefore, by classifying plants according to the degree of drought hardiness, a modified version of the scale by Pyatnitskii [8] and Kosaev [1] was used. Plants with very low drought hardiness require regular watering during the vegetation period, at least 2-3 times a week in summer. This group includes hygrophytes predominately and mesohygrophytes partially. Among plants with low drought hardiness, irreparable harm to their growth and development is observed in case of breaks in watering for more than 15-20 days. The group includes most of mesohygrophytic and mesophytic plants. Middle draught-hardy

plants can survive without watering 20-25 days, but the shrinkage of up to half of the leaves and young shoots is observed. This group includes primarily xeromesophytes, mesoxerophytes, and partially mesophytes. Introduced species with high drought hardiness have significant negative signs after a break in watering for 30-35 days. A part of mesoxerophytes and most xerophytes belong to this group. Plants with very high drought hardiness also need to maintain high enough for the type of decoration and growth watering (once in every 10-15 days), but at the same time, especially in the adult stage, can survive without significant damage in the absence of watering throughout the entire vegetation period. This group includes some of the xerophytes and all ultra-xerophytes.

Salt resistance. The division of introduced species into groups is carried out in a generalized form according to the classifications by Migunova [9] and Smirnov [10]: a) halophytes (grow successfully at the salt content of 2.5-3% or more); b) the most salt-resistant (limit of salt content in the soil, in which plants do not lose decorative and meliorative qualities – 2-3%); c) salt-resistant (1.5-2%); d) the most salt-tolerant (1.1-1.5%); d) salt-tolerant (0.7-1.1%); e) low salt-tolerant (0.4-0.7%); low salt (less than 0.3-0.4%) and h) salt-tolerant.

Winter hardiness is diagnosed on a scale used in the practice of the Department of Dendrology of PBG RAS [2] and on the development by Tatarintsev [11]: a) high winter-hardy – not damaged by frost even in unusually severe winters; b) winter-hardy – slightly freeze (mainly annual shoots – up to 50-100% of the length in severe winters); c) middle winter-hardy – significantly damaged by frost (biennial and older shoots) in severe winters; d) little winter-hardy – freeze significantly even in normal winters, and in severe winters freeze out completely and e) non-winter-hardy – freeze out in ordinary winters.

Exactingness to soil fertility is understood in the narrow sense as the demand for soil saturation with nutrients (oligotrophs, mesotrophs, megatrophs and eutrophes).

Phytophage resistance. Plant damage classification scheme by A.N. Kalinichenko [12] with the exception of index 0 – "healthy plant" and with the names of the groups in reverse order, but with the index by the author is used for the diagnosis: 1) high resistance – the plant is not damaged at all by pests and diseases or is not damaged by more than 10% of anatomical organs; 2) middle resistance – damage to the maximum of 11-25% of the surface of the habit, strongly affected organs are not found; 3) low resistance (25-50%) and 4) very low resistance – plants are strongly affected, it leads to the death of more than 50% of their number.

Gas resistance. Classifications by Dobrovolskii [13] and Ilkun [14] are used: plants are classified as gas resistant, relatively gas resistant, low gas resistant and non-gas-resistant.

For the section II of the scale *Decorative-habitual properties*, it should be noted that in connection with low percentage of plants' durable shape of growth in native Mangystau flora, trees and shrubs get more points. In the event of disputable situations on the features 2.5 Abundance and 2.7 Flowering aesthetics, it is possible to estimate them jointly, involving 4-5 experienced introducers.

The last section of the scale IV *Economic, biological, and scientific value* is the only one based on the scale with the open principle, i.e., the number of evaluation points can potentially go beyond the allotted (20). The reason for this was the fact that the overall importance of introduced species depends on both the diversity of practical use and the value in each individual sector of human economic activity, as well as the uniqueness in terms of preserving the gene pool.

To test the objectivity of plants' perspective evaluation, the scale was initially tested by the example of 31 representatives of native and 124 representatives of foreign dendroflora with different shapes of growth, decorative, sustainability, and economic value. As a result, the IX class (very high introduction value) includes Tamarix ramosissima and Juniperus virginiana (82-83 points); the VIII class (high) – Malacocarpus critlimiiolius, Elaeagnus oxycarpa, Tamarix elongata and Tamarix meyeri, a hybrid of Tamarix meyeri x Tamarix elongata, Haloxylon ammodendron and Convolvulus persicus (71-76 points); the VII class (high) – Ulmus pumila, Tamarix leptostachys, Tamarix laxa, Tamarix hohenackeri, and its hybrids with Tamarix elongata and Tamarix ramosissima, Halimodendron halodendron, Nitraria schoberi, Calligonum borszczowii and Calligonum caput-medusae (62-70 points), and the class VI (middle) – Tamarix bungei and Rhamnus sintenisii (51-59 points), and class IV (low) – Tamarix litwinowii (39 points).

The complex scale, even within a relatively small sample of plants of local and foreign flora (155 taxa), mainly with high and very high biological stability, gives a significant spread of evaluation points, which confirms its complexity, objectivity and a fairly high reliability, coinciding with the general preliminary opinion of the introducers about the value of certain taxa. The distribution of taxa by classes is almost symmetrical compared to the previously tested scales [1-5] with the average index, which accounts for 23.9% of plants. Extremely low perspective was diagnosed for 2.6% of the recorded species and forms; very low – for 4.5%; low – for 9.7%; decreased – for 16.8%; increased – for 22.6%; high – for 14.2%, and very high – for 5.8%.

Work on the transition of the regional scale into the electronic language of the special computer program DInCeR, which in addition to the module of plants' introduction value diagnostics also contained procedures, forms, and databases designed to enter and store a variety of registration information on systematics, location in the collection, distribution areas, morphology, ecology, herbarium samples, with illustrations, photos, and drawings of plants, was completed in MEBG (Mangyshlak Experiment Botanical Garden) in 2015.

The main menu of the program contains 11 points: File, Edit, Enter, Search, Viewing, Lists, Herbarium, Range, Database, Service, and Reference (Figure 1).

In the floral database, all 254 fields are divided into input and view forms into 12 groups (pages): Taxonomy (Figure 2), Names, Arrangement, Morphology, Stability (Figure 3), Decorative effect, Reproducibility, Application, In addition, Card, Drawings, and Text Messages.

The complex regional scale of plants' introduction value diagnostics is implemented in the Program on 4 pages of the form of input and viewing of information: Stability, Decorative effect, Reproducibility, and Application.

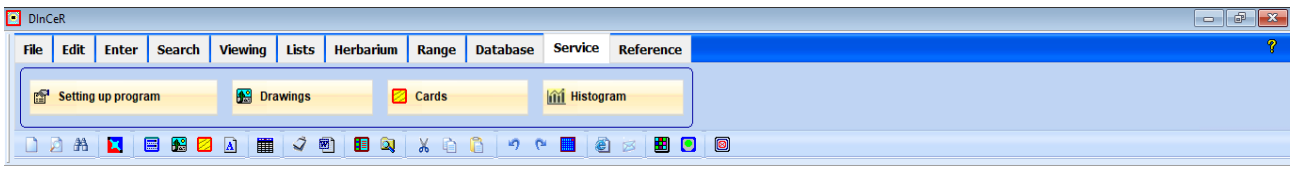

Fig. 1: The main menu of DInCeR

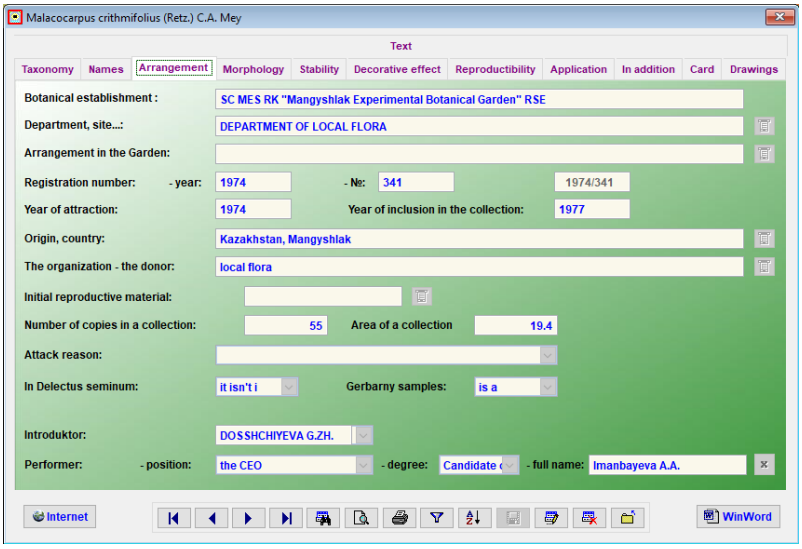

Fig. 2: The page Arrangement of the form of input and viewing of information

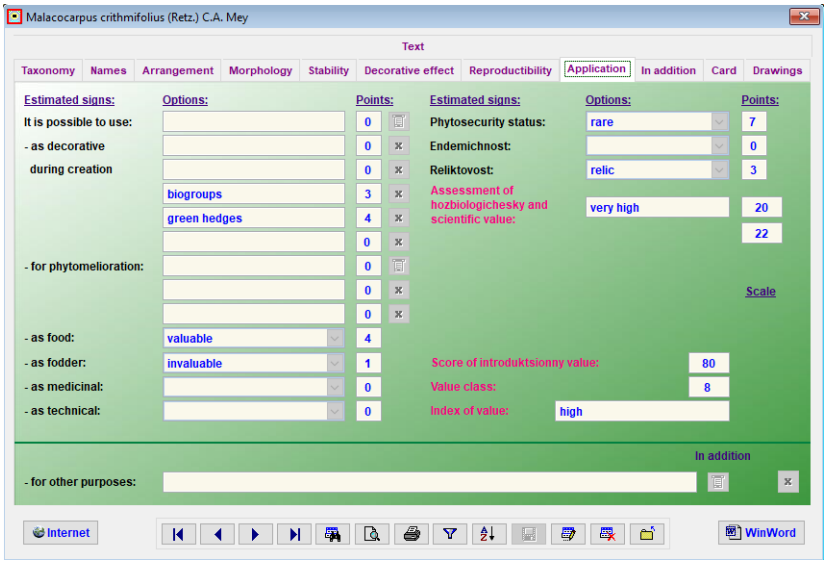

Fig. 3: The page Application of the form of input and viewing of information

When the user selects one or another evaluation option feature, the program automatically calculates the points and the taxon ranking by classes and indices of perspective (Figure 3).

There are several ways for quick search of plants that are available when one selects the Search point in the Main menu: Identifier, Latin, Russian name, National name, Family and name, Any word.

The information about the plant can be printed, saved on a server, sent by e-mail or to external editors and programs in various graphics and text formats (txt, doc, docx, xls, xlsx, rtf, pdf, tif, xml, etc.).

The range of plants can be selected in DInCeR in two variants: according to diagnostic features and to the introduction value. The first one allows assigning of up to 30 taxonomic, diagnostic, and decorative-habitual indicators, simultaneously interesting to the user. The second variant as the main one involves the use of indicators of introduction value (assessment of biological stability, decorative properties, reproductive ability and economic, biological, and scientific value).

DInCeR also has an opportunity of program output of plants' geographical location on the interactive Yandex map on the Internet according to the predetermined coordinates in GPS or decimal degrees (Figure 4).

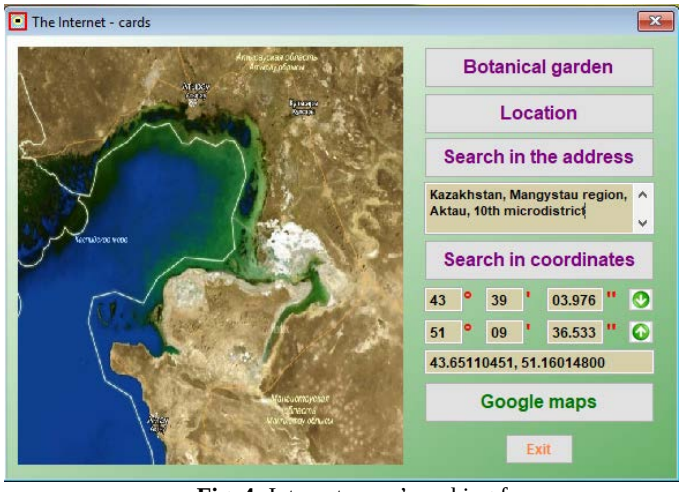

Fig. 4: Internet maps' working form

It is also possible to automatically build histograms of the introduction value and display them in Excel and WinWord (Figure 5).

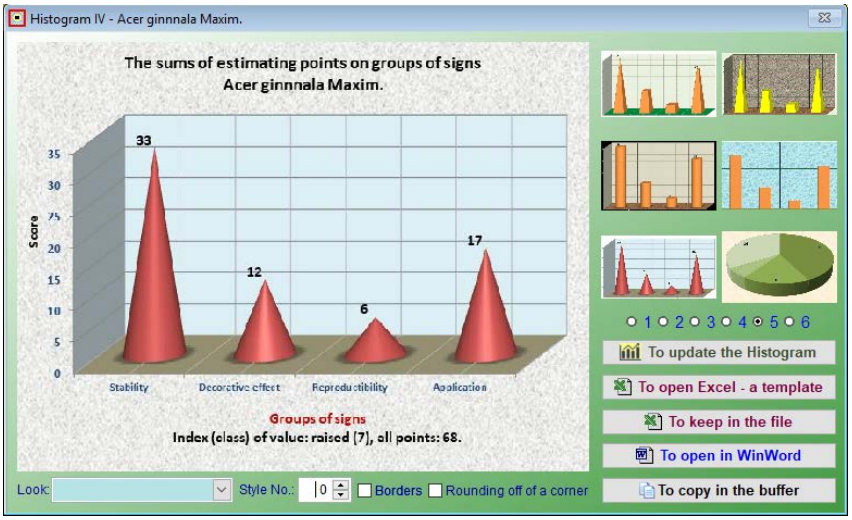

Fig. 5: Histograms' working form

Currently, the electronic database of the program contains records for 1,002 collection introduced species from 3 botanical gardens, 6 taxonomic divisions, 9 classes, 14 underclasses, 29 super-orders, 56 orders, 9 suborders, 58 families, and 146 botanical genera. Almost half (46.3%) of taxa with the most completed information entered into the database are foreign trees and shrubs. The second place according to the specific weight in the database is given to the representatives of the rosary (16.4%). The part of taxa in the gymnosperms and areas of climbing and flowering plants in the total composition of the information base is 6.5-6.9%.

According to the results of diagnosing the introduction value carried out with the program, the list of the most promising plants for Mangystau conditions includes 304 names, including 28 coniferous, 49 foreign-deciduous, 26 climbing, and 61 fruit and berry woody plants, as well as 20 representatives of the local dendroflora and 120 varietal roses.

DInCeR has the Certificate of State Registration of the Rights to the Copyright Object No. 2339 of December 14, 2015, received in the Ministry of Justice of the Republic of Kazakhstan.

CONCLUSION

Further development and implementation of a complex scale of plants' introduction value diagnostics and the computer program for PC in the practice of botanical research in arid regions will greatly simplify the creation of information databases, allow searching for taxa quickly and, in general, will expand the possibilities of work with information about the introduced species, as well as reduce the cost for selection of differentiated by soil-meliorative conditions range of plants for the creation of green devices for various functional purposes.

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