

ARTICLE

Herbaceous plants with variegated leaf color, perspective for urban landscaping

Plantas herbáceas com coloração foliar variegada, promissoras para paisagismo urbano

Alexander Vladimirovich Kabanov¹  and Yulia Anatol'evna Khokhlacheva^{1*} 

¹Tsitsin Main Botanical Garden of Russian Academy of Sciences, Moscow, Russia.

Abstract: The article presents the results of a comparative analysis of the quantitative and qualitative composition of a sample of variegated herbaceous species and cultivars (36 names) from the collection fund of the Laboratory of Ornamental Plants, Tsitsin Main Botanical Garden, Russian Academy of Sciences. In the Poaceae Barnhart, Asteraceae Giseke, Lamiaceae Martinov and Saxifragaceae Juss. families have been found the largest number of genera containing species, which include forms with this leaf color. The analysis of data from long-term field experiments allowed us to assume the presence of a multidirectional influence of adaptive characteristics on the stability in the culture of different groups of introduced plants with variegated leaf color. Variegated plants are the most widely represented in the modern collection fund of the Laboratory of Ornamental Plants. For them, differences in stability in culture were revealed depending on the ratio of the differently colored parts of the leaf blade. Variegated plants have been studied according to their belonging to ecological groups, donor regions, life forms and the systematic status of natural ancestral species.

Keywords: collection fund, introduction, laboratory of ornamental plants, Main Botanical Garden, plants with variegated leaf color.

Resumo: O artigo apresenta os resultados de uma análise comparativa da composição quantitativa e qualitativa de uma amostra de introdutores herbáceos variegados (36 nomes) do fundo de coleta do laboratório de plantas ornamentais do Jardim Botânico Principal de Tsitsin, Academia Russa de Ciências. Mostra-se que o maior número de gêneros contendo espécies, em que se notam formas com esta cor foliar, pertencem às famílias Poaceae, Asteraceae, Lamiaceae e Saxifragaceae. A análise de dados de experimentos de campo de longo prazo nos permitiu supor a presença de uma influência multidirecional de características adaptativas na estabilidade na cultura de diferentes grupos de plantas introduzidas com coloração foliar variegada. Para as amostras variegadas, as mais amplamente representadas no moderno fundo de coleta do laboratório de plantas ornamentais do Jardim Botânico Principal de Tsitsin, Academia Russa de Ciências, foram reveladas diferenças de estabilidade na cultura em função da proporção das partes de cores diferentes da lâmina foliar. Este grupo de introdutores também foi estudado por pertencer a grupos ecológicos, regiões doadoras, formas de vida e o status sistemático de espécies ancestrais naturais.

Palavras-chave: fundo de arrecadação, introdução, Jardim Botânico Principal, laboratório de plantas ornamentais, plantas com coloração de folhas variegadas.

Introduction

The creation and maintenance of collection funds has historically been a fundamental activity of botanical gardens (Zykova et al., 2021). One of the modern tasks of botanical gardens is to enrich the cultural flora. This is achieved by attracting new or previously insufficiently studied species, forms and cultivars with a complex of valuable economic and decorative features (Bondorina et al., 2020). This task will not lose its relevance for a long time. One of the main advantages of representatives of the group of variegated plants (plants with white or cream edging, spots and stripes on the entire surface of the leaf blade) is the possibility of prolonging the decorative effect (Zhang et al., 2020, Zhang et al., 2021). In some cases, the decorative effect can be maintained throughout the growing season.

Variegated plants are one of the promising groups for use in landscaping. At the same time, the issue of adaptive stability of individual variegated cultivars continues to be relevant (Chen et al., 2012; Dong et al., 2020; Pao et al., 2020; Zhao et al., 2020; Galipot et al., 2021; Gao et al., 2021; Liu et al., 2021; Zhang et al., 2021; Mareri et al., 2022; Bossinger and Spokevicius, 2023).

The study of the effect of differently colored parts of the leaf on photosynthesis activity has also been carried out in the Tsitsin Main Botanical Garden, Russian Academy of Sciences since 2018. One of the model objects of research are representatives of the genus *Hosta* Tratt. In previous studies, it was found that the presence of yellow-green parts in the color of the leaves has a compensatory function. This feature allows the plant to adapt to places in bright sunlight (Voronina et al., 2021).

Based on the results obtained earlier, this experiment included the entire spectrum of variegated forms and cultivars from the collection fund of the Laboratory of ornamental plants in Tsitsin Main Botanical Garden, Russian Academy of Sciences (Laboratory). According to the autumn inventory of 2023, the total collection includes 1,012 species and varieties, as well as 5,296 varieties and garden forms. This is a representative sample covering

the widest possible variety of plants in the temperate zone of the globe. This sample allows for a comprehensive research to study and compare the adaptive capabilities of variegated forms with their natural ancestral species.

This study is one of the stages of a comprehensive research of the entire spectrum of variegated cultivars in the collection fund of the Laboratory. At this stage, the collection fund was screened according to such parameters as geographical and ecological relevance, systematic origin.

The purpose of the presented research is a study of variegated forms and cultivars of herbaceous plants on the basis of the collection fund of the Laboratory of Ornamental plants, Tsitsin Main Botanical Garden, Russian Academy of Sciences, determination of the features of their cultivation in the conditions of central Russia.

Materials and Methods

The research work presented in this article was carried out in the period from 2010 to 2023 on the base of the collections of the laboratory of ornamental plants in the Main Botanical Garden of the Russian Academy of Sciences. Currently, a unique complex of introduced plants has been formed in the laboratory of ornamental plants, promising for cultivation in the soil and climatic conditions of central Russia. In our Laboratory plants with colored leaves are represented by 272 names. In our earlier work, we identified 108 samples (Bondorina et al., 2018). In the current work the objects of the study are 36 cultivars (Table 1). They were selected from the collection fund of the laboratory as the most stable for cultivation in the conditions of the Central part of Russia, but requiring clarification in terms of the prospects of their use in mass urban landscaping. All the studied plants were grown in typical conditions characteristic of the ecological preferences of their ancestral species (plants of forest communities in the “Shadow Garden” exposition, plants of mountain scree and rocks in the “Rock Plants” exposition, meadow and steppe plants in the open, illuminated areas of the “Ornamental Plants” exposition).

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Table 1. The studied variegated plants

Family	Cultivar
Apiaceae Lindl.	<i>Aegopodium podagraria</i> L. 'Variegata'
	<i>Astrantia major</i> L. 'Variegata'
Apocynaceae Juss.	<i>Vinca minor</i> L. 'Variegata'
Asparagaceae Juss.	<i>Camassia leichtlinii</i> (Baker) S.Watson 'Sacajawea'
	<i>Convallaria majalis</i> L. 'Albostriata'
	<i>Hosta x hybrida</i> hort.(cultivars)
	<i>Polygonatum odoratum</i> (Mill.) Druce 'Variegatum'
Asphodelaceae Juss.	<i>Hemerocallis fulva</i> f. <i>amgustifolia</i> Baker
Asteraceae Giseke	<i>Heliopsis scabra</i> Dunal (= <i>H. helianthoides</i> var. <i>scabra</i> (Dunal) Fernald) 'Variegata'
	<i>Petasites japonicus</i> (Siebold & Zucc.) Maxim. 'Variegata'
	<i>Solidago flexicaulis</i> var. <i>latifolia</i> (L.) Pursh (= <i>S. flexicaulis</i> L.) 'Variegata'
Boraginaceae Juss.	<i>Brunnera macrophylla</i> (Adams) I.M.Johnst. (copra)
	<i>Pulmonaria rubra</i> Schott 'David Ward'
	<i>Pulmonaria saccharata</i> Mill. (cultivars)
Brassicaceae Burnett	<i>Arabis procurrens</i> Waldst. & Kit. 'Variegata'
Buxaceae Dumort.	<i>Pachysandra terminalis</i> Siebold & Zucc. 'Variegata'
Crassulaceae J.St.-Hil. P	<i>Sedum kamschaticum</i> Fisch. & C.A.Mey. (= <i>Phedimus kamschaticus</i> (Fisch. & C.A.Mey.)) 'Variegatum'
Cyperaceae Juss.	<i>Carex morrowii</i> Boott 'Variegata'
Euphorbiaceae Juss.	<i>Euphorbia polychroma</i> Kern. (= <i>E. epithymoides</i> L.) 'Variegata'
Iridaceae Juss.	<i>Iris pseudacorus</i> L. 'Variegata'
Lamiaceae Martinov	<i>Lamium maculatum</i> L. 'Variegata'
	<i>Mentha suaveolens</i> Ehrh. 'Variegata'
	<i>Physostegia virginiana</i> Benth. 'Variegata'
Liliaceae Juss.	<i>Tulipa x hybrida</i> hort. (copra)
Phytolaccaceae R.Br.	<i>Phytolacca americana</i> L. 'Variegata'
Poaceae Barnhart	<i>Arrhenatherum elatius</i> (L.) P.Beauv. ex J.Presl & C.Presl 'Variegatum'
	<i>Glyceria maxima</i> (Hartm.) Holmb. 'Variegata'
	<i>Miscanthus sinensis</i> Andersson (cultivars)
	<i>Molinia caerulea</i> Moench 'Variegata'
	<i>Phalaroides arundinacea</i> (L.) Rauschert (= <i>Phalaris arundinacea</i> L.) (cultivars)
	<i>Spartina pectinata</i> Bosc ex Link 'Variegata'
Polemoniaceae Juss.	<i>Phlox paniculata</i> L. 'Elizabeth'
Polygonaceae Juss.	<i>Fallopia japonica</i> (Houtt.) Ronse Decr. (= <i>Reynoutria japonica</i> Houtt.) 'Variegata'
Rosaceae Juss.	<i>Filipendula ulmaria</i> (L.) Maxim. 'Variegata'
	<i>Sanguisorba menziesii</i> Rydb. 'Dali Marble'
Saxifragaceae Juss.	<i>Saxifraga umbrosa</i> L. 'Variegata'

The systematic affiliation of the studied plants, their ecological distribution, ecological groups and life forms are given in accordance with published scientific papers (Bezdelev and Bezdeleva, 2006; Rysin, 2009) and based on information from Internet sources (Primary Floras, 2023; World Flora, 2023).

The calculation of the areas occupied by the colored part was carried out using the AutoCAD program (Figure 1).



Figure 1. Tracing of differently colored areas with further calculation of their areas.

Statistical processing of the obtained experimental data was carried out using the program «Statistica Base» in accordance with classical methods (Zajcev, 1990).

Results and Discussion

The first stage of the work was the screening of the collection fund of the Laboratory. It was conducted in order to identify a group of cultivars with variegated leaves.

Variegated forms of herbaceous plants have long been represented in the world cultural flora. But when forming the collection fund of the Laboratory for a long time, the selection of varietal cultivars was not a priority. The exception is representatives of individual genera (*Hosta* Tratt., *Pulmonaria* L., *Brunnera* Steven). In some genera, plants with variegated leaf coloration are represented by single samples (*Convallaria* L., *Petasites* Mill., *Physostegia* Benth., *Phlox* L.). At the same time, a number of samples are cultivated for a long time. For more than 20 years, the collection fund includes the following plants: *Pachysandra terminalis* Siebold & Zucc. 'Variegata', *Pulmonaria saccharata* Mill., *Polygonatum odoratum* (Mill.) Druce 'Variegatum'.

The studied plants underwent a long introduction study. It was revealed that not all the studied variegated plants are stable in the conditions of the central part of Russia and remain decorative throughout the growing season.

During the growing season, stable coloration of leaf blades was observed in yellow-mottled *Solidago flexicaulis* L. 'Variegata' and *Phytolacca americana* L. 'Silberstein'; white-mottled *Filipendula ulmaria* (L.) Maxim. 'Variegata', *Fallopia japonica* (Houtt.) Ronse Decr. 'Variegata', all variegated plants of the genus *Hosta*, *Brunnera*, *Miscanthus* Andersson.

A form was identified in which reduced viability is observed, it weakly reproduces vegetatively, it is characterized by frequent reversions (*Phlox paniculata* L. 'Elizabeth').

Plants with unstable coloration of leaf blades have been identified. *Iris pseudacorus* L. 'Variegata' is decorative, but the variegated coloration of its leaf blades is unstable and manifests itself at the beginning of the season. In addition, this cultivar has a slow growth rate (compared to the original species).

The white-mottled form of *Hemerocallis fulva* var. *angustifolia* Baker is also decorative. It grows well in the conditions of the central part of Russia. But with vegetative reproduction, it is characterized by instability of the manifestation of variegated foliage.

There was also no decrease in resistance and ability to vegetative renewal in the white-mottled cultivar *Sanguisorba menziesii* Rudb. 'Dali Marble'. It differs from the natural species by a very late flowering period.

A decrease in viability and reproduction rates was not recorded in forms with variegated leaf coloration from genera such as *Vinca* L., *Euphorbia* L., *Brunnera*.

The variegated cultivar *Heliopsis helianthoides* (Linnaeus) Sweet 'Variegata' has a low decorative value and reduced viability.

The economically valuable signs of variegated cultivars from the Poaceae Barnhart family were analyzed. It is revealed that the following cultivars are characterized by stability and stability during cultivation in Central Russia: *Phalaroides arundinacea* L. ('Luteopicta', 'Feeseey', 'Tricolor'), *Arrhenatherum elatius* (L.) P.Beauv. ex J.Presl & C.Presl ('Variegatum'), *Alopecurus pratensis* ('Aureovariegatus'), *Molinia caerulea* (L.) Moench ('Variegata'), *Spartina pectinata* Bosc ex Link, *Glyceria maxima* (Hartm.) Holmb.

In the introduction assessment of variegated representatives of *Miscanthus sinensis* (Thunb.) Andersson found that the least stable in culture is the white-mottled variety 'Variegatus'. Cultivars with yellow-mottled leaf color ('Zebrinus', 'Strictus', 'Little Zebra') are stable. At the same time, the absence of a number of phenological phases – flowering and fruiting – is characteristic for all variegated representatives of this species in the conditions of the central part of Russia.

Currently, it is relevant to study the adaptive potential of representatives of the group of variegated plants. This is due to the presence of significant differences in their degree of stability (Mable, 2019). Studies were conducted on the comparative assessment of growth and development, as well as the study of the ecological plasticity of three variegated representatives of the genus *Hosta*: *H. undulata* (Otto & A.Dietr.) L.H.Bailey and its two varieties – *H. undulata* var. *univittata* (Miq.) Hyl. and *H. undulata* var. *albomarginata* F.Maek. (Voronina et al., 2021). At this stage of the work, it has been established that *H. undulata* var. *univittata* is characterized by the most stable growth rates and the content of photosynthetic pigments in the leaves during the entire growing season. This indicates its high adaptive potential and allows us to recommend this variety for urban landscaping.

The studied variegated plants were studied by belonging to ecological groups, regions, life forms, and the systematic status of the natural species to which they belong. Generalization of the information obtained allows optimizing the search for new samples for the collection fund of the Laboratory.

In the study sample, the majority of variegated forms were obtained on the basis of forest species (31); meadow species are represented by fewer names (21); species with a wide response rate (confined to both forest and meadow communities) are also represented quite widely. At the same time, species that are ecologically confined to steppes, mountain slopes and scree, as well as coastal communities are represented by single samples (Figure 2).

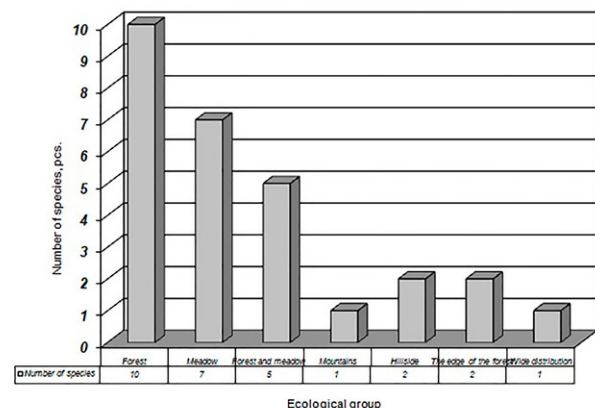


Figure 2. Distribution of species, the progenitors of the studied variegated forms, by ecological groups.

In the spectrum of life forms, based on the classification proposed by Serebryakov I.G. (Serebryakov, 1964), the following predominate: short rhizome and long rhizome herbaceous polycarpics (Figure 3). These life forms predominate among herbaceous polycarpic species of forest and meadow communities.

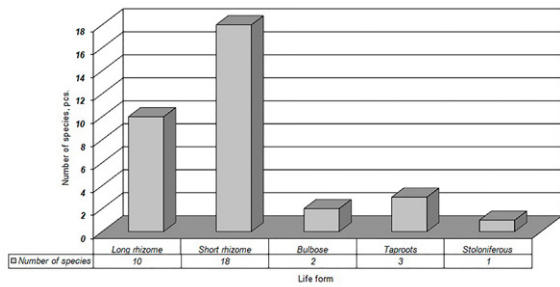


Figure 3. Distribution of the studied variegate plants by life forms.

The distribution of species, on the basis of which forms and cultivars with variegated leaf color were selected, by region is analyzed. It is established that there is no dominance of any region in the composition of the modern collection fund of the Laboratory (Figure 4).

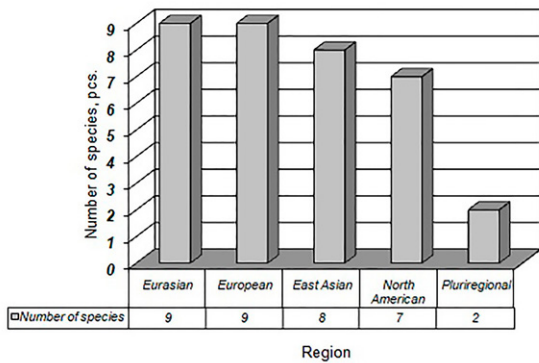


Figure 4. Distribution of species, progenitors of the studied variegate forms by region.

Of great importance is the nature of the distribution of samples with variegated leaf color among the entire spectrum of differently colored forms and cultivars in the Laboratory collection. In an earlier study on the study of color-leaved samples, 272 names of plants belonging to 55 genera and 23 families were identified (Bondorina et al., 2018). Within the framework of the current study, the analysis of the distribution of variegate forms and cultivars in various families, for which the presence of color-leaved samples was previously noted, was carried out. The studied type of staining of the leaf blade of plants in the composition of the modern collection fund of the Laboratory is predominant (Figure 5). It is noted in almost all the studied families, with the exception of Paeoniaceae Raf., Geraniaceae Juss., Primulaceae Batsch ex Borkh. (representatives of these families are characterized by a different type of

leaf blade coloration). At the same time, the greatest variety of variegate forms belongs to the Poaceae family (18% – 6 samples), 3 samples (9%) are part of the Asparagaceae Juss., Asteraceae Giseke and Lamiaceae Martinov families. The remaining families are characterized by a single occurrence of variegate forms.

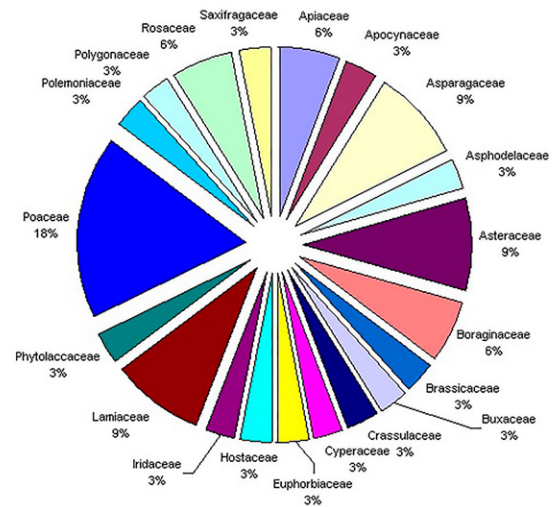


Figure 5. Representation of families containing forms with variegate coloration of leaf blades.

Assessment of the adaptive potential of variegate forms from the Laboratory collections is one of the parts of the presented work. It is carried out on the basis of a visual assessment of the vital condition of the studied samples and the features of their cultivation. To implement it, a variant of evaluating plants by three parameters with a gradation of points from 0 to 2 was developed. The following indicators were used:

- features of vegetative overgrowth (0 – absence, 1 – weak, compared with the original species, 2 – identical with the original species);
- the passage of phenological phases (0 – incomplete (the studied plants do not bloom and do not form seeds), 1 – the studied samples bloom but do not form seeds, 2 – plants go through all phenological phases);
- durability in culture (0 – the plant is unstable, falls out of the collection quickly, 1 – a plant of medium stability, unlike the original natural species, under stressful conditions (heat, snowless winters, excess moisture in the soil, lack of the sum of active temperatures, etc.) may not be preserved in the collection, 2 – the stability is the same, as in the original view).

The results of the evaluation of a sample of variegate ornamental herbaceous plants from the Laboratory collections for some components of adaptive potential are shown in Table 2.

Table 2. Assessment of adaptability of variegata introducers in the collection fund of the Laboratory

Cultivar	Features of overgrowth	Features of phenological phases	Viability	Total	Preservation of the variegata color of the leaf blade during the season
<i>Aegopodium podagraria</i> L. 'Variegata'	1	1	2	4	yes
<i>Arabis procurrens</i> Waldst. & Kit. 'Variegata'	1	2	1	4	yes
<i>Arrhenatherum elatius</i> (L.) P.Beauv. ex J.Presl & C.Presl 'Variegatum'	2	2	2	6	no
<i>Astrantia major</i> L. 'Variegata'	2	2	2	6	yes
<i>Brunnera macrophylla</i> (Adams) I.M.Johnst. (copra)	1	2	2	5	yes
<i>Camassia leichtlinii</i> (Baker) S.Watson 'Sacajawea'	1	2	1	4	yes
<i>Carex morrowii</i> Boott 'Variegata'	2	1	2	5	yes
<i>Convallaria majalis</i> L. 'Albostrata'	2	2	2	6	yes
<i>Euphorbia polychroma</i> Kern. (=E. <i>epithymoides</i> L.) 'Variegata'	1	2	2	5	yes
<i>Fallopia japonica</i> (Houtt.) Ronse Decr. (=Reynoutria <i>japonica</i> Houtt.) 'Variegata'	1	2	1	4	yes
<i>Filipendula ulmaria</i> (L.) Maxim. 'Variegata'	1	2	1	4	yes
<i>Glyceria maxima</i> (Hartm.) Holmb. 'Variegata'	2	2	2	6	yes
<i>Heliopsis scabra</i> Dunal (=H. <i>helianthoides</i> var. <i>scabra</i> (Dunal) Fernald) 'Variegata'	1	2	1	4	yes
<i>Hemerocallis fulva</i> f. <i>angustifolia</i> Baker	2	1	2	5	yes
<i>Hosta x hybrida</i> hort. (cultivars)	2	2	2	6	yes
<i>Iris pseudacorus</i> L. 'Variegata'	2	2	2	6	no
<i>Lamium maculatum</i> L. 'Variegata'	2	2	2	6	yes
<i>Mentha suaveolens</i> Ehrh. 'Variegata'	1	2	2	5	yes
<i>Miscanthus sinensis</i> Andersson (cultivars)	1	0	1	2	yes
<i>Molinia caerulea</i> Moench 'Variegata'	2	2	2	6	yes
<i>Pachysandra terminalis</i> Siebold & Zucc. 'Variegata'	1	0	2	3	yes
<i>Petasites japonicus</i> (Siebold & Zucc.) Maxim. 'Variegata'	1	1	2	4	yes
<i>Phalaroides arundinacea</i> (L.) Rauschert (=Phalaris <i>arundinacea</i> L.) (cultivars)	2	2	2	6	yes
<i>Phlox paniculata</i> L. 'Elizabeth'	1	2	1	4	yes
<i>Physostegia virginiana</i> Benth. 'Variegata'	1	1	1	3	yes
<i>Phytolacca americana</i> L. 'Variegata'	1	2	1	4	yes
<i>Pulmonaria rubra</i> Schott 'David Ward'	2	2	2	6	yes
<i>Polygonatum odoratum</i> (Mill.) Druce 'Variegatum'	2	2	2	6	yes
<i>Pulmonaria saccharata</i> Mill. (cultivars)	2	2	2	6	yes
<i>Sanguisorba menziesii</i> Rydb. 'Dali Marble'	1	1	2	4	yes
<i>Saxifraga umbrosa</i> L. 'Variegata'	2	2	2	6	yes
<i>Sedum kamschaticum</i> Fisch. & C.A.Mey. (=Phedimus <i>kamschaticum</i> (Fisch. & C.A.Mey.)) 'Variegatum'	1	2	2	5	yes
<i>Solidago flexicaulis</i> var. <i>latifolia</i> (L.) Pursh (=S. <i>flexicaulis</i> L.) 'Variegata'	1	1	2	4	yes
<i>Spartina pectinata</i> Bosc ex Link 'Variegata'	2	2	1	5	yes
<i>Tulipa x hybrida</i> hort. (copra)	1	2	2	5	yes
<i>Vinca minor</i> L. 'Variegata'	2	2	2	6	yes

All the studied variegated introducers are divided into 3 categories according to the sum of points. They differ in the degree of manifestation of the components of adaptive potential:

1) stable – the sum of 6 points (38.9% – 14 items from the volume of the studied sample). Representatives of this group are stable and durable in culture; the features of their growth and development correspond to the original appearance. Visual inhibition of growth processes due to a decrease in the area of the green part of the leaf blades was not detected;

2) Medium stable – the sum of 4–5 points (52.7% – 19 items). Representatives of this group are able to be preserved for a long time as part of the collection fund (in the conditions of the central part of Russia). However, their growth and development indicators are inferior to the original natural species






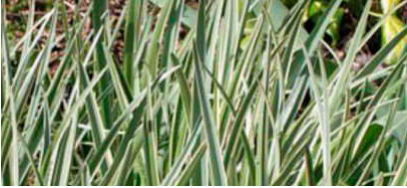
Therefore, as standards for each of the studied characteristics, cultivars were selected that differ in low variability of data over the years of the study with the desirable absence of reliable statistical differences with cultivars that own the corresponding values of the limits.

According to the length of the stem in different years of the study, the indicators of the minimum limits belong to three cultivars. In 2018 it is ‘Jan van Leeuwen’ (86.8 cm), in 2019 it is ‘Fairy’ (88.5 cm), in 2020 it is ‘Moon of Nippon’ (89.5 cm) (Table 1). At the same time, the most stable absolute indicators for this trait and the absence of significant differences at the 5% significance level with these cultivars were revealed for the cultivar ‘Bu-Te’. Therefore, according to the length of the stem, this particular cultivar is used as a standard;

3) Weakly stable – the sum of 2–3 points (8.4% – 3 names). Representatives of this group can exist in collections provided that there is a high level of agricultural technology that differs from the cultivation of the original natural species. Visually marked inhibition of growth (compared with the original species); there is a slowdown in the passage time, and even the absence of a number of phenological phases.

The work was carried out to study the nature of the distribution of the differently colored parts of the leaf blade in the studied plants. When comparing the data on the areas occupied by the colored part with the assessment of adaptability, ambiguous results were obtained (Table 3).

Table 3. The nature of the distribution of the colored parts of the leaf blade in the studied variegated plants

Cultivar	The area occupied by ... %		Assessment of adaptability, number of points	Features of leaf blade coloring
	... the colored part	... the green part		
<i>Aegopodium podagraria</i> L. ‘Variegata’	41.72±0,23	58.28±0.4	4	
<i>Arabis procurrens</i> Waldst. & Kit. ‘Variegata’	26.26±0.5	73.74±0.17	4	
<i>Arrhenatherum elatius</i> (L.) P.Beauv. ex J.Presl & C.Presl ‘Variegatum’	73.39±0.4	26.61±0.7	6	
<i>Astrantia major</i> L. ‘Variegata’	44.34±0.1	55.66±0.6	6	
<i>Brunnera macrophylla</i> (Adams) I.M.Johnst. ‘Longtrees’	71.46±0.24	28.54±0.1	5	
<i>Camassia leichtlinii</i> (Baker) S.Watson Sacajawea	46.17±0.14	53.83±0.27	4	

<i>Carex morrowii</i> Boott 'Variegata'	50.67±0.1	49.33±0.3	5	
<i>Convallaria majalis</i> L. 'Albostrata'	24.38±0.2	75.62±0.1	6	
<i>Euphorbia polychroma</i> Kern. (= <i>E. epithymoides</i> L.) 'Variegata'	40.58±0.2	59.42±0.3	5	
<i>Fallopia japonica</i> (Houtt.) Ronse Decr. (= <i>Reynoutria</i> <i>japonica</i> Houtt.) 'Variegata'	68.08±0.14	31.92±0.17	4	
<i>Filipendula ulmaria</i> (L.) Maxim. 'Variegata'	25.84±0.15	74.16±0.25	4	
<i>Glyceria maxima</i> (Hartm.) Holmb. 'Variegata'	55.03±0.17	44.97±0.5	6	
<i>Heliopsis scabra</i> Dunal (= <i>H. helianthoides</i> var. <i>scabra</i> (Dunal) Fernald) 'Variegata'	58.51±0.13	41.49±0.17	4	
<i>Hemerocallis fulva</i> var. <i>angustifolia</i> Baker	42.24±0.16	57.76±0.21	5	
<i>Hosta x hybrida</i> hort. 'Albomarginata'	23.37±0.25	76.63±0.37	6	
<i>Iris pseudacorus</i> L. 'Variegata'	63.2±0.25	36.8±0.12	6	

Herbaceous plants with variegated leaf color, perspective for urban landscaping

<i>Lamium maculatum</i> L. 'Variegata'	79.88±0.31	20.12±0.15	6	
<i>Mentha suaveolens</i> Ehrh. 'Variegata'	53.56±0.14	46.44±0.1	5	
<i>Miscanthus sinensis</i> Andersson 'Variegatus'	55.89±0.2	44.11±0.12	2	
<i>Molinia caerulea</i> Moench 'Variegata'	53.21±0.4	46.79±0.3	6	
<i>Pachysandra terminalis</i> Siebold & Zucc. 'Variegata'	32.52±0.1	67.48±0.22	3	
<i>Petasites japonicus</i> (Siebold & Zucc.) Maxim. 'Variegata'	29.96±0.1	70.04±0.31	4	
<i>Phalaroides arundinacea</i> (L.) Rauschert (=Phalaris <i>arundinacea</i> L.) 'Feeseey'	49.24±0.2	51.76±0.22	6	
<i>Phlox paniculata</i> L. 'Elizabeth'	66.68±0.23	33.32±0.15	4	
<i>Physostegia virginiana</i> Benth. 'Variegata'	36.94±0.1	63.06±0.27	3	
<i>Phytolacca americana</i> L. 'Variegata'	13.4±0.1	86.6±0.31	4	

<i>Polygonatum odoratum</i> (Mill.) Druce 'Variegatum'	31.9±0.12	68.1±0.28	6	
<i>Pulmonaria rubra</i> Schott 'David Ward'	24.92±0.1	75.08±0.21	6	
<i>Pulmonaria saccharata</i> Mill. 'Majeste'	57.64±0.22	42.36±0.19	6	
<i>Sanguisorba menziesii</i> Rydb. 'Dali Marble'	21.05±0.13	78.95±0.31	4	
<i>Saxifraga umbrosa</i> L. 'Variegata'	40.0±0.1	60.0±0.2	6	
<i>Sedum kamschaticum</i> Fisch. & C.A.Mey. (= <i>Phedimus kamschaticus</i> (Fisch. & C.A.Mey.)) 'Variegatum'	23.1±0.12	76.9±0.36	5	
<i>Solidago flexicaulis</i> var. <i>latifolia</i> (L.) Pursh (= <i>S. flexicaulis</i> L.) 'Variegata'	37.83±0.12	62.17±0.22	4	
<i>Spartina pectinata</i> Bosc ex Link 'Variegata'	47.68±0.21	52.32±0.41	5	
<i>Tulipa x hybrida</i> hort. 'Esperantho'	17.4±0.14	82.6±0.28	5	
<i>Vinca minor</i> L. 'Variegata'	17.44±0.14	82.56±0.36	6	

All the studied plants (from Table. 2) can be divided into 4 groups according to the ratio of the differently colored parts of the leaf blade:

- Group I ($\leq 25\%$) – 8 items;
- Group II (25.1 – 50%) – 15 items;
- Group III (50.1 – 75%) – 12 items;
- Group IV ($\geq 75.1\%$) – 1 name.

When comparing the assessment of the adaptability of the studied plants and the proportion of colored parts of their leaf blade, multidirectional results were obtained. Thus, for group I (with the smallest proportion of the colored part in the leaf blade), unstable and weakly resistant plants were not detected. At the same time, 4 samples belong to the stable and medium-stable groups.

In group II, with an increase in the colored fraction to 50% of the total area of the leaf blade, medium-resistant samples (8 names) prevail. For 5 samples, the adaptability score is 6 (stable) and 2 samples are weakly stable.

In group III, which is characterized by a ratio of the colored part of the leaf blade of more than 50%, 5 samples received the highest adaptability score (6), for 6 samples – an average adaptability score (4-5 points) and 1 sample is weakly resistant (2 points).

The sample belonging to group IV (*Lamium maculatum* ‘Variegata’) has a high adaptive potential (6 points), provided that more than 75% of the total area of the leaf blade is occupied by the variegate part.

The data obtained allow us to recommend samples with an adaptive potential of at least 5 points for introduction into landscaping for the conditions of the USDA winter hardiness zone 4 (Figure 6).

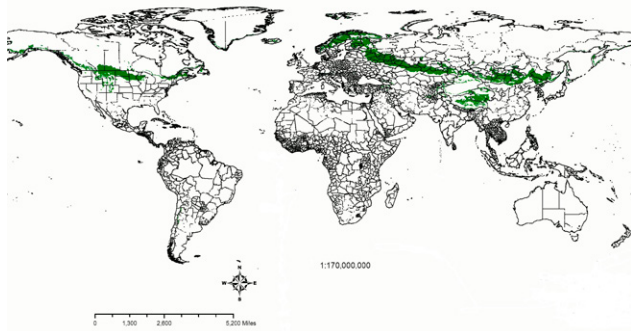


Figure 6. The fourth zone of frost resistance of plants according to the USDA classification.

Based on the results of the conducted research, based more on the assessment of adaptive potential, for the urban gardening in the conditions of the 4 zone of winter hardiness: *Arrhenatherum elatius* ‘Variegatum’, *Astrantia major* ‘Variegata’, *Brunnera macrophylla* ‘Longtrees’, *Carex morrowii* ‘Variegata’, *Convallaria majalis* ‘Albostriata’, *Euphorbia polychrom* ‘Variegata’, *Glyceria maxima* ‘Variegata’, *Hemerocallis fulva* var. *angustifolia*, *Hosta x hybrida* (representatives of a complex of cultivars with biological characteristics similar to the cultivar ‘Albomarginata’), *Iris pseudacorus* ‘Variegata’, *Lamium maculatum* ‘Variegata’, *Mentha suaveolens* ‘Variegata’, *Molinia caerulea* ‘Variegata’, *Phalaroides arundinacea* ‘Feesey’, *Polygonatum odoratum* ‘Variegatum’, *Pulmonaria rubra* ‘David Ward’, *Pulmonaria saccharata* (copra), *Saxifraga umbrosa* ‘Variegata’, *Sedum kamtschaticum* ‘Variegatum’, *Spartina pectinata* ‘Variegata’ *Tulipa x hybrida* (representatives of a complex of cultivars with biological characteristics similar to the cultivar ‘Esperantho’), *Vinca minor* ‘Variegata’. They are characterized by high adaptive potential and decorative.

Conclusions

Screening of the collection fund showed that for 20 families represented in the collection fund of the Laboratory of Ornamental Plants, Tsitsin Main Botanical Garden, Russian Academy of Sciences, the presence of variegate forms was revealed.

It is established that for individual variegate forms, the stability in culture depends on the ratio of the differently colored parts of the leaf blade. But for most of the samples studied, no direct relationship was found.

It was revealed that most of the forms and cultivars presented in the collection fund were obtained on the basis of natural species associated with forest and meadow communities.

At the current stage of the study, no relationship has been revealed between the geographical proximity of the species of their ancestors and the presence of variegated introducers created on their basis.

Based on visual analysis, a variant of assessing the adaptive potential of variegated introducers is proposed and tested. Generalization of the information obtained allows optimizing the algorithm for searching for new samples for the collection fund.

It is recommended to use the assessment of adaptive potential as one of the selection criteria when introducing variegated plants into urban landscaping. The recommended adaptability score should be 5 points. Of the studied number of cultivars, 21 names were recommended for mass introduction.

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Author contribution

AVK and JAK: field work and data capture, processing and data analysis. JAK: literature review and writing, English translation.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data Availability Statement

Data will be available on request.

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