

Evaluation of tulip (*Tulipa* L.) decorative capacities and resistance to *Tulip breaking potyvirus* in the tulip collection of the Botanical Garden of Vilnius University

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The tulip collection of the Department of Plant Systematics and Geography of the Botanical Garden of Vilnius University comprises 240 tulip species and cultivars belonging to 15 classification groups [1]. In this study, 206 tulip cultivars, classified into 1–11 groups, were analysed estimating their decorative capacities and resistance to the most prevalent and damaging *Tulip breaking potyvirus* (TBV). The investigation was carried out in 1997–2005. Decorative capacities have been evaluated in a 5-point scale. TBV was identified by the test-plant, electron microscopy and serological methods. Initial detection of TBV-infected plants was carried out according to symptom expression on tulip leaves and flowers. By their decorative capacities, 117 tulip cultivars (57% to all investigated) were scored the highest point (4–5); 25% of the cultivars were selected as resistant to TBV, 35% as average resistant, and 40% as not virus-resistant. Darwin hybrid tulips were most resistant to TBV.

Key words: tulip, tulip classification, decorative capacities, resistant, tulip breaking potyvirus

INTRODUCTION

The tulip (*Tulipa* L.) is a *Liliopsida* and belongs to the *Liliaceae* Juss. family [1]. The major centre of origin is Central Asia [2]. Its diversification took place from the region of Tien-Shan and Pamir–Altai to the north and northeast (Siberia, Mongolia and China), south to Cashmere and India, and west to Afghanistan, Iran, the Caucasus and Turkey. *Tulipa* includes about 100–144 species [3–7].

Since the 16th century tulips have been among the most popular decorative bulb plants in Europe. Tulips are divided into 15 groups; currently, there are about 3000 species and cultivars [1, 2, 5, 6].

Tulip collection at the Department of Plant Systematics and Geography of the Botanical Garden of Vilnius University (BGVU) was started accumulating in 1997. Currently, there are 240 tulip species and cultivars in the collection. It is constantly replenished with new taxa with the view of accumulating a modern, collection assessed by introductive research and intended for public viewing.

A very important factor for successful maintenance of flower collections is their phytosanitary state. Virus diseases are of great importance because of their harmfulness and difficulties in disease control. The possible measures to control virus diseases are only of a prophylactic character. Tulip is very susceptible to virus diseases; 22 viruses have been reported on this crop [8]. The most prevalent and damaging disease is tulip breaking, caused by *Tulip breaking potyvirus* (TBV). TBV has been reported from many countries in both hemispheres and is likely to appear wherever tulips are grown. In Lithuania, six viruses have been identified to affect tulip, TBV being the most prevalent and damaging for this crop [9].

An essential part of introductive research is evaluation of resistance to virus infection, as this is the main factor specifying the value of the cultivar and limiting its cultivation.

The objective of the present work was to analyse the composition of the accumulated collection, to evaluate its decorative capacities and phytosanitary

state. Such analysis was topical, as the decorative capacities and vegetative potential of these decorative herbaceous bulb plants under climatic conditions of our country are diminished by virus and fungous diseases [2, 4]. However, concrete data concerning evaluation of the resistance of tulip cultivars to virus and fungous diseases in scientific literature are scarce. More intense investigation has been carried out only with a limited number of cultivars [10–14].

MATERIALS AND METHODS

The study collection comprises 240 tulip species and cultivars. In accordance with the international nomenclature, tulips are divided into 15 classification groups [1, 3, 4]. Tulip cultivars of 1–11 groups are analysed in this study. There are about 200 cultivars of such tulips in the collection. Tulip cultivars selected in Lithuania are not specified in this publication. Information about the tulip collection is presented in accordance with the classification groups.

Data concerning resistance to TBV of selected cultivars of high decorative value are presented in this study.

Decorative capacities have been evaluated in a 5-point scale designed for this crop [4]. The system was based on the evaluation of colour and form of the flower and its stability, resilience of the petals, harmony of plant height and flower size, as well as the decorative capacity of leaves. The decorative capacity of the tulip cultivars was evaluated within the limits of the classification group. We used various literary sources to describe the form of the flower [1, 4, 15–18].

Viruses were identified by the test-plant, electron microscopy and serological methods [19]. Initial detection of virus-infected tulips was carried out by establishing symptom expression on leaves and flowers. According to their resistance to TBV, the cultivars were distributed into three conditional groups. Group 2 (the most resistant cultivars) contained up to 20% of affected plants, Group 1 (average degree of resistance cultivars), contained 20–50% of affected plants, and Group 0 (non-virus-resistant cultivars) contained more than 50% of affected plants.

Based on long-term investigation of the vegetative propagation of tulips (1983–1992), data on the most easily propagated tulip cultivars are presented (Table) [20, 21].

RESULTS

Within the limits of each group, general data on tulip cultivars, their decorative capacities and the information concerning their virological state and vegetative propagation are presented.

TBV was identified by symptoms in the host plant, and particle morphology was established by electron

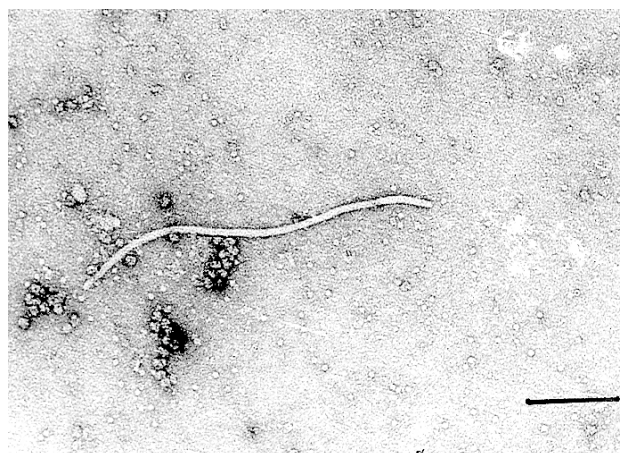


Fig. 1 Particle of TBV. Bar represents 200 nm



Fig. 2. TBV symptom on 'Blue Heron' cultivar



Fig. 3. TBV symptoms on 'Aladdin' cultivar

microscopy (EM). EM revealed filamentous particles 750 nm long and 12 nm wide (Fig. 1). Symptoms of tulip breaking disease caused by TBV are usually present throughout the growing season and are expressed in all above-ground parts of the plant. The main types of leaf symptoms are an inconspicuous mottle, a distinct chlorotic mottle or streaks, broad bandings of chlorotic tissue, and silver or necrotic elliptical rings or line patterns. The most conspicuous symptoms are pronounced on flowers. In culti-

vars with flowers containing anthocyanins, break patterns are formed in petals by intensification or removal of colours in sectors (Figs. 2, 3). In some cultivars, the break is expressed only by intensification of pigment, and when it occurs in flowers which are normally deeply coloured the break symptom may not be readily noticed. The three most widely recognized types of break are full break (deficient in pigment), self-break (colour intensified) and average break (full and self-break in the same petals). The type of break depends on cultivar and the stage of plant development in which infection occurs [9]. There are no pigmentation effects in white- or yellow-flowered cultivars, although flower shape may be changed. Infection also alters the colour of the stigma, and for the non-pigmented cultivars this is a useful diagnostic symptom.

Natural transmission of TBV is carried out by several aphid species in non-persistent manner. Progeny bulbs usually become infected and develop symptoms and, in absence of roguing, virus can accumulate rapidly in stock [8].

Group 1 – Single early tulips (early flowering)

This is genetically an old group of cultivars. At the end of the 17th century it was formed of Djuk van Tol's group of taller seedlings. BGVU has 10 cultivars of this group (3.7% of all the tulip cultivars in the collection). Most of them are average in height (30–50 cm), flower in the end of April – first half of May. What concerns decorative capacities, during the observation period 7 cultivars of this group (70%) were scored highest points (4–5); 14% of the cultivars were resistant to TBV, 43% cultivars were resistant to an average degree, and the other tulip cultivars (43%) of this group were not virus-resistant (Table).

Group 2 – Double early tulips (early flowering)

The first double early tulip (*Tulipa lutea centifolia*) was described by Vallot in 1665. BGVU has four cultivars of this group in its collection (1.7% of all the tulips in the collection). They burst into flower in the first half of May, are not high (20–30 cm), with firm stems bearing a well upraised double flower till the end of blossom. 'Monsella' and 'Peach Blossom' stay in blossom extremely long (16 days). What concerns decorative capacities, during the observation period three cultivars of this group (75%) were scored highest points (4–5) 19% of tulip cultivars were resistant to an average degree, and 33% were not virus-resistant (Table).

Group 3 – Triumph tulips (mid-season flowering)

The group was formed in 1915 of seedlings obtained by crossbreeding the Single Early and Darwin cultivars. BGVU collection contains 54 cultivars of this group (22.5% of all the tulips in the collection); 43 tulips of this group have been investigated. They are rather high (50–60 cm); a wide array of colours is available; the majority have cup-shaped flowers, petals resist to unfold even in the sun. As for their decorative capacities, during the observation period 31 cultivars of this group (84%) were scored highest points (4–5); 19% of the cultivars were resistant to TBV, 32% were resistant to an average degree, and the other cultivars (48%) of this group were not virus-resistant (Table).

Group 4 – Darwin hybrid tulips (mid-season flowering)

The first cultivars in this group of tulips were obtained by D. W. Lefeber in 1936 by crossing *T. fosteriana* 'Madame Lefeber' with a Darwin cultivar. The BGVU collection contains 16 cultivars of this group (7% of all the tulips in the collection). Dar-

Table. Evaluation degree of TBV infection in decorative or highly decorative cultivars

Group	Cultivar	Resistance to TBV (2, 1, 0)	Group	Cultivar	Resistance to TBV (2, 1, 0)
1	'Apricot Beauty'	0	5	'Joan Cruickshank'	0
1	'Galway'	0	5	'Kingsblood'	0
1	'Olga'	1	5	'Magier'	2
1	'Joffre'	2	5	'Maureen'	2
1	'Prince of Austria'	0	5	'Menton'	0
1	'Prinses Irene'	1	5	'Mother's Day'	1
1	'Prins Carnaval'	1	5	'Pandion'	0
2	'Marechal Niel'	0	5	'Princess Margaret Rose'	0
2	'Monsella'	1	5	'Queen of Bartigons'	0
2	'Peach Blossom'	1	5	'Queen of Night'	1
3	'Abu Hassan'	0	5	'Renown'	0
3	'Abra'	1	5	'Shirley'	1
3	'Algiba'	0	5	'Sweet Harmony'	1
3	'Arabian Mystery'	1	5	'White Giant'	2
3	'Attila'	0	6	'Ballade'	2
3	'Baronesse'	1	6	'China Pink'	0
3	'Dreaming Maid'	0	6	'Jacqueline'	0

3	'Fidelio'*	1	6	'Lilac Time'	0
3	'Garden Party'*	0	6	'Mariette'*	0
3	'Gavota'*	2	6	'Maybole'*	1
3	'Golden Melody'	2	6	'Red Shine'	0
3	'Grevel'	0	6	'Slavik'	1
3	'High Noon'	0	6	'Tres Chic'*	2
3	'High Society'	1	6	'White Triumphator'	2
3	'Ingmar Stenmark'	0	7	'Blue Heron'	0
3	'Invasion'	0	7	'Burgundy Lace'*	0
3	'Jacques Fath'*	0	7	'Canova'	0
3	'Judith Leyster'	2	7	'Crystal Beauty'	2
3	'Kees Nelis'*	1	7	'Fancy Frills'*	1
3	'Kerbert'*	0	7	'Hamilton'*	2
3	'Leen van der Mark'	1	7	'Laverock'*	2
3	'Lucky Strike'*	0	7	'Lisca'*	1
3	'Lustige Witwe'	0	7	'Maja'*	2
3	'Negrita'	1	7	'Markland'	0
3	'Page Polka'	2	7	'Sagitta'	1
3	'Preludium'*	1	7	'Swan Wings'	3
3	'Prince Charles'*	0	8	'Angel'*	3
3	'Remagen'	1	8	'Doll's Minuet'	0
3	'Rijnland'	2	8	'Dolores'*	1
3	'Rosario'*	0	8	'Esperanto'	1
3	'Sansón'*	2	8	'Green River'	0
4	'Ad Rem'*	1	8	'Groenland'*	0
4	'Big Chief'	1	8	'Hollywood Star'*	2
4	'Dawnglow'	1	8	'Spring Green'	1
4	'Eric Höfsjö'	2	8	'Violet Bird'	0
4	'Forgotten Dreams'*	2	10	'Black Parrot'*	1
4	'Gordon Cooper'	1	10	'Blue Parrot'*	0
4	'Olympic Flame'	1	10	'Bird of Paradise'	1
4	'Pink Impression'	0	10	'Estella Rijnveld'	1
4	'Scarborough'*	2	10	'Green Wave'	2
4	'Sheffield'	2	10	'Rococo'	2
4	'Silvestran'*	2	10	'Texas Flame'	0
5	'Aristocrat'*	1	10	'Weber's Parrot'*	1
5	'Aristocrat Imperial'	1	11	'Carnaval de Nice'*	1
5	'Black Eagle'	0	11	'Double Prominence'*	2
5	'Black Magic'	0	11	'Double Gudoshnik'	2
5	'Blushing Beauty'*	1	11	'Lilac Perfection'*	1
5	'Cum Laude'	0	11	'Miranda'	2
5	'Georgette'	0			

Notes. Sign * indicates especially decorative tulip cultivars (evaluated by 5 points), other tulips listed in the table have been evaluated by 4 points.

Bald style shows tulips easily propagated in the vegetative way.

Resistant to TBV: 2 – resistant (the most resistant cultivars included up to 20% of affected plants), 1 – average degree of resistance (contained 20–50% of affected plants), 0 – not virus-resistant (contained more than 50% of affected plants).

win hybrid tulips burst into flower somewhat earlier than Triumph tulips. They are high (60–80 cm), with firm and strong stems, big leaves, cup-shaped flowers. According to their decorative capacities, during the observation period 11 cultivars of this group (69%) were scored highest points (4–5); 45% cultivars were resistant to TBV, 45% were average resistant and the other tulip cultivars (10%) of this group were not virus-resistant (Table).

Group 5 – Single late tulips (late-flowering)

Obtained at the end of the 19th century, the Cottage Tulip group is called single late now. The BGVU collection contains 37 cultivars of this group (15.4% of all the tulips in the collection). These are high tulips (60–80 cm), various in colour (from white to purple blackish); they flower rather late (in the second half of May). 'Rosy Wings' is the first in the group to unfold. One of the darker and bursting

into flower later than others and flowering rather long is 'Black Swan'. What concerns decorative capacities, during the observation period 21 cultivars of this group (57%) were scored highest points (4–5); 9% of the cultivars are resistant to TBV, 38% are resistant to an average degree, the other tulip cultivars (52%) of this group are not virus-resistant (Table). It is universally recognized that cultivars of this group are vulnerable to TBV.

Group 6 – Lily-flowering tulips (late-flowering)

The parentage of the first Lily-flowering tulips was *T. retroflexa* crossed with the Cottage tulip. The BGVU collection contains 20 cultivars of this group (8.3% of all the tulips in the collection). Flowers of tulips of this group resemble the flower of a lily, their petals are sharp and inflected. The colour array is wide – from white to purple. Their 40–70 cm high stems are rather slender, those of higher plants get sinuous after rain. Lily-flowered tulips flower in the second half of May. According to their decorative capacities, during the observation period 10 cultivars of this group (50%) were scored highest points (4–5). 30% of the cultivars were resistant to TBV, 10% being resistant to an average degree; the other tulip cultivars (60%) of this group are not virus-resistant (Table). It is universally recognized that cultivars of this group are vulnerable to TBV.

Group 7 – Fringed tulips (late-flowering)

In 1981, when amendments to the international classification of tulips were made, fringed tulips which earlier belonged to the Parrot, then to Darwin and Single late groups, were singled out into a separate group. The BGVU collection contains 21 cultivars of this group; they make 8.7% of all the tulips in the collection; 18 tulip cultivars of this group have been investigated. Fringed tulips are distinguished among the other tulip groups by their originality, as their petals are incised and look as if frosted. Flowers of these tulips are most often of regular cup-shape or oval. Colours of most of them are pastel, rich in undertones. Tulips grow up to 50–70 cm high. They flower in the second half of May. 'Sundew' tulips have longest lasting flowers. According to their decorative capacities, during the observation period 12 cultivars of this group (57%) were scored highest points (4–5). 17% of the cultivars were resistant to TBV, 42% were resistant to an average degree, the following tulip cultivars (42%) of this group were not virus-resistant (Table).

Group 8 – Viridiflora tulips (late-flowering)

This is a new group singled out into a separate one only in 1981. It was obtained by crossbreeding Viridiflora (*Tulipa viridiflora*) with other cultivars. The BGVU collection contains 13 cultivars of this group, they make 5.4% of all the tulips in the collection. These are very impressive tulips, the back of their petals is green, and the rimming varies in undertones (white, yellowish, red). While flowering, the green colour discharges into the main colour creating various

tones. The plants are 30–70 cm high, in most cases stems are strong and perfectly survive nasty weather. These tulips flower in the middle of May. According to their decorative capacities, during the observation period nine cultivars of this group (69%) were scored highest points (4–5). 22% of the cultivars are resistant to TBV, 33% are resistant to an average degree, the other tulip cultivars (44%) of this group are not virus-resistant (Table).

Group 9 – Rembrandt tulips (late-flowering)

Tulips of this group originate from Darwin or Cottage groups of cultivars. Multi-flowered tulips belonging to this group are on the verge of extinction in the world. Flowers of Rembrandt tulips are striped, cultivars are few; there were tulips of the 'Rembrandt Mix' cultivar in our collection, but in 2005 all the plants were removed and destroyed, because they were significantly infected (up to 95%) by TBV virus.

Group 10 – Parrot tulips (late-flowering)

Parrot tulips were started cultivating as far back as the 17th century. The BGVU collection contains 17 cultivars of this group (7% of all the tulips in the collection). These are tulips with curly or chiselled petals. Flowers are mostly big, therefore their supple stems cannot bear them and after wind and rain they incline. They grow up to 40–70 cm high. Mostly they flower late – in the second half of May. According to their decorative capacities, during the observation period eight cultivars of this group (47%) were scored highest points (4–5). 25% of the cultivars were resistant to TBV, 62% were resistant to an average degree, the other tulip cultivars (13%) of this group were not virus-resistant (Table).

Group 11 – Double late tulips (late-flowering)

The first Double late tulips were described at the end of the 17th century. The BGVU collection contains eight cultivars of this group, they make 3.7% of all the tulips in the collection. Their flowers are big, double, similar to those of peonies. The big flowers are sensitive to rain, after it their stems cannot bear flowers, stems of higher cultivars break or become sinuous. Double late tulips flower in the second half of May and reach 60 cm in height. According to their decorative capacities, during the observation period five cultivars of this group (62%) were scored highest points (4–5); 50% of the cultivars were resistant to TBV, 25% were resistant to an average degree, the other tulip cultivars (25%) of this group being not virus-resistant (Table).

DISCUSSION

The Department of Plant Systematics and Geography of the Botanical Garden of Vilnius University has accumulated a collection of 240 tulip species and cultivars of 15 classification groups. This article analyses tulip cultivars of 1–11 classification groups.

The decorative capacities of tulip cultivars were monitored during the whole period of observation in a 5-point system; evaluation was made in each classification group. This publication gives a detailed analysis and evaluation of the selected most decorative tulips (117 cultivars, 57% of 1–11 groups of the tulips in the collection that have received highest scores).

In 1983–1992, carrying out an introductive investigation on immune resistance and an investigation of the intensity of tulip propagation at the Department of Bulb Flowers of Kaunas Botanical Garden, we ascertained that the main setback in the development of the majority of tulip cultivars is virus infection, especially *Tulip breaking potyvirus* (TBV). Only the majority of Darwin Hybrid Tulip cultivars were resistant, and this determined their development in Lithuania and in the world. However, the decorative resources of the cultivars in this group are very limited; in this sense, the latter are surpassed by many of older and newly selected cultivars of other groups.

Developing a new collection of tulips in BGVU since 1997, we encountered a problem of virus infection again. During investigations in the previous years we established that the spread of this disease was of epidemic character. After a vigorous outburst of this disease in 1985–1986 we visited the botanical gardens of Moscow, Minsk, Salaspils, and everywhere a TVB epidemic was affirmed, though it unequally infected different cultivars. In 1997–2002, tulips were rather resistant; tulips in the BGVU collection were infected insignificantly (up to 20%). TBV outburst has been traced since 2003. As for infection, the years 2003–2005 have been acknowledged as epidemic.

The most resistant to TBV tulips have been selected. Among all the classification groups of tulips, the fourth group, Darwin hybrid tulips the first cultivars of which were registered in 1942, are least vulnerable to virus diseases. The group was formed of seedlings obtained after crossbreeding tulips of the species *T. fosteriana* with the existing at that time cultivars of the Darwin group. Up to then, TBV had infected the majority of tulip cultivars. In comparison with others, tulips of the other cultivars of the Darwin hybrid tulip group are genetically younger and sappy. Initially, it was supposed [2] that tulip cultivars of this group are fully resistant to TBV, however, recent investigations showed that TBV, though insignificantly, also infects tulips of the Darwin hybrid group. However, it can be controlled by removing infected plants from the collection. The Fringed tulip group, distinguished for the grace of flowers due to decorative incised petals that resemble frost, is comparatively young in the sense of origin. Most of the cultivars were selected with the aid of artificial mutagenesis from genetically older cultivars. This may be the reason why they are less resistant

to viruses, or maybe the compensatory mechanism of the features of cultivars plays a role there: the more beautiful the flowers, the weaker immune resistance. TBV more intensively infects tulips of the Single early and Single late, Lily-flowering, Viridiflora groups, somewhat less decorative tulips of the Double early, Double late and Parrot groups. A greater outburst of TBV was evidenced in 2003–2005 not only at the Department of Systematics and Geography of the Botanical Garden of Vilnius University, but also in Kaunas Botanical Garden, Minsk Botanical Garden [22]. Such outburst of TBV was apparently caused by abundance of stressors: the long-lasting freeze of soil, the fact that the vegetation of all the investigated tulips started two weeks later, besides, there was also an influence of the fluctuation of temperatures (low temperature at night and high temperature during the day).

The state of each collection greatly depends on the climate conditions. We noticed that a temperature of (1–2 °C below zero usually has no serious consequences, however, a temperature of 3–4 °C below zero chills leaves or tops of leaves. Such plants are easily infected by botrytis (*Botrytis tulipae* (Lib.) Lind.), they also lose decorative capacity. In 1997–2004, the collection was not significantly harmed by spring frosts in this sense. In 2005, long-lasting spring frosts damaged leaves of the sprout plants of the majority of cultivars, especially of early sprouts: this was the main reason conditioned by an especially negative climatic regime for more pronounced manifestation of botrytis.

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**VILNIAUS UNIVERSITETO BOTANIKOS SODO
KOLEKCIJOS TULPIŲ (*Tulipa* L.) DEKORATYVUMO
IR JAUTRUMO TULPIŲ MARGLIGĖS VIRUSUI
ÁVERTINIMAS**

Santrauka

Vilniaus universiteto botanikos sodo Augalø sistematikos ir geografijos skyriaus kolekcijoje auginama 240 rūšiø ir veisliø tulpiø. Ðiam straipsnyje pateikiami duomenys apie tirtas 1–11 klasifikaciniø grupiø veisliø tulpes. Tirtos 206 veislės 1997–2005 metais buvo analizuojamas ir ávertinamas kiekvienos grupės tulpiø veisliø dekoratyvumas bei jautrumas tulpiø margligės virusui (*Tulip breaking potyvirus*, TBV). Pagal dekoratyvumą aukðčiausius ávertinimus (4–5 balus) gavo 117 tulpiø veislės, ir tai sudaro 57%. Ið jø atrinktos atsparios (25%), vidutinio atsparumo (35%) ir neatsparios (40%) TBV veislės. Atspariausios Ðiam patogeniui, net ir TBV protrūkio metais (2003–2005), yra Darvino hibridiniø tulpiø veislės.

Nuo 2002 m. pagal Lietuvos valstybinę programą „Genofondas“ Vilniaus universiteto botanikos sodas, vykdydamas valstybinę mokslo programą „Lietuvos genetiniø iðtekliø moksliniai tyrimai“ tema „Lietuvos dekoratyviniø augalø genofondo kaupimas, tyrimas ir iðsaugojimas“, atlieka dekoratyviną ir fitovirusologiną tulpiø rūšiø bei veisliø patikrinimą ir ávertinimą.