Resistance of Chinese asters (*Callistephus chinensis* Nees.) to Fusarium wilts (*Fusarium oxysporum* f. sp. *callistephi* (Beach) Snyder and Hansen) evaluated using artificial inoculations

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ABSTRACT: The resistance of Chinese asters to *Fusarium* wilt was tested by artificially inoculating the root systems. A mixture of *Fusarium* isolates was prepared with a concentration of about 10^4–10^9 propagules per litre of the pathogen. 63 cultivars of both domestic and foreign origin were evaluated in the 1st year, 95 in the 2nd year and 89 in the 3rd year. Clear, statistically valid differences in mortality, both with experiments involving artificial inoculations and considering natural infections, make it possible to divide aster varieties into three groups based in their resistance to infections. The first set can be described as resistant. This includes the Matsumoto, Einf. Madeleine and Americká kráska series, and several others. The second set can be described as being moderately resistant. This includes the Chryzantémokvěté and Standy series, and the cultivars Matsumoto Pink, Princes Armida and Jitka. The third set can be described as sensitive. This includes the Průhonický trpaslík, Jehlicovité and Pastel series and several others. A statistical analysis of the results shows that the Einf. Madeleine series of cultivars is the most resistant to *Fusarium* wilt. This series is phenotypically similar to the original botanical species. Resistance was evaluated by recording the differences in mortality rates between artificially-inoculated plants and non-inoculated group (controls).

Keywords: *Callistephus*; *Fusarium*; resistance; inoculation; cultivars

A persistent problem in growing Chinese asters is their sensitivity to the fungal pathogens *Fusarium oxysporum* f. sp. *callistephi* (Beach) Snyder and Hansen (*FOC*), and *Verticilium alboatrum* Reinke *et* Berth., which cause wilt. The large number of flowers and the long flowering period, combined with being easy to grow, make Chinese asters very popular. They have a wide range of uses. However, their high sensitivity to the fungal pathogens *Fusarium oxysporum* f. sp. *callistephi* (Beach) Snyder and Hansen (*FOC*) and *Verticilium alboatrum* Reinke *et* Berth., which cause *Fusarium* wilt, is a significant and persistent problem. It is a significant limiting factor for both professional growers as well as amateur gardeners. As far as we are aware, no similar comparison of the sensitivity of Chinese aster to *FOC*, has been published in the last 15 years, either in the Czech Republic or abroad.

MATERIALS AND METHODS

Plant material and weather data

Domestic and foreign cultivars from all groups of Chinese asters were chosen for the experiments. The number of cultivars tested varied each year, from 63 to 95, depending on the success in growing from seed and obtaining seeds from companies.

The trial was conducted in the years 2003–2005. The first year (2003) was warmer than average and the driest: the average temperature was 10.3°C and total rainfall was 394.6 mm; however the average values during observations were 20.0°C and 36.45 mm. In 2004, the average temperature was 9.9°C and rainfall was 530.1 mm, compared to the average data from the observation period, i.e. 18.1°C and 58.47 mm. In the last year of the trial, the average temperature was

9.5°C and total rainfall was 556.1 mm, whereas the respective values from the observation period were 18.2°C and 65.5 mm. Overall, it can be concluded that the weather data in the trial area for the years 2004 and 2005 were close to the long-term average, while 2003 was by 1.3°C warmer than the long-term average, and about 23% less rainfall was recorded than the average.

Isolation of the pathogen

For the isolation and cultivation of *FOC,* the techniques described by Krátká and Dušková (1991) and Nováková (1998) were used. Stem sections with the length of about 5 mm were taken from infected tissues showing visible signs of necrosis, disinfected with 70% ethyl alcohol, briefly scorched by flame and immediately placed on Komada's medium in Petri dishes. The whole process of isolating and cultivating *FOC* was conducted in the protective atmosphere of a flow-box (growth chamber). The inoculated media were incubated at 20°C (nights) and 24°C (days), with 12-hour day length. The inoculated plant material used for the isolations was kept in dry and hermetically sealed PVC bags. They can be safely stored only for one year, so the process has to be repeated every year. The inoculation was done using the solution of isolates for watering the tested plants. The mixture of isolates was prepared from the cultivated isolates of *FOC* grown on agar. Sufficiently large and sporulating isolates of *FOC* were taken from the Petri dishes and homogenized in a shaker with 1 litre of distilled water (Stuchlíková, Kováčiková 1993; Szczech 1999; Molina-Rodriguéz et al. 2003).

The evaluation of resistance to *FOC* under field conditions

The field experimental design for each cultivar consisted of 30 plants that were tested in two replications (60 plants in total) each year in the field inoculated by the *FOC* pathogen. Another field was used as a control (not inoculated group) with 10 plants in two replications (20 plants in total). Seeds of the plants to be tested were sown in a box with seedling substrate (Peat obtained from Soběslav, a. s.) and the seedlings were grown in a greenhouse before their planting out at the end of May with a spacing of 0.4 × 0.2 m. The planting was organized using the method of randomized squares so that the squares with the same cultivars did not neighbour. Quantities of 120–150 l of fusarium mixture from isolates, with the concentration of 10^4–10^9 propagules per litre, were prepared for the inoculations. The trial plots were inoculated with this mixture by using a watering can to apply 10-litre. Tested plants were inoculated immediately after their planting out when the soil surface around the plants was still loosened.

Evaluations of *Fusarium* resistance were made at 6–7-day intervals, from the 1st June till the end of September, by recording numbers of dead plants. The percentage of surviving plants was calculated and consequently, each cultivar was assigned to one of the five classes of *Fusarium* resistance (Table 1).

The evaluation of resistance to *FOC* after artificial inoculation of plants in the greenhouse (the plant pot experiment)

The same method of preparing the mixture of isolates was used as for the field experiment. The seeds were sown into seed trays and plants at the 4 true-leaf stage were used for the plant pot experiment. Substrate B (Peat from Soběslav, a. s.) was disinfected with granulated Basamid (200 g/m^3). The pot experimental design consisted of two variants (inoculated and not inoculated), and 20 plants for each of 30 cultivars were tested. The pot experiments ran from April till June and the observations were made at 6–7-day intervals. Individual evaluations were made in the same way as for the field experiments.

The inoculations of young plants were made according to the method described by Stuchlíková and Kováčiková (1993). Approximately one third of the root length was removed from the tips and the plants were then left to soak for about 1 minute in a suspension of the mixture of isolates with a concentration of 1×10^4 propagules per ml. The inoculated plants were then planted in pots (ø 100 mm) using a sterile substrate and placed in a greenhouse with a daytime temperature of 20°C.

The method of statistical analysis

For the statistical evaluation have used Kruskal-Wallis one factor analysis and multiple *t*-test. *U*-test

Table 1. Scale for assessing Chinese asters for resistance to *FOC*

Percentage of mortality	Rating scale	Level of resistance
0–20	5	very high
21–40	4	high
41–60	3	middle
61–80	2	low
81–100	1	none

Table 2. Distribution of Chinese asters in homogeneous groups (inoculated variant)

Homogeneous group 1	Rating of resistance	Homogeneous group 2	Rating of resistance	Homogeneous group 6	Rating of resistance	Homogeneous group 13	Rating of resistance
Matsumoto Lavender	5	Matsumoto White	4	Matsumoto Gelb	4	Průhonický trpaslík modrý	2
Matsumoto Blush	5	Matsumoto Lachsrosa	4			Průhonický trpaslík bílý	2
Matsumoto Rose	5	Matsumoto Reinweiss	4	Homogeneous group 7		Chryzantémokvětá Sázava	2
Matsumoto Hellblau	5	Matsumoto Leuchtendrot	4	Riesen Prinzess mix	4		
Matsumoto Dunkelblau	5	Matsumoto Salmon	4	Chryzantémokvětá Jizera	3	Homogeneous group 14	
Matsumoto Red	5	Matsumoto Apricot	4			Průhonický trpaslík žlutý	2
Einf. Madeleine Karmin	5	Purple Kurenai	5	Homogeneous group 8		Průhonický trpaslík šarlatový	2
Einf. Madeleine Rosa	5	Pommax mix	5	Princes šarlatová	3	Princes Suzan	2
Einf. Madeleine Dunkelblau	5			Chryzantémokvětá tm. fialová	3		
Einf. Madeleine Hellblau	5	Homogeneous group 3				Homogeneous group 15	
Einf. Madeleine Weiss	5	Matsumoto Light Blue	4	Homogeneous group 9		Průhonický trpaslík sv. růžový	2
Americká kráska Ball Silberrose	5	Fan mix	5	Jitka	3	Chryzantémokvětá sv. modrá	2
Americká kráska Katka	5			Bukett mix	3		
Americká kráska modrá	5	Homogeneous group 4				Homogeneous group 16	
White Kurenai	5	Princes Zlatý svazek	5	Homogeneous group 10		Chryzantémokvětá Vltava	1
Improved Kurenai	5	Prinzess mix	5	Chryzantémokvětá bílá	3	Jehlicovitá žlutá	1
Gerda	5			Jaune Clair	3	Jehlicovitá bílá	1
Princes Patt	5	Homogeneous group 5				Jehlicovitá karmínově červená	1
Standy Dunkelblau	5	Matsumoto Pink	3	Homogeneous group 11		Nina	1
		Matsumoto mix	5	Bleu d'Azur	3	Královna trhu červená	1
		Standy mix	4			Pastel mix	1
		Rose Kurenai	5	Homogeneous group 12			
		Princes Armida	4	Růžové poupátko	3		
		Chryzantémokvětá Ohře	4				

was used for evaluation of significant differences in regression of plant mortality.

The testing was done to evaluate the mortality of inoculated and mortality of un-inoculated plants in all years. The homogeneous groups of resistance 1 to 16 were defined with statistical software UNISTAT, version 5.1. Clusters analysis and construction of dendrograms were performed with MVSP software, version 3.1.

Table 3. Periods of acute infection pressure of *FOC* (inoculated variant)

Period of testing	First infection pressure	Second infection pressure
1st year (2003)	27. 6.–17. 7.	1. 8.–20. 8.
2nd year (2004)	14. 6.–3. 7.	25. 7.–13. 8.
3rd year (2005)	27. 6.–10. 7.	1. 8.–20. 8.

RESULTS

Statistical analysis identified 16 homogeneous groups, numbered 1 to 16; between which highly significant differences were found. The most resistant cultivars of Chinese asters were found within Einf. Madeleine series; they were all placed in the group 1 (with the highest resistance). They are phenotypically very similar to the original botanical species, and its members are known in the Czech Republic as Margaretky (Průchová 1970, 1972). The Matsumoto and Americká kráska series also had a significant number of cultivars in the group 1 (Table 2).

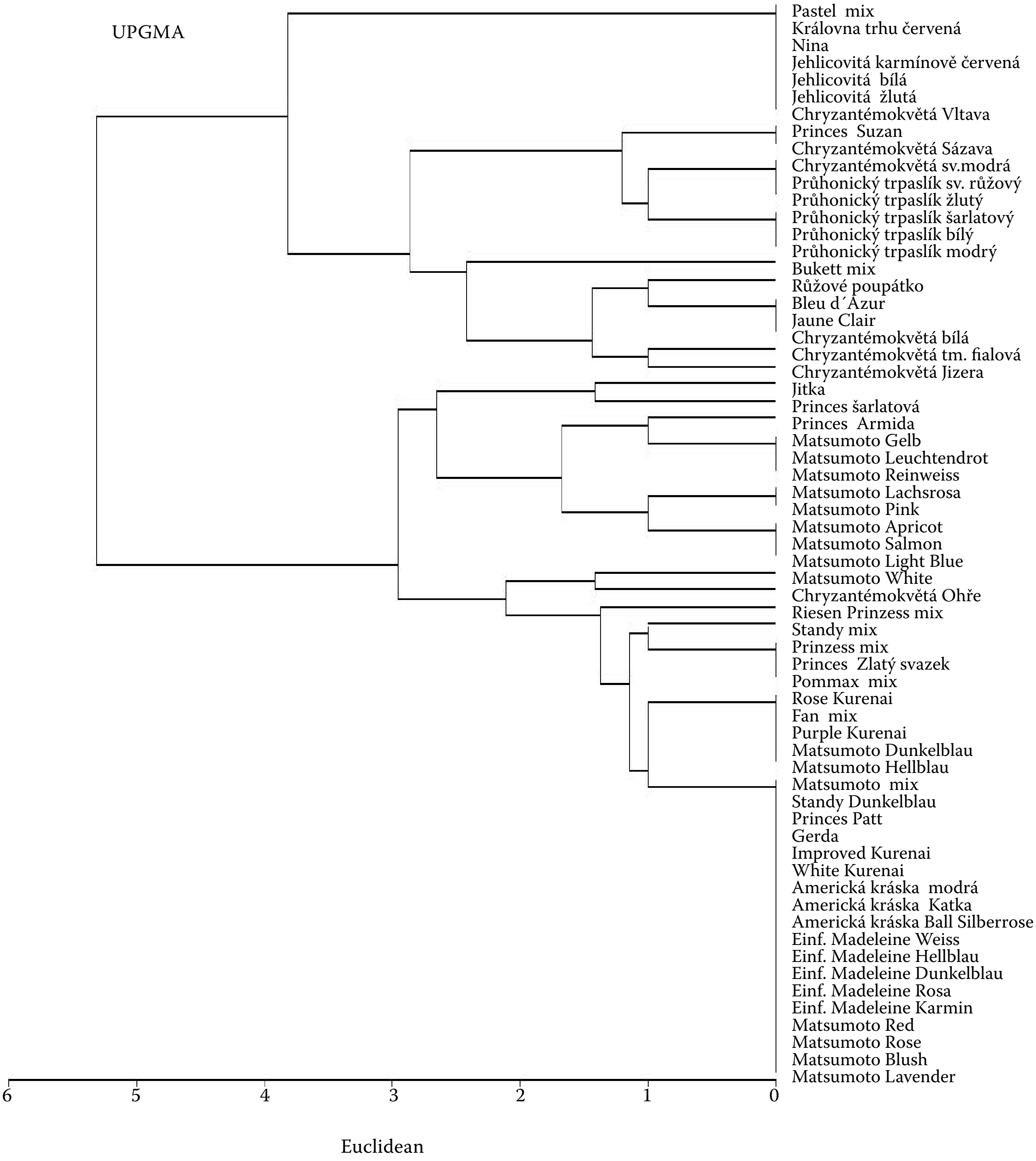
The cultivars from the Jehlicovité series were all placed in group 16, being the most susceptible, along with the cultivars Nina, Chryzantémokvětá Vltava, Královna trhu červená and Pastel mix. A susceptibility to the pathogen was also confirmed in the Průhonický trpaslík dwarf series, which is known to be sensitive, and its representatives were assigned to groups 12–15. Another dwarf series, German Straussenfeder, and the Chryzantémokvěté series were classified as sensitive. High levels of resistance to *Fusarium* were not generally found in the Princes series, although some cultivars, such as Princes Patt and Princes Zlatý svazek, are more resistant than the others. Moderate levels of resistance were observed in the Pommax and Pompon Hellviolett series. Interestingly, statistical analyses assigned the cultivar Princes Zlatý svazek to group 4, but according to the point system of evaluation it was rated as highly resistant (class 5, Table 2). Similarly, the results differed in the case of the cultivars Purple Kurenai (group 2), Rose Kurenai and Matsumoto mix (group 5), all of which were rated as highly resistant (class 5) according to the point system. Group 5 is interesting because it comprises the cultivar Matsumoto Pink, which was rated as having intermediate resistance (class 3, Table 2); however it is grouped with the other cultivars showing high and very high levels of resistance.

The sixteen homogeneous groups can be divided into three sets according to their degree of resistance to *Fusarium*. Set 1 contains groups 1 to 4, with high or very high resistance. Set 2 contains groups 12 to 16, with higher degrees of susceptibility to the infection. Set 3 contains groups 5 to 11, with intermediate resistance.

Significant differences were found between the results obtained in the second year and the other two years. This was probably due to the synergetic effect of the fungus *Fusarium solani* (Martius) Saccardo present in the soil according to the analysis of soil samples taken from the test plots; it caused the premature deaths of some of the tested plants. The values for the evaluation of resistance with artificial inoculation under field conditions differed every year; the greatest differences were observed in the second year. *FOC* infection periods were recorded several times under field conditions (Table 3). The second year differed from others by the earlier beginning of the 1st and 2nd infection periods (June 14 and July 25). In the first year, the first infection period, resulting in a large loss of young plants without setting of any flowers, took place from June 27 till July 17. The second infection period was recorded at full flowering, from August 1 till August 20. In the second year the loss of plants was earlier (from June 14 till July 3), and was the result of the combined effect of *FOC* and the fungus *Fusarium solani* (Martius) Saccardo.

Cluster analysis of UPGMA and Euclidean distance of subject of the data for the inoculated plants (Fig. 1) generated a dendrogram of aster varieties separated into relatively homogeneous groups on the basis of their resistance to *FOC* inoculation.

The un-inoculated group of Chinese asters, used to compare and evaluate resistance to the pathogen, comprised exactly the same cultivars as the group of artificially inoculated plants. The un-inoculated groups were exposed to the natural infection with the *FOC* pathogen in the soil. Statistical analysis identified only 13 distinct homogeneous groups, in comparison to the 16 groups identified in the inoculated plants; most cultivars were ranged in the 1st ho-mogeneous group (Table 4). The remaining tested cultivars from the Princes series (except for the cultivar Princes Suzan) and some cultivars from the

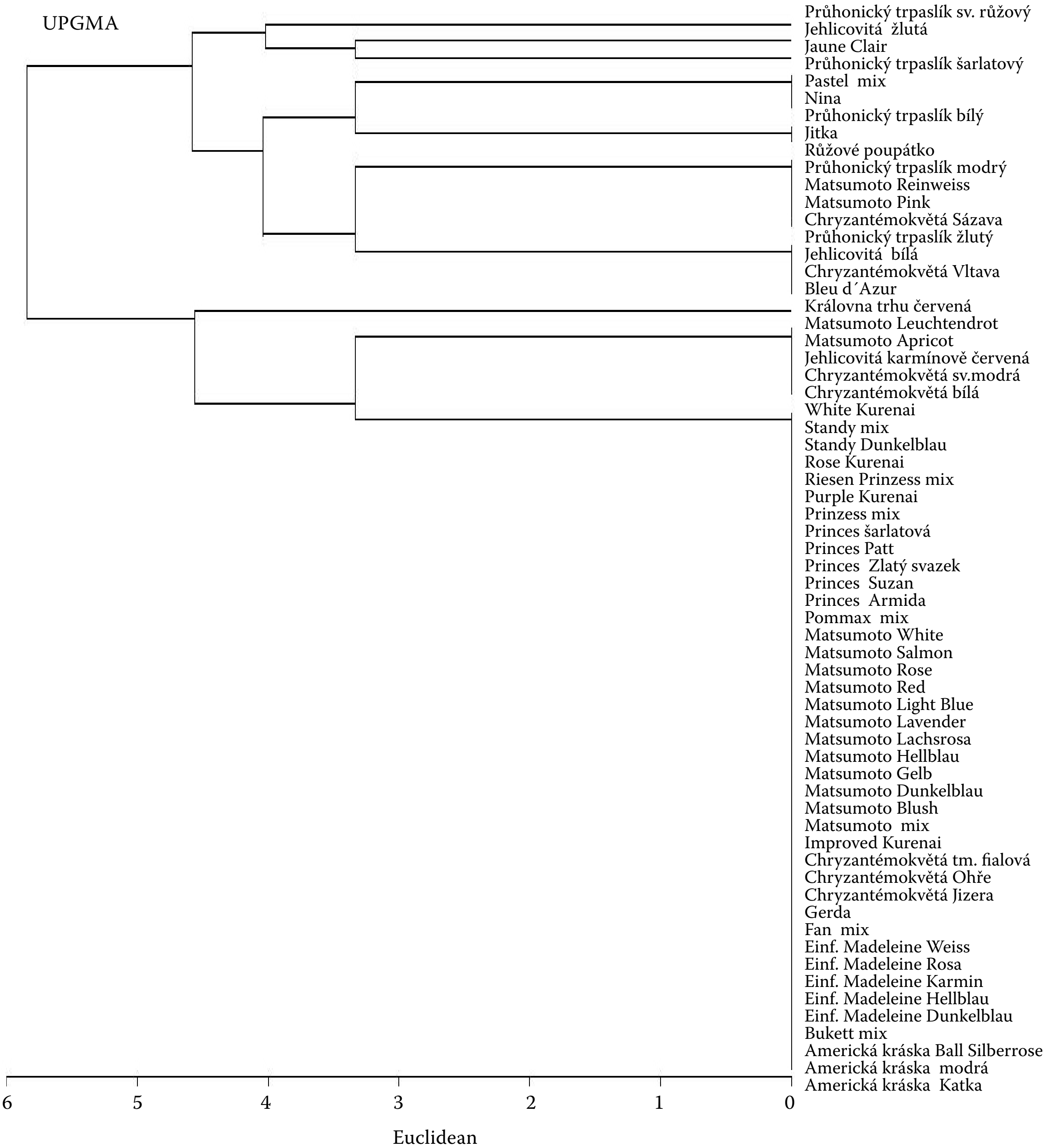


1. Cluster analysis assigns aster varieties to homogeneous groups using data from inoculations

Chryzantémokvěté series were placed in the 1st set, too. The sensitivity of cultivars from the Průhonický trpaslík and Jehlicovité series to *FOC* was confirmed under natural conditions. On the other hand, two cultivars from the Matsumoto series were classified as sensitive cultivars. Some cultivars (Matsumoto Apricot, Jehlicovitá žlutá, Bukett mix) with a very high level of resistance were placed in homogeneous groups 4 and 5, just like some of the cultivars in the inoculated group. The un-inoculated group of asters can be transferred into three sets, similarly to those identified in the inoculated group. The 1st set comprises cultivars in the homogeneous groups 1 and 2. The 2nd set comprises cultivars in the homogeneous groups 6, 7, 8, 9, 10, 11 to 13. The 3rd set comprises cultivars which were difficult to place in either of the above two groups, being the homogeneous groups 3, 4 and 5. A dendrogram based on Euclidean distances

Table 4. Distribution of Chinese asters in homogeneous groups (not inoculated variant)

Homogeneous group 1	Rating of resistance	Homogeneous group 2	Rating of resistance	Homogeneous group 8	Rating of resistance
Matsumoto Lavender	5	Chryzantémokvětá Ohře	5	Královna trhu červená	4
Matsumoto Dunkelblau	5	Chryzantémokvětá tm. fialová	5		
Matsumoto Blush	5	Chryzantémokvětá Jizera	5	Homogeneous group 9	
Matsumoto Hellblau	5	Riesen Prinzess mix	5	Průhonický trpaslík bílý	4
Matsumoto Rose	5	Pommax mix	5	Jitka	4
Matsumoto Red	5	Prinzess mix	5	Matsumoto Reinweiss	4
Matsumoto Light Blue	5	Standy mix	5		
Matsumoto Salmon	5			Homogeneous group 10	
Matsumoto White	5	Homogeneous group 3		Matsumoto Pink	4
Matsumoto Lachsrosa	5	Princes Suzan	5	Průhonický trpaslík modrý	4
Matsumoto Leuchtendrot	5	Matsumoto Gelb	5		
Einf. Madeleine Karmin	5	Matsumoto mix	5	Homogeneous group 11	
Einf. Madeleine Rosa	5	Chryzantémokvětá bílá	5	Průhonický trpaslík sv. růžový	4
Einf. Madeleine Dunkelblau	5	Chryzantémokvětá sv. modrá	5	Jehlicovitá bílá	4
Einf. Madeleine Hellblau	5				
Einf. Madeleine Weiss	5	Homogeneous group 4		Homogeneous group 12	
Americká kráska Ball Silberrose	5	Růžové poupátko	4	Průhonický trpaslík žlutý	4
Americká kráska Katka	5	Jehlicovitá karmínově červená	5	Průhonický trpaslík šarlatový	4
Americká kráska modrá	5	Matador mix	4	Bleu d'Azur	4
Standy Dunkelblau	5			Chryzantémokvětá Vltava	4
Princes Zlatý svazek	5	Homogeneous group 5			
Princes Armida	5	Bukett mix	5	Homogeneous group 13	
Princes Patt	5			Nina	3
Rose Kurenai	5	Homogeneous group 6		Pastel mix	4
Princes šarlatová	5	Jehlicovitá žlutá	5		
Improved Kurenai	5	Matsumoto Apricot	5		
Purple Kurenai	5				
White Kurenai	5	Homogeneous group 7			
Gerda	5	Chryzantémokvětá Sázava	4		
Fan mix	5	Jaune Clair	4		



2. Cluster analysis assigns aster varieties to homogeneous groups using data from natural infections

was constructed using UPGMA cluster analysis. Clusters are relatively homogeneous (Fig. 2). The cultivars are divided into clusters according to similar values of achieved resistance in conditions of the area with natural contents of pathogenic elements. In the separate clusters there are cultivars with the same or similar level of resistance or susceptibility to *FOC*.

The infection pressure from *FOC* in the un-inoculated group of plants differed from that of the artificially inoculated plants; during the whole period of testing there was only one significant natural infection period in each year, not two (Table 5).

A highly significant correlation was found between the inoculated group and the un-inoculated group in all the years of testing, which means that the results from both groups were very similar. The significant differences in the losses of plants of individual cultivars between both groups and among the years were confirmed by the analysis of variance and evaluated using *U*-tests. The results show that there are statistical differences between both groups in the individual years of observation.

The last approach for testing the resistance of Chinese asters to *FOC* was the plant pot experiment in the greenhouse. This provides controlled conditions for testing resistance and excludes the undesirable effects of pathogens, local environment and weather. A part of this test was set to assess the pathogen's virulence. The results of individual test periods were different among groups, years and even among individual cultivars; mostly they did not agree with the results from the field experiment (Table 6). In the 1st year, the Průhonický trpaslík and Chryzantémokvěté series along with the cultivar Nina displayed the highest level of losses (60–100%) in both groups. The Princes series suffered 100% losses only in the inoculated group, with lower levels of losses (30–60%) in the not inoculated group. The opposite was observed in the case of cultivar Růžové poupátko, a higher level of loss (100%) was found in the not inoculated group and a lower level (35%) in the inoculated group. Cultivars of the Matsumoto series had the lowest level of losses in both groups.

In the 2nd year the losses were lower in both groups and the values were relatively similar. Marked differences between cultivars were observed in all groups. The cultivars Matsumoto Apricot, Matsumoto Leuchtendrot, Průhonický trpaslík žlutý, Jehlicovitá žlutá, Gerda, and Chryzantémokvětá Ohře were shown to be the most susceptible (60–100%) in the inoculated group, and the cultivars Matsumoto White, Gaia, Chryzantémokvětá Sázava, Jitka, Princes Patt, Průhonický trpaslík červený and Straussenfeder Dunkelblau were shown to be the most resistant (20–0%). Among the control cultivars, the Matsumoto and Princes series and Jehlicovitá bílá and Jehlicovitá žlutá exhibited the lowest losses, and the cultivars Gerda, Chryzantémokvětá Sázava and Růžové poupátko exhibited the highest.

In the last year the inoculated group was almost completely affected by *FOC*. The level of losses was 100% for almost all cultivars, except Standy Purpurrot, Princes Patt, Princes Zlatý svazek, Nina, Chryzantémokvětá Ohře and Chryzantémokvětá Sázava. Moderate losses were recorded in the not inoculated group. The Matsumoto series had the lowest level of losses (20%) and the cultivars Nina, Princes Zlatý svazek, Standy Dunkelblau, Standy Purpurrot and Chryzantémokvětá Ohře had the highest losses. Other cultivars with minimal or no losses were Einf. Madeleine Karmin, Pompon Hellviolett, Princes Patt and Průhonický trpaslík.

Table 5. Acute infection pressure from *FOC* (not inoculated plants)

Period of testing	Time of infection pressure
1st year (2003)	18. 7.–24. 7.
2nd year (2004)	11. 7.–24. 7.
3rd year (2005)	11. 7.–17. 7.

DISCUSSION

The marked susceptibility of certain cultivars of Chinese asters to *Fusarium* has been confirmed under field conditions, as noted in the earlier studies by Hoffmann (1964), Persiel and Lein (1989), Krátká and Dušková (1991). We have studied in greater detail the differences in resistance between individual cultivars and groups of varieties. Resistance is a very important characteristic of each cultivar, and is not necessarily linked with membership to any particular series or group of coloured cultivars. This is demonstrated by the Matsumoto, Princes and the Chryzantémokvěté cultivars. On the basis of current knowledge, the resistance or susceptibility is not linked to any phenotypical character (such as height, colour and type of flower growth). Several authors have identified a clear relationship between the resistance of some cultivars and Ca^+ and Mg^+ contents in their stems, but the influence of anthocyanins and phenolic compounds has not been confirmed. The results show that susceptible cultivars can occur in all groups. Maurer and Maurer (1984) argued that the poor plant breeding produces poor results. This theory is supported by the fact that during the resistance testing there were almost no observed plants showing different shape, type of growth or shade of colour in the flowers. Under field conditions, plant susceptibility or resistance to disease is linked to the concentration of pathogen in the soil, and probably depends also on the time probably depends on the time taken to reach these harmful concentrations take place. Krátká and Dušková (1991) documented that the reactions of plants to the presence of a pathogen differ with the season of year in which testing takes place; it appears that the length of the day is one of the essential environmental factors.

CONCLUSION

On the basis of these experiments it is possible to say that the selection of Chinese asters which are tolerant, or even resistant to *FOC* from the existing, extensive range of cultivars is definitely possible. A significant number of varieties were

Table 6. Average losses of inoculated asters in plant pots

I. year/cultivars	Rating of resistance	II. year/cultivars	Rating of resistance	III. year/cultivars	Rating of resistance
Blanche	1	Americká kráska Ball Silberrose	3	Einf. Madeleine Karmin	1
Bleu d'Azur	1	Gaia	5	Chryzantémokvětá Ohře	2
Bleu Foncé	1	Gerda	2	Chryzantémokvětá Sázava	1
Gerda	1	Chryzantémokvětá Jizera	4	Chryzantémokvětá sv. modrá	1
Chryzantémokvětá bílá	1	Chryzantémokvětá Ohře	2	Jehlicovitá žlutá	1
Chryzantémokvětá Ohře	1	Chryzantémokvětá Sázava	4	Jehlicovitá karmínově červená	1
Chryzantémokvětá sv. modrá	1	Jehlicovitá bílá	4	Královna trhu bílá	1
Chryzantémokvětá Vltava	1	Jehlicovitá žlutá	1	Matsumoto Gelb	1
Jaune Clair	2	Jitka	5	Matsumoto Hellblau	1
Jitka	1	Královna trhu bílá	3	Matsumoto Pink	1
Matsumoto Dunkelblau	4	Matsumoto Apricot	1	Matsumoto Reinweiss	1
Matsumoto Gelb	5	Matsumoto Leuchtendrot	1	Matsumoto Salmon	1
Matsumoto Red	5	Matsumoto White	5	Matsumoto White	1
Matsumoto White	4	Princes Armida	3	Nina	1
Nina	1	Princes Suzan	3	Pompon Hellviolett	1
Princes Armida	1	Princes Patt	5	Pompon Weis	1
Princes Suzan	1	Princes šarlatová	3	Princes Suzan	1
Princes Patt	1	Průhonický trpaslík bílý	4	Princes Zlatý svazek	1
Princes šarlatová	1	Průhonický trpaslík modrý	3	Princes Patt	1
Průhonický trpaslík bílý	1	Průhonický trpaslík sv. růžový	4	Průhonický trpaslík modrý	1
Průhonický trpaslík modrý	1	Průhonický trpaslík šarlatový	5	Průhonický trpaslík sv. růžový	3
Rose Salmon	1	Průhonický trpaslík žlutý	2	Průhonický trpaslík šarlatový	1
Rose Vif	1	Růžové poupátko	3	Průhonický trpaslík žlutý	1
Rouge Sang Foncé	2	Straussenfeder Dunkelblau	5	Standy Dunkelblau	1
Růžové poupátko	4	Straussenfeder Hellblau	5	Standy Purpurrot	1

identified as having highly tolerant (or even resistant) to *FOC* infections, while others exhibited a variable response and some were sensitive or even very susceptible. 38% of the 63 varieties subjected to statistical analysis showed high tolerance to artificial inoculations with *FOC*. This figure rose to 73% when the plants were exposed to natural infections under field conditions. It is therefore evident that the tolerance of the cultivars is closely linked to the growing conditions and the levels of pathogenic organisms in their environment. In general, the most resistant were the cultivars with simple flowers, which are phenotypically the most similar to the original botanical species. In conclusion, it is possible to recommend the members of the Einf. Madeleine group, and some of the Matsumoto and Princes groups, as cultivars with a high resistance to *FOC* and hence suitable both for breeding purposes and general cultivation.

The results of this study will be useful for the selection of cultivars suitable for horticultural production and also for breeding of new cultivars with higher levels of resistance to *Fusarium* wilt.

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Vyhodnocení odolnosti čínských aster (*Callistephus chinensis* Nees.) k fuzariovému vadnutí (*Fusarium oxysporum* f. sp. *callistephi* (Beach) Snyder and Hansen) pomocí umělé inokulace

ABSTRAKT: Trvalý problém při pěstování čínských aster je jejich citlivost k houbovým patogenům *Fusarium oxysporum* f. sp. *callistephi* (Beach) Snyder and Hansen (*FOC*) a *Verticilium alboatrum* Reinke *et* Berth., které vyvolávají vadnutí rostlin. Odolnost čínských aster k fuzariovému vadnutí byla testována pomocí inokulace kořenového systému. Směs izolátů fuzaria byla připravena v koncentracích patogenních propagulí 10^4–10^9/l. Ve třech po sobě následujících letech bylo hodnoceno 63 (v prvním roce), 95 (ve druhém roce) a 89 (ve třetím roce) domácích i zahraničních odrůd aster. Zřetelné a statisticky významné rozdíly v úhynech rostlin jak v pokusech po umělých inokulacích, tak i po přirozených infekcích, umožnily rozdělit odrůdy aster z hlediska odolnosti vůči této chorobě do tří skupin. Odrůdy první skupiny mohou být popsány jako odolné. Do této skupiny patří především odrůdy série Einf. Madeleine, dále odrůdy sérií Matsumoto, Americká kráska a několik dalších. Odrůdy druhé skupiny mohou být popsány jako středně odolné. Mezi ně patří odrůdy sérií Chryzantémokvěté a Standy i odrůdy Matsumoto Pink, Princes Armida a Jitka.

Odrůdy třetí skupiny mohou být popsány jako citlivé. Mezi ně patří celkově nejcitlivější odrůda Průhonický trpaslík, dále odrůdy sérií Jehlicovité a Pastel a několik dalších. Statistická analýza výsledků ukázala, že odrůdy série Einf. Madeleine jsou vůči fuzariovému vadnutí nejodolnější; tato série je fenotypově podobná původnímu botanickému druhu.

Klíčová slova: *Callistephus*; *Fusarium*; odolnost; inokulace; odrůdy

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