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WINFOLIA SYSTEM - INSTRUMENT FOR PEST AND DISEASE ATTACK EVALUATION IN PEACH AND NECTARINE ORCHARD

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Abstract

This study aims to screen new peach and nectarine cultivars for disease sensitivity. The peach orchard was planted in 2017 using 14 peach and 16 nectarines new cultivars, grafted on various rootstocks: Adesoto, Myrobalan 29C, Saint Julien A, and GF677 on two different planting systems: Trident and Vertical Axis. The planting distances varied from 4.0 x 1.5 m for Vertical Axis (1,666 trees/ha - 1,666 axis/ha) to 4.0 x 2.0 m for Trident (1,250 trees/ha - 3,750 axis/ha). The research was conducted over six years, and in the last year, 2023, leaves were analyzed in the growing season and at the end (late November). The leaves were harvested at three heights (bottom, half, and top of the tree canopy). Only ten leaves per cultivar were analyzed, and the incidence of the bacterial disease Xanthomonas arboricola pv. pruni (XANTPR) and Pseudomonas syringae pv. persicae (PSDMPE) was measured using a scanner and the WinFolia Software. Significant differences in bacterial disease incidence were registered in nectarine cultivars, according to the tree canopy, and the vertical axis showed more sensitivity.

***Key words**: Xanthomonas arboricola, Pseudomonas syringae, cultivars, sensitivity.*

INTRODUCTION

Unlike most other cultivated species, *Prunus persica* (L.) Batsch is a diploid species that self-pollinates naturally (Byrne et al., 2012). China is the world's largest producer of peaches and nectarines, followed by Spain, Italy, Greece, Turkey, and the U.S.A., with a global annual production of ~26 million tons in 2022 (FAOSTAT, 2024; EU Peach and Nectarine Consumption, 2022) In Europe and North America, the yearly consumption of peaches reaches 6.1 kg per person (compared to 15 kilograms of apples), a significant amount considering all fruits available during summer. (EU Peach and Nectarine Consumption, 2022).
Plant diseases still impact society and the economy today. According to the Food and Agriculture Organization (FAO), around 25% of crop loss is attributed to diseases, pests, and weeds. For example, each year, the rice blast disease destroys enough rice to equal Italy's rice production (Dean et al., 2005). The way that crop diseases spread is a crucial component. Viruses, bacteria, fungi, and other pests and pathogens are essential factors in the disease of leaves and plants, regardless of climatic changes (Wakelin et al., 2018). There are several reasons why measuring or estimating plant disease is necessary. Understanding the degree of attack is essential to quick management since disease and yield loss are strongly correlated.
In plant breeding, it is important to rate crop resistance and susceptibility to disease, but sometimes it may also involve the planting system (Stănică, 2019). Estimating plant resistance is a tool for crop protection so pesticides can be applied efficiently. Analysis of plant disease and symptom severity solves fundamental problems and concerns in plant stress biology (Martinelli et al., 2015).
Pseudomonas syringae pv. *persicae* (*P. s.* pv. *persicae*) was found for the first time in the Ardèche region in France and described under the name *Pseudomonas mors-pronotum* f. sp. *persicae*. The bacteria overwinter in cankers, dead and symptomless buds, and systemically infected branches (Vigouroux, 1970; Kennelly et al., 2007). During spring, bacteria that have

invaded leaf scars may become active, leading to bud blasts and die-back of shoots and branches (Young, 1987b). Symptom manifestation varies based on tree age, with trees under six years old being more vulnerable. It causes olive-green discoloration on shoots and branches during winter, quickly turning brown. A relationship exists between disease severity, plant dormancy, and early severe frost in autumn and winter (Young, 1987; 1988). The bacterium on young nectarine leaves initially creates angular, water-soaked patches that turn necrotic, measuring 1-2 mm in diameter and surrounded by a chlorotic halo. The necrotic tissue may vanish, causing a shot-hole effect. Young nectarine fruits may have superficial circular, dark olive-colored, greasy patches of 1-2 mm in size (Young, 1987b). *Xanthomonas arboricola* pv. *pruni* (Xap) is the source of bacterial spot, a dangerous peach disease that causes severe defoliation and black surface pitting, cracking, or blemishes on peach fruit. Identified for the first time in 1903 in the USA, the disease has spread worldwide and has been reported from all continents (Diagnostics, 2006; Socquet-Juglard et al., 2013). Eventually, severe leaf spot infections can cause early tree defoliation, reducing vigor and winter hardiness. Bacterial spots influence the worldwide economy. Under favorable conditions, bacterial spots can affect 100% of the fruit in peach orchards (Fleming et al., 2022). It is widespread in all fruit-growing areas on all stone fruits in Romania. Due to the attack, significant damage was recorded in plums, peaches, or apricots through strong defoliation and fruit fall in varieties susceptible to the attack of this bacterium (Florea et al., 2019). For the past 80 years, conventional disease measures have been frequently used to achieve acceptable accuracy and precision in naked-eye disease assessments. These techniques are overly subjective, however. There is now a chance to evaluate diseases more objectively thanks to new technology (reliability, precision, and accuracy) (West et al., 2003). The WinFolia software is one of these. The software's capabilities to accurately measure various leaf parameters, such as area, shape, perimeter, length, and width, allow for the early detection of pests and disease symptoms that may manifest on the leaves correlated to their color. Thus, this work aimed to screen new peach and nectarine cultivars for sensitivity to *Xanthomonas arboricola* pv. *pruni* (Smith) and *Pseudomonas syringae* pv. *persicae*.

MATERIALS AND METHODS

The peach orchard was planted in 2017 in the Experimental orchard of the Faculty of Horticulture of the University of Agronomic Sciences and Veterinary Medicine of Bucharest, using 14 peach and 16 nectarines new cultivars, grafted on various rootstocks: Adesoto, Myrobalan 29C (M29C), Saint Julien A, and GF677 on two different planting systems: Trident and Vertical Axis.

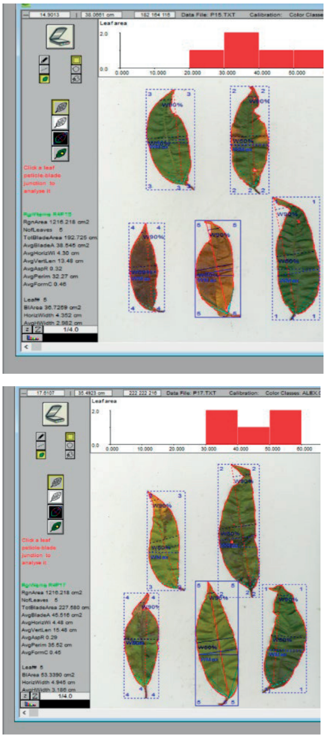
The planting distances varied between 4.0 x 1.5 m for Vertical Axis (1,666 trees/ha - 1,666 axis/ha) to 4.0 x 2.0 m for Trident (1,250 trees/ha - 3,750 axis/ha). The peach and nectarine cultivars are presented in Figure 1.

Peach		Nectarine	
Cultivar	**Rootstock**	**Cultivar**	**Rootstock**
Sugar Time	Adesoto	Honey Late	Saint Julien A
Springbelle	Mirobolan 29C	Nectaross	Saint Julien A
Cardinal	Mirobolan 29C	Stark Red Gold	Saint Julien A
Royal Majestic	Adesoto	Maria Anna	Saint Julien A
Royal Glory	Adesoto	Nectareine	Adesoto
Nabby	GF677	Guerriera	Saint Julien A
Royal Summer	GF677	Nectagrand 4	Saint Julien A
Royal Summer	SAINT JULIEN A	Caldessi 2000	Saint Julien A
Sweet Dream	GF677	Honey Royale	GF677
Royal Jim	Adesoto	Nectagrand 1	Saint Julien A
Sweet Henry	Adesoto	Big Top	GF677
Red Top	Mirobolan 29C	Big Fire	GF677
Sweet Ivan	GF677	Big Bang	GF677
Sweet Juana	GF677	Delta	Mirobolan 29 C
Gladys	GF677	Early Sun Grand	Saint Julien A
Lucius	GF677	Nectabelle	GF677

Figure 1. Peach and nectarine cultivars

The analyses were conducted over the 6 years (2018-2023). Thirty leaves per cultivar were harvested at three heights: base, middle, and top. The leaves were stored at 3°C and 90% humidity. Ten leaves were randomly selected from a total number of leaves and were analyzed using the Epson Expression 11000XL scanner, then interpreted by the WinFolia software. In 2023, leaves were evaluated twice during the vegetative period: first on July 11 and November 4, and then at the end of November on the 28th. Results and dendrograms depict this indication.

The WinFolia system, created by Regent Instruments Canada Inc., includes an Epson 11000XL scanner and image processing software (Figure 2).



a

b

Figure 2. Royal Summer/GF677 (a) and SJA (b)
(Trident system planting)

RESULTS AND DISCUSSIONS

Bacterial disease sensitivity determined with WinFolia system

None of the peach and nectarine cultivars were immune to the bacterial disease attack (Tables 1 and 2), confirming the results of Werner et al. (1986).

Comparing nectarine cultivars' sensitivity (Table 1), in the 2018-2023 period, Nectabelle/GF677 [39.68% on Vertical Axis (VA) and 37.66% on Trident (T)] presented the highest values on the attack. Big Bang/GF677 and Nectagrand1/SJA had similar values. The lowest values were at Big Fire/GF677 (26.25% - VA). Analyzing the dynamic in the 2023 months, Big Bang/GF677 recorded significantly higher values on 11.07.2023 - 55.7% (T) and 04.11.2023 - 58.75% (T).

The lower values at the end of November were primarily due to leaves drop. When comparing the influence of the system planting, Vertical Axis, and Trident, the Vertical Axis system generally showed higher values than the Trident towards the end of the analyzed period.

Table 1. Nectarine cultivars under Winfolia analysis: bacterial disease attack (%) in 2018-2023
on two different canopies, Vertical Axis and Trident

Genotype/Rootstock	2018-2023				11.07.2023				4.11.2023				28.11.2023			
	VA		T		VA		T		VA		T		VA		T	
Early Sun Grand/SJA	37.1259	abc	33.6418	ab	17.5260	bc	15.6800	cd	9.8280	def	19.5345	c	33.3010	abc	24.0530	bcd
Caldessi2000/SJA	33.4493	abcd	27.8447	bcd	4.6170	e	5.5910	de	5.0740	ef	17.4650	cd	33.4200	abc	46.2210	a
Nectagrand1/SJA	38.5968	ab	38.3987	ab	10.8940	bcde	9.4590	cde	46.1070	b	7.4730	de	44.6010	a	42.7780	ab
Nectagrand4/SJA	27.6083	cd	28.7337	bcd	10.1330	bcde	4.6130	e	7.5860	ef	6.5440	de	14.0150	d	32.4270	abcd
Guerriera/SJA	27.0685	cd	36.2822	ab	4.6750	e	5.8680	de	8.3350	ef	21.5280	c	17.4320	cd	12.6960	d
Nectabelle/GF677	39.6790	a	37.6634	ab	17.6260	bc	11.6290	cde	57.4750	a	5.8900	e	28.5930	abcd	20.4370	cd
Honey Late/SJA	32.5513	abcd	31.4535	abc	7.6420	cde	2.7890	e	7.7030	ef	3.6750	e	26.0850	bcd	14.5700	d
Nectaross/SJA	28.8390	bcd	27.6942	bcd	29.2710	a	17.0120	c	5.4910	ef	7.7740	de	17.5420	cd	14.6200	d
Nectareine/Adesoto	28.6438	bcd	22.1320	cd	6.6760	de	4.9720	e	4.5330	ef	4.1810	e	39.9690	ab	18.5810	d
Stark Red Gold/SJA	30.1023	abcd	31.4142	abc	16.0930	bcd	4.9720	e	2.9330	f	4.1810	e	20.8930	cd	18.5810	d
Big Bang/GF677	32.9617	abcd	41.5058	a	12.1230	bcde	55.8660	a	58.0150	a	58.7460	a	15.0660	cd	20.4380	cd
Big Fire/GF677	26.2520	d	34.1332	ab	16.4380	bcd	17.4320	c	15.4460	cde	43.5910	b	24.4960	bcd	16.6830	d

For the peach, in the 2018-2023 trends, the highest VA value was 48.43% (Sweet Ivan/GF677), while the lowest was 20.46% (Cardinal/M29C). For the Trident canopy, the highest value was 43.04% (Royal Summer/SJA), and the lowest was 14.30% (Sweet Henry/Adesoto). Vertical Axis and Trident systems showed an increasing trend in bacterial attack values over the year. Specific cultivars were more susceptible in the Trident canopy (ex., Royal Summer/GF677), while others presented uniform behavior on both systems (ex., Sweet Henry/Adesoto). Sweet Ivan/GF677 and Big Bang/GF677 cultivars generally showed higher values on the Vertical Axis than on the Trident canopy.

Research conducted by Adaskaveg & Förster (2023) focusing on the bacterial spot and other common bacterial diseases in stone fruits could share common observations regarding patterns (Adaskaveg & Förster, 2023).

Table 2. Peach cultivars under Winfolia analysis: bacterial disease attack (%) 2018-2023 on two different canopies, Vertical Axis and Trident

Genotype/Rootstock	2018-2023				11.07.2023				4.11.2023				28.11.2023			
	VA		T		VA		T		VA		T		VA		T	
Cardinal/M 29C			20.4553	ef			21.1610	bc			7.8460	de			20.0900	bc
Royal Summer/SJA	32.9998	de	43.0367	a	8.0700	ef	18.5280	c	4.6560	def	7.0240	de	36.1020	a	29.0440	abc
Sugar Time/Adesoto	29.5952	e	29.1993	bcde	22.9040	bcd	17.7600	c	15.3300	bc	24.4520	b	26.7920	a	30.4620	abc
Red Top/M29C	37.6228	bcde	34.3912	abcd	10.2880	def	34.4610	a	13.1990	bcd	15.4540	c	24.7040	a	28.7200	abc
Royal Glory/Adesoto	35.7567	cde	31.9617	abcde	30.6350	ab	31.2880	ab	17.4790	b	10.2070	cd	21.8710	a	33.8630	abc
Sweet Henry/Adesoto	36.9923	bcde	14.3003	f	4.0070	f	9.6920	c	1.6760	f	1.6390	e	30.6190	a	19.2920	bc
Sweet Juana/GF677	45.2302	abc	27.3847	cde	24.1360	bc	12.0590	c	1.0350	f	1.7800	e	22.2280	a	27.5040	bc
Royal Jim/Adesoto	39.6698	abcde	27.6295	cde	34.0170	ab	18.2600	c	44.1010	a	6.9820	de	40.2350	a	16.1030	c
Lucius/GF677	39.1632	abcde	34.1302	abcd	13.3500	cdef	17.3600	c	3.2790	ef	8.3110	de	30.0240	a	35.8220	abc
Royal Majestic/Adesoto	33.7687	de	39.1182	abc	31.2920	ab	36.1370	a	7.8440	cdef	12.7990	cd	25.2700	a	38.5220	abc
Sweet Ivan/GF677	48.4270	a	33.3300	abcd	20.7330	bcde	13.3150	c	8.1750	cdef	5.9320	de	36.3680	a	25.3010	bc
Sweet Dream/GF677	40.0648	abcde	36.7173	abc	22.6670	bcd	18.1350	c	8.0680	cdef	8.1030	de	30.7920	a	17.6710	bcbc
Royal Summer/GF677	36.2702	cde	31.1532	abcde	39.0120	a	17.2850	c	7.6850	cdef	6.8340	de	30.8440	a	50.1800	a
Nabby/GF677	47.2792	ab	40.6300	ab	33.8260	ab	21.7110	bc	7.7130	cdef	5.8130	de	39.8170	a	38.8740	ab

Analyzing the rootstock influence on the tree sensitivity to bacterial attack, Royal Summer/SJA presented lower values than Royal Summer/GF677 on the Vertical Axis and higher on the Trident system in 2018-2023. The trends were similar in the summer and beginning of fall in 2023. The trees on SJA are less vigorous than GF677, but the results were not in line for both canopies.

Morphological leaf parameters

WinFolia software analysis includes an accurately measured series of leaf morphological parameters, from which a leaf area comparison between cultivars and system planting is presented below.

The biological characteristics of the cultivar influence the trunk circumference and the constructive parameters of the canopies. Leaf area is correlated to tree vigor, canopy shape, and rootstocks (Peşteanu, 2021). At nectarine (Figure 3), comparing the cultivars grafted on similar rootstocks, there were differences in the leaf area on the SJA rootstock. Stark Red Gold/SJA had a leaf area of 6.95 cm^2 (VA), while Caldessi2000/SJA had a lower leaf area of 5.75 cm^2 (VA). On the GF677 rootstock, Nectabelle/GF677 had a higher leaf area (6.95 cm^2) than other cultivars on the same rootstock (ex., Big Fire/GF677 with 5.92 cm^2). On the Trident planting system, leaf area values were similar or slightly higher than on the Vertical Axis.

Genotype/ Rootstock	Leaf Area			
	VA		T	
Early Sun Grand/SJA	34.3089	ab	34.3012	b
Caldessi2000/SJA	28.7275	c	31.5578	b
Nectagrand1/SJA	33.4287	abc	33.7184	b
Nectagrand4/SJA	32.5815	abc	33.3962	b
Guerriera/SJA	30.8808	bc	32.5718	b
Nectabelle/GF677	34.7561	ab	35.3537	ab
Honey Late/SJA	31.5251	abc	33.6139	b
Nectaross/SJA	32.8342	abc	35.0963	ab
Nectareine/M29C	34.4914	ab	34.2653	b
Stark Red Gold/SJA	34.7576	ab	33.5407	b
Big Bang/GF677	33.4109	abc	31.9784	b
Big Fire/GF677	29.6077	bc	32.0596	b
Big Top/GF677	29.9222	bc	35.0355	ab

Figure 3. Nectarine cultivars under WinFolia analysis: leaf area (cm^2) 2018-2023 on two different canopies, Vertical Axis and Trident (values cumulated for five leaves)

For peach (Figure 4), the highest value on the Vertical Axis system was registered for Royal Summer/SJA (8.24 cm^2), even higher than on the vigorous rootstocks such as GF677 (Stănică et al., 2020) and M29C. As nectarine cultivars, the trees on the Trident system planting presented similar or slightly higher values than those on the Vertical Axis.

Genotype/ Rootstock	Leaf Area			
	VA		T	
Cardinal/M 29C			36.2005	cdefgh
Royal Summer/SJA	41.1986	a	40.8637	abc
Sugar Time/Adesoto	34.8799	bcd	37.5602	bcdefgh
Red Top/M29C	33.3087	bcd	36.1167	cdefgh
Royal Glory/Adesoto	31.2090	cd	38.4258	abcde
Sweet Henry/Adesoto	36.1509	bc	33.0709	gh
Sweet Juana/GF677	32.2844	cd	32.2208	h
Royal Jim/Adesoto	30.8315	d	34.4613	defgh
Lucius/GF677	33.0261	bcd	33.5553	efgh
Royal Majestic/Adesoto	33.3950	bcd	36.6003	bcdefg
Sweet Ivan/GF677	33.9028	bcd	34.6793	defgh
Sweet Dream/GF677	34.6267	bcd	34.5953	defgh
Royal Summer/GF677	37.7526	ab	38.8014	abcd
Nabby/GF677	34.7271	bcd	31.6928	h
Gladys/GF677	35.0761	bcd	33.0812	fgh
Springbelle/M29C			42.4258	a

Figure 4. Peach cultivars under WinFolia analysis: leaf area (cm^2) 2018-2023 on different canopies, Vertical Axis, and Trident (values cumulated for five leaves)

The dendrograms illustrate the similarities or differences between various peach and nectarine cultivars based on the degree of bacterial attack. The cultivars were analyzed across two canopies, Vertical Axis ("_axis") and Trident ("_t"), and different rootstocks. This analysis can support identifying patterns of resistance or susceptibility among the cultivars.

Both dendrograms (Figures 5 and 6) showed that the interaction between canopies, rootstock, and inherent cultivar traits shaped similarities or differences in bacterial disease levels among cultivars. Rootstocks like GF677 and Adesoto also contributed to cultivar clustering, highlighting bacterial resistance profiles.

Research by Tsogbadrakh et al. (2024) and Oliveira et al. (2018) they have identified comparable effects of canopy shape on disease susceptibility when canopies tend to have lower bacterial incidence than those with denser forms. These findings differed from our results for some cultivars, where the Vertical Axis system exhibited greater susceptibility.

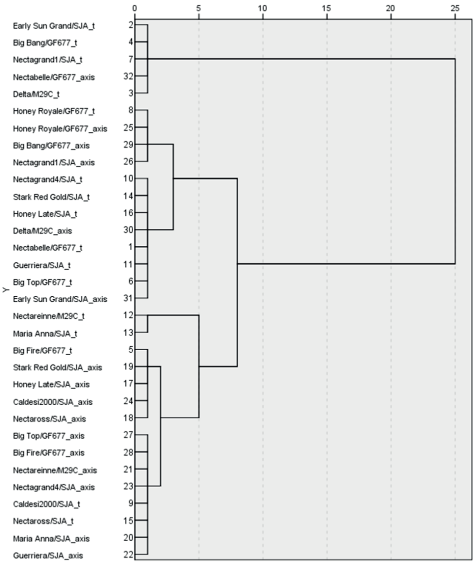


Figure 5. Nectarine cultivars dendrograms on bacterial disease sensitivity

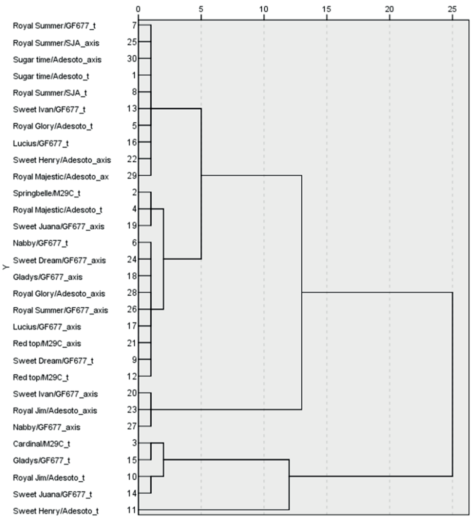


Figure 6. Peach cultivars dendrograms on bacterial disease sensitivity

CONCLUSIONS

The canopies and rootstock-cultivar combinations influenced leaf area, impacting plant health, disease resistance, and growth conditions. Trident canopy shape tended to exhibit higher leaf area values in some cultivars, suggesting favorable leaf development within this training system. Significant differences in vigor were observed among the cultivars studied, with Myrobalan 29C and GF677 generally presenting greater vigor. However, significant differences in bacterial disease incidence were registered in nectarine and peach cultivars, with the Vertical Axis showing more sensitivity for more cultivars.

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