RESEARCH ARTICLE

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Response to economically important fungal diseases of plum cultivar-rootstock combinations

ABSTRACT

The present study was conducted during the period 2020–2023 under the agroecological conditions of the Troyan plum-growing region, with the aim of assessing the susceptibility of plum cultivar–rootstock combinations to three economically important fungal diseases: rust (*Tranzschelia pruni-spinosae*), shot hole disease (*Stigmina carpophila*), and red leaf spot (*Polystigma rubrum*). Four widely grown plum cultivars (Cacanska Lepotica, Hanita, Jojo, and Stanley), grafted onto six rootstocks (Brompton, GF 655-2, SJ A, Wavit, Wangenheim, and *Prunus cerasifera*), were evaluated under natural infection conditions.

Climatic parameters were recorded annually to determine their influence on pathogen development. Significant differences in disease severity were observed among cultivars and rootstocks. The highest incidence of shot hole disease was recorded in the Hanita/Wavit combination (44.66% in 2022), while the cultivar Stanley showed pronounced susceptibility to rust when grafted on Brompton and Wavit rootstocks (31-37%). In contrast, combinations Cacanska Lepotica involving GF 655-2 and Wavit rootstocks exhibited the lowest overall disease susceptibility.

These results highlight the critical role of rootstock selection in reducing disease pressure and improving the resilience and sustainability of plum orchards under changing climatic conditions.

Highlights

This study presents a comprehensive multi-year evaluation of the response of plum cultivar–rootstock combinations to major fungal diseases under variable climatic conditions.

Rootstock selection significantly influenced disease severity and yield stability across all studied cultivars.

Integration of long-term climatic data with disease assessments provides new insights for climate-resilient plum production.

Key words: *Prunus domestica* L.; climate change; cultivar–rootstock combinations; fungal diseases; yield stability

Introduction

Plum (*Prunus domestica* L.) production is strongly influenced by climatic conditions, which determine both yield quantity and fruit quality. Temperature and precipitation regimes affect key physiological processes, including flowering, fruit set, and fruit development, as well as the epidemiology of major fungal diseases. Several studies have demonstrated close relationships between climatic variability and plum productivity. For example, Iancu et al. (2013) reported that yield variability in the cultivar 'Anna Späth' was more strongly related to fruit number than to average fruit weight under fluctuating climatic conditions.

Climate plays a major role in determining the distribution, phenology, fruit quality, and diseases and pests of perennial fruit crops. The physiological and yield characteristics of fruits are sensitive to the changing global climate, as climatic factors such as temperature, precipitation, etc. have a direct relationship with the regulatory physiological events in fruit trees. (Bhattacharjee et al., 2022). Although rising atmospheric CO_2 concentrations may stimulate vegetative growth, the overall impact of climate change on fruit production remains uncertain, especially in relation to disease development under altered temperature and humidity regimes.

Intensive plum production systems require high agrotechnical and phytosanitary inputs, which increase production costs and environmental pressure. This highlights

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the need for quantitative assessment of environmental factors and phytopathological risks in order to support sustainable orchard management (Yan et al., 2023). An effective strategy for reducing chemical inputs involves the use of resistant cultivars and appropriate rootstocks, which can significantly influence tree vigour, phenology, and susceptibility to diseases.

Among the most economically important fungal diseases affecting plum orchards are shot hole disease, caused by *S. carpophila*, red leaf spot caused by *P. rubrum*, and plum rust caused by *T. pruni-spinosae*.

Shot hole disease affects leaves, shoots, and fruits, leading to premature defoliation, reduced photosynthetic activity, and yield losses, particularly under cool and humid conditions (Ahmadpour, 2018; Ivanova et al., 2012; Khromykh et al., 2020; Molnár et al., 2022). Its development is favored by prolonged wet and cool conditions (Leonov & Bulgakov, 2020).

Red leaf spot is highly dependent on early-season moisture and temperature, resulting in characteristic red to brown leaf lesions and premature leaf fall in susceptible cultivars (Mitre et al., 2015). Plum rust typically develops during warm and humid summer periods and may cause severe defoliation and tree weakening in heavily infected orchards.

Previous studies have shown that the severity of these diseases varies considerably depending on cultivar susceptibility, climatic conditions, and orchard management practices (Bálint et al., 2016; Mitre et al., 2015; Stefanova et al., 2021). However, information on the combined effects of cultivar–rootstock interactions and climatic variability on disease development and yield stability remains limited, particularly under mountain and semi-mountain agroecological conditions.

The aim of the present study was to evaluate the susceptibility of major plum cultivar–rootstock combinations to shot hole disease (*S. carpophila*), red leaf spot (*P. rubrum*), and plum rust (*T. pruni-spinosae*) under the agroecological conditions of the Troyan region during the period 2020–2023. By integrating multi-year climatic data with disease severity assessments and yield measurements, the study seeks to provide practical guidance for the selection of resilient cultivar–rootstock combinations suitable for sustainable plum production in the context of climate change.

Materials and Methods

Experimental site and plant material

The study was conducted during the period 2020–2023 in an experimental plum orchard located at the Research Institute of Mountain Stockbreeding and Agriculture, Troyan, Bulgaria. The orchard is situated in a mountainous plum-growing region characterized by moderate continental climate conditions.

Four plum cultivars (*P. domestica* L.) widely used in commercial production—Cacanska Lepotica, Hanita, Jojo, and Stanley—were evaluated. The cultivars were grafted onto six rootstocks: five clonal rootstocks (Brompton, GF 655-2, SJ A, Wavit, and Wangenheim) and one generative rootstock (*P. cerasifera*).

Experimental design and orchard management

The experiment was established using a randomized block design with three replications. Each cultivar–rootstock combination was represented by three trees per replication. The plantation was established in 2003, with a planting scheme spacing of 4.0 × 1.7 m and trained and maintained according to standard commercial plum-growing practices for the region. No irrigation or fungicide treatment is applied. Annual winter pruning is applied.Assessment of fungal diseases

The natural development of three economically important fungal diseases of plum was monitored under natural infection conditions: shot hole disease caused by *Stigmina carpophila*, red leaf spot caused by *Polystigma rubrum*, and plum rust caused by *Tranzschelia pruni-spinosae*.

Disease assessments were carried out visually at the end of June each year, after the main infection period, when disease symptoms were clearly expressed (Arnaudov & Vassilev, 2020). From each cultivar–rootstock combination, 200 leaves were randomly collected to determine disease severity.

Disease severity was evaluated using a five-point scale according to Nedev et al. (1979), where: 0 - no visible symptoms; 1 - single lesions; 2 - up to 25% of the leaf surface affected; 3 - 25–50%; 4 - 50–75%; 5 - more than 75% of the leaf surface affected.

For each combination, a disease index (I) was calculated using the McKinney (1923) formula:

$I = \frac{\sum(n \times k)}{N \times K} \times 100$, where

I is the disease index (%), n is the number of leaves in each disease category, k is the corresponding score, N is the total number of assessed leaves, and K is the maximum possible score (5).

Yield assessment

Yield was determined at the end of each growing season (2020–2023). In 2022, no yield was recorded due to unfavorable climatic conditions during the flowering period, characterized by high precipitation in April (95.8 mm), as well as damage caused by *Monilia*, which compromised the production. All fruits from each assessed tree were harvested and weighed individually using an electronic balance. Yield data were expressed as kilograms per tree and used to evaluate the relationship between disease severity, cultivar–rootstock combinations, and productivity.

Meteorological data

Daily meteorological data, including precipitation (mm day⁻¹) and average air temperature (°C day⁻¹), were recorded using a METOS Compact automatic agrometeorological station (Pessl Instruments GmbH, Austria) located in close proximity to the experimental orchard.

The monitoring period covered the interval from 15 April to 15 October for each year of the study (2020–2023). Climatic data from the study period were compared with a 20-year reference period (2001–2020) to assess deviations from long-term averages (Table 1).

Table 1. *Annual and vegetation precipitation (mm) (2020-2023).*

Year	Annual precipitation (mm)	Vegetation (IV-IX) precipitation (mm)
2001-2020 (20 year base period)	861.2	552.4
2020	679.6	382.6
2021	606.1	285.0
2022	545.3	362.3
2023	563.5	495.7

Statistical analysis

The standard error bar is marked in the figures. Descriptive statistical analyses were performed to summarize disease severity and yield data across years, cultivars, and rootstocks.

Results

Climatic conditions during the study period

During the period 2020–2023, climatic conditions in the Troyan region showed pronounced deviations from the long-term reference period (2001–2020). Winters were characterised by higher-than-average air temperatures, particularly in January–February 2023, when mean January temperature reached 5.3 °C compared with the long-term average of −0.3 °C.

Precipitation distribution was highly variable between years. The highest monthly precipitation values were recorded in May and June 2023, creating favourable conditions for the development of fungal diseases requiring high humidity. In contrast, the vegetation periods of 2020–2022 were characterised by relatively low precipitation totals, contributing to plant stress. Annual precipitation totals for all experimental years remained below the long-term average (861.2 mm), with the highest annual amount recorded in 2020 (679.6 mm) (Figure1).

Disease incidence and severity

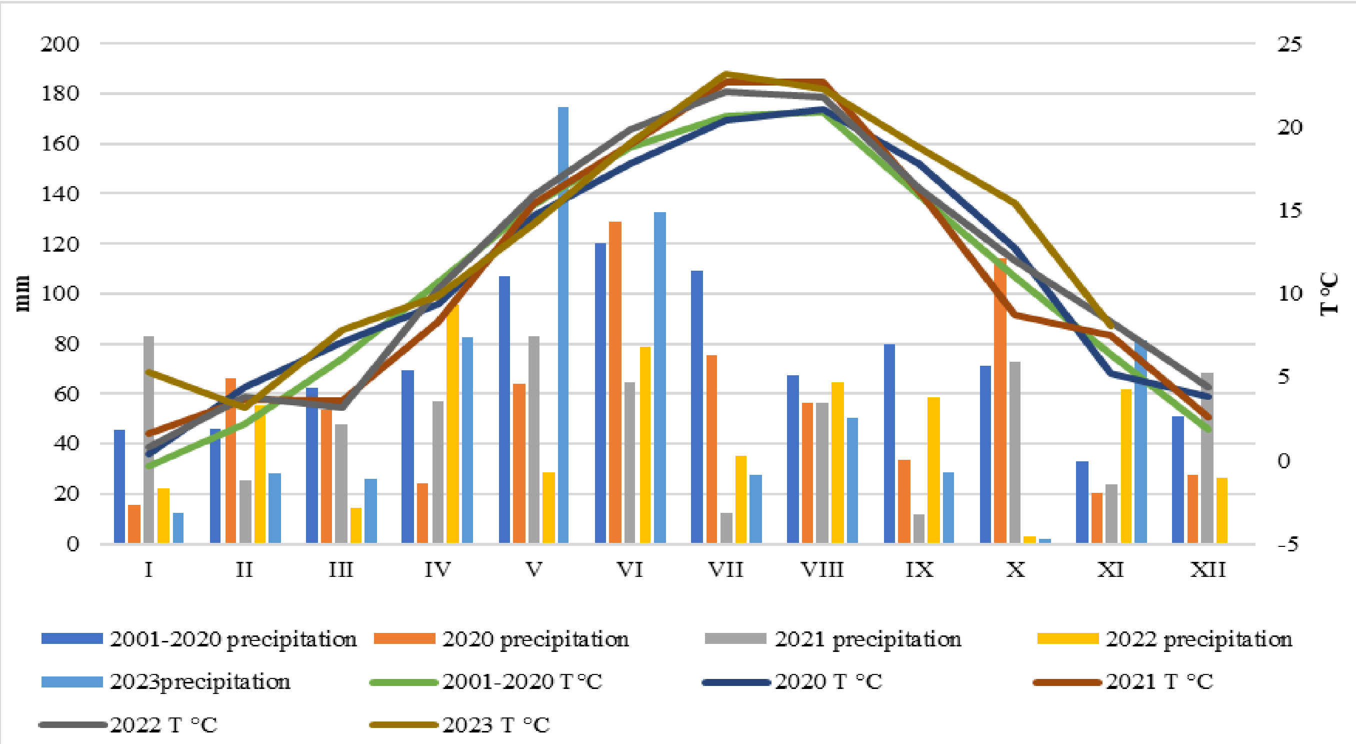

Figure 1. *Average monthly temperatures and total precipitation amounts for the study period (2020-2023) and 20-year base period (2001-2020).*

No red leaf spot symptoms were observed in 2020 and 2021. Disease pressure increased markedly in 2022 and 2023 on the Cacanska Lepotica, coinciding with periods of higher humidity and temperature fluctuations. The highest levels of severity were observed in strong-vigorow rootstocks Brompton (18.6%) and *P. cerasifera* (14.66%), while the lowest levels of infection were recorded in what is considered a very weak vogor rootstock - Wavit (1.6%) in 2023.

Shot hole disease was the most prevalent disease across all cultivars and years. Disease severity varied considerably among cultivar–rootstock combinations, ranging from 9.33% to 44.66%. The highest disease index was recorded in the Hanita/Wavit combination in 2022 (44.66%). Increased disease incidence was frequently observed on Brompton, St. Julien A (SJ A), and *P. cerasifera* rootstocks, considered to have high growth vigor, whereas lower severity values were consistently recorded on GF 655-2 and Wangenheim rootstocks.

Plum rust showed moderate to high incidence depending on the year and cultivar. Disease severity ranged from 4.0% to 31.2%. The cultivar Stanley exhibited the highest susceptibility, particularly when grafted onto SJ A and Brompton rootstocks. In contrast, cultivars grafted onto GF 655-2 and Wavit generally displayed reduced rust incidence.

Cultivar-specific responses

Cacanska Lepotica exhibited relatively low overall susceptibility to all three diseases, particularly when grafted onto GF 655-2 and Wavit rootstocks (Figure 2).

Hanita showed moderate susceptibility to rust but high susceptibility to shot hole disease (Figure 3).

Jojo displayed moderate disease levels overall, while Stanley was the most susceptible cultivar (Figures 4 and 5).

Yield performance

Figure 6 shows the following trends:

• Stanley, although productive in 2020, has declined in 2021, probably due to increased phytopathological pressure.

• Hanita and Jojo, despite high pathogen attack, have shown relatively stable yields with a moderate increase in recent years.

• C. lepotica, especially on rootstocks GF 655-2, Wavit and SJ A, has demonstrated high and stable productivity: 35–53 kg/tree in individual years.

There is a clear correlation between plant health status and yield potential. Increased attack index by powdery mildew and rust correlates with reduced yield, especially in

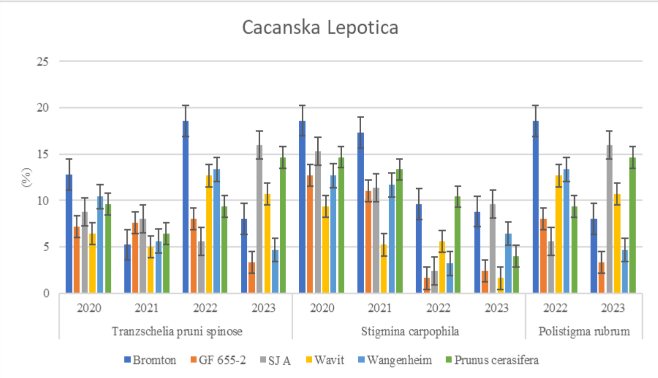

Figure 1. *Fungal disease incidence (%) in combinations of the Cacanska Lepotica cultivar (2020-2023).*

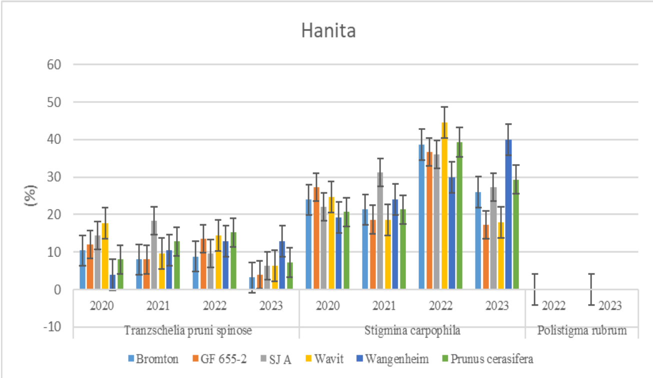

Figure 3. *Fungal disease incidence (%) in Hanita cultivar combinations (2020-2023).*

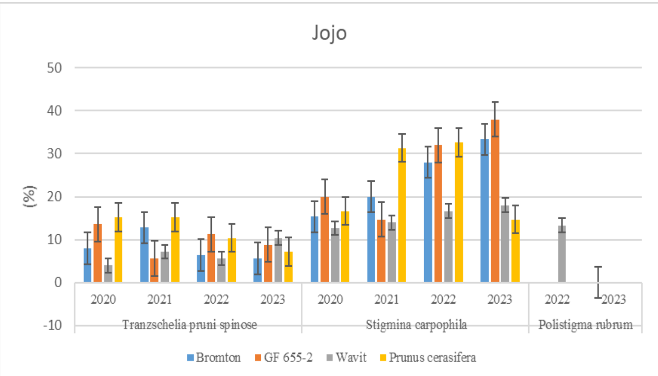

Figure 4. *Fungal disease incidence (%) in Jojo cultivar combinations (2020-2023).*

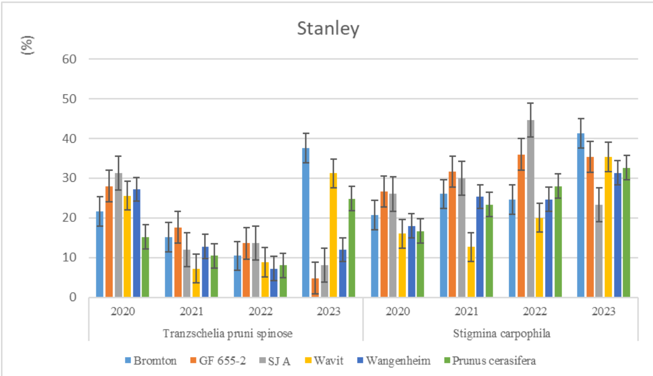

Figure 5. *Fungal disease incidence (%) in Stanley cultivar combinations (2020-2023).*

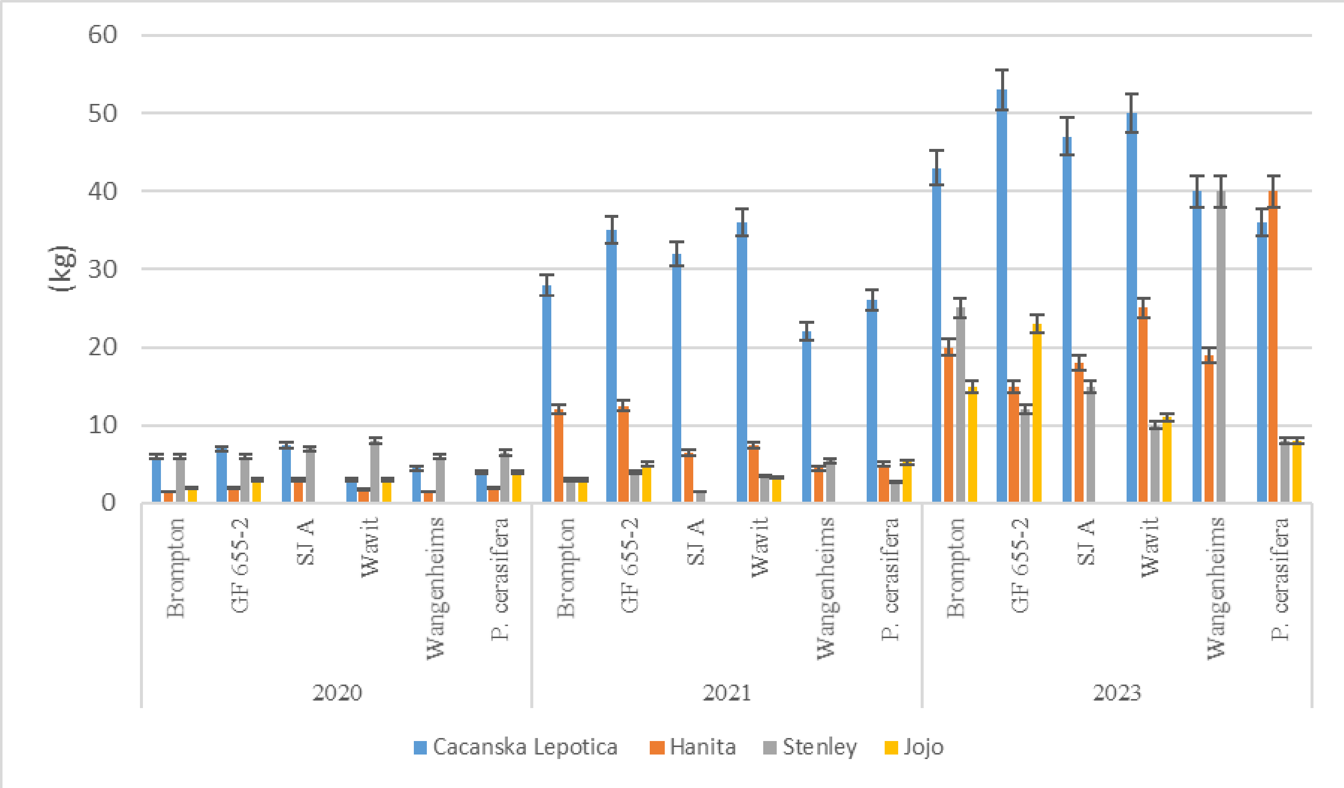

Figure 6. *Yield per tree (kg).*

susceptible varieties such as Stanley

The combined effect of diseases and adverse climatic conditions has a significant impact on plum yields. The selection of resistant cultivars and rootstocks, as well as the implementation of appropriate agrotechnical measures, can mitigate these effects and improve yields. In 2022, the degree of attack by leaf diseases was recorded, but in fact, no real commercial yields were recorded from any variety-rootstock combination, due to the unfavorable climatic conditions at flowering, pollination, and fruit set damages caused by *Monilinia* epiphytotic.

Correlation analysis

A direct relationship is observed between rainfall (humidity) and the severity of powdery mildew and red leaf spot Peak disease rates were recorded in 2022 and 2023, coinciding with higher humidity levels.

A negative relationship between yield and disease severity is particularly pronounced in Stanley, where a high infection index leads to a significant reduction in yields

1. Climate and diseases

Humidity, rainfall and high air humidity favor the development of the fungal diseases Shot hole (*S. carpophila*), Rust (*T. pruni-spinosae*) and Red leaf spot (*P. rubrum*). Warm and humid spring/summer - higher attack rate, Dry and warm periods - lower disease pressure

2. Diseases and yield

Diseases reduce photosynthetic leaf area; Affect fruit set and development; Leads to low yield, especially in sensitive varieties like Stanley

3. Climate and yield

Spring frosts, prolonged drought or extreme temperatures can damage flowers, fewers, leading to reduced fruit set; These conditions slow down vegetative growth, increase plant stress, and make the trees more vulnerable to diseases

Annual precipitation (in total) is not directly beneficial, and is even associated with a decrease in yield — probably because some of it falls outside the growing season and creates an unfavorable background (Table 1).

Discussion

The results of the present study demonstrate that the development and severity of major fungal diseases in plum orchards are strongly influenced by the interaction between cultivar, rootstock, and climatic conditions. Pronounced inter-annual variability in disease pressure observed during 2020–2023 confirms the decisive role of weather patterns in shaping disease epidemiology, particularly under mountain agroecological conditions.

Shot hole disease emerged as the most damaging pathogen across all cultivars, which is consistent with previous reports identifying this disease as a major limiting factor in plum production (Ivanova et al., 2012; Molnár et al., 2022). The exceptionally high disease severity recorded in certain cultivar–rootstock combinations, such as Hanita/Wavit, indicates that rootstock choice can significantly amplify or mitigate host susceptibility. Rootstocks such as Brompton, SJ A, and *P. cerasifera* were frequently associated with increased disease pressure, whereas GF 655-2 and Wangenheim consistently reduced disease severity, suggesting a potential role of rootstock-mediated vigor control and phenological synchrony in disease resistance. Bubici et al. (2010) considered Golden Plumza to be the most susceptible, showing disease severity of up to 46% and twig defoliation of 20–40%, this variety, along with Angeleno and Fortune, showed the earliest infections with disease in all years of observation. For this reason, trees of these varieties, but mainly Golden Plumza, may also be useful as "bioindicators" for early prediction of *S. carpophila* infection.

Plum rust severity was highest in the cultivar Stanley, confirming its known susceptibility reported in earlier studies (Bálint et al., 2016; Mitre et al., 2015). Reduced rust incidence on GF 655-2 and Wavit rootstocks indicates that these rootstocks may limit pathogen development potentially through improved canopy aeration or altered leaf microclimate. Red leaf spot occurrence was strongly linked to years with higher early-season precipitation, which supports findings by Mitre et al. (2015) that emphasize the importance of moisture availability during leaf expansion.

Rootstocks provide an alternative to improve fruit yield and quality, achieve early harvest, minimize juvenile stage, control tree vigor, allow high density planting. The choice of rootstock is crucial as climatic and soil factors have a significant influence (Bhattacharjee et al., 2022).

Yield responses closely reflected disease pressure. The strong negative correlation between shot hole disease severity and yield confirms the substantial economic impact of this pathogen. Cultivars exhibiting stable yields, particularly Cacanska Lepotica grafted onto GF 655-2 and Wavit, demonstrated that appropriate rootstock selection can buffer the negative effects of disease pressure and climatic stress. Similar relationships between disease incidence and yield stability have been reported for *P. domestica* L. under diverse environmental conditions (Alexandru et al., 2019; Minkov et al., 2024).

Overall, the findings highlight that cultivar–rootstock interactions are a critical, yet often underestimated, component of integrated disease management strategies. In the context of climate change, where increased temperature variability and altered precipitation patterns are expected to intensify phytopathological risks, the use of disease-tolerant rootstock combinations represents a sustainable alternative to increased fungicide dependence.

Conclusions

This study provides a comprehensive multi-year assessment of the susceptibility of major plum cultivars grafted onto different rootstocks to three economically important fungal diseases under the agroecological conditions of the Troyan region.

Climatic variability during the period 2020–2023 significantly influenced disease development, confirming the sensitivity of plum disease epidemiology to changing temperature and precipitation regimes.

Disease severity was strongly dependent on cultivar–rootstock combinations. Rootstocks Brompton, SJ A, and *P. cerasifera* were associated with higher disease pressure, whereas GF 655-2 and Wangenheim consistently demonstrated lower susceptibility across cultivars.

A strong negative relationship between fungal disease severity, particularly shot hole disease, and yield was confirmed, underlining the agronomic importance of disease management through appropriate cultivar–rootstock selection.

The results demonstrate that targeted rootstock selection can effectively mitigate phytopathological risks and enhance yield stability, providing a practical framework for the establishment of resilient plum orchards under changing climatic conditions.

Novel contribution: Unlike previous reports that address cultivar susceptibility or general disease occurrence, this study demonstrates how specific cultivar–rootstock interactions modify both disease pressure and yield stability. These findings provide a practical decision-making framework for growers and breeders, enabling the establishment of more resilient plum orchards with reduced dependence on fungicide applications.

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Data Availability: All data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Conflict of Interest: The authors declare no conflict of interest.

References

Ahmadpour A. 2018. Review of shot-hole disease of stone-fruit trees. Plant Pathol Sci, 7(2): 1–13.

Alexandru I, Cristea S, Hoza D. 2019. Effectiveness of treatments on the attack of *Polystigma rubrum* pathogens and *Stigmina* *carpophila* on plum in Șoimari location, Prahova county. Scientific Papers. Series B, Horticulture, 63(2): 79-82.

Arnaudov V, Vassilev D. 2020. Reaction of some nectarine cultivars to *Stigmina carpophila* (Lev.) Ellis. Bulgarian Journal of Crop Science, 57(4): 18–22.

Bálint J, Szabó A, Tófalvi B, Puia C, Balog A. 2016. Comparing disease resistance of local and international plum cultivars (*Prunus domestica*) from Eastern Transylvania, Romania. J Plant Dis Prot, 123, 317–320.

Bhattacharjee P, Warang O, Das S, Das S. 2022. Impact of Climate Change on Fruit Crops:- A Review. Curr World Environ, 17(2): 319-330.

Bubici G, D'Amico M, Cirulli M. 2010. Field reactions of plum cultivars to the shot-hole disease in southern Italy. Crop Protection, 29 (12): 1396-1400.

Iancu M, Chitu E, Sumedrea D. 2013. The influence of the variation of main climatic factors on the fruiting processes of plum, on different fertilizer management systems. Acta Hortic, 981: 255-262.

Ivanova H, Kalocaiova M, Bolvansky M. 2012. Shot-hole disease on *Prunus persica* – the morphology and biology of *Stigmina carpophila*. Folia oecol, 39(1): 21–27.

Khromykh NO, Lykholat YV, Anishchenko AA, Didur OO, Gaponov AA, Kabar AM, Lykholat TY. 2020. Cuticular wax composition of mature leaves of species and hybrids of the genus *Prunus* differing in resistance to clasterosporium disease. Biosyst. Divers, 28: 370–375.

Leonov N, Bulgakov T. 2020. Biological protection of plum from shot hole disease in the humid subtropics of the Krasnodar region (Russia) BIO Web Conf., 21 (2020) 00035.

McKinney HH. 1923. A new system of grading plant diseases. J Agric Res, 26: 195 -218.

Minkov P, Todorova S, Stefanova B. 2024. A Parallel Study of the Attitude to Economically Important Diseases in Plum Cultivars in the Troyan and Gabrovo Regions under Changing Abiotic Factors. Journal of Mountain Agriculture on the Balkans 27(2): 253-274.

Mitre I, Tripon A, Mitre I, Mitre V. 2015. The response of several plum cultivars to natural infection with *Monilinia laxa, Polystigma rubrum* and *Stignima carpophila*, Notulae Scientia Biologicae, (1): 136-139.

Molnár B, Szabó S, Holb IJ. 2022. Temporal Dynamics of Incidence of Shot Hole Disease Affected by Training Systems and Cultivar Susceptibilities in an Integrated Plum Orchard. Journal of Fungi, 8(6): 580.

Nedev N, Grigorov Y, Baev H, Serafimov S, Strandzhev A, Kavardzhikov L, Lazarov K, Nikolov N, Dzuvinov V, Popova L, Slavov N, Iliev P, Stoyanov D, Kunev I, Vishanska Y, Topchiyska M. 1979. Methodology for studying plant resources in fruit plants (in Bulgarian). Plovdiv Research Institute of Fruit Growing, 49 – 55.

Stefanova B, Minkov P, Popski G. 2021. Monitoring of *Polistigma Rubrum, Tranzschelia Pruni Spinosae, Stigmina Carpophila* in Plum Rootstock-Cultivar Combinations for the Troyan Region. Scientific Papers. Series B. Horticulture, 65(1): 243-250.

Yan X, Ye D, Tang Y, Muneer MA, Christie P, Tou C, Xu W, Shen B, Xu J and Zhang J. 2023. Potential mitigation of environmental impacts of intensive plum production in southeast China with maintenance of high yields: Evaluation using life cycle assessment. Front Plant Sci, 14:1158591.