preliminary report / prethodno saopštenje

received: 22 January 2015, accepted: 13 February 2015
published online: 23 March 2015
doi:10.5937/ratpov52-7569
52:1 (2015) 39-43

Winter Garlic Rust (*Puccinia* spp.) Rate under Organic and Conventional Production Conditions

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Summary: Due to low requirements for fertilizers and pesticides, garlic is a valuable crop in organic systems, although production may be hampered by diverse pathogens. In recent years, garlic rust (*Puccinia* spp.) has been increasingly present in our agro-ecological climate, developing into a significant problem for garlic production. The aim of the study was twofold: i) to monitor winter garlic rust rate in organic and in conventional production, and ii) to monitor genotype sensitivity to the pathogen in both production systems. Trials were conducted in 2012/2013 in Bački Petrovac, Serbia at the Institute of Field and Vegetable Crops in Novi Sad, and included 30 genotypes planted in organic and conventional field, simultaneously. Disease severity was evaluated visually, using a scoring system between zero and five. Overall average infection intensity score in conventional plots was 1.18, and in organic plots 0.79. There was no statistically significant difference between infection intensity in conventional versus organic plots. Nevertheless, reactions of certain genotypes to the causal agents of rust differed across organic and conventional plots ranging from no apparent infection symptoms in organic to severe symptoms in conventional plots.
Keywords: garlic, genotype sensitivity, infection intensity, organic crop production, rusts, *Puccinia*

Introduction

Garlic (*Allium stivum* L.) is a plant species often grown in organic systems. Fresh, dehydrated, or utilized as a spice, garlic has significant nutritional value and medical properties. Various authors have studied its anti-microbial and therapeutic qualities (Ankri & Mirelman 1999, Lalošević et al. 2013, Vlajić et al. 2014a). However, the area planted with garlic in Serbia is relatively small, between 7,000 and 10,000 ha (Bošnjak et al. 2010).

Plant rusts, caused by the fungus *Basidiomycota*, order *Uredinales* are some of the most destructive plant diseases. Throughout world history they have provoked famine, and in some cases destruction of whole economies (Agrios 2005). The first report of garlic rust was in England in 1809 (Ivanović & Ivanović 2001), and it was reported in Serbia in Rakovica in 1910 (Ranojević 1910). Until recently, it has not been considered to be of major importance for garlic production (Cruz Medina & García 2007). Lately causal agents of the disease, however, have increasingly been present in our climate, developing into a significant problem. Within the genus *Puccinia* there are two species: *Puccinia porri* Wint. and *Puccinia allii* Desn. *Puccinia allii* Desn. is a common cosmopolitan pathogen, present in onions, garlic and leeks, and reported in Europe, Asia, Africa, North and South America and New Zealand (Gäumann 1959, Majewski 1970). *Puccinia porri* Wint. infects leeks and garlic (Ivanović & Ivanović 2001). It has been reported that the aforementioned pathogens also infect Welsh onions (*Allium fistulosum* L.), chives (*Allium schoenoprasum* L.) and other alliums (Szabo et al. 2008).

The aim of the present study was to determine winter garlic rust rate in organic and in conventional production, and to monitor the sensitivity of 30 genotypes to the pathogens, under production conditions of both systems.

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Acknowledgements: We are thankful to Dr. Zenobia Lewis from the University of Liverpool for critically reading this manuscript. This work was supported by TR 31030 Project of the Ministry of Education and Science of the Republic of Serbia.

Materials and Methods

The trial was conducted in Bački Petrovac, in the Institute of Field and Vegetable Crops in Novi Sad, and included 30 genotypes of different geographic origin (Tab. 1) planted in organic and conventional field, simultaneously. In September 2012, cloves were manually planted in triple 300 cm long rows spaced 30 cm apart and with within-row spacing of 10 cm, resulting in a population density of 90 plants per plot. Plot size was 1.8 square meters. Soil management was carried out according to standard procedures. In both organic and conventional fields, no pesticides were applied during the entire growing season. The trial was conducted in a randomised block design with three replicates. Each replicate comprised of 10 plants (*n*=30).

Table 1. Geographical origin of the winter garlic genotypes

N°	Genotype	Location of collecting site	Latitude of collecting site *	Longitude of collecting site	Elevation of collecting site
1	JBL-1	Aleksandrovo, Serbia	453800N	203600E	75
2	JBL-2	Temerin, Serbia	452500N	195300E	79
3	JBL-3	Zmajevo, Serbia	452658N	194154E	75
4	JBL-3/13	Rimski Šančevi, Serbia	451941N	195037E	81
5	JBL-4	Kupusina, Serbia	454422N	190042E	85
6	JBL-5	Subotica, Serbia	460601N	193956E	116
7	JBL-5/21	Rimski Šančevi, Serbia	451941N	195037E	81
8	JBL-6	Subotica, Serbia	460601N	193956E	116
9	JBL-7	Đala, Serbia	460957N	200654E	74
10	JBL-8/16	Rimski Šančevi, Serbia	451941N	195037E	81
11	JBL-8/17	Rimski Šančevi, Serbia	451941N	195037E	81
12	JBL-8/23	Rimski Šančevi, Serbia	451941N	195037E	81
13	JBL-9	Buđanovci, Serbia	445400N	195200E	77
14	JBL-12	Bački Petrovac, Serbia	4522139N	193550E	80
15	JBL-13	Bački Petrovac, Serbia	4522139N	193550E	80
16	JBL-15	Novo Selo, Serbia	433807N	205222E	236
17	JBL-16	Bački Petrovac, Serbia	4522139N	193550E	80
18	JBL-18	Čačak, Serbia	435320N	202101E	242
19	JBL-18.1	Spain	------N	------W	---
20	JBL-19	Idvor, Serbia	451100N	203100E	77
21	JBL-21	Klek, Serbia	452500N	202900E	78
22	JBL-22	Sremska Kamenica, Serbia	451319N	195038E	108
23	JBL-23	Rusko Selo, Serbia	454523N	203456E	76
24	JBL-25	Stepanovićevo, Serbia	452450N	194154E	86
25	JBL-27	Stepanovićevo, Serbia	452450N	194154E	86
26	JBL-28S	Chechnya, Russia	------N	------E	---
27	JBL-29	Chechnya, Russia	------N	------E	---
28	JBL32SA	Sarajevo, BIH**	435123N	182448E	540
29	JBL-40	Glogovac, Serbia	440234N	211849E	118
30	JBL-43	Bačko Petrovo Selo, Serbia	454200N	200500E	78

* Latitude of collecting site is expressed as degree (2 digits), minutes (2 digits) and seconds (2 digits) followed by N (North). Longitude of collecting site is expressed as degree (2 digits), minutes (2 digits) and seconds (2 digits) followed by E (East) or W (West). Every missing digit (minutes or seconds) is indicated with a hyphen. Elevation of collecting site expressed in meters above sea level.
** Bosnia and Herzegovina

On 17 June 2013 infection intensity rate under conditions of natural infection, was visually evaluated by scoring from zero to five (Tab. 2). The garlic was in the phenophase of intensive development of garlic bulbs.

Data (mean monthly temperatures and total monthly precipitation) from the weather station at Bački Petrovac (http://www.hidmet.gov.rs/) were used to obtain weather data for the growing seasons studied (Fig. 2).

Differences across genotypes in rust infection rates were examined using one-way analysis of variance (ANOVA). Differences in mean were tested using Duncan's new multiple range test. Differences were considered to be significant at *P*=0.05. All statistical analyses were performed using the statistical software package Statistica Version 10 (StatSoft, Inc., Tulsa, Oklahoma, USA).

Table 2. Infection intensity scale (IIS) (Vlajić 2013)

IIS	Symptoms description
0	No visible symptoms of infection
1	Less than 5% of the leaf area is covered with pustules (Fig. 1A)
2	5.1-10% leaf area covered with pustules
3	10.1-25% leaf area covered with pustules
4	25.1 - 50% leaf area covered with pustules
5	More than 50% of the leaf area is covered with pustules (Fig. 1B)

Figure 1. Rust on winter garlic leaves. Panel A, less than 5% of the leaf area covered with pustules (genotype JBL 5). Panel B, more than 50% of the leaf area is covered with pustules (genotype JBL 9). Photo S. Vlajić

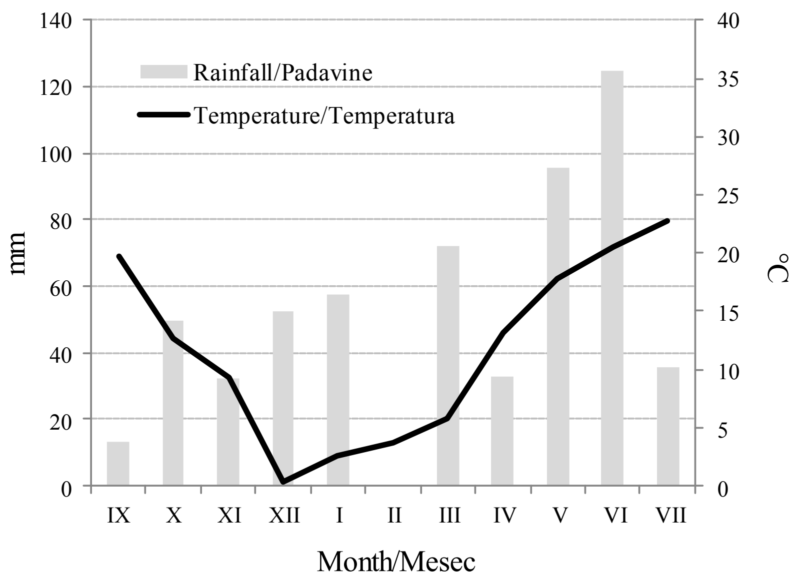

Figure 2. Rainfall (mm) and temperatures (°C) during the winter garlic growing season

Results and Discussion

Overall average infection intensity scores were not significantly different for winter garlic plants in conventional (1.18) versus organic plots (0.79). However, different genotypes differed significantly in their reactions to the rust causal agent (Tab. 3). The most sensitive conventionally produced genotype was JBL 9 (3.30), while the most tolerant was JBL 32, which experienced no visible symptoms of infection (0.00). In the organic system, 4 genotypes showed no visible symptoms of rust infection (JBL 6; 15 JBL, JBL 16; JBL 23), while JBL 3 was the most sensitive (3.26).

The potential mechanisms underlying plant tolerance to garlic rust causal agents are diverse. Regarding production system genotypes, genotypes JBL 15, JBL 16, JBL 23, and JBL 32, performed a high level of tolerance. Waxy coating on leaves may prevent water retention, thus preventing favourable conditions for spore germination (Alam et al. 2007). The resistance might also be based on the hypersensitive response-preventing penetration of pathogenic haustoria into the host cell (Heath 1981). Garlic resistance to rust is polygenic and located in the geneplasm (Qi et al. 2000). Infection is achieved at 16-22°C (Duthie 1997), while in water uredospore germinate at 5-25°C (Morinaka 1985). The extremely mild winter of 2012/2013 made vitality maintenance of the pathogen infectious spores possible and infection therefore significant. The subsequent mild spring, with frequent rainfalls, resulted in substantial garlic rust development. During April, the mean temperature recorded was 13.2°C with 32.9 mm of rainfall, thus creating favourable primary infection conditions. Moderate temperatures (17.8°C) and precipitation (95.5 mm) in May favoured the further development of the pathogen. Subsequent favourable temperatures (June 20.5°C; July 22.7°C) and increased rainfall (June 124.5 mm; July 35.4 mm) again favoured the pathogen (Fig. 2). With higher infection intensity rate, damage made by garlic rust can be considerable. In our agroecological region, the pathogen causes plants to form smaller cloves and therefore smaller bulbs, contain less dry matter, and have lower quality (Vlajić 2013).

Table 3. Rust rate in winter garlic plants in conventional and organic plots. The values shown are mean ±SD for 30 replicate plants of each genotype. Different lower-case letters indicate significant differences at $P<0.05$ by Duncan's range test.

Genotype	Infection intensity score	
	Conventional plot	Organic plot
JBL-1	2.76^{j}	3.26^{g}
JBL-2	2.03^{fgh}	0.40^{bc}
JBL-3	2.13^{hi}	1.33^{ef}
JBL-3/13	1.43^{de}	1.10^{ef}
JBL-4	2.03^{fgh}	1.00^{de}
JBL-5	0.63^{abc}	0.03^{ab}
JBL-5/21	0.30^{a}	0.66^{cd}
JBL-6	0.73^{abc}	0.00^{a}
JBL-7	1.13^{cd}	1.40^{f}
JBL-8/16	0.83^{abc}	1.06^{ef}
JBL-8/17	1.53^{defg}	1.16^{ef}
JBL-8/23	0.46^{ab}	0.24^{ab}
JBL-9	3.30^{k}	0.20^{ab}
JBL-12	1.90^{efgh}	1.00^{de}
JBL-13	0.56^{ab}	0.33^{abc}
JBL-15	0.83^{abc}	0.00^{a}
JBL-16	0.90^{bc}	0.00^{a}
JBL-18	1.54^{defg}	1.23^{ef}
JBL-18.1	2.10^{fgh}	1.13^{ef}
JBL-19	0.67^{abc}	0.16^{ab}
JBL-21	2.56^{ij}	1.37^{ef}
JBL-22	1.53^{defg}	0.03^{ab}
JBL-23	0.63^{abc}	0.00^{a}
JBL-25	0.43^{ab}	1.56^{ef}
JBL-27	0.33^{ab}	0.18^{ab}
JBL-28S	0.67^{abc}	2.33^{fg}
JBL-29	0.20^{a}	0.23^{ab}
JBL32SA	0.00^{a}	0.86^{de}
JBL-40	0.49^{ab}	0.87^{de}
JBL-43	0.81^{abc}	0.63^{cd}
Mean	1.18	0.79

In California, garlic rust occurrence may reduce garlic yield and soluble solids content, by more than 50% and 15% respectively, and increase economic damage by more than 27% (Koike et al. 2001). Crop rust management is limited both for organic as well as for conventional garlic production and includes prevention and sanitation: four-year crop rotation, crop residues incorporation, and removal of wild onions. In terms of increased pathogens suppression, such disease management is deficient. The use of plant extracts in plant disease control in organic production systems is of important significance. CH 100, a formulation containing tobacco and cabbage extract, has been shown to significantly reduce *P. allii* infection rate (Huang et al. 1992). In Serbia pesticides based on Ciram have been registered for the suppression of the causal agent of rust in terms for conventional production, but without satisfactory effectiveness in practice (Vlajić et al. 2014b). Results suggest that specific nutrients ratio of organic fields can result in a decreased rust rate, although in some genotypes a higher infection rate was produced compared to the same genotype cultivated in conventional field. Balanced ratio of nutrients favourably affected plant growth and development, and resulted in the development of tolerance to the pathogen.

Conclusions

Greater infection intensity was recorded in the conventional plot (1.18) compared to the organic one (0.79). Whether garlic has been produced in an organic or in a conventional way, genotype responses to the causal agent of rust differed considerably. In the organic field we observed genotypes without visible symptoms of infection. Selection of such genotypes could provide efficient and environmental-friendly protection of garlic cultivated in organic systems.

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Intenzitet infekcije rđe (*Puccinia* spp.) na jesenjem belom luku u uslovima organske i konvencionalne proizvodnje

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Sažetak: Beli luk predstavlja značajnu biljnu vrstu u organskim sistemima proizvodnje, čije gajenje može biti otežano uticajem različitih patogena. Rđa luka (*Puccinia* spp.) na našim prostorima primećena je davno, ali poslednjih nekoliko godina zabeležena je intenzivnija pojava. Cilj rada bio je praćene intenziteta infekcije u uslovima organske i konvencionalne proizvodnje, kao i reakcija genotipova na prisustvo patogena. Ogled je postavljen 2012/2013. godine u uslovima organske i konvencionalne proizvodnje. U tu svrhu posađeno je 30 genotipova jesenjeg belog luka. Intenzitet infekcije ocenjivan je vizuelnom metodom, upotrebom skale ocene od 0 do 5. Prosečna ocena ispitivanih genotipova u konvencionalnoj parceli bila je 1,18, a u organskoj 0,79. Nije utvrđena statistički značajna razlika između intenziteta infekcije na konvencionalnoj i organskoj parceli. Reakcije genotipova na prisustvo patogena bile su različite - pojedini genotipovi su bili bez vidljivih simptoma infekcije u uslovima organske proizvodnje, dok su u uslovima konvencionalne proizvodnje simptomi na istim genotipovima bili uočljivi.

Ključne reči: beli luk, intenzitet infekcije, osetljivost genotipova, organska proizvodnja, *Puccinia*, rđa