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DOI: 10.1515/ahr-2016-0017

Acta Horticulturae et Regiotecturae – Special Issue
Nitra, Slovaca Universitas Agriculturae Nitriae, 2016, pp. 15–17

EFFECTIVENESS OF THE BIOLOGICAL CONTROL OF GARLIC (*ALLIUM SATIVUM* L.)

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In two-year field experiments (2014 and 2015), the effect of used preparations on health status of leaves and roots and bulbs on two cultivars of garlic: 'Arkus' and 'Garpek' was studied. During investigations: Polyversum WP (*Pythium oligandrum*), Trifender WP (*Trichoderma asperellum*) and RhizoVital 42 (*Bacillus amyloliquefaciens*) and standard fungicide Topsin M 500 SC (tiophanate methyl) were used. Unprotected plants presented control. The obtained results showed that in the first year of the studies, all the tested formulations effectively protected the roots and bulbs of garlic against rot, except RhizoVital 42 for 'Arkus' variety and Trifender WP for cultivar 'Garpek'. In 2015, all tested preparations, without exception, limited root rot and the rot of basal part of bulbs both cultivars of garlic. The applied biological preparations had no significant effect on health of the leaves of garlic in 2014 and in 2015 for cultivar 'Garpek', while in the second year of studies, all the tested formulations effectively limited the dieback of leaves of the garlic cultivar 'Arkus'.

Keywords: *Pythium oligandrum*, *Trichoderma asperellum*, *Bacillus amyloliquefaciens*, tiophanate methyl, fungal pathogens

Garlic is a medicinal plant, with wide application in medicine, in particular through the secretion phytoncide allicin which is a breakdown product of sulfoxide alliin. Unfortunately, despite the production of bactericidal substances, garlic is infected by some pathogens, especially fungal, both during the growing season and the period after harvesting. The quality of garlic can be determined by many factors, but the most important among them are health bulbs, which were used for planting and a place for cultivation and crop rotation. The most dangerous diseases of garlic include *Fusarium* root rot and onion caused by the fungus *Fusarium* and white rot bulbs, which is the cause of *Sclerotium cepivorum* (Koike et al., 2007). Particularly, white rot is a major threat to crops due to the very long term survival of sclerotia of the fungus that can survive in soil for 8 years. A big threat to garlic, even during the growing season, are the fungi *Alternaria* spp., causing dieback of leaves usually after earlier being infected by the perpetrator of downy mildew, or infection of the roots by *Fusarium* spp. A permanent threat to the garlic cultivation is the fungi *Botrytis* spp., causing *Botrytis* leaf blight and also a more harmful disease – neck rot of bulbs. Less frequently are observed signs of rust caused by *Puccinia alli* on the leaves of garlic, which lead to yellowing and dying of leaves (Schwartz and Mohan, 2008).

Unfortunately, there are registered only a few fungicides for chemical protection of garlic in Poland – iprodione and mixture of cyprodinil and fludioxonil – for protection against *Botrytis* spp. and *Sclerotinia sclerotiorum*; mixture of fluopicolide and propamocarb hydrochloride protection against downy mildew, and *Alternaria* blight. Therefore, there shall be found other preparations – biotechnical and biological, that would be helpful in protecting garlic, especially against the most dangerous soil pathogens.

The aim of the study was to determine effectiveness of the chosen biological preparations in the protection of garlic against pathogens causing root rot and heel bulbs as well as dieback of leaves.

Material and methods

Field experiments were carried out in 2014 and 2015 on two cultivars of garlic: Polish 'Arkus' and Chinese 'Garpek' at the Mydlniki – Experimental Station of the Agricultural University in Krakow. The following biological plant protection products were applied as a bulb dressing before planting and 4 times during the growing season: Polyversum WP (*Pythium oligandrum* – 10^6 oospores in 1 g) at dose 0.05%, Trifender WP (*Trichoderma asperellum* – 5×10^8 spores in 1 g) at dose 0.02–0.05% and RhizoVital 42 (*Bacillus amyloliquefaciens* $>2.5 \times 10^{10}$ CFU/ml) at dose 0.05%. As the standard fungicide Topsin M 500 SC (tiophanate methyl – 500 g in 1 l) at dose 0.15% was used. Unprotected plants presented control. During the harvesting the symptoms on the leaves, the roots and basal part of bulbs were determined by 4 points scale, with 0 – no symptoms, 1 – 5% infestation 2 – 6–25% infestation 3 – infestation of 25–50%, 4 – infestation greater than 51%. From the obtained data, infestation indices were calculated (Mazur et al., 2004). After harvesting, mycological analyses were also carried out on infested roots and bulbs. The results were subjected to statistical analysis by the Duncan's test in two-factor system: cultivar of garlic and the used preparation.

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Results and discussion

Table 1 shows the results of analyses of health status of roots and basal part of bulbs from both cultivars of garlic in 2014. Standard fungicide and the preparation Trifender WP limited root rot and bulbs of cultivar 'Arkus' the most effectively. The preparation Polyversum WP was quite effective in the protection of garlic bulbs and roots. However, RhizoVital 42 was ineffective. For cultivar 'Garpek' the most effective was Polyversum WP and Topsin M 500 SC and, in contrast to the variety 'Arkus', quite significantly effective was RhizoVital 42. The preparation Trifender WP showed no significant efficacy in the protection of bulbs and roots of garlic. The mycological analysis showed that the predominant fungi isolated from infected bulbs and roots were fungi *Fusarium* spp.

In the next year of the study – 2015 – all used preparations showed significant efficacy in the protection of garlic: both tested cultivars against rot basal part of bulbs and roots (Table 2). Interestingly, standard fungicide showed the least effectiveness among the applied formulation in protecting the bulbs and roots of both cultivars. Most effective protection was provided by preparation RhizoVital 42 to protected cultivar 'Arkus', and by variety 'Garpek' – Polyversum WP. The mycological analysis confirmed the dominant role of the fungi of the genus *Fusarium* as cause of rot the roots and bulbs of garlic.

In the first year of the research, results of leaf health analyses showed no significant differences between the various combinations and between cultivars. On the leaves there were observed only secondary symptoms of *Fusarium* root rot, which were yellowing and drying of the ends of the leaf blade.

In the following year of study, there also additionally occurred rust (*Puccinia allii*) on leaves, which resulted in further yellowing and dieback of leaves. Also, the course of the weather conditions in 2015 – prolonged periods without rain and high air temperatures above 30 °C – a period of drought exacerbated the symptoms of dieback of leaves (Table 3). The results of analyses of leaf health showed that all the preparations used were significantly effective for the variety of 'Arkus', but for the cultivar 'Garpek', none of the used preparations significantly protected the leaves before dieback.

Table 1 Health status of garlic roots and basal parts of bulbs in 2014 – indices of infestation (%)

	'Arkus'	'Garpek'	Mean values
Polyversum WP	7.76 bc	5.51 abc	6.59 ab
Topsin M 500 SC	3.30 a	6.79 abc	4.90 a
Trifender WP	4.91 ab	9.64 cd	7.09 ab
RhizoVital 42	12.70 de	6.33 abc	9.27 b
Control	16.82 e	14.11 de	15.44 c
Mean values	8.46 a	8.24 a	

Note: means followed by the same letter do not differ with 5% of significance (Duncan's multiple range test)

Table 2 Health status of garlic roots and basal parts of bulbs in 2015 – indices of infestation (%)

	'Arkus'	'Garpek'	Mean values
Polyversum WP	6.09 ab	4.76 a	5.40 a
Topsin M 500 SC	8.20 ab	10.47 b	9.30 b
Trifender WP	7.71 ab	8.77 ab	8.23 ab
RhizoVital 42	5.00 a	5.82 ab	5.40 a
Control	20.73 c	15.97 c	18.29 c
Mean values	8.95 a	8.78 a	

Table 3 Health status of garlic leaves in 2015 – indices of infestation (%)

	'Arkus'	'Garpek'	Mean values
Polyversum WP	31.55 abc	37.21 bcd	34.36 a
Topsin M 500 SC	27.75 a	39.14 cd	33.32 a
Trifender WP	29.86 ab	38.33 cd	34.03 a
RhizoVital 42	26.10 a	37.17 bcd	31.50 a
Control	40.82 d	43.87 d	42.35 b
Mean values	31.11 a	39.13 b	

The results indicate the effective influence the microorganisms used to reduce root rot, and basal part of garlic bulbs. Previous studies by Patkowska (2006) reported high usefulness *Pythium oligandrum* in the protection of pea and bean against fungal pathogens, including soil pathogens. Similarly, research by Kurzawińska and Mazur (2007) on the health status of potato tubers found out that applied *P. oligandrum* limited infestation of potato tubers by important pathogens. Kowalska (2011) in her experiments confirmed the high efficiency of *Trichoderma asperelleum* in the protection of strawberries against *Botrytis cinerea*, causing prolongation of fruit storage without loss. Also, research on protection of Chinese aster showed high efficacy of *T. asperellum* and *P. oligandrum* in reducing soil fungi, especially the genus *Fusarium* (Nawrocki, 2013). Also, *Bacillus amyloliquefaciens*, in addition to its antibacterial capabilities, can effectively limit the growth of fungi of the genus *Fusarium* (Yuan et al., 2012).

Conclusion

In the first year of the studies, all the tested formulations effectively protected the roots and bulbs of garlic against rot, except RhizoVital 42 for the 'Arkus' vaiety and Trifender WP for the cultivar 'Garpek'.

In 2015, tested preparations, without exception, inhibited root rot and rot of basal parts of bulbs in both cultivars of garlic.

The applied biological preparations had no significant effect on the health of the leaves of garlic in 2014 and in 2015 for the cultivar 'Garpek', while in the second year of studies, all the tested formulations effectively limited the dieback of leaves of the garlic variety 'Arkus'.

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