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Garlic dry rot: a comprehensive study from field to fork on causal agents and disease management

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ABSTRACT

Since 2002, *Fusarium proliferatum* has been reported as the main causal agent of garlic dry rot during the postharvest stage, but information on the development of the disease throughout the production chain was nearly absent. Dry rot has caused huge economic losses in the past few years (up to 30 % of the yield), symptoms are visible on bulbs during storage as necrotic spots and in the most severe attacks, white mycelium may become visible on cloves. Few pest management strategies were tested in the recent past, but none were satisfactory. Due to the economic effect that this pathogen can have on local productions, the thesis aimed to deeply investigate the pathosystem with a field to fork approach and to test new strategies to control fungal infections.

First of all, the work focused on garlic (*Allium sativum* L.) cropping season, intending to clarify the role of *F. proliferatum* in bulb infection as well as the impact of crop growing conditions on the development of the pathogen. A 3-year study was conducted in Piacenza (northern Italy) by sampling six garlic farms with different dry rot history (three highly contaminated and three low contaminated). Soil samples were recovered at sowing time for the counting of fungal colony-forming units (CFU). Plant samples were collected at three relevant growth stages, from April to July, for which disease severity assessment and fungi isolations were performed. *Fusarium* was the most frequently isolated genus, and *F. proliferatum* and *F. oxysporum* the dominant species during the garlic cropping season. *F. oxysporum* was dominant in the first year of the study, but *F. proliferatum* registered the highest incidence in all the farms tested. *F. oxysporum* incidence was correlated with dry weather, whereas *F. proliferatum* was enhanced in rainy years. To conclude, *F. proliferatum* is confirmed to be associated with garlic bulbs, even at crop's early growth stages and symptoms are visible mainly on roots and basal plates at the field stage, related to *F. oxysporum*.

Then, the focus was made in detecting the presence of *F. proliferatum* on garlic bulbs during prolonged storage, and to identify other fungal species associated with garlic dry rot. Moreover, fumonisin contamination in symptomatic and asymptomatic cloves were detected. Samples of 100 plants were collected over three production seasons in six farms located in Northern Italy at three-time points (at harvest, processing, and 6 months storage at –4° C). Results obtained lead to think that *Fusarium*–garlic pathosystem is split into two parts: basal plate/root and bulb. *F. proliferatum* had the highest incidence in infected bulbs and was confirmed as the causal agent of postharvest dry rot in garlic (mean incidence: 35.4%). *F.*

oxysporum co-occurred with *F. proliferatum* but symptoms were visible only on basal plate/root. Dry rot incidence slightly increased during cold storage (from 14.6% at processing to 18.4% at 6-month storage); although, *F. proliferatum* incidence was stable during cold storage, fumonisin were produced from harvest through storage. Cloves showing symptoms were more contaminated compared to those asymptomatic, both by the fungus (mean incidence 39% vs 25.3%) and the toxin (287.0 vs 24.4 μg kg^{-1}). Therefore, cold storage limits garlic dry rot, but health concerns related to fumonisin should be seriously considered.

Regarding disease management, garlic crop is commonly propagated by plant parts (cloves). To protect garlic crop from early growth stages it is important to find commercial products able to control the pathogen growth on seedlings. The experiment aimed to test *in vitro* and *in vivo* the efficacy of triazoles and biocontrol agents (BCAs) against *F. proliferatum* and *F. oxysporum*. In *in vitro* trials, the best performance was achieved by propiconazole+prochloraz (100%), followed by tebuconazole (88.9%). BCAs were less effective but still showed great capacity to control the pathogen with maximum growth inhibition of 80% (*Trichoderma harzianum +T. gamsii*). In both cases, temperature influenced the capacity to control the pathogen with minimum effect at 25°C compared to lower temperatures. *In vivo* bacterial BCAs showed a similar capacity to control Fusaria compared to chemical products (mean of severity index 18.6% and 11.7%, respectively) and did not show side effects on root length. *In vitro* and *in vivo* results are comparable, except for *Trichoderma,* with the worst performances in terms of disease severity on plants.

Finally, a field trial was designed to verify the efficacy of chemical and biological active ingredients as seed coating both at crop stage and postharvest, simulating the entire production chain, by taking into account visible symptoms and incidence of fungi. All products tested reduced the severity of symptoms on basal plates at the field stage, but none of them was able to reduce *Fusarium* incidence. A postharvest analysis conducted on bulbs demonstrated the efficacy of Tebuconazole, *B. subtilis*, and *Trichoderma+B. subtilis* in reducing the number of cloves showing symptoms per bulb (mean 34.3% vs control 45.8%). Moreover, Tebuconazole was able to reduce the incidence of *F. proliferatum* by 48% with respect to untreated control. The trial highlighted also that the incidence of *F. proliferatum* increased by 37% when garlic bulbs were kept for 15 days at room temperature simulating storage at consumers houses. Results obtained in the trial are promising and seed coating had a positive effect on garlic dry rot postharvest;

although further studies are needed to test the persistence of seed coating treatments after prolonged storage period, especially when the product is kept outside cold chambers.