

Humic product enhances the effect of a biological agent: combined application of *Trichoderma sp.* and Lignohumate® to suppress a pathogen of cabbage clubroot

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Possibility of humic products to enhance the effect of biological agents to suppress plant pathogens is often reported. Development of new formulations of environmentally friendly products based on both humics and biological products is highly relevant, especially for tropical regions, where plants are susceptible to numerous fungi diseases.

The objective of this study were: (1) to evaluate how effective is the combined application of *Trichoderma sp.* and humic product Lignohumate® (LH) to control cabbage clubroot, a disease caused by the soil-borne fungi *Plasmodiophora brassicae* and (2) to estimate the best ratios for a combined humic-biological formulation.

The field experiment was conducted in Bali (Indonesia) using cabbage (*Brassica oleracea* L.) susceptible to clubroot disease. *Trichoderma asperellum* isolated from cabbage plantation was applied in levels: 0 (control), 1×10^6 , 2×10^6 , and 3×10^6 spores per plant. LH was used in concentrations 0, 0.01, 0.02, 0.05, 0.1, 0.5, 1.0, and 2% (w/v) to pour planted cabbage. Leaf area and chlorophyll content were measured after planting. After harvest the disease incidence, total amount of galls on roots, root and canopy dry weight, and microbial population (bacteria, fungi, and *Trichoderma*) were determined.

Results. Experimental field was heavily infected with clubroot: incidence of disease achieved 88% at the control treatment. When added separately, both tested products contributed to a decrease in the incidence of 1.3-1.8 times (up to 66 and 49%). Effect of *Trichoderma* alone was visible, but statistically insignificant, whether LH alone at highest doses (1 and 2%) was able to decrease the pathogen infection. At combined application of *Trichoderma* with LH at rates higher than 0.02% the positive effect was much more pronounced, and in some cases the incidence of disease decreased up to 42-58%. The combination of treatments that gave the best effect was the *T. asperellum* treatment on population of 3×10^6 spores with LH-dose 0.5% which provided the least disease incidence (7.1%).

Besides of disease incidence, both products affected also the root galls formation, reducing their amount on cabbage roots in 2-3 times. LH enhanced the effect of *Trichoderma* and at the most effective treatment (*T. asperellum* population of 3×10^6 CFU with 0.5% LH) the minimum amount of galls was observed: 1 against 19 in control. At LH rates 1% and 2% amount of galls on roots was higher than at 0.05%. The lowest root weight, indicating minimum level of root infection, was also observed for the same treatment. The highest content of chlorophyll in leaves and canopy dry yield was recorded for 0.5% concentration of LH. Application of LH also stimulated the microbial population in soil, and the concentration of 0.5% provided the highest increment of bacterial and fungi population.

Conclusion. Humic product LH demonstrated the capacity to enhance the effect of antagonistic fungi *Trichoderma* to suppress the pathogen of clubroot disease *Plasmodiophora brassicae*. The best combination of humic and biological products was 3×10^6 spores of *T. asperellum* and 0.5% LH. The higher concentrations of LH did not provide further positive effects.

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