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Growth, yield and quality of spring tomato and physicochemical properties of medium in a tomato/garlic intercropping system under plastic tunnel organic medium cultivation

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ABSTRACT

Continuous cropping poses a number of issues to tomato cultivation under plastic tunnels in China, and the intercropping of garlic with tomato may help to solve these problems. In this study, we compared tomato/garlic intercropping with tomato monoculture and investigated the differences in the physicochemical properties of the medium, as well as the growth, yield and quality of spring tomato, under plastic tunnel organic medium cultivation during the year 2011–2012. The results showed that the pH value was higher and the EC value was lower in the intercropping medium than in the monoculture medium. The alkaline hydrolysis content of the intercropping medium did not change significantly over the tomato growth period, but available phosphorus and available potassium were both reduced continuously. The alkaline phosphatase and cellulase activities were both higher in the intercropping medium, while urease activity was lower. The invertase activity in the intercropping medium was significantly lower than in the monoculture medium before tomato transplanting but showed a nonsignificant difference at the fruit set stage of the tomato. The total microorganism population decreased for a short period after the garlic harvest in the intercropping medium but recovered to the level of the monoculture (control) at fruit set stage of the tomato. Intercropping increased the bacterial and actinomycetous populations but decreased fungal population in comparison to monoculture. The intercropped garlic inhibited the growth of the spring tomato, but this inhibition decreased after the garlic harvest. The chlorophyll contents in the leaves were increased, but the photosynthetic rate was decreased, for the intercropping spring tomato compared to the monoculture tomato. The tomato fruit quality, in terms of the titratable acid, vitamin C and dry matter contents, was significantly higher in the intercropping system, while the solid matter, soluble protein and soluble sugar contents did not differ significantly between the two methods. Intercropping reduced the total spring tomato yield but produced a higher net income than did monoculture. In conclusion, intercropping garlic with tomato can improve both the microorganism populations and the enzyme activity of the medium, which together reduce the obstacles of continuous tomato production.

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1. Introduction

The use of organic substances such as crop straw, mushroom residue, manure, paper waste and green waste as culture media in horticultural crop production has many benefits. Crop management and product quality maintenance are both more easily achieved in culture systems using these media. Such systems also help to resolve the problem of waste disposal in farmland and village settings (Urrestarazu et al., 2005) and to protect the environment, because organic residues can be used as growth media after proper composting (Carmona et al., 2012). Moreover, organic culture media are very useful in alkaline soil, sandy areas and wastelands, as well as on lands associated with industrial facilities, where the problem of secondary salinization poses an obstacle to continuous cropping. In recent years, this technology has developed rapidly and has been adopted widely in China. However, most farmers grow the same fruit or vegetable, such as tomato, cucumber, pepper or eggplant, year after year in the same culture medium under a greenhouse or plastic tunnel, reutilizing the medium and thereby lowering the production cost. This cultivation habit is mainly due to the limited vegetable growing knowledge and technology of producers, and continuous cropping has presented obstacles to production that are in dire need of solutions (Li et al., 2012). Continuous cropping may cause imbalances of nutrients

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in the soil or medium and lead to acidification and secondary salinization. The practice also often leads to the accumulation of autotoxic substances and harmful microorganisms, which cause disorders of the crop rhizosphere (Xiao et al., 2012). Reasonable intercropping cultivation could maximize crop growth and productivity (Cecilio et al., 2011), utilize resources more efficiently (Javanmard et al., 2009) and increase the microbial diversity in the medium (Hauggaard-Nielsen and Jensen, 2005). Intercropping could also balance the nutrients in the medium (Corre-Hellou et al., 2011), lower the damage caused by pests and diseases (Hauggaard-Nielsen et al., 2001) and improve the quantity (Li et al., 2001) and the quality (Caviglia et al., 2011) of products.

Both shoot and root ecology are key to achieving high and stable crop yields. In an intercropping system, the shoot and root growth of the different crops affect each other. A reasonable intercropping system can also create a good environment for the root and shoot growth of both crops and produce the maximum yield. It is of great importance to investigate the crop growth and environment of both shoots and roots in intercropping systems, as such studies can inform the evaluation and improvement of the intercropping model.

Previous studies in the field have mainly focused on crop growth, yield and quality in medium cultivation (Meng et al., 2011). Only limited reports are available on intercropping in medium cultivation under plastic tunnels. In recent years, the simultaneous rapid increase in world population and decrease in agricultural acreage have brought considerable attention to resource shortages and environmental issues, which has subsequently aroused the interest of government officials and scientists from across the world in high-intensity agriculture (Sim and Wu, 2010). Intercropping under plastic tunnels provides a method to alleviate these major problems. Garlic, with its broad spectrum of antibacterial effects, is a traditional crop planted in great abundance in open fields and is consumed widely in China (Zhou et al., 2011). The demand for fresh and early-harvested garlic is rapidly increasing. Tomato is the most common fruit or vegetable cultivated on substrate media under plastic tunnels in China, but the obstacles of successive cropping have become a major problem. With the goal of achieving a high-efficiency and sustainable method for utilizing substrate medium in tomato/garlic intercropping under plastic tunnels, we conducted an experiment to investigate the growth, yield and quality of tomato, as well as the physicochemical properties of the cultivation medium, in the intercropping system.

2. Materials and methods

2.1. Materials

The tomato cultivar 'Difenni' (Syngenta) and the garlic cultivar 'Caijiapo Red Skin' were used in this experiment. An organic medium consisting of decomposed corncob, wheat bran and mushroom residues in a 5:4:1 ratio was used as the culture medium. A rectangular trough 3.3 m in length, 0.6 m in width and 0.3 m in depth was dug for each treatment, and the culture medium was used to fill each trough. A layer of polyethylene plastic film was placed underneath the culture medium to separate it from the soil. Drip irrigation was used throughout the experiment.

2.2. Experimental design

This study was conducted under a plastic tunnel during the year 2011–2012 at the Horticultural Experimental Station (N 34°16′, W 108°4′), College of Horticulture, Northwest A&F University, Yangling, Shaanxi province, China. This area is characterized by freezing winters and hot summers, and plastic tunnel producers in the region usually grow two croppings of tomato per year, a spring crop and an autumn crop. A randomized complete block design (RCBD) with two treatments, intercropping (tomato/garlic) and monoculture (tomato as the control) was replicated three times in this experiment. The autumn tomato was transplanted in July 2011 and grown until November, when conditions became too cold, while the spring tomato was transplanted in March 2012 and grown until July, when conditions became too hot. Two rows of tomato, with 9 plants in each row, were transplanted in each trough, with a row spacing of 40 cm and a plant spacing of 41 cm. Garlic cloves were intercropped into the autumn tomato in September 2011, grown over the winter and harvested in April 2012. In each trough, five rows of garlic were planted between two rows of tomato, with a row spacing of 10 cm and a plant spacing of 8 cm; two garlic cloves were also planted between each pair of tomato plants. Water and fertilizers were applied throughout the experiment according to the needs of tomato crop, while only a single application of water was given to the garlic.

2.3. Research method

2.3.1. Medium sampling

Medium samples were collected at different growth stages of the tomato crop: before tomato transplanting (BTT; March 29th, 2012), fruit set stage (FSS; April 21st, 2012), early fruit stage (EFS; May 20th, 2012), middle fruit stage (MFS; June 19th, 2012) and late fruit stage (LFS; July 19th, 2012), respectively. The samples from each test plot were collected at 5 points where the distance to a tomato plant was 5 cm at a depth of 0–15 cm using an auger (5 cm diameter). The collected samples were mixed thoroughly to make a composite sample of each treatment for each replication. A portion of each sample was stored at 4 °C for microbial analysis, and the remainder was air-dried at room temperature (25–30 °C) for the analysis of physicochemical properties.

2.3.2. Medium pH and EC measuring

To measure the pH value and the electrical conductivity (EC) of the medium, a solution was prepared by shake extracting the medium with water in a 10:50 (W:V) ratio for 30 min on an electric shaker. The pH value was then measured using a pH meter (PHS-3C, LIDA, Shanghai, China), and the EC value was measured with a microprocessor conductivity meter (DDS-12DW, Xiaoshan, China) that had been standardized with 0.01 and 0.001 mol L^{-1} KCl for 30 min (Jayasinghe et al., 2010).

2.3.3. Medium nutrient content measuring

For the available nitrogen measurement, a 2 g sample of medium was weighed and placed in the outer core of a glass Petri dish. A 2 mL aliquot of 2% boric acid reagent (20 mL 3% bromocresol green indicator was added per 1000 mL boric acid, and HCl or NaOH was used to adjust the pH to 4.5) was placed inside the core of the dish, and the dish was then covered with lead and gum. The lead was then slightly removed from one corner, and 10 mL of 1 mol L^{-1} NaOH solution was gently added to the outer core of the dish with a pipette. The covered dish was incubated at 40 °C for 24 h. Finally, titration was conducted with 0.02 mol L^{-1} H_2SO_4 solution.

For the available phosphorus measurement, a 2 g sample was weighed and put into a 200 mL shaking bottle with 50 mL of 0.5 mol L^{-1} $NaHCO_3$, then shaken for 30 min on an electric shaker. To decolorize the solution, active carbon was used and then removed by filtering with two layers of filter paper. A 1 mL sample of the filtrate was mixed with 5 mL of 0.5 mol L^{-1} $NaHCO_3$ and 5 mL of ammonium molybdate solution and shaken well. An additional 39 mL of distilled water was added to the bottle and shaken well. After 30 min, the available phosphorus content was determined

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