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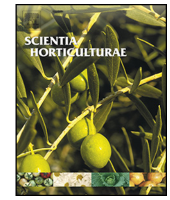

Effect of companion plants on tomato greenhouse production

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ABSTRACT

The objective of this study was to assess the effect of companion plants as marigold (*Tagetes patula* L.), basil (*Ocimum basilicum* L.), lettuce (*Lactuca sativa* L.) and white mustard (*Sinapis alba* L.) on (i) greenhouse tomato yield and fruit quality; (ii) root-knot nematodes infestation and (iii) energy effectiveness of tomato production. The experiment was carried out during three consecutive years (2011–2013) in an unheated greenhouse. White mustard caused significant decrease in early and total yield of tomatoes as well as decreased the average fruit weight. Marigold, basil and lettuce did not decrease significantly the tomato productivity. Chemical parameters of tomato fruit quality, including antioxidants content, measured twice in a harvest period, were positively affected by the intercrop systems in most cases. Although all tested companion plants suppressed to some extent the development of *Meloidogyne* spp., the white mustard and marigold were the most promising ones having effectiveness of 53.45% and 46.38% against the root-knot nematode invasion. The control treatment had the highest energy intensity (1.43 MJ kg^{-1}), mostly due to the costs for manual weed control. The manual operations for weed control in intercropping systems decreased three times. The lowest energy intensity (1.03 MJ kg^{-1}) was established for marigold as companion plant of tomato. Based on the obtained results white mustard and marigold could be considered as most promising companion crops in greenhouse tomato production.

1. Introduction

Greenhouse vegetable production is associated with extensive application of chemical fertilizers and pesticides. A growing concern has been observed due to the increased pollution of the environment and increasing risk for food security and safety. The European Union established rules for the sustainable use of pesticides and promotion of low pesticide-input management including non-chemical methods (Directive 2009/128/EC). The most frequently used fumigant methyl bromide has been phased out in the EU in the framework of the Montreal Protocol provisions and following the implementation of Regulation (EC) 2037/2000. Its chemical alternatives are object of re-evaluation, while the non-chemical means (soil solarization, soil steaming, use of bioagents etc.) are intensively studied (Lamovšek et al., 2013; Samaliev, 2009; Wang and Brent, 2009). Integrated systems for plant protection and nutrient management are coming in strong in protected cultivation. Attention has been paid on harnessing natural processes in order to maintain the soil fertility and protect the crops with lower inputs of chemicals.

Companion planting is an intercropping practice often associated with organic agriculture, applied mainly in the field. Growing of two or more plants together usually is a method for disease management in crop production but could also alter positively the microclimatic conditions around the canopy, add organic matter and nitrogen to the soil, to retain water and nutrients, to suppress weeds, etc. (Bomford, 2009; Gómez-Rodríguez et al., 2003). Besides possible benefits of growing two (or more) plant species together a disadvantage could be the competition for light, water and nutrients with the main crop. This interference may cause yield reduction of the main crop (Borowy, 2012; Jędrszczyk and Poniedziałek, 2007; Lu et al., 2000). The detrimental effect could be minimized by several techniques used in the production systems with cover crops: adjustment of irrigation and fertilization management (Kołota and Adamczewska-Sowińska, 2013); restriction of companion crops growth by mowing or sowing companion crops with or after planting the main crop (Adamczewska-Sowińska and Kołota, 2008; Caamal-Maldonado et al., 2001); choosing the most suitable plant species as companion crops. The right management of the intercropped systems could result even in increased yield of the main crop (Lu et al., 2000; Mandal and Dash, 2012).

Greenhouse production is assessed as very intensive, with cash crops rotation during the whole year. Nevertheless, companion plants could be integrated in greenhouse production practices as a part of Integrated Plant Production Systems. Alternative

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methods for control of nematodes by intercropping with marigold and aromatic plants have been investigated in greenhouse conditions (Youssef et al., 2011; Hooks et al., 2010; Kaşkavalci et al., 2009) indicating an increased interest to find sustainable solutions for pest management in protected cultivation.

A preliminary study was carried out in order to investigate the effect of intercropping tomato with several plant species on (i) greenhouse tomato yield and fruit quality; (ii) root-knot nematodes infestation and (iii) energy effectiveness of tomato production. Four plant species marigold (*Tagetes patula* L), basil (*Ocimum basilicum* L.), lettuce (*Lactuca sativa* L.) and white mustard (*Sinapis alba* L.) were selected for intercropping with tomato. It was known that they have good compatibility with tomato crop and/or allelopathic benefits, but no knowledge was available regarding their influence on fruit quality. The current study was focused mostly on tomato crop. The four plant species were assessed only for their benefits or/and harms to the main crop and their yields were not taken into consideration. In order to be concise, the used approach with some inaccuracy is termed here as intercropping, but these plants could also be referred to cover crops as their growth was restricted by mowing and placing plant residues on soil surface, forming layer of organic mulch.

2. Material and methods

The experiment was carried out during three consecutive years (2011–2013) at Maritsa Vegetable Crops Research Institute, Bulgaria. Tomato variety Dimerosa (Enza Zaden, the Netherlands) was grown in an unheated greenhouse. It is a pink fruited beef tomato hybrid for fresh consumption with indeterminate growth habit.

2.1. Experimental conditions and design

Soil characteristics (0–30 cm layer; prior tomato transplanting): pH 7.3; EC 0.90 mS cm^{-1}; NO_3^- 55.0 mg dm^3; P 2.8 mg dm^3; K 64.8 mg dm^3; Ca 154.8 mg dm^3; Mg 75.0 mg dm^3, determined in water extract 1:2 (Sonneveld, 1990), 0.25% total nitrogen (Kjeldahl) and 10.3% organic matter content (dry combustion at 550 °C).

The greenhouse air temperatures varied between 10.6–17.9 °C during the nights and reached 31.8–38.4 °C during the days. The relative humidity was usually 30–70% during the day and 50–80% during the nights, and solar radiation varied between 100 and 250 W m^{-2}.

Tomato seeds were sown on 19–23 of January (days varied depending on the year) in foamed polystyrene plug trays with 198 inverted pyramid cells, filled with peat moss and perlite in the ratio 1:1 (v/v). One seed per cell was sown. At the stage of first true leaves (on 1–8 of March) the plants were pricked out in plastic pots, containing 0.5 L of mixture peat moss and perlite in the ratio 1:1 (v/v). On 4–5 of April plants were transplanted in soil supplemented with mineral fertilizers in amounts determined in accordance with the recommendations following the analysis. Fertilizers were applied as base dressing (triple superphosphate and potassium sulfate) and post-planting fertigation (ammonium nitrate, potassium nitrate, monopotassium phosphate). Nutrients were supplied in the following rates: N 300 kg ha^{-1}; P_2O_5 260 kg ha^{-1} and K_2O 500 kg ha^{-1}. Harvesting period began on 3–7 of June and ended on 22–24 of July. Plant density was 3.5 plants per m^2. Tomato plants were trained at wires and pruned to a single stem by removing all side shoots. The growing tip was pinched off at the fourth cluster. During the three experimental years the main pests that infested tomato crop were onion thrips (*Thrips tabaci* Lindeman), western flower thrips (*Frankliniella occidentalis* Perg.), potato aphid (*Macrosiphum euphorbiae* Thomas), green peach aphid (*Myzus persicae* Sulz.), tomato leaf miner (*Tuta absoluta* Povolny), greenhouse whitefly (*Trialeurodes vaporariorum* Westw.), two spotted spider mite (*Tetranychus urticae* Koch.). The most important disease was late blight (*Phytophthora infestans* (Mont.) De Bary). Plant protection practices started at nursery stage and continued after transplanting by spraying with proper pesticides. All sprayings were applied at label level in accordance with the recommendations, following the diagnostics of pest infestations and disease incidence. Weeds were controlled manually throughout the whole experimental period. Irrigations were performed on 3–4 days intervals with average amount of water 15–40 L m^{-2}. During the cultivation irrigation, plant nutrition and protection, regular cultural practices, etc. were applied as needed, uniformly through all experimental plots.

Seeds from marigold var. Mix (OpalZi Ltd., Bulgaria), basil var. Genoveser (Minkova Ltd., Bulgaria) and lettuce var. Cherna Gumurdjinska (Minkova Ltd., Bulgaria) were sown in peat:perlite (1:1 v/v) substrate. When first true leaves of marigold and basil, and 3–4 leaf of lettuce were formed seedlings were planted in the greenhouse with plant density 4.2 plants per m^2. Seeds from white mustard var. Metex (Saaten Union, Germany) were undersown directly in soil with seeding rate 2.5 g m^{-2}. The four plant species were placed between rows a week after transplanting of tomato plants. Their growth rate was restricted by mowing and placing plant residues on soil surface to form mulch layer of approximately 5 to 8 cm thickness. Three (marigold and basil) to five (mustard) growth restrictions were performed during the growing period in 20–30 days intervals. Lettuce plans were cut at maturity about 3 cm above the soil surface and leaves were left on soil surface.

Experimental treatments were as follows: 1. Control–tomato monoculture; 2. Tomato + marigold; 3. Tomato + basil; 4. Tomato + lettuce; 5. Tomato + white mustard. Each treatment was presented in triplicate; each replication was composed of eight tomato plants. Plot size per each treatment was 85 m^2. The experimental design was a randomized complete block.

2.2. Research indexes

Fruits were harvested weekly at the fully-ripening state, (visually assessed according to a color scale from 1 to 8, where 1 corresponds to mature green and 8 to deep pink). The yield from the first three harvests was considered as early yield. The yield was provisory divided in two categories according to the fruit weight: marketable yield – containing fruits above 50 g weight and non-marketable yield – formed by fruits weighted bellow 50 g. The total yield was calculated by combining the yield from all harvests. Mean fruit weight and number of fruits per plant were also determined.

For quality analysis fruits were picked two times during the maximum fruiting named as: harvest I (20–21 of June) and harvest II (10–11 of July). Harvest I was composed by fruits from first and second cluster, while harvest II – by fruits from third and fourth cluster. An average sample from 20 fully ripened fruits, homogenized to juice, was used for the analysis of total soluble solid content (TSS), expressed in Brix and determined with a hand-held refractometer; ascorbic acid content by Tillman's reaction (Tillmans et al., 1932); titrable acidity by using titration with NaOH and total sugars by iodometric determination method of Schoorl–Regenbogen. The content of total polyphenols (TP) was quantified in a lyophilized sample according to the method of Singleton and Rossi (1965) at λ = 765 nm and expressed as milligrams gallic acid equivalents per kilogram (mg GAE kg^{-1}) fresh weight (FW). Sample dry matter content, was determined by oven drying to the constant weight.

The experiment was conducted on naturally nematode infested soil. Soil samples (20 cm top layer) were taken before cover crops sowing and at the end of the experiment to assess the Initial nematode population density (Pi) and Final nematode population density