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Protected Cultivation of Tomato to Enhance Plant Productivity and Reduce Pesticide Use

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Abstract

Vegetable farming is an important source of income in mountainous areas of northern Thailand. Field cropping of vegetables or ill managed greenhouse production generates problems, especially the excessive use of agro-chemicals. In contrast, the production in state-of-the-art greenhouses, which are insect-proof, can reduce pesticide use, and improve water and fertiliser use efficiency.

The aim of the presented study was to compare the overall pesticide use between greenhouse production and field cropping and investigate the influence of UV radiation on plant health and yield formation in tomato (*Solanum lycopersicum* L.). Three varieties were planted in a substrate from peat and coconut fiber and randomly arranged in 4 blocks with 8 plants of each variety in two greenhouses and in the open air. One greenhouse was covered with a UV opaque and another with a UV open plastic film. Photosynthetic active radiation and UV radiation were monitored continuously along with climatic data in each greenhouse and outside. Pest infestation was monitored visually and pest management was responsive. Plant growth and the number of fruit were monitored once per week. Ten weeks after planting, two plants of each block and variety were destructively sampled and analysed for nutrient partitioning. Tomatoes were continuously harvested starting from the eighth week and analysed for mineral composition and classified into marketable yield, undersized fruit and fruit affected by cracking and blossom end rot (BER).

As expected, pesticide use inside the greenhouse could be reduced substantially, but crop damage which required pesticide spraying was caused by thrips. The infestation was lower under UV opaque foil due to lack in orientation of the pest insects in absence of UV radiation. In both greenhouses plant growth was enhanced as compared to outside. The occurrence of BER was slightly higher inside, possibly due to higher temperatures during an extraordinarily long dry season.

An appropriate set up of greenhouses can substantially improve the productivity and reduce the use of pesticides.

These findings need to be confirmed under conditions in the practice and the real yield potential under the conditions in northern Thailand must be analysed.

Keywords: Blossom end rot, greenhouse, *Solanum lycopersicum*, Thailand, thrips

Introduction

The open field production of vegetables is subjected to various severe restrictions in the lower latitudes: Heavy rain, thunderstorms, excessive solar radiation, temperatures and humidity levels above plant growth optima; (Kleinhenz et al. 2006, Max et al., 2009, 2012) the high insect pest infestation pressure (Fuchs et al 2006; Nguyen et al. 2009) and fungal diseases (Heine et al. 2011). Protected cultivation can provide sustainable solutions for these problems. Besides the obvious features, such as the protection against heavy rain or the exclusion of certain pest insect species by insect screens, greenhouses covers can offer some additional benefits: Materials with a predominant diffuse light transmission, for instance, are leading to a more homogenous light distribution and a deeper penetration into the crop canopy. By employing photoselective materials, light and microclimatic conditions inside greenhouses can be purposefully manipulated. UV opaque cover materials, for example, effectively reduce the immigration of pest insects which have their vision within the UV range. Thereby, insecticide applications can be reduced (Nguyen et al. 2009, Max et al. 2012). Vegetable production can be increased more than double-fold as compared to open field cultivation – even when only low-tech greenhouse structures are used (von Zabeltitz 1997). Furthermore, compared to staple crops the production of horticultural crops can create higher incomes per unit of area (Tesfaye et al. 2011), offering an interesting alternative for small scale farmers.

For the given reasons, in many countries in the tropics, including Thailand, the use of greenhouses for horticultural production is steadily increasing since several years. Within the country, there is a pronounced concentration of greenhouse horticulture in the mountainous regions of northern Thailand, particularly in the province of Chiang Mai. Comparatively little dedicated research and developmental work on protected cultivation systems for this region has been conducted yet. The greenhouse designs used in the region are mostly copies of structures used in countries in temperate, Mediterranean or other semi-arid subtropical regions. These structures not specifically designed and constructed for the climatic conditions prevailing in northern Thailand. Moreover, due to inappropriate constructional designs, use of low quality materials, improper implementation and lack in maintenance the overall quality of the greenhouses used in northern Thailand is rather low. Hence, the potential of greenhouses to increase yields and product quality is considered to remain largely unexploited until now. This implies that employing greenhouses of appropriate quality can increase yields and improve product quality.

The aim of this study was to evaluate whether and to what extent certain modifications of greenhouse design – in comparison to an outdoor plantation – would lead to improved yields and product quality in the climate of northern Thailand. In a first experiment three tomato cultivars fertigated by a drip irrigation system were used in this study. Each one greenhouse with either UV-transmitting or UV-opaque roof plastics were compared with an outdoor plantation.

Materials and Methods

The experiment was set up at 2nd February 2013 at the end of the rainy season in Thailand, so that early plant development and flowering was in dry season, while fruit growth and ripening was in the rainy season.

Three treatments were applied: a.) “UV open”, b.) “UV opaque” and c.) “Outside”. Treatments a.) and b.) were conducted in greenhouses which were covered with 200μm coextruded PE/EVA films, transparent/silver with anti-dust/anti-drip coatings. “FVG SUN SILVER 5 COOL” for treatment “UV open” and “FVG SUN 5 PRO” for “UV opaque”. Both greenhouses were mounted with UV-stabilized HDPE insect screens, 110g/qm, transparent with a mesh size of 0.28 x 0.78 mm and a shading effect of 20%.

3 tomato cultivars per treatment were planted in a randomized block design with 4 repetitions and 8 plants each. The varieties were one indeterminate (“Inlay”, T1) and two semi determinate (“Diamond Pink”, T2; “Thepprathan”, T3). All plants were fertigated twice per day by use of drip

irrigation with an EC 1.2 solution containing equal amounts of Yara Kristalon (13-40-13 + ME) and Calcinit (15-0-0). To prevent BER, Chelated Calcium EDTA solution was sprayed to the fruits twice after fruit set.
During the course of the experiment air temperature, rel. air humidity, rain (outside), wind speed (outside) and inside the greenhouses photosynthetic active radiation (PAR) and total UV-radiation was recorded in an hourly interval. Plant growth was measured and abundances of pest insect species were visually assessed once per week. Harvesting took place 12 until 20 weeks after planting. Total yield and above ground biomass were summed for each treatment and compared by ANOVA.

Results and discussion

As expected, the level of pest insect infestation was much lower inside the greenhouses than outside. Spider mites (*Tetranychus* sp.) were only observed outside. The infestation with leaf miners (*Liriomyza brassicae* Riley), aphids (*Myzus Persicae* Sulzer) and whiteflies (*Bemisia tabaci* Gennadius) was very high outside and low inside both greenhouses, as insect screens effectively prevented most of the invasion. Thrips (*Thrips tabaci* Lindemann) occured inside, as the animals are smaller than the meshs of the insect screen. In “UV open“, there was medium thrips infestation, while in “UV opaque“ there was a low thrips infestation, probably because the animals need UV light for their orientation (Nguyen et al. 2009).
Pest management was responsive and only applied when pest infestation occurred. Consequently, the pesticide use in the greenhouses was substantially lower than outside and lower under UV-opaque than under UV open film (Table 1).

Table 1. Applied pesticides during six months vegetative and reproductive cycle

	Imidacloprid (g)	Cypermethrin (cc)	Dinotefurann (g)	Abamectin (cc)	Spinosad (cc)
UV open	7.0	21.0	7.0	14.0	3.5
UV opaque	3.5	14.0	3.5	7.0	3.5
outside	17.5	42.0	14.0	28.0	3.5

Yields in this study were generally low – probably due to high inside air temperatures and humidity during flowering, which might have caused the pollen to stick, while manual pollination. Plant growth was higher inside the greenhouses. After transplanting of the seedlings the growth rate was higher under the UV opaque cover, but after ten days the differences had disappeared. At harvest, there was a tendency for the plants under UV open cover to be more vigorous, however, biomass production was not significantly higher than under the UV opaque cover (Table 2).

Table 2. Fresh above ground biomass at harvest (g)

	T1		T2		T3	
UV open	997.77	ab	**591.36**	**c**	**695.60**	**bc**
UV opaque	**1041.27**	**a**	457.51	bc	638.68	bc
Outside	386.27	d	297.71	bd	497.62	bd

Different letters in rows and columns, respectively, indicate significant differences at α = 0.01

Fruit cracking was mainly found outside, while BER was evenly found in all treatments and disappeared after foliar application of CaO.

Table 3. Total marketable yield (g/plant) after staggered harvesting

	T1		T2		T3	
UV open	474.4	ab	342.3	a	331.7	a
UV opaque	**757.4**	**a**	**593.8**	**b**	**486.5**	**a**
Outside	336.5	b	593.4	ab	374.0	a

Different letters in columns indicate significant differences at $\alpha = 0.01$, differences in rows are not significant

After separation of undersized, cracked and BER affected fruit the marketable yield was highest under the UV opaque cover and generally higher inside than outside with the exception of T2 which had the same marketable yield outside as under UV opaque cover.

Conclusion

It was shown that greenhouse production of tomato under the climatic conditions in Northern Thailand can reduce the occurrence of pest insects and, thus, the need for the application of pesticides. Temperature and humidity levels inside the greenhouse seem to be the major problem leading to lower yields. Therefore, commercial production is so far mainly found in higher altitudes. More research on ventilation and appropriate cover materials is needed.

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