

# *Trichoderma harzianum* application increases cucumber (*Cucumis sativus*) yield in unheated glasshouse

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## Abstract

Effects of *Trichoderma harzianum* on yield and fruit characteristics of cucumber grown in an unheated glasshouse, were studied. Seeds of three cultivars, i.e., Y-43-F1, Y-44-F1 and Y-135-F1 were sown in peat; seedlings were transplanted to vials and planted in the glasshouse soil on April 29, May 5 and, May 15, 2003, respectively. *T. harzianum*, obtained as a commercially available product (Trichoflow WP<sup>TM</sup>, Agrimm Technologies Ltd., New Zealand;  $10^8$  cfu g<sup>-1</sup>) was applied to the soil root zone at three dosages, i.e., 4, 10 and 24 g m<sup>-2</sup>. The data regarding total yield (g plant<sup>-1</sup>), early yield (g plant<sup>-1</sup>), fruit weight (g fruit<sup>-1</sup>), number of fruits per plant, number of early fruits per plant; mean fruit length (cm) and mean fruit diameter (mm) were analyzed statistically. The main effect of dosage was significant only for total yield for which the 4 g m<sup>-2</sup> resulted in the highest total yield per plant with 2162.44 followed by the 24 g m<sup>-2</sup>, 10 g m<sup>-2</sup> and control (1931.67, 1859.11 and 1499.67 g plant<sup>-1</sup>, respectively). Early yield was also positively affected by *T. harzianum* at a dosage of 10 g m<sup>-2</sup> producing an early yield of 1130.56 g plant<sup>-1</sup>. The cultivar main effect, except for the mean fruit diameter, was significant. Interaction between dosages and cultivars was non-significant for all the characteristics studied. However, the application of *Trichoderma harzianum* significantly increased total yield in cucumber.

**Key words:** Unheated glasshouse, organic/ecologic production, conventional cucumber production

## Introduction

Cucumber (*Cucumis sativus*) is produced in large areas both in glasshouses and in the field in Turkey as well as in the world. Turkey, with an annual production of ca. 1,750,000 Mt, ranks among the top producers (Anonymous, 2004). Cucumbers, although not providing a great food value, are appreciated both for flavor and texture (Nonecke, 1989). In the Mediterranean Region, comprising also southern Turkey, as well as in coastal areas in northern part of the country, glasshouse crop production is realized without the help of extra heating. In unheated glasshouse, in general, winter growing of lettuce is followed, in early spring (in the middle of April), by cucumber and tomato production lasting until early August (Altintas, 1999).

From early seedling stage to later stages, cucumbers are at high risk to pathogen attack and diseases (fungi) and therefore pesticides were used commonly and often. In fact, in the organic/ecological production such practices are not used and instead various biological agents are employed (Rossman and Miller, 1996; Waage, 2000). *Trichoderma harzianum*, a biological agent, is used successfully, mainly due to its mycoparasitic effects against various plant pathogenic fungi, i.e., *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Botrytis*, *Sclerotinia* and *Peronospora* (Harman, 1996; Mannina *et al.*, 1997; Harman, 2000; Lewis and Lumsden, 2001; Poldma *et al.*, 2001; Howell, 2003).

Effects of *Trichoderma harzianum*, as a biological agent, have been well documented and furthermore it was found to have increasing effects on the development of cucumber plants (Poldma *et al.*, 2000). Under hydroponic and axenic growth conditions, cucumber plants attain increased seedling emergence, larger root

and leaf area, increased height, shoot length and dry weight (Yedidia *et al.*, 2001). Such growth promoting effects were also demonstrated in cotton seedlings, where *Trichoderma viride* application induced significantly growth of the seedlings (Hanson, 2000). Also, cabbage and lettuce development was significantly increased by *Trichoderma longipile* and *Trichoderma tomentosum* (Rabeendran *et al.*, 2000).

In addition to plant development, the effect *Trichoderma* on yield was studied. While onion yield was not positively affected by the application of *Trichoderma* spp. (Poldma *et al.*, 2001) cucumber yield was significantly increased (Poldma *et al.*, 2002). In the cucumber experiment, carried out for four subsequent seasons, yield from the control plots were superior to those treated with *Trichoderma* spp. in the initial three seasons whereas in the fourth season yield from the treated plots was significantly higher than the control. The present authors determined that *Trichoderma harzianum* was not effective in total yield in tomato, whereas early yield was positively affected (unpublished). Limited number of previous reports on the effects of *Trichoderma* spp. on yield therefore shows that the results are inconsistent. Therefore, the present work was carried out to find out if *Trichoderma harzianum*, besides its antagonistic effects on plant pathogenic fungi, is effective under our conditions in increasing the yield of cucumbers grown in soil in unheated glasshouse conditions.

## Materials and methods

The experiment was conducted in an unheated glasshouse at the Department of Horticulture, Faculty of Agriculture, Trakya University, Tekirdag, Turkey, in the spring-summer of 2003. The

three cultivars used were Y-43-F1, Y-44-F1 and Y-135-F1 (Yuksel Seed Co., Turkey). *Trichoderma harzianum* used was a commercially available product (TrichoFlow WP™, Agrimm Technologies Ltd., New Zealand). Seeds were sown in peat (Plantaflor, Type 3, Germany) on 29 April, 2003 and seedlings were transplanted to vials of ca. 200 ml at the cotyledon leaf stage and planted in the glasshouse on 15 May, 2003. The harvest period started from 20th June and ended on 31st July, 2003. Total harvest period was 42 days and yield from the first half of the total period of harvest was considered as the early yield. *T. harzianum* was applied three times during the growing period, *i.e.*, at sowing, transplanting in the vials and planting in the greenhouse soil. *T. harzianum*, in the form of wettable powder was suspended in water and drenched in the soil in the root zone. The water suspensions of *T. harzianum* prepared for the dosages tested were divided equally among the plants in the plots and then drenched in the root zone. Properties of soil in the glasshouse up to 0-30 cm depth were pH, 7.5; P<sub>2</sub>O<sub>5</sub>, 26.3 kg da<sup>-1</sup>; K<sub>2</sub>O, 33.1 kg da<sup>-1</sup> and organic matter 3.9%.

A factorial design in split plots was used where *T. harzianum* application were the main plots. The experiment was with three replications in which plots for dosages and the control treatment contained ten plants. Plants of each cultivar were divided into four groups and *T. harzianum* was applied to the three groups of the four, in three dosages (*T. harzianum* Dosage = TD) at 4 g m<sup>-2</sup>, 10 g m<sup>-2</sup> and 24 g m<sup>-2</sup> where 10 g m<sup>-2</sup> being the company recommended dosage for the product. The *T. harzianum* product contained 10<sup>8</sup> cfu per gram. Temperatures during the experiment varied, which are presented in the Table 1. The characteristics studied were total yield (g plant<sup>-1</sup>), early yield (g plant<sup>-1</sup>), fruit weight (g fruit<sup>-1</sup>), number of fruits per plant, number of early fruits per plant, mean fruit length (cm) and mean fruit diameter (mm). Data obtained were analyzed statistically using MSTAT statistical software and least significant differences between the means were calculated at *P*=0.05 (Nissen, 1982).

Table 1. Temperatures during the growing season (°C).

Months	Average minimum temperature	Average maximum temperature	Minimum temperature	Maximum temperature
May	7	32	4	35
June	9	32	7	37
July	11	35	12	38

## Results and discussion

The study on the effect of *T. harzianum* on cucumber yield revealed that total yield, early yield, fruit weight, number of fruits per plant, number of early fruits per plant, mean fruit length, mean fruit diameter, the interaction between *Trichoderma* dosages and cultivars were non significant. The main effects, except for the mean fruit diameter, the cultivar main effect was significant, whereas the dosage main effect was significant only for the total yield.

**Total yield:** It was demonstrated that interaction between dosages and cultivars was statistically non-significant whereas both the main effects were significant (Fig. 1). The highest total yield was obtained from 4 g m<sup>-2</sup> (2162.44 g plant<sup>-1</sup>) and lowest from the control (1499.67 g plant<sup>-1</sup>) followed by the 24 g m<sup>-2</sup> and 10 g m<sup>-2</sup>

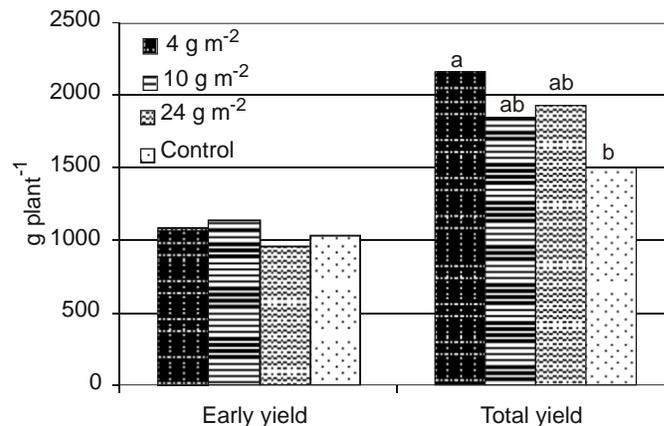


Fig. 1. Effects of *T. harzianum* on early and total yield of cucumber (Dosage main effect LSD 584.62, *P*=0.05)

dosages with 1931.67 g plant<sup>-1</sup> and 1859.11 g plant<sup>-1</sup>, respectively. The highest total yield was obtained from cv. Y-44-F1 (2440.25 g plant<sup>-1</sup>) and the lowest was from Y-135-F1 with 1337.33 g plant<sup>-1</sup>. The interaction effect was non-significant and the highest yielding combinations were 24 g m<sup>-2</sup>TD x Y-44-F1 (2560.33 g plant<sup>-1</sup>), 4.0 g m<sup>-2</sup>TD x Y-44-F1 (2540.67 g plant<sup>-1</sup>) and 10.0 g m<sup>-2</sup>TD x Y-44-F1 (2515.00 g plant<sup>-1</sup>). Whereas, the lowest total yield *i.e.*, 928.33 g plant<sup>-1</sup>, was obtained from the control of the cultivar Y-135-F1.

**Early yield:** Only the cultivar main effect was significant and the cvs, Y-44-F1 and Y-43-F1 produced the highest early yield with 1209.75 g plant<sup>-1</sup> and 1113.50 g plant<sup>-1</sup>, respectively (Fig. 2). The cultivar Y-135-F1 on the other hand produced the lowest early yield with 824.58 g plant<sup>-1</sup>. The main effect of dosages was non-significant and 10 g m<sup>-2</sup>TD resulted in highest early yield (1130.56 g plant<sup>-1</sup>) followed by the 4 g m<sup>-2</sup>TD (108.89 g plant<sup>-1</sup>) and control (1030.44 g plant<sup>-1</sup>). The highest dosage, *i.e.*, 24 g m<sup>-2</sup> resulted in the lowest early yield with 952.22 g plant<sup>-1</sup>. The interaction between the dosages and the cultivars showed the highest early yield in Y-44-F1 without the *Trichoderma* application (1581.33 g plant<sup>-1</sup>), whereas the second highest early yield was from 10 g m<sup>-2</sup>TD x Y-43-F1 (1284.00 g plant<sup>-1</sup>). The lowest early yield was from the control treatment of the cultivar Y-135-F1 (512.33 g plant<sup>-1</sup>).

**Fruit weight:** The main effect dosage and interaction effect were non-significant, cultivar main effect was significant and the fruits of Y-44-F1 were heaviest (137.37 g fruit<sup>-1</sup>) followed by Y-135-F1 and Y-43-F1 (Table 2). The dosage main effect was non-significant statistically and 4 g m<sup>-2</sup>TD resulted in the heaviest fruits with 125.26 g fruit<sup>-1</sup>, followed by 10 g m<sup>-2</sup> (123.02 g fruit<sup>-1</sup>), 24 g m<sup>-2</sup> (122.34 g fruit<sup>-1</sup>) and control (112.49 g fruit<sup>-1</sup>). The interaction effect, was non-significant and the heaviest fruits were obtained from the combination of 24 g m<sup>-2</sup>TD x Y-44-F1 (145.63 g fruit<sup>-1</sup>) whereas the lowest individual fruit weight was from the control of Y-43-F1 (101.17 g fruit<sup>-1</sup>).

**Total number of fruits per plant:** The main effect of *Trichoderma* dosages and interaction between the cultivars and dosages were statistically non-significant whereas the cultivar main effect was significant. The number of fruits in cultivars Y-44-F1, Y-43-F1 and Y-135-F1 was 17.72, 16.03 and 11.68 fruits plant<sup>-1</sup>, respectively (Table 3). The 4 g m<sup>-2</sup>TD resulted in the highest number of fruits (17.13) and lowest in control (13.07). The highest number of fruits, *i.e.*, 19.03, was recorded in the combination of 4 g m<sup>-2</sup>TD x Y-44-F1, while it was least (8.77) in control of the cultivar Y-135-F1. The cv. Y-135-F1 produced the lowest number of early fruits

Table 2. Effects of *Trichoderma harzianum* on fruit weight (g fruit<sup>-1</sup>)

Dosage (g m <sup>-2</sup> )	Cultivars			Mean
	Y-43-F1	Y-44-F1	Y-135-F1	
4.0	118.50	134.53	122.73	125.26
10.0	115.37	140.40	113.30	123.02
24.0	112.27	145.63	109.13	122.34
Control	101.17	128.90	107.40	112.49
Mean	111.83b	137.37a	113.14b	—

Cultivar main effect LSD= 9.40 (P=0.05)

Table 3. Effects of *Trichoderma harzianum* on number of fruits plant<sup>-1</sup>

Dosage (g m <sup>-2</sup> )	Cultivars			Mean
	Y-43-F1	Y-44-F1	Y-135-F1	
4.0	18.73	19.03	13.63	17.13
10.0	15.77	17.73	10.93	14.81
24.0	15.73	17.57	13.40	15.57
Control	13.90	16.53	8.77	13.07
Mean	16.03a	17.72a	11.68b	—

Cultivar main effect LSD=2.809 (P=0.05)

Table 4. Effects of *Trichoderma harzianum* on number of early fruits plant<sup>-1</sup>

Dosage (g m <sup>-2</sup> )	Cultivars			Mean
	Y-43-F1	Y-44-F1	Y-135-F1	
4.0	9.63	7.83	8.73	8.73
10.0	8.60	7.53	8.43	8.19
24.0	9.30	8.57	6.90	8.26
Control	8.43	8.33	5.47	7.41
Mean	8.99a	8.07ab	7.38b	—

Cultivar main effect LSD = 0.969(P=0.05)

(7.38) followed by Y-44-F1(8.07) and Y-43-F1(8.99)(Table 4). Main effect of dosage recorded the highest number of early fruits from 4 g m<sup>-2</sup> TD (8.73) followed by the dosages of 24 g m<sup>-2</sup>, 10 g m<sup>-2</sup> and control with the early fruit yield of 8.26, 8.19 and 7.41, respectively. It has been observed that in all the dosages tested the control treatments performed inferior to the *Trichoderma* treatments.

**Average fruit length:** Statistical analysis showed that dosage main effect and interaction effects were non-significant for fruit length, while cultivar main effect was significant. The longest fruits were obtained from Y-44-F1(18.80 cm) followed by Y-43-F1 and Y-135-F1. The fruit length decreased with increasing dosages, and the smallest fruit length was from the control (16.11 cm).

**Average fruit diameter:** Neither the main effect of dosages and cultivars nor the interaction effects were significant in relation to fruit diameter. In all varieties, control resulted in the lowest fruit diameter.

We have demonstrated that *T. harzianum* affects significantly the yield of cucumber where the lowest dosage (4 g m<sup>-2</sup>) resulted in the highest total yield. Early yield was also positively affected and the application of 10 g m<sup>-2</sup> resulted in highest early yield compared to the other dosages and the control. The increase obtained in cucumber yield clearly showed the effectiveness of the biological agent besides its main functionality. These results are in line with those of Poldma *et al.* (2002) who found that *Trichoderma viride* applied plots produced significantly higher yield in comparison to that of control plot both for total and the

early yield. Contrary to the findings presented here, in tomato, following the same *Trichoderma* regime. *T. harzianum* was not found effective in the enhancement of total yield. The early tomato yield was positively affected but the effect was statistically non-significant (unpublished). In outdoor grown onion, *Trichoderma* effect was non-significant in the enhancement of yield (unpublished). Similarly, Poldma *et al.* (2001) found that differences between the onion yields of *Trichoderma viride* treated and untreated (control) plots were non-significant.

The main effect of *T. harzianum* dosages was significant only in the total yield and in almost all other characteristics studied, *T. harzianum* applied plots resulted in superior data in comparison to the control. The *T. harzianum* was found significantly effective for total yield but not for early yield, which may have been due to incomplete establishment of the *T. harzianum* population in the root zone in the early growing period. Probably the establishment of the population takes more time and are more pronounced under control conditions. In other words, the effects of *T. harzianum* can only be optimal or available after passing of a particular time period for establishment of the population in the rhizosphere and the time period. Contrary to this speculation, in cabbage *T. viride* was significantly effective in increasing the shoot and root dry weight after 28 days, whereas the effect was non-significant after 42 days, *i.e.* at the end of the cultivation period (Rabeendran *et al.*, 2000). Unavailability of the significant effect by *Trichoderma* on yield after 42 days may have been due to adverse conditions experienced by the *T. viride* employed at the root zone resulting in the ineffectiveness of the population at the end of the cultivation period. It seems that the *Trichoderma* effect may vary as per vegetable species. It may be plausible that in order to get maximum returns from *Trichoderma* application time and dosage must be carefully adjusted as per the requirements of the crops.

In the aforesaid discussion, the effect of *T. harzianum* on increased total yield of cucumber was compared with the early yield of tomato which was affected non-significantly by the treatment (unpublished). The time periods for early yield in tomato and total yield in cucumber, calculated from planting seedlings in the glasshouse soil, were almost the same, *i.e.*, ca. 90 days and an additional 30 days was to pass for data to be obtained as the total yield in the tomato experiment. In both the experiments, averages for the dosage main effects showed that, even though statistically non-significant, early tomato yield was increased about 1.40 times by the application of the lowest dosage, *i.e.*, 4 g m<sup>-2</sup>, however, the significant increase in total cucumber yield in the present study was, at the highest, *i.e.*, 1.44 times in comparison to the control at the same lowest dosage. Subsequently it can be argued that *T. harzianum* was effective for about 90 days to bring out increase in yield for both the crops, however the non-significant effect in early yield of tomato may be due to diminishing effect of *Trichoderma* after the 90 day period. It may therefore be suggested that additional applications of *T. harzianum* may be helpful to a probable significant increase in the tomato. Time and frequency of application therefore may be a determining factor for the effectiveness of the treatment and can be ascertained separately.

The effect of *Trichoderma* on the enhancement of growth and development as well as on yield is not dependant on the species of the *Trichoderma* employed. In cabbage, *Trichoderma longipile* and *Trichoderma tomentosum* (Rabeendran *et al.*, 2000), in

cucumber *Trichoderma viride* (Poldma *et al.*, 2002) and *T. harzianum* in the present study, and in cotton, *Trichoderma virens* (Hanson, 2000) were effective in the promotion of the mentioned characteristics. Alternatively, it may be speculated that more favorable results can be obtained from the *Trichoderma* species isolated locally compared to the use of the commercial *Trichoderma* products.

The enhancement of plant growth as well as increase in yield may be attributed partly due to enlarged total root surface area (ca. 95% increase) which help the root system explore larger volumes of soil for nutrients (Yedidia *et al.*, 2001), which is important in good maintenance of plants especially in nutrient poor soils. *T. harzianum* also help roots make insoluble phosphates and micronutrients available to plants both *in vitro* (Altomare *et al.*, 2001) and in hydroponic growth conditions (Yedidia *et al.*, 2001). This was confirmed by significantly high levels of Fe and P in leaves and shoots which indicated increased transport mechanisms of these elements from roots to shoots. In the present study microelement levels of plant organs and the variation in the root volume were not studied but such data may have been helpful in the better evaluation of *Trichoderma* effect.

In conclusion, *Trichoderma harzianum*, applied to the soil root zone at the dose of 4 g m<sup>-2</sup>, significantly increased the total yield in cucumber. Almost in all the characteristics studied application of *T. harzianum*, although statistically non-significant, resulted in higher yield and better fruit characteristics in comparison to the control.

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