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Original Article

Effects of Mycorrhiza Inoculation and Grafting for Sweet Pepper (*Capsicum annuum* L.) Crop Under Low-Tech Greenhouse Conditions

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Abstract

In low-cost, unheated greenhouses and tunnels the use of arbuscular mycorrhizal fungi (AMF) and/or grafting can be a less expensive and sustainable solution to combat the adverse effects of monoculture, instead of costly soilless culture. The aim of the present study was to investigate the effects of a commercially available AMF inoculant and grafting on sweet pepper, under circumstances of modelling commercial low-tech greenhouse production. 'SV9702PP F1' sweet pepper hybrid was cultivated for seven months in an unheated greenhouse. Beside the control, three treatments were applied: ungrafted AMF treated plants, plants grafted on 'Bagi F1' hybrid and AMF treated plus grafted plants. AMF was applied into the planting holes just before transplanting. AMF treatment had positive effects on relative chlorophyll content of leaves (expressed in SPAD value), on plant stand, on plant mass production, on yield and on root colonization rate, despite the high presence of indigenous populations of AMF in the greenhouse soil. With the applied rootstock/scion combination, grafting did not significantly affect the aforementioned parameters. SPAD values were increased by the AMF treatment during periods when smaller doses of nitrogen (less than 0.8 g N per m^{-2} $week^{-1}$) were applied. Significant positive correlation was found between root colonization rate and marketable yield. AMF treatment increased the yield by 18% (from 12.43 to 14.74 kg m^{-2}), mostly due to higher number of fruits. Yield increase was mainly realised during the last third of the harvest period, when the applied nutrient doses were low and temperature conditions were suboptimal.

Keywords: plant mortality; plant mass; root colonization; SPAD value; yield parameters

Introduction

Pepper (*Capsicum annum* L.) is the 7th on the list of produced vegetables in the World (FAOSTAT, 2017) being among the three most important crops in greenhouse production. In Hungary, pepper is traditionally the most significant greenhouse vegetable share of pepper exceeds 40% both in greenhouse surface and in produced quantity. Increasing demand for a reliable production and the lack of effective soil disinfectant methods are the main reasons why Hungarian pepper producers switch to soilless cultivation. The soilless technology, however, needs high investment, which sometimes is not reasonable in low-tech, unheated tunnels and greenhouses (FruitVeB, 2018).

The use of mycorrhizal fungi or grafting can be a less expensive and a sustainable solution to combat the adverse effects of monoculture, instead of costly soilless culture (Lee *et al*., 2010; Vosátka *et al*., 2012). Arbuscular mycorrhizal fungi (AMF) are defined as symbiotic micro-organisms

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living in the roots and connected to the host plant (Pereira *et al*., 2016).

About 80% of the world's plant families are hosts for a symbiotic mushroom (Vosátka *et al*., 2012), therefore members of the Solanaceae family, including pepper species (*Capsicum* sp.), can also act as target plants (Chen *et al*., 2012). Generally, inoculation with AMF can improve the efficiency of water and nutrient uptake (Balliu *et al*., 2015), increase tolerance against abiotic stress (Bakr *et al*., 2017; Ma *et al*., 2019) and diseases (Vosátka *et al*., 2012; Yuan *et al*., 2016) and therefore provides better growth and higher yield (Balliu *et al*., 2015; Bakr *et al*., 2018). Although almost all the horticultural crops are symbiont partners, the use of AM fungi in intensive horticulture has been neglected (Hernádi *et al*., 2012).

Pepper is a common test-plant of mycorrhizal experiments and advantages of inoculation were proved at numerous times (Perreira *et al*., 2016). Mycorrhizal inoculation proved especially effective in facilitating the uptake of nitrogen, phosphorous and potassium under saline environment (Al-Karaki, 2017), helped plant growth (Boonlue *et al*., 2012; Jezdinsky *et al*., 2012), enhanced yield (Tanwar *et al*., 2013; Abdel Latef and Chaoxing, 2014; Selvakumar *et al*., 2018) and improved tolerance against different wilt diseases (Zheng *et al*., 2005; Goicoechea *et al*., 2010). Despite these promising results, mycorrhization has not been widely used for the commercial sweet pepper cultivation (Pereira *et al*., 2016).

Grafting is commonly used in the case of fruit vegetables, including solanaceous crops, with the aim to improve tolerance against biotic and abiotic stress (Lee *et al*., 2010). Pepper is a less common target species of grafting compared with tomato or watermelon (Penella *et al*., 2017), despite the fact that tolerance against drought, salt or heat can be improved with the use of suitable rootstocks (López-Marín *et al*., 2013; López-Marín *et al*., 2017; Penella *et al*., 2017); even more, efficiency of water and nutrient uptake can be enhanced (Ropokis *et al*., 2019), accumulation of heavy metals, e.g. cadmium, in the fruit can be reduced (Morikawa, 2017), or resistance can be reached against fungal or bacterial wilt (Jang *et al*., 2012; Matsunaga *et al*., 2015), against viruses (Penella and Calatayud, 2018) or against nematodes (Sánchez-Solana *et al*., 2016). As a result of the above effects, the overall plant mass, yield quantity and quality can improve (Colla *et al*., 2008; Camposeco-Montejo *et al*., 2018; Ropokis *et al*., 2019).

Hence, both mycorrhizal treatment and grafting mean a chemical-free solution for integrated vegetable production by enhancing the efficiency of water and nutrient uptake and promoting tolerance against abiotic and biotic stress. Joint use of mycorrhization and grafting improved the yield of greenhouse-cultivated tomato under saline conditions (Oztekin *et al*., 2013) and of mini-watermelons raised in an open-field experiment (Miceli *et al*., 2016). However, to our knowledge, combined effects of the above treatments on pepper cultivation have not been examined yet.

The aim of the present study was to examine the effect of grafting, mycorrhization and the combined effect of these two factors on pepper plant growth and yield, under circumstances modelling commercial low-tech greenhouse conditions.

Materials and Methods

Plant material

'Bagi F1' hybrid was used as rootstock and Hungarian yellow wax type 'SV9702PP F1' hybrid was grown as scion in the experiment. The latest is considered to be the most important pepper type in Hungarian greenhouse pepper cultivation (FruitVeB, 2018), however, it is particularly sensitive to abiotic stress. 'Bagi F1' hybrid has intermediate resistance towards bacterial wilt and *Phytophthora* blight; in addition, it has L3 gene to provide high resistance to tobamo viruses. 'SV9702PP F1' has L4 gene which is highly resistant to tobamo viruses and has intermediate resistance to tomato spotted wilt virus.

Seedling growing

Rootstock was sown on the 5th of March 2018 to 40-cell seed trays. For grafting, 'SV9702PP F1' was sown on the 12th March 2018 to 128-cell trays, while 40-cell trays were used for ungrafted control, sown on the 23rd March 2018. Splice grafting took place on the 9th April 2018 at the stage of two-leafed seedlings.

Seedlings of six to eight true leaf-stage were transplanted on the 8th May 2018 at an 80 cm row distance and at 30 cm distance between plants in the rows (4.2 plants m^{-2}).

Experimental design

A two-factor experiment was set to examine the effect of grafting and the effect of mycorrhizal inoculation. For mycorrhizal treatment, for every seedling, 30 g of a commercial product Symbiom, containing six different arbuscular mycorrhizal species (*Claroideoglomus etunicatum, Claroideoglomus claroideum, Funneliformis mosseae, Funneliformis geosporum, Glomus microaggregatum,* and *Rhizophagus intraradices*) was added into the planting hole. After inoculation, seedlings were immediately transplanted. Altogether a control and three treatments were applied, repeated five times with 20 plants in one repetition. AMF inoculated and non-inoculated treatments were divided into two blocks, separated by isolation plant rows. The five grafted and ungrafted plant parcels were randomly located within the inoculated and non-inoculated blocks.

Description of the study site

Experiments were conducted in a multispam, unheated greenhouse with a gutter height of 2,5 m at the Gödöllő-Szárítópuszta Research Unit of the Szent István University. The greenhouse was built in 2017 and was used for pepper cultivation in that year, while forecrop was lettuce in the same year of the trial.

The soil of the study site is sandy loam, slightly basic (pH= 8.0), with medium active lime content (1.7%) and low salt concentration (< 0.02%). There were recorded 0.87% organic matter and 7.7 mg kg^{-1} KCl soluble nitrate-nitrogen level, indicating a low nitrogen availability. Ammonium-lactate soluble P_2O_5 and K_2O content were measured as 132 and 116 mg kg^{-1}, respectively, meaning medium phosphorous and low potassium availability.

Air temperature was measured during the cultivation period by Voltcraft DL121-TH thermometer, at the growing point of the plants. The average air temperature of the whole growing season was measured to be 20.7 °C, while the average of each month from May to November was 23.9, 23.8, 24.6, 24.7, 19.5, 14.9 and 11.9 °C, respectively, being lowerthan the optimal 22-25 °C from September to November.

Cultivation technology

Water regime and nutrition management was applied based on general cultivation practice. One week before the planting, a compound fertilizer of 15:30:15 composition was applied to the parcels, meaning a fertilization of 3 g N, 6 g P_2O_5 and 3 g K_2O per m^{-2}. Irrigation and fertigation were realized by drip tapes starting at -20 kPa tensiometer values. On average, three fertigation's per week were conducted, meaning 70 occasions for the whole cultivation period. Fertigation was complemented by irrigation where necessary. In the last month of the cultivation period, no fertilizer was distributed on the parcels. A total of 513 mm water and the following amount of nutrients were applied through fertigation for each square meter: 29 g N, 10 g P_2O_5, 33 g K_2O, 10.5 g CaO and 5.5 g MgO, including micro elements. Nitrogen content varied between 0.6 and 1.8 g N per m^{-2} $week^{-1}$, reaching the maximum level between mid-July and late August.

Plants were staked and stringed, but were not pruned. There were 15 harvests carried out between 25th June and 21st November, at the beginning of the period picking the fruits weekly and later once every 10-14 days.

Data collection

To describe the early generative development of the plants, first flowering was recorded for each individual. To describe the nitrogen status of the plants, relative chlorophyll content (expressed in SPAD values) of the youngest full-grown leaves was measured by Minolta SPAD 502 device at five occasions (7th June, 10th July, 6th August, 13th September and 10th October). Marketable and cull fruits were divided during harvest and the number and weight of fruits were recorded. The number of specimens that dried out as a result of wilting was also recorded, therefore yield per plant data could also be calculated. After the last harvest, the total weight of undeveloped fruits was also measured, and then fresh leaves and shoots were weighed. Total aboveground biomass was calculated based on the above data.

At the end of the experiment, three soil and root samples in each parcel unit from a 25×25×25 cm soil core at the base of the plants were collected. Following the protocol by Vierheilig *et al.* (1998), 500 mg of fine root for each sample was cleaned with KOH and stained with an ink-vinegar solution. Root samples were examined and mycorrhizal colonization rate was measured using the methodology of Giovannetti and Mosse (1980).

Statistical procedures

Before analysis, data expressed in percentage values were transformed on the following way: $\arcsin\sqrt{x}$. The effect of treatments was analysed by two-way ANOVA, except data calculating plant mortality. Averages were statistically divided by using Fischer's least significant difference test at 5% confidence level. In the case of mortality, homoscedasticity of the four groups was not proved therefore Student's two sample t-test was applied in case of homoscedasticity and Welch's t-test was applied in case of heteroscedasticity. Correlation analysis was applied to describe connection between mycorrhizal colonization rate and biomass, as well as between colonization and yield.

Results and Discussion

Mycorrhizal colonization rate

Mycorrhizal colonization level was measured as significantly ($p = 0.0044$) higher in AMF treatment (75% for ungrafted and 77% for grafted plants) than in control plants (68% for ungrafted and 65% for grafted plants), meaning that mycorrhizal inoculation proved to be successful. Despite that the experimental site was only recently involved in cultivation, the average colonization level of the control plants was over 65%. Previous studies also reported a high presence of indigenous AMF populations in the soil of one out of our other research units (Duc *et al.*, 2017; Bakr *et al.*, 2018). According to the results of two-way ANOVA, grafting treatment and mycorrhization × grafting interaction had no considerable effect on colonization rate, which means that the roots of grafted and ungrafted plants reacted similarly to inoculation. This result is in harmony with the findings of Miceli *et al.* (2016) examining watermelon in an open field experiment.

Plant development

Plants were developing well in the experiment; the first flowers appeared within approx. two weeks after transplanting. On the average of the examined 100 plants for each treatment, difference between the earliest flowering (ungrafted control plants flowered 16.2 days after transplanting) and the latest (grafted control plants flowered 17.0 days after transplanting) was less than one day, which is smaller than the detection accuracy. Consequently, neither mycorrhization nor grafting had a significant effect on flowering time and on the vegetative/generative balance of the plants in the early phase. On the contrary, Ortas *et al.* (2003) and Boonlue *et al.* (2012) experienced earlier flowering as an effect of mycorrhizal inoculation in open field experiments. In the hereby case flower initialization has already started at the time of transplanting and flowering started to form approximately two weeks after mycorrhizal inoculation, therefore, time shortage hindered the appearance of growth-stimulating effects of mycorrhization (Mayer *et al.*, 2019).

In three cases out of the five measuring times, referring to the beginning and to the end of the cultivation season, relative chlorophyll content resulted in higher SPAD values in the treatments of AMF (Table 1). These values indicate higher chlorophyll concentration (Estrada-Luna and Davies, 2003) and better nitrogen supply (Li *et al.*, 2009). Similarly to the findings of Al-Karaki (2017), at the period of more intensive fertilization, mycorrhization had no effect on SPAD values and AMF could only promote nitrogen uptake in the case of lower nutrient levels. Effect of mycorrhizal inoculation on pepper SPAD values, chlorophyll concentration and photosynthetic activity is a controversial topic. Cekic *et al*. (2012) reported positive effect, Haghighi and Barzegar (2017) found that mycorrhization only improved photosynthetic activity, but not chlorophyll content, while in the works of Kaya *et al*. (2009), Jezdinský *et al*. (2012) and Beltrano *et al*. (2013) no effect of mycorrhization was proved. Moreover, Aissa *et al*. (2016) and Bakr *et al*. (2018) found ambiguous SPAD results. Grafting showed a significant effect on relative chlorophyll content only at the beginning of the cultivation period (Table 1); a month after transplanting SPAD values of ungrafted plants were slightly, but significantly higher than those of grafted ones. Based on the current observations, first fruit set somewhat retarded the development of grafted plants, explaining the above results. However, similarly to our results, Morikawa (2017) reported no difference between the SPAD values of grafted and ungrafted full-grown pepper plants.

Plant mortality

During the experiment some individuals have wilted, namely (average ± SE): control + ungrafted 11 ± 5%, mycorrhized + ungrafted 1 ± 1%, control + grafted 16 ± 5%, mycorrhized + grafted 8 ± 5%. Exact causes of wilting were not identified. Due to the high variances, only values between mycorrhized ungrafted and control grafted treatments showed a significant difference, but the tendency of values clearly showed the positive effect of mycorrhization, whereas mortality was reduced by AMF inoculation. These findings are in agreement with previous results of Ozgonen and Erkilic (2007), Goicoechea *et al*. (2010) and Oyetunji and Salami (2011), who reported mycorrhizal inoculation effective against *Phytophthora*, *Verticillium* and *Fusarium* infections, respectively. Conversely, grafting did not prevent wilting, despite that rootstocks were resistant to bacterial wilt and *Phytophthora blight*. An open field experiment with mini-watermelon proved the positive effect of grafting combined with mycorrhizal inoculation, resulting in full stock at the end of the trial contrary to 10% mortality of control plants (Miceli *et al*., 2016).

Aboveground biomass production

AMF treatment significantly increased the aboveground biomass production (Table 2), while grafting treatment and the grafting x AMF interaction had no effect on the values. Mycorrhization increased the weight of the fruits, but not the vegetative part of the plants. This finding is in harmony with the results of Haghighi and Barzegar (2017), but contradicts studies reporting the enhancement of pepper leaf and shoot weight by mycorrhization (Beltrano *et al*., 2013; Abdel Latef and Chaoxing, 2014; Aissa *et al*., 2016). The inefficiency of grafting on plant vegetative biomass of the current experiment is in agreement with the results of Aidoo *et al*. (2018) and Ergun and Aktas (2018), however, opposes to the positive effect reported by Colla *et al*. (2008), Morikawa (2017) and Ropokis *et al*. (2019). Literature calls the attention to the importance to choose proper rootstock + scion pair in the case of pepper in order to realize its improvement (Colla *et al*., 2008; Camposeco-Montejo *et al*., 2018; Ropokis *et al*., 2019).

Mycorrhized plants produced a higher fruit ratio by 2.5% (Table 2), indicating their higher efficiency in producing higher yield per plant biomass, due to their increased photosynthetic activity. Haghighi and Barzegar (2017) and Selvakumar *et al*. (2018) published similar results. Bakr *et al*. (2018) found that mycorrhizal inoculation improved the effectiveness of photosystem II in a processing tomato trial. In their review, Pereira *et al*. (2016) explained higher photosynthetic activity augmented by mycorrhization with the improvement in uptake of certain microelements (Fe, Mn, Zn and Cu). Increased photosynthetic activity due to mycorrhizal inoculation could explain that a significant correlation was found between the level of mycorrhizal colonization and the quantity of plant biomass ($r = +0.4922$, $N = 20$, $p = 0.0275$). Based on the results of two-way ANOVA, grafting also had a significant positive effect on weight ratio of fruits (Table 2). Therefore, grafted plants proved to be more generative than ungrafted ones under the same cultivation circumstances.

Marketable yield

The average yield of over 12 kg m^{-2} of the parcels considered to be satisfying compared to yields achieved by producers under similar circumstances. These results prove that, except for the lower temperature conditions at the end of the season, plants mostly grew under relatively stress-free circumstances, which is one of the most important aims of greenhouse cultivation.

Table 1. Effects of arbuscular mycorrhiza fungi (AMF) inoculation and grafting on relative chlorophyll content (SPAD value, mean ± SE) of sweet pepper 'SV9702PP F1' leaves

Treatment	Grafting	Days after transplanting 31	64	91	129	156
Control	Ungrafted	44.9 ± 0.4 Ba	56.9 ± 0.3 Ba	57.3 ± 0.6 Aa	50.1 ± 0.8 Aa	51.9 ± 0.6 Ba
	Grafted	43.6 ± 0.4 Bb	57.1 ± 0.3 Ba	57.9 ± 0.5 Aa	49.1 ± 0.7 Aa	52.3 ± 0.6 Ba
AMF	Ungrafted	45.3 ± 0.4 Aa	57.3 ± 0.3 Aa	57.7 ± 0.6 Aa	50.3 ± 0.6 Aa	54.2 ± 0.5 Aa
	Grafted	44.8 ± 0.4 Ab	58.1 ± 0.3 Aa	58.5 ± 0.5 Aa	49.8 ± 0.6 Aa	53.1 ± 0.5 Aa
Significance of source of variation (ns = not significant, * p < 0.05, ** p < 0.01)						
Mycorrhizal inoculation		*	*	ns	ns	**
Grafting		*	ns	ns	ns	ns
Inoculation × grafting interaction		ns	ns	ns	ns	ns

Note: Different letters between treatments denote significant differences (Fisher's least significant difference test, p < 0.05); capital letters represent mycorrhizal effect, small letters represent grafting effect

Mycorrhizal treatments resulted in significantly higher yield by 18% compared to control parcels (Table 3). Number of fruits was primarily responsible for this result by 15% increase; however, fruit size has also improved by 4%. Literature even reported higher yield increment as an effect of mycorrhizal treatment, although under more extensive circumstances. In the experiment of Al-Karaki (2017), mycorrhization enhanced both fruit number and fruit average weight resulting in a yield growth of 38%. Hernádi *et al*. (2012) and Regvar *et al*. (2003) reported even higher yield growth, 65% and 83%, respectively. On the contrary, in some experiments, the yield-enhancing effect of mycorrhizal treatment was not proved (Russo and Perkins Vaezie, 2010; Duc *et al*., 2017), while Ortas (2012) found season-affected the impact of mycorrhization in an open-field trial.

Grafting treatment and mycorrhization × grafting interaction had no significant effect on yield in our experiment (Table 3). Some studies concluded similarly (Aidoo *et al*., 2018; Ergun and Aktas, 2018), however, researchers mostly reported improvement in yield quantity as a result of grafting (Penella and Calatayud, 2018). In the hereby study, mycorrhization was exclusively responsible for the 18% yield increase. In the publication of Oztekin *et al*. (2013) and Miceli *et al*. (2016) mainly mycorrhizal inoculation counted for higher yield, but grafting also favoured it, reporting a 30% increase for the combined treatment in tomato and 27% in the case of watermelon.

Temporal evolution of the cumulative yield reveals that differences among AMF treated and control plants became statistically significant for the last five harvest occasions (Fig. 1). At that period, fertilization was less intensive and the temperature was much lower than the optimum. It is evident that mycorrhization was responsible for that difference, as a significant correlation was found between root colonization rate and total yield ($r = +0.5153$, $N=20$, $p = 0.0200$), being stronger when focusing on only the last five harvests ($r = +0.6066$, $N=20$, $p = 0.0046$). Therefore, the positive effect of AMF inoculation was proven even in the case of a definitely high natural mycorrhiza population.

One of the reasons for higher yield of mycorrhized plants is presumably the improvement of nutrient availability under less favourable conditions at the end of the season. Phosphorous uptake of pepper can strongly retard on lower temperatures (Ropokis *et al*., 2019) and on basic soils similar to that of our research unit. However, soils of greenhouses usually have a high phosphorus reserve; they can contain thirty times higher total than water-soluble phosphorus, according to Sonneveld and Voogt (2009). It is widely documented that in the case of pepper, mycorrhiza treatment can help the uptake of less accessible phosphorus (Sharif and Claasen, 2011; Beltrano *et al*., 2013; Tanwar *et al*., 2013; Aissa *et al*., 2016).

Table 2. Effects of arbuscular mycorrhiza fungi (AMF) inoculation and grafting on aboveground plant mass production (g per plant, mean ± SE) of sweet pepper 'SV9702PP F1'

Treatment	Grafting	Stem + leaves	Marketable fruits	Cull + unripened fruits	Total weight	Weight ratio of fruits
Control	Ungrafted	628 ± 25 Aa	3,163 ± 118 Ba	402 ± 203 Ba	4,196 ± 127 Ba	85.0 ± 0.5% Bb
	Grafted	597 ± 14 Aa	3,235 ± 180 Ba	413 ± 185 Ba	4,245 ± 212 Ba	85.8 ± 0.5% Ba
AMF	Ungrafted	636 ± 45 Aa	3,565 ± 174 Aa	579 ± 246 Aa	4,782 ± 167 Aa	86.8 ± 0.3% Ab
	Grafted	557 ± 25 Aa	3,656 ± 139 Aa	442 ± 198 Aa	4,655 ± 105 Aa	88.1 ± 0.5% Aa
Significance of source of variation (ns = not significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)						
Mycorrhizal inoculation		ns	*	*	**	***
Grafting		ns	ns	ns	ns	*
Inoculation x grafting interaction		ns	ns	ns	ns	ns

Note: Different letters between treatments denote significant differences (Fisher's least significant difference test, $p < 0.05$); capital letters represent mycorrhizal effect, small letters represent grafting effect

Table 3. Effects of arbuscular mycorrhiza fungi (AMF) inoculation and grafting on main parameters of marketable yield (mean ± SE) of sweet pepper 'SV9702PP F1'

Treatment	Grafting	Fruit number (pieces m^{-2})	Fruit weight (g per piece)	Yield (kg m^{-2})
Control	Ungrafted	153 ± 3 Ba	80 ± 1 Ba	12.35 ± 0.26 Ba
	Grafted	159 ± 11 Ba	79 ± 2 Ba	12.50 ± 1.03 Ba
AMF	Ungrafted	177 ± 8 Aa	84 ± 1 Aa	14.77 ± 0.76 Aa
	Grafted	182 ± 6 Aa	81 ± 1 ABa	14.71 ± 0.49 Aa
Significance of source of variation (ns = not significant, * $p < 0.05$, ** $p < 0.01$)				
Mycorrhizal inoculation		**	*	**
Grafting		ns	ns	ns
Inoculation x grafting interaction		ns	ns	ns

Note: Different letters between treatments denote significant differences (Fisher's least significant difference test, $p < 0.05$); capital letters represent mycorrhizal effect, small letters represent grafting effect

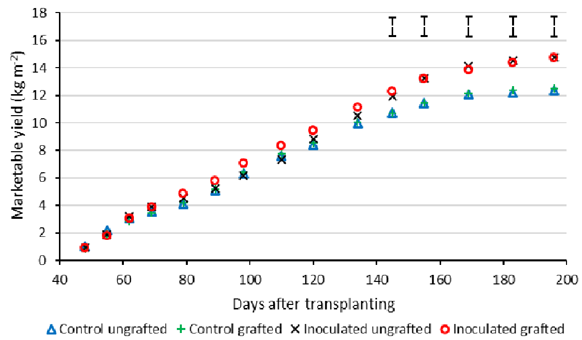

Fig. 1. Effects of arbuscular mycorrhiza fungi (AMF) inoculation and grafting on the evolution of cumulative marketable yield of sweet pepper 'SV9702PP F1'. Note: Least significant difference at 95% probability level is indicated as an error bar for dates when a significant difference was found between mycorrhiza inoculation treatments

Conclusions

Modelling a low-tech greenhouse cultivation technology, yield of 'SV9703 PP F1' Hungarian wax type sweet pepper was significantly increased by AMF inoculation despite high natural symbiont population. The results revealed that mycorrhized plants produced higher yields for the same unit of green biomass than non-mycorrhized control, especially at the end of the cultivation season, with lower temperatures and limited fertilization. Higher relative chlorophyll content also proved better nutrient use as an effect of mycorrhizal inoculation. Based on the hereby results, mycorrhizal treatment can provide an effective and simple method to increase late season yield in unheated greenhouses, when producers take less attention to the plants and suboptimal temperatures occur. Yet grafting with the rootstock/scion combination of 'Bagi F1'/'SV9703 PP F1' did not reveal an effect on most of the examined parameters. AMF treatment generally improved plant health and therefore resulted in greater yield, but in the case of grafting, primarily, the selection of the optimal rootstock for the given scion is crucial and has a determinative effect on yield.

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Conflict of Interest

The authors declare that there are no conflicts of interest related to this article.

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