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RESEARCH ARTICLE (Open Access)

The effects of endogenous mycorrhiza (*Glomus spp.*) on plant growth and yield of grafted cucumber (*Cucumis sativum l*) under common commercial greenhouse conditions

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Abstract

The objective of the study was to evaluate the effect of the Arbuscular mycorrhizae (AM) fungi on plant growth and yield of grafted cucumber seedlings. The experiment was conducted in a plastic greenhouse located in Shipol, Mitrovica municipality of Kosovo.Graded seeds of cucumber (cv. Ekron F1), and graded seeds of a rootstock (cv. Nimbus F1*; C. maxima* Duchesne x *C. moschata* Duchesne), were sown in polysterol trays. Three types of grafted seedlings; self-grafted (SEG), splice grafted (SG) and root pruned splice grafted (RPSG) were simultaneously produced in equal number as inoculated and non- inoculated with endogenous mycorrhiza. The combined effects of grafting methods and endogenous mycorrhiza (*Glomus spp*.) application on the growth parameters during the nursery period as well as growth rate and yield after transplanting were tested under common commercial conditions. The different grafting methods of cucumber seedlings on *C. maxima* x *C. moschata* (SG versus RPSG) have significant effects on seedlings growth parameters. Despite of commonly higher relative growth rate of RPSG seedlings till the transplanting time, SG seedlings have a significantly higher total plant dry weight (W). No difference was found regarding leaf dry weight (LW), while a significantly larger leaf area was found for RPSG seedlings. No effect of AM fungi presence was found regarding the growth parameters of grafted cucumber seedlings during the nursery stage, but the presence of AM fungi has significantly improved the growth rate of each grafting method after transplanting, as also increased the total harvested yield. The highest yield was recorded by AM inoculated RPSG seedlings.

Keywords: mycorrhiza, grafting, cucumber, growth rate, yield.

1. Introduction

In nature, plants are frequently exposed to adverse environmental conditions that have a negative effect on plant survival, development and productivity. Drought and salinity are considered the most important abiotic factors limiting plant growth and yield in many areas [13].There is a common request for the commercial production of vegetable transplants to provide a fast stand establishment coupled with enhancement in one or more attributes of earliness, uniform maturity, and yield quantity and quality [10]. Arbuscular mycorrhizal fungi long have been known to have a positive effect upon growth of their host plant [17], most notably in low nutrient soils. Like other vegetables, cucumber (*Cucumis sativus L.*) can live in a symbiotic association with arbuscular mycorrhiza (AM). In the cucumber / AM symbiosis, the fungus takes up nutrient salts and water from the soil and makes them accessible for the plant partner [7, 22], while the plant supplies the fungus with essential carbohydrates produced during photosynthesis [5]. As the fine fungal hyphae can penetrate and exploit the soil to a much greater extent than the plant's own root hairs, mycorrhizal symbiosis increases both the ecological and the physiological fitness of the plant [11]. In case of cucumber, benefits obtainable from optimal use of AMF can include: enhanced tolerance against soil-borne diseases [6, 9, 15, 23], pests [19] and nematodes [14, 16], increased drought tolerance and reduced water consumption [21].This has a huge impact on the cultivation of cucumber by increasing plant growth, plant health and crop yield [3, 20]. In the recent years commercial AM inoculate became available and has been used successfully to promote commercial cucumber growth in many countries [18]. Therefore, the objective of this study was to evaluate the effect of the Arbuscular mycorrhizae fungi on plant growth and yield of grafted cucumber seedlings.

2. Material and Methods

The experiment was conducted from mid-April to mid-July of the year 2013, in a plastic greenhouse located in Shipol, Mitrovica municipality of Kosovo ($42^0$52'52.71'' N and 20^0 51'18.06'' E). Graded seeds of cucumber (cv. Ekron F_1), and graded seeds of a rootstock (cv. Nimbus F_1; *C. maxima* Duchesne x

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C.moschata Duchesne), were sown in polysterol trays, one seed for each plugs (60 cm^3), filled with a mixture (vol: vol; 9:1) of commercial Klassmann peat compost and expanded clay grains contains spores of endogenous mycorrhyza. In another variant, similar trays were filled up with the same mixture (vol: vol; 9:1) of commercial Klassmann peat compost, but empty (non- inoculated, expanded clay grains) as control. After germination, plants were periodically and equally irrigated.

Fourteen days after sowing, cucumber seedlings were grafted onto *C. maxima* Duchesne x *C.moschata* Duchesne by two different grafting methods; splice grafting (SG) and root pruning splice grafting (RPSG). Additionally, an abundant number of seedlings were self grafted by splice grafting method (SEG). For each grafting method, an equal number of seedlings were produced as inoculated or non-inoculated with endogenous mycorrhyza fungi.

Two weeks after grafting, 6 plants of each experimental unit were randomly selected and harvested. After the harvest, the roots were carefully washed out from the substrate by using a soft water jet and 2 mm sieves. Meanwhile, the plant leaves were photocopied and further transformed to leaf areas (LA) by means of the specific area of the copy paper. Afterwards, all parts of harvested plants were dried at 70°C for 24 h to determine the dry weight of root (RW), leaf (LA), steam (SW) and the whole plant (W).

End of nursery period (fourteen days after grafting), 40 plants of each experimental unit were, as well, randomly selected and transplanted in a commercial plastic greenhouse, by a four replication randomized block design, with 10 plants for each replication. Irrigation of transplanted plants was conducted twice a week with equal amounts of water per each replication. Fertigation was applied twice periodically till the end of experiment with the same nutrient solution (N 140 mgL^{-1}, P 70 mgL^{-1}, K 210 mgL^{-1}).

Plant height (cm), number of newly formed leaves per plant and the yield per each replication, were successively recorded during the whole production cycle. Thefactorial analyses of variances was conducted by SAS/STAT 9.2 (SAS Institute, USA) for each experimental parameter, and the respective means were separated by least significant differences test (LSD) at 5% significance level.

3. Results and Discussion

3.1. The effects of grafting methods and AM fungi presence on growth parameters of cucumber seedlings during the nursery period

Grafting method had a significant effect on growth parameters of grafted seedlings (Table 2). Grafted on *C. maxima* x *C. moschata*, cucumber seedlings had a significantly higher shoot dry weight (SW), as well as a significantly higher total dry matter of the plant (W), versus self-grafted seedlings (Table 1). The same was true for leaf area, but self grafted seedlings (SEG) did have anyway, significantly higher dry weight of leaves, which indicates there were significant differences between SEG and SG and RPSG seedlings regarding leaf thickness. That difference could probably explained by specific influences of different rootstock species on the scion leaf morphology. The difference in root dry matter between SEG and SG seedlings is also explained by different morphological characteristics of the respective rootstock species (*C. sativum* versus *C. maxima* x *C. moschata*). It is a well known fact that the root systems of common commercial cucurbitacea rootstocks are characterized by a high vigor growth.

Different grafting method of cucumber seedlings on *C. maxima* x *C. moschata* (SG versus RPSG) did also have significant effects on seedlings growth parameters. Despite of commonly higher relative growth rate of RPSG seedlings till the transplanting time [4, 2], SG seedlings have a significantly higher root mass. They did also have significantly higher stem dry weight (SW) and total plant dry weight (W). Still, no difference was found regarding leaf dry weight (LW), while a significantly larger leaf area was found for RPSG seedlings (Table 1).

Meantime, with the exception of root dry weight, no effect of AM fungi presence was noted regarding the growth parameters of grafted cucumber seedlings during the nursery stage. Also, except for RW and SW, no significant effect was found for other growth parameters due to grafting x AM fungi interaction (Table 2).

3.2. *The effects of grafting methods and AM fungi presence on growth rate and yield of transplanted cucumber seedlings.*

Strong, significant effects of grafting methods, AM fungi inoculation and the interaction of grafting methods with AM presence were found for plant height and the number of newly formed leaves of cucumber plants transplanted in a common commercial greenhouse, as well as for total harvested yield (Table 4).

Table 1. Root dry matter (RW), stem dry matter (SW), leaf dry matter (LW), leaf area (LA) and plant dry matter (W) of AMF inoculated (Myc) and non-inoculated (Ctrl) grafted cucumber seedlings (SEG, SG, RPSG), two weeks after grafting (mean values, different letters indicate significant difference at P<0,05).

Grafting methods	Growth parameters				
	RW (gr plant^{-1})	SW (gr plant^{-1})	LW (gr plant^{-1})	LA (cm^{2}plant^1)	W (gr plant^{-1})
SEG Ctrl	0.046^{b}	0.038^{d}	0.133^{a}	19.658^{c}	0.218^{d}
SEG Myc	0.047^{b}	0.039^{d}	0.135^{a}	19.637^{c}	0.221^{d}
SG Ctrl	0.058^{a}	0.256^{a}	0.100^{b}	25.777^{b}	0.385^{ab}
SG Myc	0.062^{a}	0.233^{ab}	0.086^{b}	24.208^{b}	0.371^{ab}
RPSG Ctrl	0.040^{b}	0.174^{c}	0.107^{b}	37.141^{a}	0.322^{c}
RPSG Myc	0.047^{b}	0.198^{bc}	0.100^{b}	37.845^{a}	0.346^{bc}

Table 2. The significance of grafting methods, AM fungi presence and grafting method x AM fungi interaction effects on the growth parameters of cucumber seedlings two weeks after grafting.

Source of variation	Pr > F				
	RW	SW	LW	LA	W
Grafting	<.0001	<.0001	<.0001	<.0001	<.0001
Myc	0.0001	0.8955	0.0452	0.4399	0.7561
Grafting*Myc	0.0110	0.0165	0.1247	0.7266	0.5974

Table 3. Plant height (cm), leaf number and yield (gr/variant) of AMF inoculated (Myc) and non-inoculated (Ctrl) grafted cucumber seedlings (SEG, SG, RPSG) under commercial greenhouse conditions (mean values, different letters indicate significant difference atP<0, 05)

Grafting methods	Plant height (cm)	Number of leafs (no.)	Yield.
SEG Ctrl	86.6 d	11.3 c	14262.5 ed
SEG Myc	89.8 c	11.7 c	14587.5 d
SG Ctrl	88.1 dc	11.3 c	16465.0 c
SG Myc	94.8 b	12.4 b	17052.5 cb
RPSG Ctrl	93.9 b	12.2 b	17550.0 b
RPSG Myc	98.1 a	12.9 a	18827.5 a

Table 4. The significance of grafting methods, AM fungi presence and grafting method x AM fungi interaction effects on plant height, number of leaves and yield of cucumber plants

Source of variation	Pr > F		
	Plant height	Number of leafs	Yield
Grafting	<.0001	<.0001	<.0001
Myc	<.0001	<.0001	0.0001
Grafting*Myc	0.0004	<.0001	0.0487

The tallest plants were recorded for RPSG seedlings, followed by SG seedlings and self grafted (SEG) ones at the end (Table 3). Having the same order, as well, for the number of leaves, indicates that the differences regarding plant height were due to the higher emerge rate of newly formed leaves and not linked with the length of internodes. As we have stated in a previous paper, as fruit setting of parthenocarpic cultivars of cucumber is directly linked with the emergency rate of new leaves, the faster stem elongation rate provided by RPSG grafting means a larger number of harvested fruits [2]. The increase in the stem growth rate was evidently reflected to an increase in the daily harvesting rate and the total yield.

The influence of AM fungi was also highly positive, promoting growth and providing a higher yield. Almost with no exception, the presence of AM fungi has significantly improved growth parameters of transplanted seedlings for each grafting method, as also increased the total harvested yield (Table 3). The highest yield was recorded by AM inoculated RPSG seedlings. AM fungi presence has significantly increased the total harvested yield for SG and SEG seedlings also, indicating enhanced capabilities of AM inoculated plants. The fungi develop a dense hyphal network that extends far into the soil while still remaining connected to the root. This extra radical mycelium provides the plant with water and nutrients that would otherwise remain inaccessible to roots [1, 8, 12]. We also did found increased uptake of several nutrients in grafted cucumber seedlings due to AM fungi inoculation (non published data), which have strongly supported the faster growth and higher yield of respective grafted seedlings.

4. Conclusions

Grafting method had a significant effect on growth parameters of grafted seedlings. Meantime, with the exception of root dry weight, no effect of AM fungi presence was noted regarding the growth parameters of grafted cucumber seedlings during the nursery stage. Also, except for RW and SW, no significant effect was found for other growth parameters due to grafting x AM fungi interaction.
Strong, significant effects of grafting methods, AM fungi inoculation and the interaction of grafting methods with AM presence were found for plant height and the number of newly formed leaves of cucumber plants transplanted in a common commercial greenhouse, as well as for total harvested yield. The highest yield was recorded by AM inoculated RPSG seedlings.

The greenhouse production of cucumber plants can be maximized by the proper combination of grafting method with the inoculation of arbuscular mychorrhyza fungi. The improved water and nutrient status due to a young fast growing root system provided by root pruning splice grafting method (RPSG) and enhanced nutrient absorption capacity by AM fungi presence in the young transplanted plants, provides the best performance of cucumber plants under common commercial production conditions.

5. References

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