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Impact of Six Distinct Growth substrates on the Survival and Root Elongation of Grafted Tomato and Pepper Seedlings

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الباحث الاول[1]: فيروز بوعجيلة
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Abstract

A study was conducted at the Horticulture Department at Omar Al Mukhtar University, Al Jabal Al-Khader, Libya in 2022 to investigate the impact of six growth media; peat moss, sand, soil, peat moss and sand (1:1), peat moss and soil (1:1), and soil and sand (1:1), on the survival and root elongation of grafted tomato (Solanum lycopersicum) and sweet pepper (Capsicum annuum) seedlings. The experiment comprised 12 treatments representing all combinations of the two factors and followed a randomized complete block split-plot design with 4 replications. Findings indicated that among the growth substrates tested, peat moss, followed by the combination of peat moss and sand, exhibited the highest survival rates and root elongation for grafted tomato and pepper seedlings, surpassing the outcomes observed with alternative treatments.

Keywords: Peat moss; Sand; Survival; Grafting; Root elongation; Splice.

تأثير ستة بيئات نمو مختلفة على بقاء واستطالة جذور شتلات الطماطم والفلفل المطعمة

المستخلص: أجريت هذه الدراسة في قسم البستنة بجامعة عمر المختار، الجبل الأخضر، ليبيا في عام 2022، لدراسة تأثير ستة بيئات نمو؛ البتموس، والتربة، والرمل، و البتموس والرمل (1:1)، و البتموس والتربة (1:1)، والتربة والرمل (1:1)، على بقاء واستطالة جذور الشتلات المطعمة للطماطم **(Solanum lycopersicum)** والفلفل الحلو **(Capsicum annuum)**. وتضمنت التجربة 12 معاملة تمثل جميع تركيبات العاملين واتبعت تصميم القطعات العشوائية الكاملة مع 4 مكررات. أشارت النتائج إلى أنه من بين بيئات النمو المختبرة، أظهر ا البتموس، يليه مزيج البتموس والرمل، أعلى معدلات بقاء واستطالة جذور لشتلات الطماطم والفلفل، متجاوزة النتائج التي لوحظت مع المعالجات البديلة.

الكلمات المفتاحية: البتموس، الرمل، التطعيم، استطالة الجذور، الأصل و الطعم.

INTRODUCTION

Grafting is a well-established horticultural technique in which a scion (aboveground part) is fused with a rootstock through a graft union, resulting in a composite plant that combines the favorable traits of both components (Davis et al., 2008; Kawaguchi et al., 2024). This method has been extensively applied in commercial vegetable production across Asia, Europe and United States, where it is utilized to manage soil-borne diseases, enhance plant vigor, and improve overall yield performance (Bahadur et al., 2024; Buojaylah et al., 2024; Nagila; Dabirian et al., 2017; Lee et al., 2010; Reshma et al., 2024; Sakata et al., 2007; Wimer et al., 2015). However, in North Africa, particularly in Libya, the use of grafting in vegetable crop production remains limited. One of the key barriers to its widespread adoption among small-scale farmers in the region is the lack of comprehensive, research-driven information to support its implementation. This gap in knowledge hinders the potential benefits grafting could offer to local vegetable production systems.

Solanaceous crops (family Solanaceae) are typically regarded as easy to graft, primarily due to the simplicity and efficiency of the splice grafting technique (Johnson et al., 2011). This method is widely used and yields high graft success rates, with over 95% survival reported for tomatoes when healing is performed under controlled conditions.

Although the grafting procedure itself requires less than a minute per plant, the healing phase, which is crucial for graft success, spans approximately two weeks. During this healing process, a functional vascular connection is established between the scion and rootstock, allowing for the integration of the two plant components (Davis et al., 2008; Fernandez-Garcia et al., 2004). In horticultural research, the choice of growth substrate plays a critical role in influencing the growth and development of vegetable seedlings, particularly in species such as tomato (Solanum lycopersicum) and pepper (Capsicum annuum). A study was conducted in 2025 by Erdal and Aktas compared several substrates, including peat moss, perlite, leonardite, and vermicompost, as well as their mixtures with cocopeat. The results of the study illustrated that plants grown solely in peat moss exhibited the highest biomass and fruit yield. This demonstrates how peat moss's exceptional aeration and water retention qualities are advantageous for tomato cultivation. In addition, nine distinct growth media compositions were investigated by Lohani et al., (2023) for tomato and sweet pepper seedlings in Pokhara, Nepal. According to the study, for both crops, cocopeat by itself produced the highest seedling emergence. In particular, tomato seedlings demonstrated the highest rates of emergence in cocopeat, but sweet pepper seedlings grew best in vermicompost and perlite. These results imply that enhanced seedling development is supported by peat-based medium because of their advantageous water retention and aeration qualities. Growth substrate play a pivotal role in influencing the overall development and health of vegetable seedlings, particularly during the critical early stages of growth. A study examined the impact of various growth substrates on tomato stem cuttings' rooting response in a greenhouse. In comparison to other media, the results showed that pure peat moss considerably increased plant height, root length, and overall survival %. This demonstrates how well peat moss works to encourage tomato plant root development (Alam et al., 2020). The choice of substrate affects several key physiological and biochemical processes. Numerous studies have explored the effect of various growth substrates to optimize plant growth, focusing on factors such as water retention, aeration, and nutrient availability (Gruda, 2019), however, the impact of these substrates on the survival and growth of grafted vegetable seedlings has not yet been quantified. This study was aimed to investigate the effects of six distinct growth substrates on the survival and root elongation of grafted tomato and pepper seedlings.

MATERIALS AND METHODS

Experimental Design and Treatment Establishment:

A study was conducted in 2022 at the Horticulture Department of Omar Al Mukhtar University, Al Jabal Al-Khader, Libya, to investigate the effects of six distinct growth substrates on the survival and root elongation of grafted tomato cv. Cheyenne E488 and sweet pepper cv. Gedeon F1 seedlings (Syngenta, Cairo, Egypt). The main plot treatments were different growth substrates that included peat moss, soil, sand, peat moss-sand (1:1), peat moss-soil (1:1), and soil-sand (1:1) combinations, and the sub-plot treatment was vegetable crops; sweet pepper and tomato. Peat moss and soil substrates analysis were explained in tables 1 and 2, respectively. The experiment followed a randomized complete block split-plot design with 12 treatments, representing all combinations of media, and was replicated four times to ensure the reliability of the results. Plants were self-grafted on 8 August 2022, using the splice technique, and were placed in the healing chamber for 9 days. Self-grafting was employed to mitigate the risk of genetic incompatibility and to avoid discrepancies in graft union alignment between the rootstock and scion, which could negatively impact graft survival. Grafting procedures were conducted between 8:30 AM and 11:30 AM, characterized by reduced transpiration rates and minimal water stress, as recommended by Rivard and Louws (2006).

Grafting Technique Utilized in the Study: To ensure the formation of a successful graft union, proper alignment and contact between the cambium layers of the rootstock and scion are essential. Therefore, the scion and rootstock must have similar stem diameters at the time of grafting. In this experiment, self-grafting was employed to standardize stem diameters, allowing the investigation to focus solely on the effects of six distinct growth substrates selected for this study. To graft seedlings, the splice grafted method was used following the method of Johnson et al. (2011), where both rootstock and scion plants were watered 12–24 hours before grafting, watering plants was avoided immediately right before grafting. Grafting clips were reused, so they were thoroughly cleaned and sterilized. To increase the relative humidity, we sprayed the inner surfaces of the healing chamber with water a few hours before grafting. Clean, sharp razor blades were utilized for cutting, and hands were continuously sanitized with antibacterial soap or hand gel. Two spray bottles with tap water were prepared to mist the plants frequently during the grafting process. Plants were at the 2–4 true leaf stage for optimal grafting. Grafting was performed early morning at 8:00 AM to ensure low plant transpiration, and to reduce water stress in newly grafted plants. The grafting process was performed as each plant stem was severed just below the cotyledons at an approximate 45° angle using a razor blade. The cut surfaces were then aligned and secured using a silicone grafting clip to ensure proper contact between the scion and rootstock (Fig. 1, right).

Healing Process of Grafted Seedlings: The graft healing process commenced on the day of grafting, designated as day 1. Following grafting, the healing chamber remained sealed, and plants were undisturbed for the remainder of day 1 and throughout day 2. To gradually acclimate the grafted plants to the greenhouse environment, the chamber was opened for increasing durations: 5 minutes on day 3, 30 minutes on day 4, 1 hour on day 5, 3 hours on day 6, and 6 to 8 hours on day 7. On day 8, the plants were removed from the healing chamber at 4:00 PM and transferred to a laboratory bench, where they remained for the rest of the study. During the 8-day healing period, temperature and relative humidity within the healing chamber were continuously monitored to ensure optimal conditions for graft union formation (Fig 1, left).

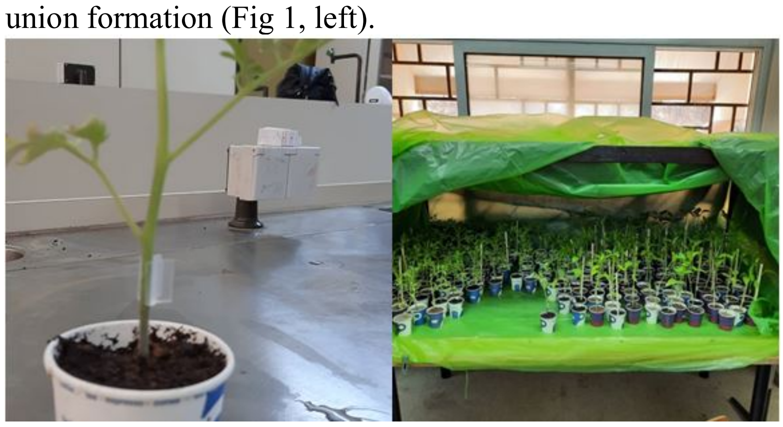

Figure: (1). Splice grafting method and healing process for grafted tomato and sweet pepperseedlings at the Horticulture Department of Omar Al Mukhtar University,Al Jabal Al-Khader, Libya.

Table:(1). Soil characteristics and properties

Measurements		
Particle Size distribution	Sand (%)	13.22
	Silt (%)	50.60
	Clay (%)	36.18
	Organic Matter (%)	2.30
	E.C (Mmhos/ cm)	1.30
	Total Nitrogen (%)	0.21
	Soil pH	7.87
	CO_3^{--}%	1.35
	P ppm	111
	K ppm	237

Table:(2). Peat moss characteristics and properties.

Measurements	Values
Organic Matter (%)	85–98
E.C (Mmhos/ cm)	0.2–1.0
Moisture (%)	40–60
pH	5.5–6.5
(%)Organic carbon	40–50
(%) Total nitrogen	0.5–1.0
C:N ratio	50:3

RESULTS AND DISCUSSION

Survival Percentage (%) of Grafted Pepper and Tomato Plants: Peat moss, either used alone or in combination with sand, provided the most favorable conditions for graft survival, while soil, both independently and when mixed with sand, resulted in significantly lower survival rates (Table 3). Peat moss demonstrated the highest and most consistent survival rate of 95% across all time points (10, 14, 18, and 22 days), without any notable decline throughout the study. Similarly, the peat moss and sand mixture (1:1) showed high survival rates, ranging from 91% on day 10 to 89% on day 22, reflecting the performance of peat moss and sand when applied individually. Sand alone also exhibited a high survival rate, beginning at 89% on day 10 and remaining relatively stable at 87% on day 22.

In contrast, the peat moss and soil mixture (1:1) resulted in moderate survival rates, starting at 74% on day 10 and slightly decreasing to 70% by day 22. The soil and sand mixture (1:1) produced lower survival percentages compared to peat moss-based treatments, with an initial survival rate of 65% on day 10 that declined to 35% by day 22. Soil alone had the poorest performance, with a survival rate of 63% on day 10, which further decreased to 30% by day 22.

The *P*-values < 0.0005 for the crop type effect indicate significant differences in survival rates between grafted tomato and pepper plants. Tomato grafts consistently exhibited higher survival rates than pepper grafts at each estimating date. On day 10, tomato grafts had a survival rate of 88%, compared to 84% for pepper grafts. By day 22, the survival rate for tomato grafts remained higher at 76%, while pepper grafts had a survival rate of 70%.

Table:(3). Survival of grafted pepper and tomato in the healing chamber after 10, 14, 18, and 22 days of grafting.

	Survival (%)[z]			
Treatment	10 d[y]	14 d	18 d	22 d
Peat moss	95 a	95 a	95 a	95 a
Soil	63 d	52 d	40 c	30 e
Sand	89 b	88 ab	90 ab	87 b
Peat moss and Sand (1:1)	91 a	90 a	92 a	89 ab
Peat moss and Soil (1:1)	74 bc	70 b	71 b	70 c
Soil and Sand (1:1).	65 c	57 c	44 bc	35 d
P-value	0.0002	0.0004	0.0002	<0.0001
Crop				
Pepper	84	76	75	70
Tomato	88	80	79	76
P-value	0.0002	0.0005	<0.0001	<0.0001

[z]All data were analyzed using analysis of variance (ANOVA) in JMP software (Version 11.0 for Windows; SAS Institute, Cary, NC). Survival was evaluated by visually estimating the turgidity of scion leaves and stems using a scale ranging from 0 to 3, where 0 indicated completely turgid leaves and stems, 1 indicated more than 50% of leaves and stems were flaccid, 2 indicated more than 70% of leaves and stems were flaccid, and 3 indicated complete wilting of leaves and stems. Only plants with a turgidity rating of 0 were classified as "surviving."
[y]Means followed by different letters within the same sampling date are significantly different at $P < 0.05$.

Plant Growth Parameters for Grafted Pepper and Tomato: The analysis of plant growth parameters for grafted pepper and tomato grown in six different media revealed significant differences in plant height and root elongation (Table 4). Peat moss produced the tallest plants (10.4 cm) and the greatest root elongation (4.8 cm), significantly outperforming other treatments ($P < 0.005$, and $P < 0.0003$, respectively). The combination of peat moss and sand (1:1) also supported relatively tall plants (9.4 cm) with moderate root elongation (3.8 cm). These findings are consistent with those reported in previous studies (Alam et al., 2020; Erdal & Aktas, 2025; Lohani et al., 2023). In contrast, soil, either alone or mixed with sand, resulted in the shortest plants and the least root elongation. Soil and sand mixtures (1:1) had the lowest root elongation at 1.8 cm. The number of leaves per plant did not show significant variation across treatments (P = 0.54). Regarding crop type, tomato plants exhibited greater height (7.8 cm) compared to pepper plants (5.4 cm), with P-values < 0.0001, although no significant differences were observed in leaf count or root elongation between the two crops. No significant interactions were observed between the six-growth substrates evaluated and crop types in this experiment ($P > 0.05$).

Table:(4). Mean plant growth parameters for grafted pepper and tomato with six different growth media.

Treatment[z]	Plant Height (cm)	Number of leaves/plants	Root elongation (cm)
Peat moss	10.4 a[y]	3.2	4.8 a
Soil	4.6 c	2.5	2.5 c
Sand	4.7 c	2.8	2.7 c
Peat moss and Sand (1:1)	9.4 ab	3.3	3.8 b
Peat moss and Soil (1:1)	9.6 ab	2.9	3.6 bc
Soil and Sand (1:1).	4.4 c	2.8	1.8 d
P-value	0.005	0.54	0.0003
Crop			
Pepper	5.4 b	2.8	2.3
Tomato	7.8 a	3	2.4
P-value	<0.0001	0.12	0.62

[z]All data were analyzed using analysis of variance (ANOVA) in JMP software (Version 11.0 for Windows; SAS Institute, Cary, NC).
[y]Means followed by different letters within the same sampling date are significantly different at P < 0.05.

This study highlights the substantial influence of growth substrate composition on the survival and development of grafted pepper (*Capsicum annuum*) and tomato (*Solanum lycopersicum*) plants. Peat moss, either utilized independently or in combination with sand, was identified as the most effective substrate, consistently yielding high survival rates (95%) and promoting optimal plant height and root elongation. These outcomes can be attributed to the inherent properties of peat moss, including its exceptional water retention capacity and aeration, which are essential for facilitating graft union formation and supporting overall plant vigor. (Oberpaur et al., 2010). The peat moss and sand mixture (1:1) also performed well, benefiting from both moisture retention and improved drainage. In contrast, soil-based media, whether used alone or mixed with sand, resulted in markedly lower survival rates, likely attributable to insufficient aeration, compaction, and suboptimal moisture regulation. This is supported by Gardner et al. (1999), who demonstrated that soil texture defined by the relative proportions of sand, silt, and clay has a significant influence on soil aeration and overall soil health. Tomato grafts consistently showed higher survival rates than pepper grafts, likely due to physiological differences such as greater tolerance to healing conditions or plant vigor, suggesting that tomatoes are more resilient or better suited to the healing environment.Peat moss produced the tallest plants and greatest root elongation, confirming its superiority as a growth medium. Significant differences in growth between peat moss-based and soil-based treatments highlight the importance of growth substrate composition. The peat moss and sand mix (1:1) also supported good growth, though sand slightly reduced peat moss's effects. Soil, especially when mixed with sand, led to the poorest growth and root elongation, likely due to its denser structure and reduced nutrient availability. While tomato plants showed greater height than pepper plants, there were no significant differences in leaf count or root elongation between the two crops. This suggests that despite tomatoes growing taller, the basic growth processes, including root elongation, were similar for both species under these conditions.

CONCLUSION

Overall, these findings underscore the importance of selecting appropriate growth substrate for graft healing and subsequent plant growth. Peat moss, either alone or in combination with sand, provided the most conducive environment for graft survival and growth, while soil-based treatments were largely inadequate. The significant crop type effect observed, particularly the superior performance of tomato grafts, provides further insight into species-specific responses to grafting and healing environments. Further research could explore the physiological mechanisms underlying these differences and evaluate the potential of alternative growth substrates or their combinations to enhance graft success in both crops.

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DUALITY OF INTEREST: The authors declare that they have no duality of interest associated with this manuscript.

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