J. Appl. Res Plant Sci. Vol. 5(2), 249-258, **2024**, https://doi.org/10.38211/joarps.2024.05.262

Research Article

OPEN ACCESS

Available on https://www.joarps.org
Journal of Applied Research in Plant Sciences
(JOARPS)
ISSN: 2708-3004 (Online), 2708-2997 (Print)

Evaluation of propagation of Bougainvillea under different plantation conditions

Mohammad Asif[1], Amir Ali[2], Khalil Ahmed[1], Qamber Khan[1], Asif Irshad[3], Musaddiq Khalid[4], Afifa Talpur[1], Safdar Ali Wahocho[1], Niaz Ahmed Wahocho[1]

[1]Department of Horticulture, Sindh Agriculture University, Tandojam, Hyderabad, Pakistan
[2]Department of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan
[3]Technical Wing of Colleges, Higher & Technical Education Department, Balochistan, Pakistan
[4]Agriculture Extension and Cooperatives Department, Balochistan, Pakistan
Corresponding author e-mail: nawahocho@gmail.com

Article Received 24-03-2023, Article Revised 12-04-2024, Article Accepted 12-05-2024.

Abstract

Bougainvillea is popularly used as an ornamental plant, appraised because of its aesthetic bracts, but it undergoes difficulty in propagation due to incompetence in root growth. Hence comprehensive research is required for improving its propagation ways to widen its cultivation. The present study was therefore conducted to explore the growth, rooting, and sprouting response of Bougainvillea cuttings to different planting conditions (tunnel and open field conditions). The research was executed by applying a randomized complete block design with factorial arrangement. Cuttings of two bougainvillea types (Climbing and Bush Bougainvillea) were used. It was noted that growth and rooting of both bougainvillea types were significantly ($P<0.05$) affected by different plantation conditions. The results elaborated that the Bougainvillea cuttings planted under tunnel conditions took less time to sprouting (5.50) with maximum branches (20.01), sprouting (88.33%) and survivability (83.33 %). The cuttings grown under tunnel conditions also exhibited maximum shoot and root biomass production (15.46 g and 1.15 g) and root numbers (12.68). Concerning the Bougainvillea types, "Bush bougainvillea" showed superior performance for most of the assessed traits in comparison with its counterpart “Climbing bougainvillea”. After reviewing the findings of this study, it is determined that bougainvillea plantation with plastic tunnels had better results in terms of sprouts, rooting and growth characteristics. Pertaining to bougainvillea types, the "Bush bougainvillea” exhibited greater results than the "Climbing bougainvillea".

Keywords: Bougainvillea propagation, planting conditions, open field, tunnel conditions Climbing and Bush Bougainvillea

Introduction

Bougainvillea is originally of the family Nyctaginaceae, possesses high ornamental value in horticulture (Zhang *et al*,. 2023). These woody vines belong to the tropical and subtropical climate, distinguished by the vibrant bracts, a long flowering period, and the great tolerance to harsh environmental conditions makes them ideal ornamental plants for environment (He *et al*., 2020). Bougainvillea is native to Peru, Southern Argentina, and Brazil in South America, but is widely cultivated as landscape plants in other warm climate regions such as the Pacific Islands, Southeast Asia, the Mediterranean, Australia, and the Caribbean Islands (Saleem *et al*., 2021). This widely grown ornamental plant (Gobato *et al*., 2016) was first explored by Louis de Bougainville in Brazil in the 18th century, he brought it to the European regions where it thrived and flourished successfully (Ahmed, 2014). Now, it is cultivated worldwide as both a shrub and a climber in subtropical and tropical gardens (Elumalai *et al*., 2012) and it has gained a wide attention in horticultural field, the pharmaceutical industry, and research practices of environment (Bautista *et al*., 2020). Bougainvillea serves as a great eco-friendly ground cover to the places that are difficult to maintain. It may suffocate weed growth (Eed *et al*., 2015). Bougainvillea can be used in bonsai and baskets as well (Kobayashi *et al*, 2007). The usage of bougainvillea has been increased due to modernization and urbanization since landscape horticulture is being popular round the globe and demand of vast production is raising in urban areas. It is tolerant to drought and pollution thus minimal care is required in comparison to other plants, and contains multiple uses (Singh *et al*., 2017). Bougainvillea has extensive blooming throughout the summer months. It significantly reduces air pollution hence, they are grown in public places particularly in gardens, urban areas, parks and tourist destinations (Heti and Siwi, 2020). Wide adaptability to different agro-climatic conditions and easy multiplication has made it a popular ornamental plant of the world. Moreover, as it is a drought and pollution resistant plant, it is well suited for industrial places and on road dividers (Kumar and Prasad, 2002). The bougainvillea has high economic and environmental value (Céline *et al*., 2006), however, this vibrant and aesthetic plant encounters difficulty during propagation (Okunlola and Akinpetide., 2016). Bougainvillea are usually propagated through stem cuttings of pencil size thickness and 15-25 cm length **(**Eed *et al*., 2015**;** Datta *et al*., 2020**;** Singh *et al*., 2020) because stem cutting is considered as the cheapest and simple method of propagation however, the success rate of propagation is very limited (Minj *et al*., 2023), due its inability to compete for establishing adventitious roots by cuttings which is a frequent issue and poses hurdles for its vegetative propagation (Céline et al., 2006). Root development is a prime stage in the vegetative propagation of wood or horticultural plants, and rooting problems will lead to significant economic losses (Mohammed and Hamid, 2014). The response of rooting can differ with variety, physiological stage of the parent plant, time of plantation of the cuttings, environmental elements of propagation chamber (Hartmann *et al*., 2011). A wide variation is often seen in different cultivars of the same species of Bougainvillea for rooting, sprouting and growth traits (Memon *et al*., 2013). Most nursery men observed a poor rooting percentage in Bougainvillea. In Pakistan, bougainvillea is generally propagated by stem cutting under open field condition in plant nurseries. However, so far, no report has been documented pertaining to plantation and evaluation of Bougainvillea cuttings under plastic tunnel conditions. The current research was therefore formulated to explore the growth, sprouting, rooting and success rate of Bougainvillea cuttings under open field and plastic tunnel conditions.

Materials and Methods

Location of the study: The study was run at the plant nursery of Horticulture department, Sindh Agriculture University Tando Jam from October to December 2022 to examine the rooting and growth response of bougainvillea cuttings under an open field and small tunnel plantation conditions.

Sources of Plant Material: Healthy stem cuttings of pencil size thickness having 20 cm length were taken from bougainvillea plants growing in the nursery of horticultural garden Sindh Agriculture University Tandojam.

Experimental design procedure and plantation of cuttings: The research was executed by employing randomized complete block design with factorial arrangements. The three replicates were used in the study and kept at random. Cuttings of two bougainvillea types (climbing bougainvillea and bush bougainvillea) were planted to execute this study. Cuttings were grown on 1st October 2022 in plastic bags comprising a medium containing equal ratio of sand and farmyard manure. The size of the plastic bag was 25 cm x 15 cm with a growing media quantity of 1.5 kg. Cuttings were planted under an open field and small plastic tunnel having a diameter of 150 cm and height of 100 cm. The cuttings were kept at the nursery under natural environmental conditions. Twenty cuttings were planted in each replication. A total of 240 cuttings were planted representing that 120 cuttings of each bougainvillea type were planted in respective plantation condition. The cuttings planted under open field conditions were irrigated daily by applying light water. However, the cuttings grown under small plastic tunnel were applied water at the interval of 20 days.

Data Recorded: Data were recorded in terms of days to sprouting, sprouts in each cutting, sprouts %, branches in individual cutting, survivability %, fresh and dry shoot biomass, fresh root biomass of individual cutting and root number in each cutting.

Data Measuring Methodology

Days to sprouting: This parameter was recorded regularly by counting the days taken for half of the number of cuttings to sprout in each planting condition.

Sprouts per cuttings: The sprouts in each cutting were recorded regularly by counting sprouts in each cutting

Sprouting %: This trait was recorded by counting the number of cuttings that sprouted in each plantation condition four weeks after plantation and expressed as a percentage of total cuttings, initially planted.

Branches per cuttings: The branches in each cutting were recorded by counting the total branches that emerged from the sprouts of each cutting at the end of experiment.

Survivability %: The survivability % was assessed as the number of cuttings surviving divided by number of cuttings that sprouted/emerged buds.

Fresh and dry shoot biomass per cutting (g): The fresh shoot biomass was calculated after removal of above ground plant parts (shoot) of each cutting by analytical balance. Dry shoot biomass was recorded by keeping the samples in the oven at 70 ^{0}C to a consistent weight.

Fresh root biomass per cutting (g): The cuttings were carefully removed from the soil. The above ground growth (shoot) and roots of sampled cuttings were separated. After that roots were washed gently by removing the excess soil attached to roots. The excess moisture in roots were removed by tissue paper; then root biomass (fresh) of sampled cuttings were measured by using digital balance.

Statistical analysis: The recorded data were subjected to analysis of variance (ANOVA) using Statistics 8.1 computer software (Statistix, 2006) followed by LSD test at 5% probability level to analyze the significant difference between treatments (Plantation conditions and bougainvillea types).

Results

Days to sprouting: Days to sprouting of Bougainvillea cuttings were significantly varied for different plantation conditions and Bougainvillea types and their interaction ($P<0.05$) as shown in Figure 1. The minimum days to sprouting of Bougainvillea 5.500) were found in Plantation under tunnel conditions, while the maximum days to sprouting (10.167) were noted in Plantation under open field conditions. In the case of Bougainvillea types, bush bougainvillea took less time to sprouting (7.500) than "climbing bougainvillea"

(8.166). The interactive effect of Plantation conditions x Bougainvillea types revealed that "Bush bougainvillea" took minimum days to sprouting (5.000) when planted under tunnel environment and the maximum days to sprouting (10.333) were obtained in the interaction of plantation under open field conditions× "Climbing bougainvillea". The LSD test indicated that variances in bougainvillea for days to sprouting within different plantation conditions as well as types were statistically significant (P<0.05).

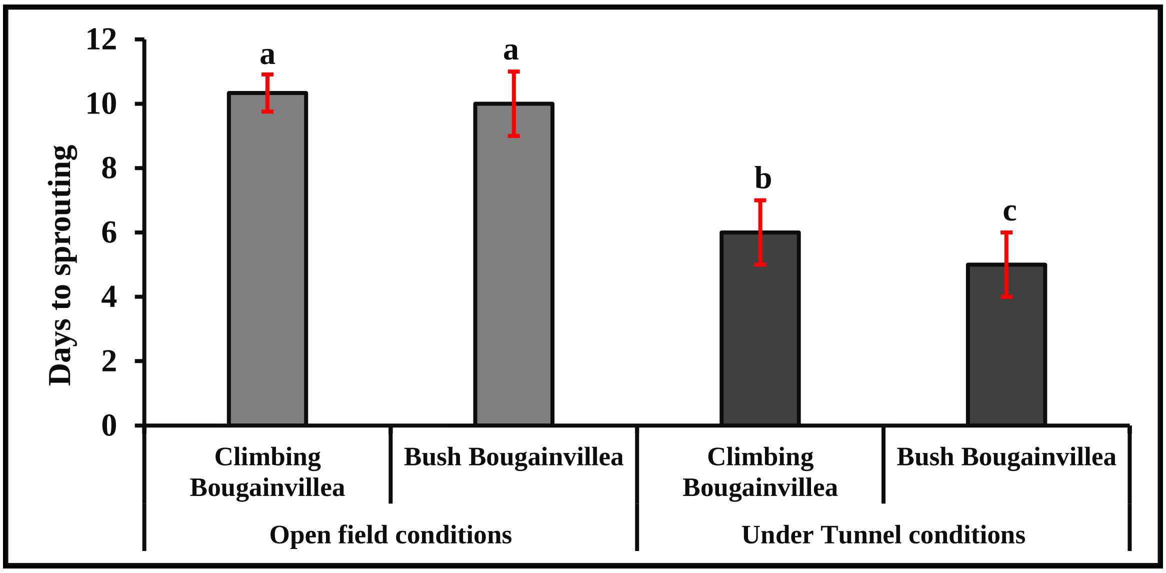

Figure 1. Days to sprouting of bougainvillea types under different planting conditions

Number of sprouts cutting^{-1}: The results in Figure 2 depict that number of sprout cutting^{-1} significantly varied due to the independent and interactive effect of various plantation conditions and Bougainvillea types. The highest number of sprouts cutting^{-1} of Bougainvillea (8.333) was determined in Plantation under open field conditions, while the lowest number of sprouts cutting^{-1} (8.166) was noted in Plantation under tunnel farming. In the case of bougainvillea types, the number of sprouts cutting^{-1} of bougainvillea type "Bush bougainvillea" was significantly higher (9.833) than "Climbing bougainvillea" (6.666). Their interactive effect showed that plantation under tunnel farming × "Bush bougainvillea" resulted maximum number of sprouts cutting^{-1} (10.000) and the lowest number of sprouts cutting^{-1} (6.333) was obtained in the interaction of Plantation under tunnel condition × "Climbing bougainvillea". The LSD test indicated that differences in bougainvillea for number of sprouts cutting^{-1} within different plantation conditions as well as types were statistically significant (P<0.05).

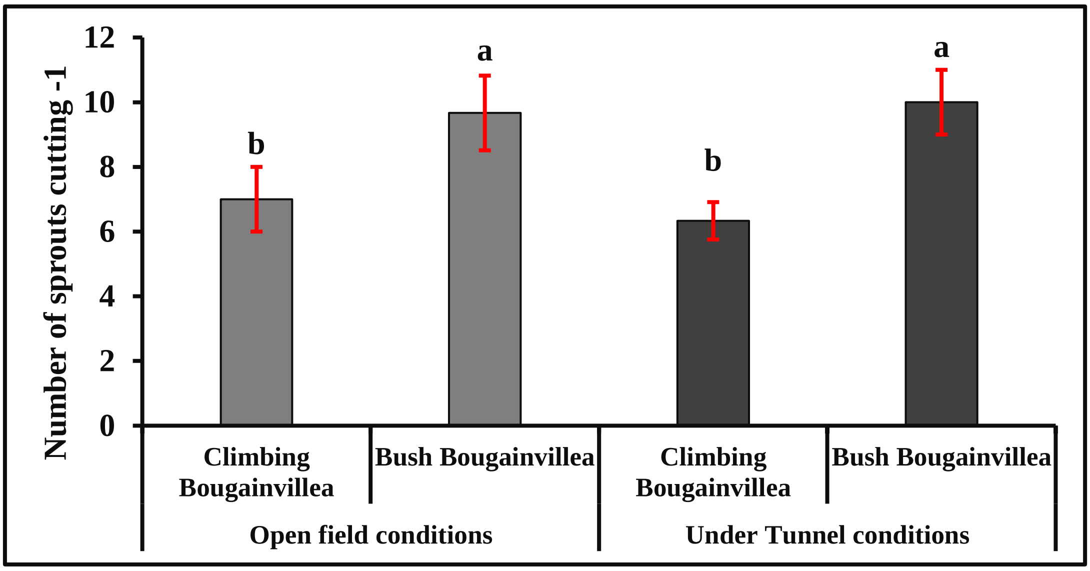

Figure 2. Number of sprouting cutting^{-1} of bougainvillea types under different planting conditions

Sprouting (%): The results of the analysis of variance showed that the interaction between different plantation conditions and Bougainvillea types significantly affected the sprouting % (P<0.05) as shown in Figure 3. The maximum sprouting % (88.333) was determined in planting of cuttings under tunnel environment, while the less sprouting % (76.000) was seen in when cuttings were planted to open field. With regards to the types, the sprouting % of "Bush bougainvillea" was significantly higher (84.000) than "Climbing bougainvillea" (80.333). The interactive effect of Plantation under tunnel conditions × "Bush bougainvillea" showed the highest sprouting % (90.000) and the lowest sprouting % (74.000) was obtained in the interaction of Planting of cuttings to open field conditions x "Climbing bougainvillea". LSD test revealed that variances in bougainvillea types for sprouting% within different plantation environments/conditions as well as types were statistically significant (P<0.05).

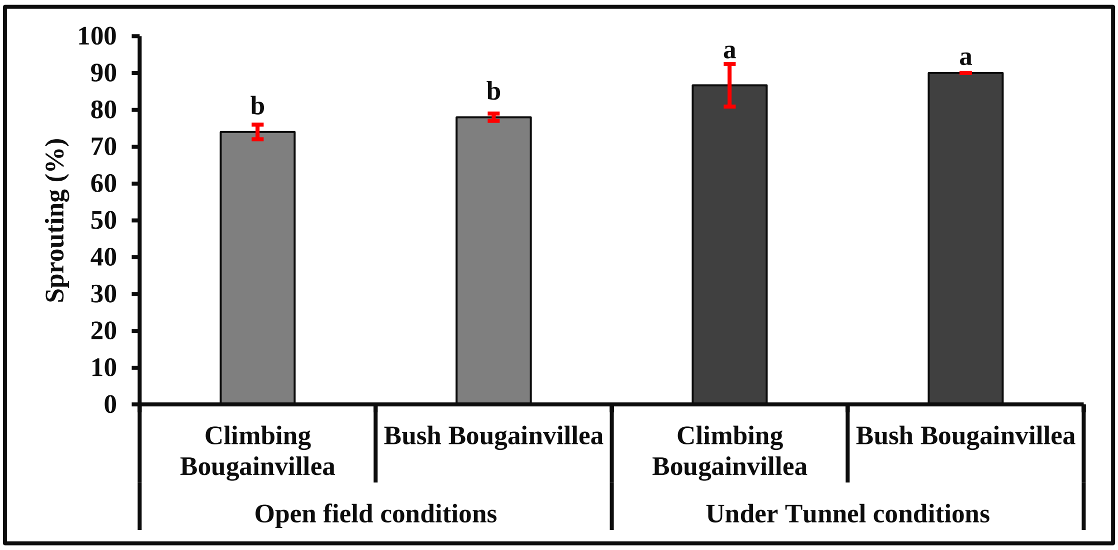

Figure 3. Sprouting % of bougainvillea types under different planting conditions

Number of branches cutting^{-1}: The data regarding the number of branches cutting^{-1} is elaborated in Figure 4. It reveals that the interaction between various plantation conditions and Bougainvillea types was significant (P<0.05). The maximum number of branches cutting^{-1} of Bougainvillea (20.017) was determined in plantation under tunnel farming, while the minimum number of branches cutting^{-1} (17.833) was noted in plantation under open field conditions. Concerning to the bougainvillea types, the number of branches cutting^{-1} of "Bush bougainvillea" was significantly higher (20.167) than "Climbing bougainvillea" (17.683). The interactive effect of Plantation under tunnel farming × "Bush bougainvillea" yielded more branches cutting^{-1} (21.333), and less branches cutting^{-1}(16.667) was obtained in the interaction of plantation of cuttings in open field conditions × "Climbing bougainvillea". LSD test showed variances in branches of bougainvillea cutting^{-1} within different plantation conditions as well as types were also statistically significant (P<0. 05).

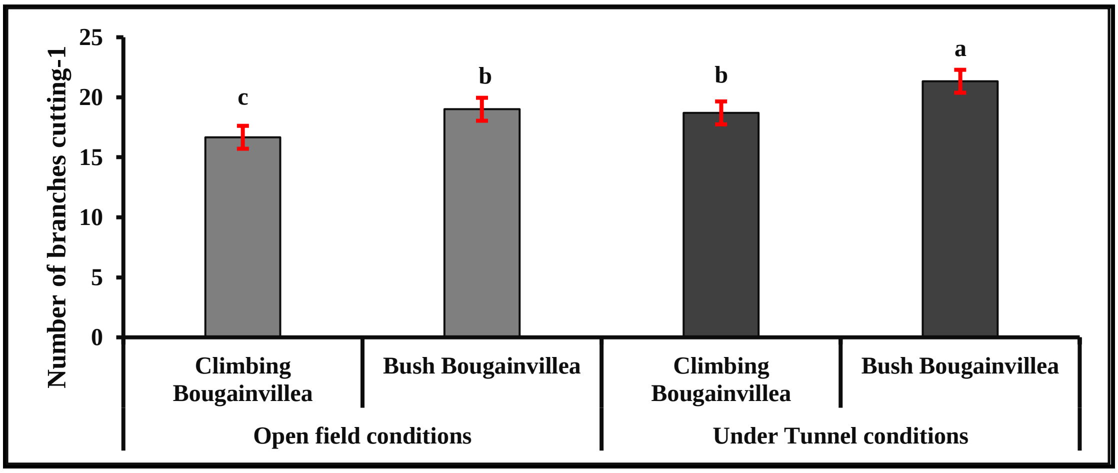

Figure 4. Number of branches cutting^{-1} of bougainvillea varieties under different planting conditions

Survivability (%): The findings regarding survivability % elaborates that the individual and interactive effect between various plantation conditions and Bougainvillea types was significant (P<0.05) as shown in Figure 5. The highest survivability % of Bougainvillea (83.333) was determined in Plantation under tunnel farming, while the minimum survivability % (78.667) was noted in plantation under open field conditions. When comparing the types it was observed that, the survivability % of bougainvillea type "Bush bougainvillea" was significantly higher (83.667) than "Climbing bougainvillea" (78.333). The interactive effect of plantation under tunnel farming × "Bush bougainvillea" produced plants of maximum survivability % (86.667) and the less survivability % (76.667) was found in the interaction of plantation of cuttings in open field conditions × "Climbing bougainvillea. It was demonstrated in LSD test that differences in bougainvillea survivability % within different plantation conditions as well as types were statistically significant (P<0.05).

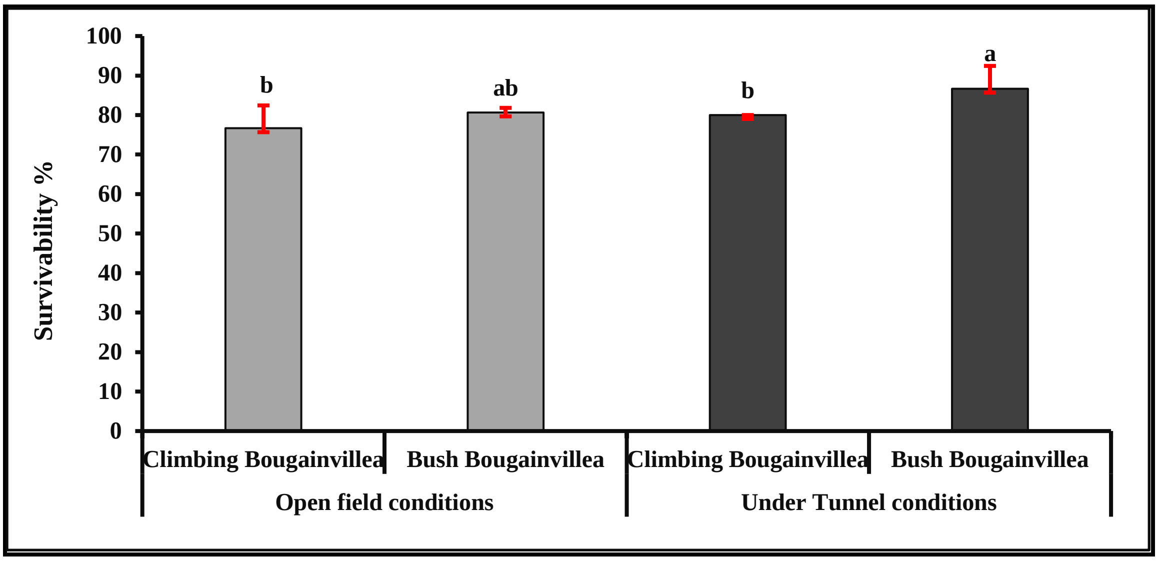

Figure 5. Survivability % of bougainvillea types under different planting conditions

Fresh biomass of shoot (g): The results of the analysis of variance showed that the interaction between different plantation conditions, types, and fresh biomass of shoots (g) was significant (P<0.05) as shown in Figure 6. The maximum fresh biomass of the shoot of Bougainvillea (15.463 g) was found in plantation of cuttings in tunnel conditions, whereas the least shoot biomass (12.965 g) was recorded in plantation of cuttings in open field environment. In case of Bougainvillea types, the fresh biomass of the shoot of "Bush bougainvillea" was significantly higher (15.132 g) than the variety "Climbing bougainvillea" (13.297 g). The interactive effect exhibited that cuttings planted under tunnel conditions × "Bush bougainvillea" produced maximum shoot biomass production (16.223 g) and the least shoot biomass production (11.890 g) was obtained in the interaction of plantation of conditions in open field conditions × "Climbing bougainvillea" when compared to the rest of the plantation conditions and types. The LSD test indicated that differences in bougainvillea fresh biomass of shoot (g) within different plantation conditions as well as types were statistically significant (P<0.05).

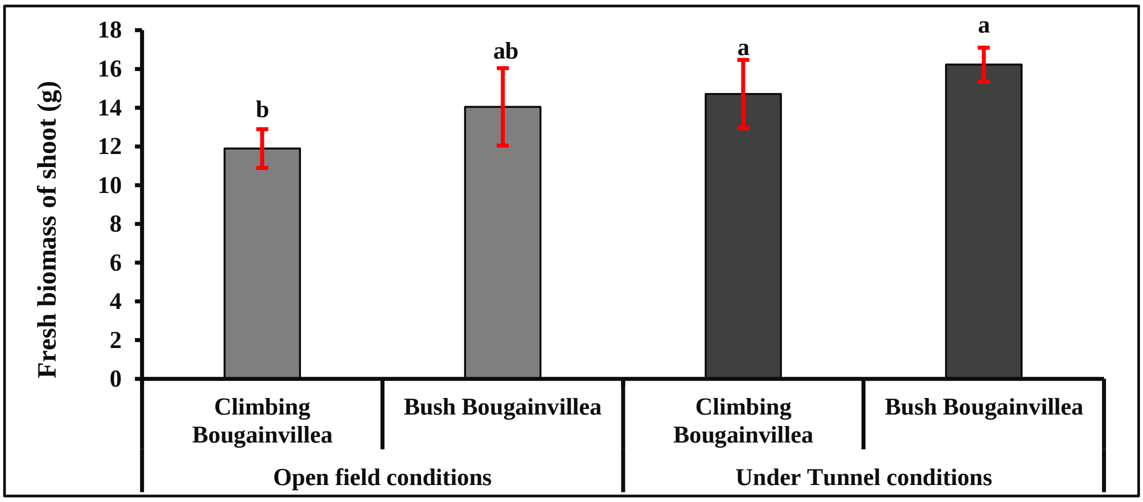

Figure 6. Fresh biomass of shoot (g) of bougainvillea types under different planting conditions

Fresh biomass of root (g): The results of the analysis of variance for fresh biomass of roots (g) showed that the independent as well as interactive effect of various plantation conditions and Bougainvillea types was significant (P<0.05) as shown in Figure 7. The greater fresh root biomass of Bougainvillea (1.158 g) was found in cuttings, planted in tunnel conditions, whereas the lowest root biomass (1.030 g) was noted in planting of cuttings in open field conditions. As far as the bougainvillea types are concerned, the fresh biomass of the root of bougainvillea type "Bush bougainvillea" was significantly higher (1.243 g) than the "Climbing bougainvillea" (0.945 g). The interaction results demonstrated that plantation of cuttings under tunnel conditions × "Bush bougainvillea" exhibited greater root biomass production (1.343 g); and less root biomass production (0.916 g) was obtained in the interaction results of plantation of cuttings in open field conditions × "Climbing bougainvillea". The LSD test indicated that variances in bougainvillea root biomass within different plantation conditions as well as types were statistically significant (P<0.05).

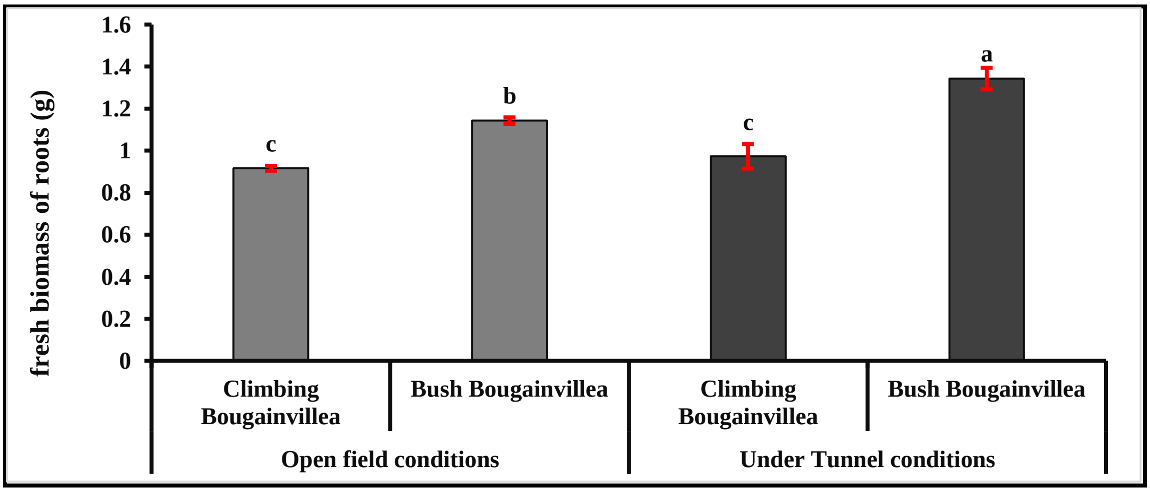

Figure 7. Fresh biomass of root (g) of bougainvillea types under different planting conditions

Number of roots cutting^{-1}: The results of the analysis of variance showed that the number of roots cutting^{-1} varied significantly due to the independent and interactive effect of different plantation conditions and Bougainvillea types (P<0.05) as shown in Figure 8. The maximum number of roots cutting^{-1} of Bougainvillea (12.683) was observed in Plantation under tunnel farming, while the minimum number of roots cutting^{-1} (10.667) was noted in plantation under open field conditions. About the bougainvillea types, the number of roots cutting^{-1} of bougainvillea type "Bush bougainvillea" was significantly higher (13.183) than "Climbing bougainvillea" (10.167). The interactive effect of plantation under tunnel farming × "Bush bougainvillea" provided with highest number of roots cutting^{-1} (14.367) whilst the less roots cutting^{-1} (9.333) was obtained in the interaction of plantation in open field conditions × "Climbing bougainvillea". The LSD test indicated that variances in bougainvillea roots cutting^{-1} within different plantation conditions as well as types were statistically significant (P<0.05).

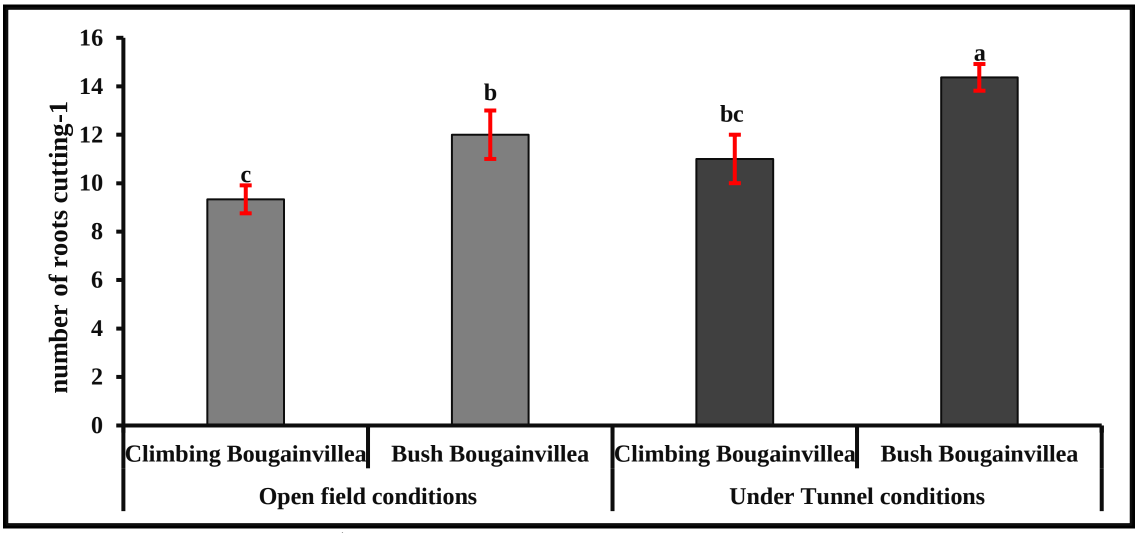

Figure 8. Number of roots cutting^{-1} of bougainvillea types under different planting conditions

Dry biomass of shoot (g): The results regarding the dry biomass of shoot are presented in the Figure 9. It depicts that the interaction between different plantation conditions and Bougainvillea types and their individual impact on dry biomass of shoot differed significantly (P<0.05). The maximum dry biomass of the shoot of Bougainvillea (4.818 g) was determined in plantation of cuttings in plastic tunnel conditions, whereas less dry shoot biomass (3.791 g) was noted in plantation in open field environment. In the case of bougainvillea types, the dry biomass of the shoot of bougainvillea type "Bush bougainvillea" was significantly higher (4.723 g) than "Climbing bougainvillea" (3.886 g). The interactive effect of plantation under tunnel farming × "Bush bougainvillea" displayed greater dry shoot biomass production (5.266 g) and the less dry shoot biomass production (3.403 g) was obtained in the interaction of plantation in open field conditions × "Climbing bougainvillea". The LSD test indicated that variances in bougainvillea dry shoot biomass within different plantation conditions as well as types were statistically significant (P<0.05).

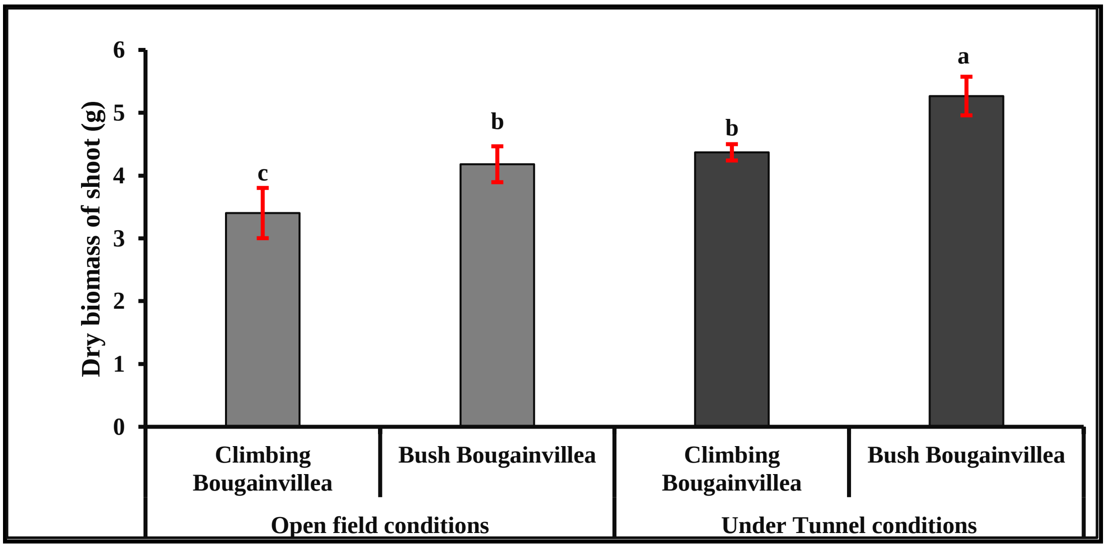

Figure 9. Dry biomass of shoot (g) of bougainvillea types under different planting conditions

Discussion

Rooting tendency of cuttings is an essential factor in plant propagation of woody plants, which differs from one specie to another, along with several other factors (Kochhar et al.,2008). However, sexual propagation (seeds) becomes the reason of genetic variability which leads the plants to encounter several kinds of diseases. Vegetative propagation through cuttings exhibits the pros of developing true to type plants within short time frame, it ensures the presence of primarily healthy material for conducting large scale plantation with rapid advantages and disease-free varieties of commercial importance (Kesari et al., 2009). Hence, propagation through stem cuttings has broader spectra with wide applications in the field of ornamental horticulture. The increasing interest in ornamental plants is due to their economic value (Kumar and Prasad, 2010), this raises the demand of increased propagation. Therefore, in our study we have explored the ways to improve the Bougainvillea propagation. Asexual means are the prime ways to carry out Bougainvillea propagation (Shrestha et al., 2023; Lin et al., 2024), but the vegetative propagation by stem cuttings is the most effective way of multiplying Bougainvillea because of its simplicity and applicability in our country (Memon et al., 2013).

In the present research, Bougainvillea types under different planting conditions were examined. The findings showed that plastic tunnels and Bush Bougainvillea exhibited good results for vegetative attributes, like the days to sprouting, sprouting %, number of sprouts per cutting. It was found that minimum days were taken to sprouting under plastic tunnels. The results were coherent with the findings of (Hussain et al., 2012) who described that minimum days to sprouting were taken by the cuttings in pomegranate grown under plastic tunnel. This rapid rooting could be due to the high temperatures and humidity retained in the plastic tunnel. Furthermore, the results are coherent with (Elgimabi., 2009), their study states that light, temperature, and humidity are regarded as essential in rooting and succeeding growth of cuttings. (Pipattanawong et al., 2007) when studied on fig states that the highest bud emergence % was found under plastic pavilions in 1.8 to 2.0 cm cutting, these findings are related to our study which showed that the highest sprouting % was observed under plastic tunnels in Bush Bougainvillea type, as Bougainvillea is less likely to grow vigilantly under open ground conditions (Alif and Nasrullah, 2023), further these findings are in line with the results of (Hussain et al., 2016) who reports maximum sprouting (79.94%) when cuttings were grown under plastic covering while minimum percentage (58.30%) was observed in cuttings grown with no covering material in the sweet lime cuttings. In case of environmental conditions, maximum sprouting (86.40%) was observed in plastic tunnel in the cuttings of pomegranate (Hussain et al., 2012). Similar observations were stated by (Elgimabi., 2009), who reported that cuttings grown under plastic tunnel provided with the best rooting and vegetative growth. Furthermore, from the findings of (Hussain et al., 2012), it was seen that the type of cuttings and environmental conditions significantly affected the number of sprouts per cuttings. Similarly in our study, Bush Bougainvillea provided superior results, and plastic tunnels were found to be best for number of sprouts.

Like our study, (Elgimabi., 2009) found maximum number of roots from the Hamelia cuttings when grown under plastic tunnels, as root development is influenced by various alterations and is regulated through a series of interconnected physiological stages (Pirdastan et al., 2020). Same trend was found for other attributes like number of roots per cutting, fresh shoot biomass, fresh root biomass and dry weight of shoot. Hence, the cuttings grown under plastic tunnels have profound impact on growth traits. Moreover, among the protected structures, plastic tunnels are cheap, and convenient way of production (kumar et al., 2015). (Singh, 2018) reported that the best results are seen in Bougainvillea when it is grown under plastic sheets. In the past few years, plastic tunnels have gained the ground because it prevents the harsh conditions during flowering, this technique can even reduce the damage of fruits and flowers (Carlen and kruger, 2008). Cultivation under high or low tunnels can make the produces better (Demchak, 2009), growing the plants under plastic (polyethylene), either with high tunnels or greenhouses, triggers environmental changes, light, temperature and relative humidity and other external conditions that can influence the productive and physiological conditions of the plant (Li et al., 2012). Usually, the physiological condition of the mother plant, timing of plantation of cutting are the main elements impacting the effectiveness of rooted woody stem cuttings in most of the horticultural plants and fruit trees (Rowezak, 2001).

Conclusions

After reviewing the data of this study, it is concluded that plantation conditions had considerable effect on sprouting, growth and rooting of both Bougainvillea types (Climbing and Bush Bougainvillea). However, Bougainvillea stem cuttings planted under tunnel conditions showed the most promising results in comparison with cuttings planted under open field conditions. In the case of Bougainvillea types, Bush Bougainvillea exhibited maximum rooting and growth response under both plantation conditions (Tunnel and open field conditions).

Recommendations

It is recommended that Bougainvillea cuttings be planted under plastic tunnel conditions for better sprouting and other growth attributes. Nevertheless, other plantation methods may also be employed for the successful propagation and multiplication of diverse ornamental plant species.

Acknowledgement:

Author is highly grateful to all the scholars who significantly subsidized and offered valuable technical support in doing study and writing the draft of the manuscript.

Author's Contribution

Planned the study and wrote the original draft of the manuscript: NA Wahocho, Conducted the study and compiled data: M Asif, Assisted in data analysis: SA Wahocho, Offered technical assistance: A Irshad, Helped in compiling the data: K Ahmed, Helped in data analysis: Q Khan, Assisted in revision of the manuscript: M Khalid, Offered technical input and helped in writing of manuscript: A. Talpur, Helped in review and editing of the manuscript: A Ali

Conflicts of interest

The authors have declared no conflict of interest

References

Ahmed, A. H. (2014). New flavone from the aerial parts of Bougainvillea glabra. IJCER Online, 73, 2250-3005.

Alif, M. I., & Nasrullah, N. (2023). Treatment of plant growth regulating substance and modification of growing media to stimulate flowering of bougainvillea in air polluted streetscape. *In IOP Conference Series: Earth and Environmental Science*, 1133.

Bautista, M.A.C., Zheng, Y., Hu, Z., Deng, Y., Chen, T. (2020). Comparative analysis of complete chloroplast genome sequences of wild and cultivated Bougainvillea (Nyctaginaceae). *Plants*, 9: 1671.

Carlen, C., & kruger, E. (2008). Berry production in changing climate conditions and cultivation systems: further research requirements. In Workshop on Berry Production in Changing Climate Conditions and Cultivation Systems. COST-Action 863: *Euroberry Research*, 838: 225-228.

Céline, S., Luc, N., Thierry, B., Hélène, C., Marie-Pierre, J., Marlène, D., Göran, S., Michel, Z., Catherine, B. (2006). Proteomic Analysis of Different Mutant Genotypes of Arabidopsis Led to the Identification of 11 Proteins Correlating with Adventitious Root Development. *Plant Physiology*, 140: 349-364.

Datta, S. K., Jayanthi, R., & Janakiram, T. (2020). Bougainvillea. Floriculture and Ornamental Plants, 1-34.

Demchak, K. (2009). Small fruit production in high tunnels. *Horticulture Technology*, 19(1): 44-49.

Elgimabi, M.E.N.E. (2009a). Improvement of propagation by hardwood cuttings with or without using plastic tunnel in Hamelia patens. *World Journal of Agricultural Sciences*. **5**(5): 522-524

Eed, A. M., Albana'a, B., & Almaqtari, S. (2015). The effect of growing media and stem cutting type on rooting and growth of Bougainvillea spectabilis plants. University Aden, *Journal of Natural and Applied Sciences*, **19**(1):141-147.

Elumalai, A., Eswaraiah, M. C., Lahari, K. M., & Shaik, H. A. (2012). In-vivo screening of Bougainvillea glabra leaves for its analgesic, antipyretic and anti-inflammatory activities. *Asian Journal of Research in Pharmaceutical Science*, **2**(3): 85-87.

Gobato, R., Gobato, A., & Fedrigo, D. F. G. (2016). Study of the molecular electrostatic potential of D-Pinitol an active hypoglycemic principle found in spring flower Three Marys (Bougainvillea species) in the Mm+ method. *Parana Journal of Science and Education*. **2(**4): 1-9.

practices. 8ed. New Jersey: Prentice Hall, 2011. 915p.

Hartmann, H.T., Kester, D.E., Davies Jr., F.T. and Geneve, R.L. (2010) Plant Propagation: Principles and Practices. 8th Edition, Prentice-Hall, New Jersey, 915 p.practices. 8ed. New Jersey: Prentice Hall, 2011. 915p.

Hartmann, H.T., Kester, D.E., Davies Jr., F.T., Geneve, R.L. (2011). Plant Propagation: Principles and Practices. 8th Edition, Prentice-Hall, New Jersey, 915.

He, M., Wang, X.H., Zhuang, Y.T., Jin, X. (2020). The complete chloroplast genome of Bougainvillea glabra. *Mitochondrial DNA B Resources*. **5**: 889–890.

Heti, H., Siwi, H.E.K. (2020). The influence of stem cutting and IBA concentration on vegetative growth of bougainvillea. *Journal Technology*, **2**(1): 2461-1484.

Hussain, I., Khattak, A. M., Amin, N. U., Aman, F., & Sajid, M. (2012). Response of different pomegranate cuttings types to different environmental conditions. *Sarhad journal of Agriculture*, **28**(1): 15-18.

Hussain, I., Nabi, G., Rehman, H., Shah, K., & Ali, S. (2016). Effect of different environmental condition on different types of Sweet lime cuttings. *Pure & Applied Biology*. **5**(2): 298-302

Kesari V., Krishnamachari A., Rangan L. (2009). Effect of auxins on adventitious rooting from stem cuttings of candidate plus tree *Pongamia pinnata* (L.), a potential biodiesel plant. Trees—*Structure and Function*. **23**(3):597–604

Kobayashi, K. D., Mcconnell, J., & Griffis, J. (2007). Bougainvillea. Honolulu (HI): University of Hawaii. 12 *(Ornamentals and Flowers*; OF-38).

Kochhar, S., Singh, S.P., Kochhar, V.K. (2008). Effect of auxins and associated biochemical changes duringclonal propagation of the biofuel plant—*Jatropha curcas*. Biomass and Bioenergy, 1-8.

Kumar, A., & Prasad, M. N. V. (2010). Propagation of Talinum cuneifolium L. (Portulacaceae), an ornamental plant and leafy vegetable, by stem cuttings. *Floriculture and Ornamental Biotechnology*, **4**(1): 68-71.

Li, X., Chen, W., & Li, Y. (2012). Study on photosynthetic characteristics of blueberry in greenhouse. *Acta Horticulture*, **926**: 315-320.

Lin, H., Xu, J., Wu, K., Gong, C., Jie, Y., Yang, B., & Chen, J. (2024). An Efficient Method for the Propagation of Bougainvillea glabra 'New River' (Nyctaginaceae) from In Vitro Stem Segments. *Forests*, 15(3): 519.

Mohammed, A., Fadwa, A., & Hamid, A., & Elbasheer, Y. (2014). Vegetative propagation of Peltophorium petrocarpum (DC) Backer ex k.Heyne: A multi-purpose tree. *Netherland journal of Agricultural science*, vol **2**(4): 113-116.

Memon, N. N., Noman A., Baloch, M. A. &, Q. D. Chachar**.** (2013). Influence of Naphthalene acetic acid (NAA) on sprouting and rooting potential of stem cuttings of Bougainvillea. *Science International Lahore*. **25**(2): 299-304.

Minj, S. K., Gupta, P. P., Kumar, R., Khilari, M., & Painkra, D. S. (2023). Root Parameter Investigation in Standardized Media for Bougainvillea (Bougainvillea comm. Ex Juss.) Propagation. *International Journal of Plant & Soil Science*, **35**(18): 1013-1017.

Rowezak, M. M. A. (2001). Response of some ornamental plants to temperature with growth substances. *M.Sc. Thesis, Faculty of Agriculture, Cairo University, Egypt*, **12**(6): 124-128.

Saleem, H., Usman, A., Mahomoodally, M.F., Ahemad, N. (2021). Bougainvillea glabra (choisy): A comprehensive review on botany, traditional uses, phytochemistry, pharmacology, and toxicity. *Journal of Ethnopharmacology*. **266**: 113-356.

Singh, B., Sindhu, S. S., Yadav, H., & Saxena, N. K. (2017). Influence of Growth Hormones on Hardwood Cutting of Bougainvillea Cv. Dr Hb Singh. *Chemical Science Review and Letters*, **6**(23): 1903–1907.

Singh, K. K. (2018). A review: Multiplication of Bougainvillea species through cutting. *International Journal of Chemical Studies*, **6**(2): 1961-1965.

Singh, K.K., Singh, S.P., Bairwa, B., Chauhan, J.S. (2020). Production technology of Bougainvillea spp. *Biotica Research Today*, **2**(6): 472-474.

Shrestha, J., Bhandari, N., Baral, S., Marahatta, S. P., & Pun, U. (2023). Effect of rooting hormones and media on vegetative propagation of Bougainvillea. *Ornamental Horticulture*, **29**: 397-406.

Statistix. (2006). Statistix 8 users guide version 1.0. Analytical software, PO box 12185, Tallahassee FI 32317 USA.

Okunlola, A. I., & Akinpetide, E. O. (2016). Propagation of Ficus benjamina and Bougainvillea spectabilis using different media. *Advances in Agriculture and Agricultural Sciences*, **2**(2): 21-27.

Pipattanawong, N., Tiwong, S., Thongyean, B., Darak, R., Thamin, P., & Techa, W. (2008). Improvement of propagation by hardwood cuttings with and without using plastic pavilions in fig (Ficus carica L.). *Agriculture and Natural Resources*, **42**(2): 207-214.

Pirdastan, M., Aboutalebi Jahromi, A., & Hassanzadeh Khankahdani, H. (2020). Effect of hydrogen peroxide, ascorbic acid and indolic-3-butyric acid on root induction and development in cuttings of Bougainvillea spectabilis. *Journal of Ornamental Plants*, **10**(3): 145-154.

Zhang, H., Huang, T., Zhou, Q., Sheng, Q., & Zhu, Z. (2023). Complete Chloroplast Genomes and Phylogenetic Relationships of Bougainvillea spectabilis and Bougainvillea glabra (Nyctaginaceae). *International Journal of Molecular Sciences*, **24**(17): 13044.