The Role of Arbuscular Mycorrhizal Fungi and their Interaction with Tuber and Storage Root Crops (Such as Potato, Yam, Sweet Potato, Cassava, Carrot, Radish, Beetroot, Turnip, etc.) in Enhancing Yield

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Abstract: ***Arbuscular Mycorrhizal Fungi (AMF) play a vital role in improving the growth and productivity of tuber and root crops, such as sweet potatoes, cassava, carrots, and radishes. Through symbiotic relationships with plant roots, AMF enhances nutrient and water uptake, offering significant benefits, particularly in nutrient - poor soils. This review explores the interactions between AMF and various tuber crops, focusing on their impact on root structure, physiological processes, and molecular mechanisms that contribute to improved yields. AMF promotes root colonization, enhances nutrient uptake efficiency, and supports the development of a more robust root system. The review highlights how AMF assists in nutrient absorption under both optimal and challenging conditions, such as drought, by improving plants' ability to tolerate environmental stress. Furthermore, the interaction of AMF with plant hormones like auxins and strigolactones is crucial for regulating root and shoot growth, ultimately influencing crop productivity. These findings suggest that AMF can significantly enhance plant growth and yield by improving root architecture and nutrient acquisition. A deeper understanding of these interactions can guide sustainable agricultural practices and demonstrate the potential of AMF inoculation to increase the productivity of tuber and storage root crops. Future research should focus on refining AMF inoculation techniques and exploring the genetic and environmental factors that influence AMF - plant symbiosis to maximize crop yields and resilience in diverse farming environments.***

Keywords: Arbuscular Mycorrhizal Fungi (AMF), Tuber and Root crop, Auxin, Citin Oligomers, Strigolactons.

1. Introduction

Sweet potato (*Ipomoea batatas),* a member of the *Convolvulaceae* family, is widely cultivated in tropical and subtropical regions due to its nutritional and economic value (Minemba et al., 2019). The crop's root system is vital for water and nutrient absorption, as well as for storing sugars produced during photosynthesis. However, low nutrient uptake and limited root differentiation are key factors hindering its production. Tuber crops, including sweet potato, cassava, and potato, exhibit diverse physiological and morphological traits and are primarily propagated vegetatively via stem cuttings, vine cuttings, or tuber sprouts. These crops are essential staples in tropical and temperate regions, providing carbohydrates, vitamins, and antioxidants crucial for human nutrition (Kondhare et al., 2021). Additionally, storage tubers and roots like yam, sugar beet, carrot, and radish play a significant role in food security and health due to their therapeutic potential, such as antimicrobial and antioxidative properties. Optimizing sweet potato production requires a focus on root morphology, which influences nutrient uptake efficiency. Studies have shown that soil quality, microbial activity, and fertilization practices significantly impact root development and yield (Wang et al., 2017). Recent advancements in in - vitro propagation techniques allow for the rapid production of disease - free plants, though further improvements are needed for effective bio - hardening and field performance (Banerjee, 2006). Microbial inoculants, such as arbuscular mycorrhizal fungi (AMF), have demonstrated potential in enhancing root structure, nutrient availability, and water absorption (Maiti et al., 2016; Nanjundappa et al., 2019). This study aims to evaluate the performance of tissue - cultured sweet potato plants through bio - hardening techniques to improve their adaptability and productivity in field conditions.

Fresh sweet potato was cultivated in a field and treated with AMF (Arbuscular Mycorrhizal Fungi) (Figure.1). AMF was initially prepared by mixing it with cow dung, vermicompost, and soil in a 1: 1: 1 ratio. AMF powder was added to the soil at a concentration of 5g/L (N. V. Singh et al., 2016), and water was added as required. This mixture was stirred daily, covered with a polythene bag, and kept in a shaded area for 7 days. After 7 days, the mixture was integrated into the soil, and sweet potato plants were cultivated. Root samples were taken after 8 - 10 days for colonization studies, revealing the presence of AMF in small amounts in the roots (Figure.1) (Ildikó Hernádi et al., 2012). AMF structures, which began penetrating the roots within 3 - 4 days, were visible as circular formations surrounded by hyphae.

Figure 1: Growth of trifoliate sweet potato (*Convolvulaceae*) influenced by Arbuscular Mycorrhizal Fungi (AMF) inoculation. The image shows the overall plant development: (A) with mycorrhizal treatment and (B) without mycorrhizal treatment (Chen et al., 2017).

AMF colonization rates vary across crop species due to differences in root structures. For instance, crops with denser root networks, like mung bean or soybean, show higher AMF penetration compared to tuber crops, where shorter roots and tuber formation may reduce AMF colonization (Lone et al., 2016). Despite these challenges, AMF enhances water and nutrient uptake, promoting plant growth and tuber development (Ashok Aggarwal et al., 2011).

Physiological Interactions Between AMF and Storage Root Crops

Nutrient uptake is essential for plant growth and development. Plants absorb water and nutrients through their roots, influenced by environmental factors like soil conditions and water availability (H. Wang et al., 2006). AMF significantly aids in nutrient and water absorption, especially under drought conditions, by improving root water retention and nutrient uptake efficiency (Naheeda Bagum et al., 2019). This is achieved through the expansion of hyphal networks that connect root systems across the field, enhancing access to phosphorus, water, and other minerals while increasing resilience to abiotic stresses such as drought, salt, and metal toxicity (A. B. Haseena et al., 2022).

Table 1: Shows how AMF helps tuber and storage root crops grow better. It improves nutrient absorption and increases yield, and drought tolerance in crops like sweet potato, cassava, and yam.

Table 1: Interaction between Arbuscular Mycorrhizal Fungi (AMF) and Tuber/Storage Root Crops for Yield Improvement

S. No	Crop	AMF Species	Effects on Yield	Additional Benefits	Application	References
1.	Potato	*Rhizophagus irregularis*	Increased total yield and tuber size by 25%, supplied up to 90% plant phosphorus, and contributed significantly to nitrogen uptake.	Enhanced phosphorus uptake, improved nutrient absorption, boosted root health, increased disease resistance, and overall plant health improvement.	Applied AMF inoculants during planting, supported growth with reduced tillage and organic amendments, reducing chemical inputs, and improving crop resilience.	Yao et al. (2003), Al - Ani et al. (2013), Deja - Sikora et al. (2020), Lone et al. (2019), Saxena et al. (2020), Wu et al. (2022), and Croll et al. (2021).
2.	Yam	*Glomus spp.*, *Acaulospora spp.*	Increased tuber weight by 20% to 56% with *Glomus* etunicatum and *Gigaspora spp.* through improved nutrient uptake.	Increased secondary metabolite content (polyphenols, flavonoids, anthocyanins by 106%), improved root development, and disease resistance.	Enhanced root colonization and seasonal benefits, supported AMF with reduced tillage, and optimized nutrient uptake.	Chen et al. (2017), Lu et al. (2015), Don - Rodrigue et al. (2013), Tchabi et al. (2010), and Oyetunji (2007).
3.	Sweet Potato	*Glomus mosseae*	Improved tuber yield, biomass, growth, resulting in higher marketable yield.	Enhanced nutrient absorption, improved drought resistance, root morphology, disease resistance, and synergy with potassium fertilization.	Promoted root colonization with AMF inoculants, enhanced AMF effectiveness with reduced tillage, and optimized nutrient uptake.	Liu et al. (2014), Seemakram et al. (2023), Alhadidi et al. (2021), Tong et al. (2013), Yuan et al. (2023), Karthikeyan et al. (2021).
4.	Cassava	• *Glomus spp.* • *Acaulospora colombiana*	Root biomass and yield increased by 16.6% to 19.4% compared to controls, with dual inoculation and AMF - vermicompost combination improving biomass and reducing nematode growth.	Nutrient availability improved in poor soils, increasing (86%) phosphorus uptake, stress tolerance, nematode resistance, and plant growth.	Maximized cassava yield with AMF inoculants, organic amendments, and sustainable pest control.	Al - Hmoud & Al - Momany (2017), Silva et al. (2021), Pena V et al. (2021), Cavallari et al. (2021), Howeler et al. (2021).
5.	Carrot	*Acaulosporaceae*	Enhanced root biomass by 30%, combining AMF with vermicompost to reduce *Meloidogyne incognita* effects.	Improved soil structure, moisture retention, and pest resistance through AMF stimulation.	Utilized AMF inoculants to promote root colonization, enhanced AMF with organic amendments, and controlled pests to boost performance.	Prasad et al. (2017), Hussain et al. (2023), Chandrasekaran et al. (2021), Regvar et al. (2021).

6.	Radish	*Glomus spp*	Increased tuber fresh weight and root biomass by 20% to 30%, with improved radish yield compared to controls.	Enhanced nutrient uptake (phosphorus, potassium), alleviated allelopathic effects, improved stress tolerance, and maintained osmotic balance with AMF.	Enhanced root colonization with AMF inoculants, supported AMF with organic amendments, and combined sustainable pest control methods.	Mitra et al. (2019), Ma et al. (2022), Hussain et al. (2023), Regvar et al. (2021).
7.	Turnip	*Gigaspora spp.*	Higher yield and improved root quality, with AMF boosting biomass, increasing yield by 23%.	Enhanced soil nutrient dynamics, improved nutrient uptake, increased stress tolerance, better root development, and higher photosynthesis.	Maximized benefits using AMF inoculants, improving effectiveness with organic amendments and combining AMF with pest control.	Angelard et al. (2022), Hussain et al. (2022), Zhang et al. (2021), Alguacil et al. (2021), Ma et al. (2021), Rezaie et al. (2021).
8.	Beet root	*Rhizophagus irregularis*	Improved root development and approximately 23% increase in yield.	Increased phosphorus biomass by up to 43% and enhanced antioxidant levels in roots.	Used AMF inoculants during planting for root colonization, enhanced with organic amendments and reduced tillage.	Hussain et al. (2022), Saboor et al. (2021), Zhao et al. (2022), Liu et al. (2022).

Molecular Interactions Between AMF and Storage Root Crops

Symbiotic associations between AMF and plant roots play a crucial role in promoting root and plant growth (Khosro Mohammadi et al., 2011). AMF improves soil nutrient uptake, including phosphorus, nitrogen, and potassium, by enlarging roots and increasing water efficiency (S. M. Yahaya et al., 2023). This symbiosis also stimulates aquaporin expression, facilitating bidirectional water flow and nutrient transport within the plant (M. Bitterlich et al., 2018; Carbajal and Balesta, 2014).

Phytohormones, such as auxin, cytokinin, gibberellins, and abscisic acid, also regulate plant growth and development (Agboola et al., 2014). AMF enhances hormonal balance, improving root health and overall plant productivity (Marleen Vanstraelen and Eva Benková, 2012). Specific signaling molecules like strigolactones in the rhizosphere further promote root growth and interaction with beneficial microbes (R. T. Kapoor et al., 2024).

Gene Expression and AMF Colonization

Genes like D27, CCD7, CCD8, and MAX1 regulate strigolactone biosynthesis and play an essential role in AMF symbiosis (Yanyan Yu et al., 2022). Additionally, microRNAs (miRNAs) regulate plant - AMF interactions by controlling gene expression at the post - transcriptional level. These miRNAs influence root structure, growth, and fungal colonization, particularly in sweet potato (Xu Ma et al., 2022). Reduced auxin receptor expression can limit arbuscular growth, underscoring the importance of these molecular interactions in plant development. Thus, AMF symbiosis significantly improves the physiological, molecular, and hormonal processes in storage root crops, enhancing water and nutrient uptake, root health, and overall plant growth.

Application of AMF for Yield Improvement

Root Staining:

Random root samples were carefully selected, washed thoroughly with water, and cut into 1 cm segments. These root segments were treated with KOH or sodium hypochlorite to enhance transparency and then placed in a water bath at 80°C for 20 minutes. The roots were subsequently stained with cotton blue dye and observed under a microscope and confocal microscopy to examine fungal growth within the root tissues (Zicheng Peng et al., 2024). The attachment of fungi to roots varies depending on the crop type and root morphology (Figure 2). As different plants have unique root characteristics, AMF inoculation protocols are often optimized to enhance fungal spore implementation and colonization.

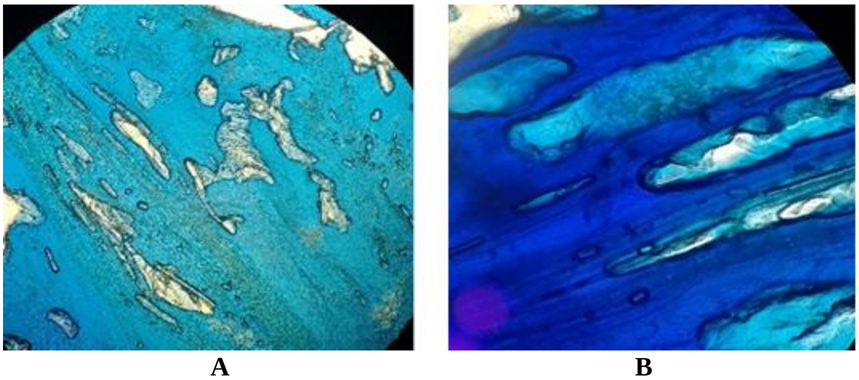

Figure 2: Sweet potato roots treated with AMF: A) Control roots, B) Roots treated with AMF, showing black spots, indicating the presence of AMF in the roots of sweet potato (Havrilla et al.2020).

2. Conclusion

A pot culture experiment was conducted to study root colonization in in - vitro - raised sweet potato plants and to evaluate the effect of Arbuscular Mycorrhizal Fungi (AMF). Observations were made on root colonization, fungal population dynamics, microbial activity in the soil, and the physiological, biochemical, and growth parameters of plants over 25 days.

Results showed that AMF colonization occurred in minor amounts in the roots of in - vitro - raised plants 25 days post - inoculation with a mixture of soil and cow dung. The treatment group achieved a 70% AMF colonization rate, while the control group (without AMF treatment) showed no such colonization.

Key physiological differences between treated and control plants were observed:

- **Greenness Index:** The treated plants showed an increase in the greenness index (scale 5), compared to the control group (scale 3).
- **Plant Length:** The treated plants exhibited an average increase in height of 10 cm compared to the controls.
- **Root Growth:** The roots of treated plants displayed an increase in growth by approximately 10 cm.

AMF inoculation significantly enhanced the physiological and growth parameters of the plants, helping maintain a balance in their physiological behavior and improving overall yield potential.

Abbreviation
AMF: Arbuscular Mycorrhizal Fungi
CCD7: Carotenoid Cleavage Dioxygenase 7
CD8: Carotenoid Cleavage Dioxygenase 8
D27: DWARF27
KOH: Potassium Hydroxide
MAX1: More Axillary Growth 1

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Conflict Of Interest
The authors report no financial or any other conflicts of interest in this work

Consent For Publication
All authors agreed and gave their consent for publication.

Author's Contributions
All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published, and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Journal of Science and Research (IJSR) requirements/guidelines.

Ethical Approvals
This study does not involve experiments on animals or human subjects.

Data Availability
Not Applicable.

References

[1] Alhadidi, N., Pap, Z., Ladányi, M., Szentpéteri, V., and Kappel, N. (2021). Mycorrhizal inoculation effect on sweet potato (Ipomoea batatas (L.) Lam) seedlings. Agronomy 11: 2019. doi: 10.3390/agronomy11102019

[2] Aggarwal, A., Kadian, N., Tanwar, A., Yadav, A. and Gupta, K. K., 2011. Role of arbuscular mycorrhizal fungi (AMF) in global sustainable development. *Journal of Applied and Natural Science*, *3* (2), pp.340 - 351.

[3] Agboola, D. A., Ogunyale, O. G., Fawibe, O. O. and Ajiboye, A. A., 2014. A review of plant growth substances: Their forms, structures, synthesis and functions. *Journal of Advanced Laboratory Research in Biology*, *5* (4), pp.152 - 168.

[4] Acharya, B., Ingram, T. W., Oh, Y., Adhikari, T. B., Dean, R. A. and Louws, F. J., 2020. Opportunities and challenges in studies of host - pathogen interactions and management of Verticillium dahliae in tomatoes. *Plants*, *9* (11), p.1622.

[5] Ahamad, L., Bhat, A. H., Kumar, H., Rana, A., Hasan, M. N., Ahmed, I., Ahmed, S., Machado, R. A. and Ameen, F., 2023. From soil to plant: strengthening carrot defenses against Meloidogyne incognita with vermicompost and arbuscular mycorrhizal fungi biofertilizers. *Frontiers in Microbiology*, *14*, p.1206217.

[6] Banerjee, A. K., Prat, S. and Hannapel, D. J., 2006. Efficient production of transgenic potato (S. tuberosum L. ssp. andigena) plants via Agrobacterium tumefaciens - mediated transformation. *Plant Science*, *170* (4), pp.732 - 738.

[7] Begum, N., Qin, C., Ahanger, M. A., Raza, S., Khan, M. I., Ashraf, M., Ahmed, N. and Zhang, L., 2019. Role of arbuscular mycorrhizal fungi in plant growth regulation: implications in abiotic stress tolerance. *Frontiers in plant science*, *10*, p.1068.

[8] Bitterlich, M., Rouphael, Y., Graefe, J. and Franken, P., 2018. Arbuscular mycorrhizas: a promising component of plant production systems provided favorable conditions for their growth. *Frontiers in plant science*, *9*, p.366362.

[9] Baum, C., El - Tohamy, W. and Gruda, N., 2015. Increasing the productivity and product quality of vegetable crops using arbuscular mycorrhizal fungi: a review. *Scientia horticulturae*, *187*, pp.131 - 141.

[10] Begum, N., Qin, C., Ahanger, M. A., Raza, SBeveridge, C. A., Ross, J. J. and Murfet, I. C., 1996. Branching in pea (action of genes Rms3 and Rms4). *Plant Physiology*, *110* (3), pp.859 - 865.

[11] Begum, N., Qin, C., Ahanger, M. A., Raza, S., Khan, M. I., Ashraf, M., Ahmed, N. and Zhang, L., 2019. Role of arbuscular mycorrhizal fungi in plant growth regulation: implications in abiotic stress tolerance. *Frontiers in plant science*, *10*, p.1068.

[12] Begum, N., Qin, C., Ahanger, M. A., Raza, S., Khan, M. I., Ashraf, M., Ahmed, N. and Zhang, L., 2019. Role of arbuscular mycorrhizal fungi in plant growth regulation: implications in abiotic stress tolerance. *Frontiers in plant science*, *10*, p.1068

[13] Begum, N., Qin, C., Ahanger, M. A., Raza, S., Khan, M. I., Ashraf, M., Ahmed, N. and Zhang, L., 2019. Role of arbuscular mycorrhizal fungi in plant growth regulation: implications in abiotic stress tolerance. *Frontiers in plant science*, *10*, p.1068

[14] Beveridge, C. A., Ross, J. J. and Murfet, I. C., 1996. Branching in pea (action of genes Rms3 and Rms4). *Plant Physiology*, *110* (3), pp.859 - 865.

[15] Bhatla, S. C., A. Lal, M., A. Lal, M., Kathpalia, R., Sisodia, R. and Shakya, R., 2018. Biotic stress. *Plant Physiology, Development and Metabolism*, pp.1029 - 1095.

[16] Cavallari, L. G., Fernandes, A. M., Mota, L. H. D. S. D. O., Leite, H. M. F. and Piroli, V. L. B., 2021. Growth and phosphorus uptake by cassava in P - deficient soil in response to mycorrhizal inoculation. *Revista Brasileira de Ciência do Solo*, *45*, p. e0210060.

[17] Chen, W., Li, J., Zhu, H., Xu, P., Chen, J. and Yao, Q., 2017. Arbuscular mycorrhizal fungus enhances lateral root formation in Poncirus trifoliata (L.) as revealed by RNA - Seq analysis. *Frontiers in Plant Science*, *8*, p.2039.

[18] del Carmen Martinez - Ballesta, M. and Carvajal, M., 2014. New challenges in plant aquaporin biotechnology. *Plant Science*, *217*, pp.71 - 77.

[19] Havrilla, C., Leslie, A. D., Di Biase, J. L. and Barger, N. N., 2020. Biocrusts are associated with increased plant biomass and nutrition at seedling stage independently of root - associated fungal colonization. *Plant and Soil*, *446*, pp.331 - 342.

[20] Hodge, A., Berta, G., Doussan, C., Merchan, F. and Crespi, M., 2009. Plant root growth, architecture and function.

[21] Hernádi, I., Sasvári, Z., Albrechtová, J., Vosátka, M. and Posta, K., 2012. Arbuscular mycorrhizal inoculant increases yield of spice pepper and affects the indigenous fungal community in the field. *HortScience*, *47* (5), pp.603 - 606.

[22] Hart, M. M. and Reader, R. J., 2002. Taxonomic basis for variation in the colonization strategy of arbuscular mycorrhizal fungi. *New Phytologist*, *153* (2), pp.335 - 344.

[23] Jacob Oyetunji, O. and Taiwo Afolayan, E., 2007. The relationships between relative water content, chlorophyll synthesis and yield performance of yam (Dioscorea rotundata) as affected by soil amendments and mycorrhizal inoculation. *Archives of Agronomy and Soil Science*, *53* (3), pp.335 - 344.

[24] Kapoor, R. T., Alam, P., Chen, Y. and Ahmad, P., 2024. Strigolactones in Plants: From Development to Abiotic Stress Management. *Journal of Plant Growth Regulation*, *43* (3), pp.903 - 919.

[25] Kaldenhoff, R., Kai, L. and Uehlein, N., 2014. Aquaporins and membrane diffusion of CO2 in living organisms. *Biochimica et Biophysica Acta (BBA) - General Subjects*, *1840* (5), pp.1592 - 1595.

[26] Kondhare, K. R., Patil, A. B. and Giri, A. P., 2021. Auxin: An emerging regulator of tuber and storage root development. *Plant Science*, *306*, p.110854.

[27] Lu FunChi, L. F., Lee ChenYu, L. C. and Wang ChunLi, W. C., 2015. The influence of arbuscular mycorrhizal fungi inoculation on yam (Dioscorea spp.) tuber weights and secondary metabolite content.

[28] Lee, E. H., Eo, J. K., Ka, K. H. and Eom, A. H., 2013. Diversity of arbuscular mycorrhizal fungi and their roles in ecosystems. *Mycobiology*, *41* (3), pp.121 - 125.

[29] Lone, R., Shuab, R., Malla, N. A., Gautam, A. K. and Koul, K. K., 2016. Beneficial effects of arbuscular mycorrhizal fungi on underground modified stem propagule plants. *J New Biol Rep*, *5* (1), pp.41 - 51.

[30] Leyser, O., 2009. The control of shoot branching: an example of plant information processing. *Plant, cell & environment*, *32* (6), pp.694 - 703.

[31] Liu, M., Zhang, A., Chen, X., Jin, R., Li, H., and Tang, Z. (2017). The effect of potassium deficiency on growth and physiology in sweetpotato [Ipomoea batatas (L.) Lam.] during early growth. HortScience 52, 1020–1028. doi: 10.21273/ hortsci12005 - 17

[32] Minemba, D., Gleeson, D. B., Veneklaas, E., and Ryan, M. H. (2019). Variation in morphological and physiological root traits and organic acid exudation of three sweet potato (Ipomoea batatas) cultivars under seven phosphorus levels. Sci. Hortic.256: 108572. doi: 10.1016/j. scienta.2019.108572

[33] Mohammadi, K., Khalesro, S., Sohrabi, Y. and Heidari, G., 2011. A review: beneficial effects of the mycorrhizal fungi for plant growth. *J. Appl. Environ. Biol. Sci*, *1* (9), pp.310 - 319.

[34] Ma, X., Zhao, F. and Zhou, B., 2022. The characters of non - coding RNAs and their biological roles in plant development and abiotic stress response. *International Journal of Molecular Sciences*, *23* (8), p.4124

[35] Maiti, R. K. and Singh, V. P., 2016. Mechanisms of resistance to drought, temperature and salinity in bean crops - A review. *Farming and Management*, *1* (2), pp.134 - 161.

[36] Nanjundappa, A., Bagyaraj, D. J., Saxena, A. K., Kumar, M. and Chakdar, H., 2019. Interaction between arbuscular mycorrhizal fungi and Bacillus spp. in soil enhancing growth of crop plants. *Fungal biology and biotechnology*, *6* (1), p.23.

[37] Pyrzanowska - Banasiak, A., Boyunegmez Tumer, T., Bukowska, B. and Krokosz, A., 2023. A multifaceted assessment of strigolactone GR24 and its derivatives: from anticancer and antidiabetic activities to antioxidant capacity and beyond. *Frontiers in Molecular Biosciences*, *10*, p.1242935.

[38] Peng, Z., Zulfiqar, T., Yang, H., Wang, M. and Zhang, F., 2024. Effect of Arbuscular Mycorrhizal Fungi (AMF) on photosynthetic characteristics of cotton seedlings under saline - alkali stress. *Scientific Reports*, *14* (1), p.8633.

[39] Rupnawar B S and Navale A M.2000. Effect of VA - mycorrhizal inoculation on growth of pomegranate layers. Journal of Maharashtra Agricultural University 25 (1): 44–6.

[40] Rupnawar, B. S. and Navale, A. M., 2000. Effect of VA - mycorrhizal inoculation on growth of pomegranate layers. *Journal of Maharashtra Agricultural Universities*, *25* (1), pp.44 - 46.

[41] Singh, N. V., Sharma, J. Y. O. T. S. A. N. A., Chandra, R., Babu, K. D., Shinde, Y. R., Mundewadikar, D. M. and Pal, R. K., 2016. Bio - hardening of in - vitro raised plants of Bhagwa pomegranate (Punica granatum). *Indian Journal of Agricultural Science*, *86*, pp.132 - 136.

[42] Schellenbaum, L., Berta, G., Ravolanirina, F., Tisserant, B., GIANINAZZI, S. and Fitter, A. H., 1991. Influence of endomycorrhizal infection on root morphology in a micropropagated woody plant species (Vitis vinifera L.). *Annals of Botany*, *68* (2), pp.135 - 141.

[43] Smith, S. E. and Read, D. J., 2010. *Mycorrhizal symbiosis*. Academic press.

[44] Séry, D. J. M., Kouadjo, Z. C., Voko, B. R. and Zeze, A., 2016. Selecting native arbuscular mycorrhizal fungi to promote cassava growth and increase yield under field conditions. *Frontiers in microbiology*, *7*, p.2063.

[45] Ullah, F., Ullah, H., Ishfaq, M., Khan, R., Gul, S. L., Gulfraz, A., Wang, C. and Zhifang, L., 2024. Genotypic variation of tomato to AMF inoculation in improving growth, nutrient uptake, yield, and photosynthetic activity. *Symbiosis*, *92* (1), pp.111 - 124.

[46] Vierheilig, H., Schweiger, P. and Brundrett, M., 2005. An overview of methods for the detection and observation of arbuscular mycorrhizal fungi in roots. *Physiologia Plantarum*, *125* (4), pp.393 - 404.

[47] Vanstraelen, M. and Benková, E., 2012. Hormonal interactions in the regulation of plant development. *Annual review of cell and developmental biology*, *28*, pp.463 - 487.

[48] Wang, H., Inukai, Y. and Yamauchi, A., 2006. Root development and nutrient uptake. *Critical reviews in plant sciences*, *25* (3), pp.279 - 301.

[49] Wang, Q., Yu, F. and Xie, Q., 2020. Balancing growth and adaptation to stress: Crosstalk between brassinosteroid and abscisic acid signaling. *Plant, Cell & Environment*, *43* (10), pp.2325 - 2335.

[50] Wu, H., Li, H., Chen, H., Qi, Q., Ding, Q., Xue, J., Ding, J., Jiang, X., Hou, X. and Li, Y., 2019. Identification and expression analysis of strigolactone biosynthetic and signaling genes reveal strigolactones are involved in fruit development of the woodland strawberry (Fragaria vesca). *BMC plant biology*, *19*, pp.1 - 19.

[51] Wang, K., Bi, Y., Zhang, J. and Ma, S., 2022. AMF Inoculum Enhances Crop Yields of Zea mays L. ‘Chenghai No.618’and Glycine max L. ‘Zhonghuang No.17’without Disturbing Native Fugal Communities in Coal Mine Dump. *International Journal of Environmental Research and Public Health*, *19* (24), p.17058.

[52] Wu, S., Shi, Z., Chen, X., Gao, J. and Wang, X., 2022. Arbuscular mycorrhizal fungi increase crop yields by improving biomass under rainfed condition: a meta - analysis. *PeerJ*, *10*, p. e12861.

[53] Yoo, C. Y., Pence, H. E., Hasegawa, P. M. and Mickelbart, M. V., 2009. Regulation of transpiration to improve crop water use. *Critical Reviews in Plant Science*, *28* (6), pp.410 - 431.

[54] Yuan, J., Shi, K., Zhou, X., Wang, L., Xu, C., Zhang, H., Zhu, G., Si, C., Wang, J. and Zhang, Y., 2023. Interactive impact of potassium and arbuscular mycorrhizal fungi on the root morphology and nutrient uptake of sweet potato (Ipomoea batatas L.). *Frontiers in microbiology*, *13*, p.1075957

[55] Zhu, B., Gao, T., Zhang, D., Ding, K., Li, C. and Ma, F., 2022. Functions of arbuscular mycorrhizal fungi in horticultural crops. *Scientia Horticulturae*, *303*, p.111219.