

Nano Bionic Effect of Multiwall Carbon Nanotubes (MWCNT) and Graphene Oxides (GO) for Climate Resilient Horticultural Plants: A Strategy for Ensuring Food Security

Jadala Shankaraswamy

Department of Fruit Science, College of Horticulture, Mojerla, Sri Konda Laxman Telangana Horticultural University, Wanaparthy-509382, Telangana, India

Received:- 01 October 2025/ Revised:- 06 October 2025/ Accepted:- 16 October 2025/ Published: 31-10-2025

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Abstract— Climate change presents some real hurdles for horticultural crops and its becoming clear that unseasonal temps, like warmer days in winter, water scarcity in summer, wild weather during cropping season especially flower bud differentiation and unseasonal rainfall creating huge crop loss. Now, there's evidence that Integrated Farming Management (IFM) techniques can actually help lessen the bad impacts and still align with current horticultural policies. IFM ensures horticultural practices are more resilient when faced with these climatic changes but in more environmental problems, using new materials like multiwall carbon nanotubes, graphene oxide, and hydrogen rich water (HRW) in horticultural could really help plants handle climate change better. Because the world's population is growing and the environment is getting worse, we need farming methods that don't harm the environment and can lessen the effects of pollution. These cool nanomaterials have impressive physical qualities, like being super strong and conducting electricity well, which can help plants grow better and withstand stress. Also, recent research in college of horticulture mojerla, Sri Konda Laxman Telangana Horticultural University on Ramanathapuram Gundu Malli (*Jasminum sambac* Ait.) shows that improved crop adaptability when it is introduced from Ramanathapuram, Tamil Nadu to Horticultural Instructional Farm, Madanapuram, Telangana and also shown extra abilities in increasing plant height, promotion of number of primary, secondary and tertiary branches, imparted good quality flower attributes and overall performance in changed climate.

Keywords— Multi-wall carbon nanotubes, hydrogen-rich water, graphene oxide, climate, resilience.

I. INTRODUCTION

Severe impacts of climate change on horticultural crops requires the implementation of effective resilience strategies to strengthen horticultural crops and their vegetative phenology. Developing climate -resilient crops through traditional crop breeding is slow and costly process and time consuming but implementing multiwall carbon nanotube and graphene oxides techniques as it entails high efficient, simple to use by farmers and target alteration to make resilient crops to changed climatic condition. Presently, the effect of crop root on crop root zone and thermal characteristics are poorly understood, and new fertilizers are rarely considered as remedy. College of Horticulture, Mojerla, Sri Konda Laxman Telangana Horticultural University explored the effect of applying multiwall carbon nano tube (MWCNT), Graphene oxide (GO), Hydrogen rich water hold significant potential for improving cultivar Ramanathapuram Gundu Malli (*Jasminum sambac* Ait.) and enhancing resilience to changed environment and abiotic stresses (Shankaraswamy et al., 2023). MWCNT surface charges may stimulate the production of water channel protein thus improving the plants water transport absorption. From the investigation two types nano inputs (MWCNT, GO) were directly uptake and translocated to roots, stems, and leaves at concentration of 10-50 mg/L that indicates that MWCNT, GO, enhance growth parameter and flower production under dwindling resources. Hydrogen rich water of 1000 ppb proved effective in freshness index of jasmine flowers while reducing the physiological loss of water. According to the several studies revealed that MWCNTs could be an alternative for control of pathogens due to activation of antioxidant defence system in plants by increasing the ascorbic acid, flavonoids content, and the glutathione peroxidase enzyme. Hence, application of MWCNT, GO, Hydrogen rich water (HRW) are promising strategy and found to be alternative to breeding approaches in plants to anticipate, prepare for, respond to, and recover from the impacts climate change, while

maintaining their essential functions and adapting to new conditions. Therefore, exogenous application of MWCNT, GO, HRW are holistic and multidimensional approach that combines efforts to adapt to unavoidable changes and mitigate future warming to ensure food security in a changing climate.

II. MULTIWALL CARBON NANOTUBE

2.1 Physical properties of MWCNTs:

Nanotechnology is quick progress has unlocked fresh possibilities for boosting horticulture's ability to bounce back from climate change. Of all the nanomaterials out there, multiwall carbon nanotubes, or MWCNTs, have really caught researchers' eyes. This is thanks to some awesome physical traits they have, like being super strong, conducting heat really well, and having great electrical properties. Because of these traits, MWCNTs are looking like a strong contender for use in growing plants that can handle climate change better. They can help plants get nutrients more effectively and also boost how well they deal with stress. We from college of horticulture, mojerla, Sri Konda Laxman Telangana Horticultural University are putting more and more weight on doing things sustainably these days, so we really need to use new materials that can soften the blow of environmental problems, especially when it comes to not having enough water and the soil getting worse. Our studies on effect of MWCNT on Ramanathapuram gundumalli (*Jasminum sambac* Ait) showing extra abilities in increased plant height, promotion of number of primary, secondary and tertiary branches, with more plant spread as well as superior flower growth attributes denoted that MWCNTs can work even better in in horticulture crops (Shankaraswamy et al., 2023). So, really getting to grips with what MWCNTs can do and how we can fit them into farming systems is super important if we want to encourage horticulture that can keep going strong even as the climate changes.

MWCNTs, or multiwall carbon nanotubes, possess physical traits that really make them promising for use in horticulture designed to hold up against climate change. Think about it: They're super strong, and conduct electricity and heat remarkably well, which means they could make agricultural materials more stable and effective. Plus, their large surface area lets them soak up a lot of stuff, which is great for cleaning up polluted water – a growing problem thanks to climate change (Reale et al., 2023) and get this: the way they're structured lets them mix easily with other materials. This leads to new composite materials that are stronger and handle heat better. This could be a big deal for making protective coatings or even improving soil, helping plants survive tough conditions and supporting sustainable farming. So, grasping these characteristics is key to using MWCNTs in forward-thinking horticulture farming approaches.

2.2 Mechanical and electrical properties that enhance plant growth and resilience:

Multiwall carbon nanotubes, or MWCNTs, have mechanical and electrical properties that can really help plants grow and handle climate change better. These nanotubes are known for being strong yet flexible, which means they can make plant tissues stronger too. This extra strength helps plants deal with tough conditions like not enough water or really hot weather. Plus, MWCNTs can conduct electricity, and this can help roots absorb nutrients and water more effectively, leading to healthier and more productive plants overall. It's especially useful when we create nanocomposite materials that go into the soil or coat the plants, making it easier for essential resources to get where they need to go. By using these properties, scientists can come up with new ways to farm sustainably and tackle the problems caused by our changing climate (Dincer et al., 2024).

2.3 Use of MWCNTs in soil enhancement and nutrient delivery systems for climate-resilient crops:

Climate change's persistent problems demand find new ways to do horticulture, especially when it comes to making soil healthier and getting nutrients to horticultural plants so crops can survive. Multiwall carbon nanotubes (MWCNTs) are proving to be a good answer, as they help improve soil and how well plants absorb nutrients. It's largely because of how MWCNTs are made that they can improve soil aeration, keep water in the soil, and hold onto nutrients-all really important for helping plants grow when the weather is not cooperating. Putting MWCNTs into soil improvement plans can also boost how easily plants can use the necessary nutrients, helping plants stay healthy and produce more. Studies lately have been pointing out how MWCNTs help turn on plant defences, which then makes them better at handling stress and still produce a good amount even when climate change is causing problems. This mix of nanotechnology and farming doesn't just back sustainable methods, but it fits right in with needing environmentally friendly new ideas in growing food, pushing us toward a more tough horticultural cropping system (Shankaraswamy and Thirupathi, 2022). By preliminary research with MWCNTs and Graphene oxides and Hydrogen rich water revealed strength of these nano-material to accelerate physiological and molecular level adaptation under shifting atmospheric conditions.

2.4 Significance in Horticultural Crops:

Multiwall carbon nanotubes, or MWCNTs, have become quite important in nanotechnology, drawing attention for how they might be used in today's farming practices. What makes them special is their design, which features several layers of graphene sheets rolled into cylinders; because of this structure, MWCNTs have impressive mechanical, electrical, and thermal characteristics that can help plants withstand climate change. These nanotubes can assist plants to grow better even when the environment is tough by making it easier for nutrients and water to reach them. This addresses important problems related to having enough food and maintaining farming for the long term. It seems that these nanotubes might also be good at soaking up contaminants from water used in agriculture, which is getting more and more important because of environmental damage and a lack of resources. Furthermore, there's evidence that MWCNTs might make soil better and help plants stay healthy, opening up a wide array of possibilities that could drastically change how farming is done to cope with climate change.

III. GRAPHENE OXIDE (GO)

The integration of graphene oxide into horticultural practices offers a potentially significant step forward in bolstering plant production against climate change effects. With global climate shifts creating substantial obstacles for conventional horticulture, the need for creative solutions to maintain food availability and long-term viability is clear. Graphene oxide, with its notable physical attributes, such as considerable mechanical robustness, thermal resilience, and impressive electrical conductivity, appears well-suited for enhancing both plant health and development. It can improve absorption of nutrients and also act as a shield against environmental pressures to plants. Additionally, the well-considered use of organic fertilizers has been shown to help revitalize soil and lessen climate change's adverse effects on how much crops produce (Kakura I et al.). This intersection of materials science with horticultural practices might just transform how we approach farming that can withstand climate-related challenges. In the same line experiment was conducted in order to see the Effectiveness of GO on Jasmine phenology and climatic adoptability when introduced from Ramanathapuram to Horticulture Instructional farm, Madanapuram, college of horticulture, Mojerla, Sri Konda Laxman Telangana Horticultural University. From results it was evident that graphene oxide had a positive impact on shelf life of flower. It could be as result of reestablishment of redox homeostasis in flower (Thirupathi et al., 2022).

3.1 Overview of Graphene Oxide and its significance in modern science:

Graphene oxide, or GO, has really grabbed the interest of scientists lately because it's so useful and has some pretty amazing properties. It's basically a single layer of carbon atoms arranged in a honeycomb pattern. Because of this structure, GO is super strong, conducts electricity well, and has a large surface area. This makes it an exciting material for lots of different uses. What's neat is that we can change its properties to fit specific needs, particularly when it comes to helping plants withstand climate change. GO can help soil hold onto water and deliver nutrients more effectively, potentially making crops more resilient to environmental challenges, which is important given our changing climate. Plus, GO's ability to have a significant impact in several fields, from health to sustainability, shows just how vital it is to pushing science forward (Engineering C et al.). Support for research, like funding from Shell Global Solutions UK, shows how important it is to invest in GO research for future innovations (Ajovalasit et al.).

3.2 Physical Properties of Graphene Oxide:

Graphene oxide's characteristics really matter when we think about how it can be used, especially for helping plants handle climate change. Its surface is really big, about 2630 m²/g, which helps it connect with living things easily, so plants can grab nutrients better. Plus, the oxygen stuff in it helps it dissolve in water, making it simple to use on farms. Because it's both strong and light, it makes things like plant containers last longer. Also, it might help soil and plants conduct electricity better, which can help plants grow and stay strong when things get tough. Because of this, it's super important to study how GO can store energy, which ties into making farming more sustainable.

3.3 Unique structural characteristics and their implications for material performance:

Graphene oxide (GO) has some pretty neat features, like a large surface area, chemistry that can be tweaked, and impressive mechanical strength. Because of these qualities, GO is uniquely suited to tackle some of today's farming problems related to our changing climate. Its properties don't just make GO perform well in different uses; they also lead to fresh ideas in climate-smart agriculture. For instance, it can make nutrient delivery systems that work well and protect crops, boosting both crop resilience and how much we can grow, as noted in (Giannini et al.). In addition to that, GO affects soil and the tiny organisms that live there, greatly improving how sustainable our farming is. It helps soil hold onto nutrients, all while trying not to mess

with the environment too much. These developments show how important new materials, like graphene oxide, are in encouraging sustainable farming methods. These methods can fight the bad effects of climate change and, ultimately, help horticulture industry to make enough food to cater the needs of growing populations.

3.4 Applications of Graphene Oxide in Horticulture:

Graphene oxide (GO) shows considerable promise when integrated into horticulture. Consider its potential to improve climate resilience specifically in plant production. GO's physical properties—it has exceptional strength and a high surface area and allow it to effectively deliver nutrients. That delivery significantly increases how much of the essential elements plants can actually use. Climate change presents major obstacles to horticultural crops productivity, so the use of climate-smart horticultural strategies including innovative uses for graphene oxide is very important for reducing negative impacts on yield and soil health (Munaweera et al., 2023). Ultimately, graphene oxide's multifunctionality makes it an important part of the push for more sustainable horticultural technologies and practices.

3.5 Role of graphene oxide in enhancing plant growth and resilience to climate stressors:

Generally speaking, incorporating graphene oxide (GO) into horticulture shows promise for improving plant growth and helping plants withstand climate-related stresses. GO has some interesting physical characteristics, like a large surface area and good conductivity, which can help plants take up nutrients and encourage root growth. This better nutrient absorption is really important for plants dealing with abiotic stressors such as drought and salinity, where it's often harder for them to get the nutrients they need. Research suggests that GO can boost plant metabolism, leading to increased photosynthetic efficiency and biomass production – both crucial for maintaining horticultural output in tough conditions. Plus, GO's ability to create a protective layer around plant roots can improve stress tolerance, lessening the harm from extreme environmental conditions. As climate change continues to threaten our food supply, using graphene oxide might be an innovative approach to strengthen plant resilience, potentially making it a key element in sustainable farming practices.

IV. HYDROGEN RICH WATER (HRW)

The horticultural sector's need for resilience, especially given climate change, has spurred interest in hydrogen-rich water (HRW). This particular water, containing extra hydrogen molecules, might help plants grow faster and handle drought conditions better. Cities are starting to use clean energy, as noted in initiatives like (Cleveland et al.), to combat climate and environmental issues. Therefore, it is crucial to look at sustainable methods in horticulture, too. We can see how HRW affects plant health in studies that show how it helps plants thrive in different environments, similar to how forests recover as described in (Abella et al., 2027). This all leads to a detailed look at what HRW is made of and how it could help horticultural crops to withstand climate change.

4.1 Overview of Hydrogen Rich Water (HRW) and its significance in Horticulture:

In the realm of horticulture, Hydrogen Rich Water (HRW) has become quite important because it may help plants better handle climate change. HRW, which has a lot of dissolved hydrogen in it, is thought to give plants protection from oxidative stress. Because of this, plants grow healthier and produce more, which is really important as the environment changes more and more. It seems that using HRW can make crops hold onto water better and take in nutrients more effectively, which are very important for farming practices that are good for the environment and follow the United Nations Sustainable Development Goals (SDGs). Also, because people are paying more attention to farming that doesn't harm the environment, HRW is being looked at as a good way to deal with the money and environmental problems that modern horticulture faces. So, it's really important to understand how HRW can help plants grow in a way that can withstand climate change.

4.2 Physical Properties of Hydrogen Rich Water:

Looking into what makes hydrogen-rich water (HRW) special shows us some interesting things about how it could help plants handle tough climate conditions. HRW seems to dissolve things better and has less surface tension than regular water. This might mean plants can soak up nutrients and water more easily. Because it's more permeable, plants could grow better and be tougher when things get stressful, like during a drought. On top of that, some studies hint that the antioxidants in HRW could fight off oxidative stress in plants, helping them grow in a healthier way. If we use these HRW qualities in farming, we might not only get more crops, but also manage our resources more sustainably. As cities try to grow food in a way that matches climate goals, really understanding how HRW and plants work together is key. This can help us find more sustainable ways to produce food, which fits in with plans like the ones talked about in (Cleveland et al., 2019).

4.3 Chemical composition and unique characteristics of HRW:

Hydrogen-rich water, or HRW, mainly features dissolved hydrogen (H₂) gas, and this is what gives it its potential to help plants grow and become more resilient. Because it has a high concentration of molecular hydrogen, it can act as a useful antioxidant, reducing oxidative stress in plants, which is quite important for horticulture that can withstand climate change. HRW also appears to help plants absorb nutrients better by improving how their roots work, helping them hold onto water in the soil, which then leads to higher crop yields. It's also worth noting that HRW can affect different physiological processes in plants, like photosynthesis and metabolism, so it plays a significant role in horticultural practices that are sustainable and given the growing need for new solutions to deal with climate change, it's increasingly important to grasp the chemical composition and properties of HRW for creating robust strategies that boost plant production.

4.4 Applications of HRW in Climate Resilient Plant Production:

The rising relevance of plant production that is climate-resilient has spurred the investigation of creative answers, one being Hydrogen Rich Water (HRW). It's worth mentioning that HRW displays physical characteristics unlike any other, properties that boost a plant's ability to deal with stress, as well as encourage growth, and improve overall crop quality when conditions are tough. It serves as a key tool in farming that is sustainable. Studies, for example, propose that when HRW is used, the germination rates of seeds can be increased significantly, and it can encourage root development, a factor that is critically important for plants dealing with drought and soils that don't have enough nutrients. This kind of resilience is especially pertinent, considering that horticultural practices have to adjust to climate change's looming impacts. Moreover, bringing HRW into crop management strategies can support broader environmental goals. This includes a decreased reliance on fertilizers that are chemical and improved water use efficiency, aligning it with circular resource management principles as mentioned in current literature on sustainable farming practices (Cleveland et al., 2019).

4.5 Impact of HRW on plant growth and stress resistance:

The use of Hydrogen Rich Water (HRW) in horticulture to boost plant growth and resistance to stress has been getting some notice lately. HRW might actually make things like photosynthesis and nutrient absorption work better, which could mean bigger harvests when things get tough. It seems to help them deal with drought and not having enough nutrients, which makes them stronger overall. It's also been noted from our research that HRW can protect against oxidative stress and decreased the post-harvest deterioration and senescence during storage by modulating the antioxidant defence system in Jasmine flowers (Shankaraswamy, 2023). HRW is becoming pretty important for building farming systems that can withstand climate change because it helps plants deal with tough environmental issues. By increasing intercellular H₂ Synthesis by lowering the incidence of rot, limiting the intensity of reproduction, lowering the amount of lipid peroxidation and enhancing superoxide dismutase activity (Shankaraswamy and Thirupathi, 2022).

V. CONCLUSION

Integrating multiwall carbon nanotubes, graphene oxide, and hydrogen-rich water shows a remarkable possibility for improving horticultural methods that withstand climate change. These high-tech materials not only boost the overall physical health of plants but also greatly strengthen their ability to resist climate-related stress. Putting MWCNTs and Graphene oxides and Hydrogen rich water to work in horticultural crops production can bounce back from climate change looks like a real step in horticulture. Combining insights from material science and horticulture might just lead to major advances in making crops more resilient in tough conditions. This kind of comprehensive research approach should be encouraged in production practices of horticultural system. Future studies should probably concentrate on refining how we make and use MWCNTs, graphene oxide, HRW to customize its characteristics for different horticultural crops situations.

ACKNOWLEDGMENT

I am extremely grateful to Dr. Girwani for providing moral support

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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