Drought management information packages for Macadamia orchards

Dr. Md Aminul Islam, Professor Dr. Geoff Slaughter

Introduction:

The macadamia industries in Australia have faced severe water shortages in recent years (Deo et al., 2017), and it is likely to be exacerbated by climate change which will trigger drought as a recurrent and inevitable problem in Australian agriculture (Jiang et al., 2020; Paudel et al., 2021). Drought is considered one of the major abiotic stresses that can limit macadamia productivity, particularly in areas with limited availability of fresh water for irrigation. In order to comprehend the drought resiliency in the macadamia industries it is therefore required that the growers consider potential risks associated with climate extremes related to water availability when planning to expand the macadamia industry. However, the current state of understanding of the water requirement for macadamia is very limited upon few studies have been conducted in Australia (Stephenson et al., 2003; Gush and Taylor, 2014) which demonstrated that water use dynamics of the macadamia trees at the orchard level are influenced by several management practices such as spacing, pruning, fertilizer application, and other soil properties. Thus, it is essential to understand the potential water requirement for different critical stages of macadamia trees which could encourage the growers to adopt innovative cultivation strategies for saving and judicious use of water (Toscano et al., 2022).

This facts sheet will provide hands-on information of the climatic requirements of growing macadamia particularly focusing on water/irrigation requirements in macadamia orchards and different management strategies to better prepare for upcoming drought conditions as well as on-farm management strategies to overcome the drought impacts.

Climatic conditions requirement:

Among the climatic variables, precipitation and temperature appeared to be the most important parameter affecting the growth and productivity of macadamia around the world. The optimum temperature for Macadamia ranges from 20–25 °C (Stephenson et al., 1986). High temperature (>30 ◦C) not only causes chlorosis of new leaves but also in coupled with less precipitation trigger drought condition in Macadamia orchards (Trochoulias and Lahav, 1983). The lowest mean annual precipitation for successful macadamia production was reported to be around 1000 mm while it can grow and produce good yield under well-distributed annual rainfall up to 2000 mm (Stephenson and Trochoulias, 1994).

Effects of water stress/drought on Macadamia trees:

Existing literature suggests that macadamias can adapt to a wide range of environments and tolerate extended periods of drought conditions (Stephenson et al., 2003; Carr, 2013; Stephenson and Searle, 2014). However, although macadamia is reported to have some degrees of tolerance to drought/water stress conditions, it can limit the growth of macadamia trees which ultimately affects yield-attributing parameters such as nut set and nut retention as well as the overall quality of nuts. The impacts of water stress under increased temperature and extended dry periods lead to an increased number of small nuts followed by premature shell hardening. Despite the tolerance of

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macadamia trees to extended drought/water stress conditions, irrigated orchards were reported to produce consistent crops as compared to traditional rain-fed crops. However, the judicial application of irrigation water is important for the sustainability of the macadamia industry under the threat of freshwater availability which can be achieved through applying water during critical growth periods and less or stopping water at others (Stephenson et al., 2014).

Thus, comprehending the drought-sensitive phenological stages would help growers to better manage this stress. For example, a significant amount of water could be conserved for critical growth periods by imposing water stress/reducing water application during non-critical stages of macadamia trees.

Sensitive growth stages of macadamia to drought/ water stress:

In the Australian context drought/water stress-sensitive phenological stages of macadamia are as follows:

Growth stages	**Months when critical growth stages are usually observed in Australia**
Floral initiation	April to May
Floral development	July to August
Nut formation and Premature nut drop	November to December
Nut maturation and oil accumulation	December to January

Source: Stephenson et al., 2003

Drought stress during flowering and nut maturation significantly reduces the yield of macadamia. Thus, supplementary irrigation during these stages while drought conditions persist was reported to have enhanced nut sets.

Supplementary Irrigation for macadamia orchards:

Macadamia is well grown in rainfall regions where a large amount of water requirement can be fulfilled from rainfall. However, supplementary irrigation is a mandatory requirement particularly during the flowering and nut maturation periods if there is not enough rain to meet the water requirement during this phenological growth period of macadamia.

A general guideline for supplementary irrigation is synthesized based on available literature which is as follows:

- During tree establishment apply 20 to 30 litres per tree for two times in a week for the first two months.
- After tree establishment apply irrigation once a week if there is no sufficient rainfall.
- During summer apply up to 130 to 150 litres per tree and 30 to 40 litre per tree during winter in each week.

- In the following years to year 10, the maximum weekly application rate would be 750 litre per tree at year 5 but it could be up to 1500 litres per tree during mid-summer when the orchard reaches to 10 year.

Some considerations for drought/irrigation management in macadamia orchards:

- Run-off must be controlled as this is an important component of water management in macadamia orchards.
- Irrigation is desirable during the first four years of tree crop establishment
- Irrigation in macadamia orchards is usually practiced or suggested where mean annual rainfall is less than 1300mm
- Micro sprinklers and drip irrigation methods were found most suitable for applying irrigation in macadamia orchards.

Other drought management strategies for macadamia orchards

1. Soil moisture conservation:

Several on-farm practices can be adopted in the macadamia orchards to conserve soil moisture.

1.1 Keeping/growing grass: Soil moisture can be conserved by keeping the grass for a long period (e.g. less mowing) in the orchard floor, particularly during the summer period. In addition, a tree-to-tree alternate row mowing of grasses could be adopted to conserve soil moisture in the macadamia orchards which could avoid drought/water stress during the summer period. In addition, planting cover crops in macadamia orchards has tremendous benefits such as conserving water, and improved soil health. Dry, exposed soils and a lack of biodiversity hinder optimal production, resulting in higher water and pesticide usage. Planting grasses and legumes between tree rows is a solution to these problems and comes with a host of other benefits.

Figure 1. Ideal orchard with grass/cover crops

Figure 2. Orchard without cover crop/grass not ideal

1.2 Using mulches: Applying mulches around the tree base is reported as one of the best methods to retain soil moisture. In addition, mulching also increases soil organic carbon which potentially enhances soil water-holding capacity and thus helps to build drought resilience of the orchards during the longer dry spells. Using 10 cm thick mulches gives the best results in soil moisture conservation and mulching should be regular routine practice in macadamia orchards. Fallen leaves, husk, grass clippings, composts, woodchips and other residues are the best options for mulching. However, compost mulching is reported to be the best option for macadamia orchards in moisture retention as well as to improve soil health.

Figure 3. Use of compost as mulching material in macadamia orchard

1.3 Building up organic matter in the inter-row: Organic matter helps to increase water holding capacity. Root system of the macadamia trees can be extended up to the inter-row in the orchards. Thus, it is important to keep this space (inter-row) with enough soil moisture and nutrient to feed the macadamia trees. Therefore, building organic matter in this area is essential and this can be done by leaving organic material (e.g. plant debris) while brooming and swiping the orchard floor. It can also help for the enhancement of the feeder root to grow well and increase nutrient uptake.

1.4 Ground cover: Using live species of legume plants as ground cover can be beneficial for macadamia orchards. This can prevent soil erosion. In addition, it can help in nutrient recycling as well as soil moisture prevention through the mulching effect. The best legume species for ground cover reported in the literature is *Dactyloctenium australe* which gives the best results under the shading of macadamia trees. Furthermore, ground cover (e.g. either living plants or mulching materials) can improve conditions to support feeder roots which play a significant role in nutrient and water uptake for macadamia plants.

Figure 4. Live legume plants used as cover crop

More information about the integrated orchard management of macadamia can be found at:

[Macadamia integrated orchard management (nsw.gov.au)]

[Lessons from the drought for macadamia growers (nsw.gov.au)]

In addition to the above-mentioned management strategies, other proven strategies for drought management in horticultural crops can be adopted in macadamia orchard management. The most important approaches reported in the existing literature are the selection of drought-tolerant planting materials and adopting water-saving approaches such as regulated deficit irrigation, rainwater harvesting, use of mulches, and irrigation during critical stages (Devin et al., 2023).

1. **Selection of cultivar and rootstock**

   The drought problem in macadamia can be minimized by selecting appropriate cultivars which are drought-tolerant. In addition, wild species of macadamia could be used as rootstock which can increase tolerance to drought conditions. Literature suggests that using wild species as rootstock is a straightforward process to increase drought tolerance in many horticultural/fruit tree crops (Martínez-G et al., 2020).

2. **Modified canopy architecture through pruning**

   Modifying the canopy architecture through proper pruning can play a vital role to adapt abiotic stress such as drought. It has been reported that compact canopy architecture fruit trees have a lower rate of transpiration which ultimately increase tolerance to drought condition. Microclimate can also be improved by protecting inner leaves from solar radiation by creating a high-density crown by pruning (Abobatta, 2021). Adopting an appropriate pruning method is reported as one of the best water-saving strategies, particularly during the drought season (Jackson et al., 2000). Principles of different pruning methods method for macadamia orchards can be found here.

3. **Application of mulching and net shading**

   Installing net shades over the canopy of horticultural/ fruit trees can decrease the total temperature affecting the water demands of the orchards. This technique has been reported to increase drought tolerance in fruit tree orchards. In addition, using appropriate mulching materials can help to retain soil moisture which ultimately improves drought tolerance of the macadamia orchards. Crop residues, grass, poultry, and livestock litter are widely used muscling materials in orchards.

4. Deficit Irrigation

Under the threats of global climate change and limited water resources availability water-saving/water-efficient irrigation strategies could be adopted in macadamia orchards. These strategies are particularly important in the arid and semi-arid regions which not only save irrigation water but also lead to reducing pesticides and fertilizer usage thus controlling groundwater contamination (Galindo et al., 2018; Faghih et al., 2021). Recent studies have also demonstrated that macadamia orchards require less water than the producers/farmers think. More about the stories can be found here. There are various types/methods of deficit irrigation strategies reported in the literature which are as follows:

4.1 **Sustained deficit irrigation:** This method of irrigation distributes the water deficit uniformly over the fruit season at any crop stage and is a practical strategy for preserving fruit quality under drought-stress conditions. In this method, the irrigation water used at any given time during the season is less than the evapotranspiration (ETc) demands. Applying less water than the evapotranspiration demands of the crop does not fill the roots and creates progressive stress in the plant during the season (Lipan et al., 2021).

4.2 **Regulated deficit irrigation:** Regulated deficit irrigation is a water-saving irrigation strategy in which water is applied in the orchards during the drought-sensitive phenological stages of the tree crops, and stop irrigating during the non-critical growth periods to drought stress (Geerts & Raes, 2009). In addition, water from precipitation during the non-critical stages can also be saved for future use. Thus, the negative impacts of water stress can be minimized by saving water from reduced water application in non-critical states (McCarthy et al., 2020, Lipan et al., 2019).

Partial root-zone drying: In this system of irrigation, water is applied in one part of the root-zone while the other part is kept dry. In this technique of irrigation, an alternate furrow system of irrigation is adopted in the orchard to allow rewatering of the dry section of the root zone first (Lipan et al., 2019). Read more about this irrigation system for horticultural crops here , and field crop here.

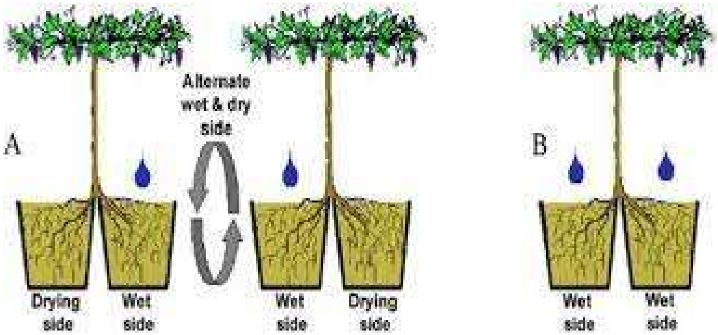

Figure 5 Partial root-zone drying (Alternate wetting and drying) irrigation in at orchards level.

4.3 Rain water harvesting technologies

Various methods of rainwater harvesting and saving water for horticultural crop cultivation, particularly in the arid and semi-arid areas of the world are reported in the existing literature. Rain water harvesting techniques not only conserve water for use during drought periods but also reduces the chances of soil erosion which are big considered as one of greatest challenges that macadamia industry particularly in Australia are facing. More about some technologies on ground can be found here. Read more about water harvesting here.

Figure 6. Use of concrete mats in macadamia orchards

Additionally, other widely used techniques of rainwater harvesting at the orchard level are i) Fanya juu terraces, ii) Negarims iii) Cocoon, which have the potentials to be replicated in other parts of the world having water scarcity in the dry land horticulture (Nyamekye et al., 2018).

Fanya juu is a rainwater harvesting technique in which terraces are built by digging and throwing soil upward along the contour. These terraces are most popular water harvesting technique used in the Sub-Saharan African countries and are suitable on slopes receiving an average annual precipitation of 500-1000 mm. This has a significant impact on decreasing slope length, thus enhancing water infiltration and decreasing the erosion of soil and runoff from sloping farmland (Mucheru-Muna et al., 2017). Read more about this technique here.

Figure 7. fanya juu terraces system of water harvesting technique.

Negarims is an indigenous rainwater harvesting technique used in semi-arid regions. In this method, small and diamond-shaped basins enclosed by embankments are created to establish fruit trees. In addition to rainwater harvesting this technique can also prevent land from soil erosion (Mucheru-Muna et al., 2017).

The Cocoon is a completely biodegradable water-efficient technology through which the around 90% survival rate of the seedling plantation can be increased. This can reduce evaporation and thus decrease irrigation water requirements. After installation, it can provide required water to the plant for up to six months (Petros et al., 2021). Read more about biodegradable cocoons here and here.

5. Plant Growth-Promoting organisms

In addition to agronomic practices (e.g. density planting, conservation tillage) application of growth-promoting bacteria, biofertilizer, and Mycorrhizae were found effective to withstand drought stress (Fathi and Zeidali 2021). It has been reported that different plant growth promoter potentially increases plant tolerance to water stress through different mechanisms thus improving drought resiliency in fruit tree orchards (Kour et al., 2022). Two significant types of plant growth-promoting microorganisms are reported in the literature as follows:

5.1 Plant growth-promoting rhizobacteria (PGPR) are a group of bacteria that enhance plant growth by colonizing with the root system of the plants and helping to survive the plants under water stress (Marulanda et al., 2009).

5.2 Arbuscular mycorrhizal fungi (AMF) are important species of fungi which create a symbiotic relationship with plant root system and helps plant to absorb water and nutrient from deeper soils. Literature indicated that proline synthesis can be regulated through application of the AMF which improves plant survival under drought stress (Chun et al., 2018).

6. Biochemical Treatments for Drought Tolerance

Various chemicals have been used to promote the internal mechanisms of plant which ultimately improve tolerance to drought conditions. Among the different chemicals, Silicon has been widely used in fruit tree cultivation. Literature indicated that Silicon enhances drought resistance in plants by improving plant water balance, and retaining photosynthetic activity, particularly under high transpiration (Tworkoski et al., 2011).

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