Int.J.Curr.Res.Aca.Rev.2023; 11(8): 20-24

EXCELLENT PUBLISHERS

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 11 Number 8 (August-2023)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2023.1108.003

Impact of Water Stress and Irrigation Scheduling on *Coffee arabica* at Jimma, South West Ethiopia: A Review

Addisu Asefa*

Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center P. Box 192, Jimma, Ethiopia

**Corresponding author*

Abstract

South-West Ethiopia is known for tropical humid and crop cultivation including coffee Arabica which is cash crops to Ethiopian as well as for the world. Coffee production in Ethiopia especially in jimma zone is dependent on rainfall. Different study has been conducted on coffee productivity and its quality improvement. In Ethiopia, there exists a wide genetic diversity among Arabica coffee cultivars for yield potential, quality and resistance to diseases. However, in spite of periodic and frequent occurrence of drought, little attention has been paid to study the response of coffee cultivars to moisture stress. Coffee cultivars are very sensitive to soil drying based on differences in mean stress score, percent plants wilting at noon and recovering during the night time, mean days to complete wilting, rate of leaf shed and rate of survival at seedling stage. On the other hand, soil moisture depletion level effect coffee growth, yield and water productivity. Proper irrigation scheduling, by which the precise timing and amount of irrigation determined has long been advocated as an improved water management technique. In this regard decreasing or increasing the amount of allowable soil moisture depletion level had significantly reduced the coffee yield, water productivity and plant height in areas like Jimma zone Gera woreda. Thus proper determination of coffee water requirement is essential, since CWR was lowest during the initial stage and highest during mid-season stage. Hence, the aim of this review was to provide information on sensitivity of coffee genotypes to moisture stress at seedling as well as reviewing the allowable soil moisture depletion level of coffee Arabica in case of Jimma area.

Article Info

Received: 10 June 2023
Accepted: 22 July 2023
Available Online: 20 August 2023

Keywords

Coffee, water stress, irrigation scheduling, drought, cultivation, cell turgor.

Introduction

Coffee has an essential source of income for the Ethiopian farmers as well as world market (Worku and Astatkie, 2010). The coffee market variability in the international trade has been affected by the low production of coffee and its quality (ITC, 2010). South-West Ethiopia is well known for tropical humid and lowland crop cultivation including coffee. The average annual precipitation of the area was 1500mm. However, the presence of Irregular pattern of rainfall has created moisture stress during the critical period of coffee cultivation and the yield has been extremely reduced.

Water stress influences crop growth and productivity in many ways; most of the responses have a negative effect on crop production. Decreasing of water level in crop minimizes cell turgor, which, in turn, reduces leaf expansion, induces stomata closure and reduces plant physiological processes, ultimately compromising grain

production rate (Santana *et al.,* 2019). Several crops and genotypes have developed different degrees of drought tolerance, drought resistance or compensatory growth to deal with periods of stress such as early maturing technique which is useful in adapting stresses, particularly midseason stress (Bidinger *et al.,* 1987).

Environmental conditions to which plants are exposed can impact metabolite synthesis through induction of physiological responses and adaptations related to biochemical changes observed in their metabolisms. The major environmental stress affecting coffee production in most producing countries is hydric stress. This stress is defined as any water content of a tissue/cell that is below the highest content displayed in its higher hydration state (Scheel *et al.,* 2016).

Water deficit has an immediate effect on plant growth, and metabolic processes ranging from photosynthesis to solute transport and accumulation are seriously affected by water stress (Hale and Orcutt, 1987). It decreases plant growth and productivity by reducing the rate of net photosynthesis (Boyer, 1976; Tesfaye *et al.,* 2013) and decreasing cell division and elongation (Pugnaire *et al.,* 1999). Under extreme conditions, permanent water deficit may develop and result in permanent wilting and death of plants by dehydration (Tesfaye, 2005; Tesfaye *et al.,* 2013).

Irrigation scheduling implies the application of suitable water to crops in right amount at the right time. Salient features of any improved method of irrigation is the controlled application of the required amount of water at desired time, which leads to minimization of range of variation of the moisture content in the root zone, thus reducing stress on the plants. Irrigation scheduling is a viable solution technique for systematically determining the time and quantity of irrigation in individual fields where there is water shortage. By scheduling irrigation, producers can maintain the soil moisture above permanent wilting point levels and conserve water by avoiding unnecessary irrigation events.

The dynamics of soil water depletion, changes in water demand from the atmosphere, as well as plant growth and phonological state in which water deficits develop, are sources of the wide variation in plant responses to drought (Medrano *et al.,* 1998).

Agricultural water management includes irrigation, and it is not simply about applying water; it includes soil, land, and ecosystem conservation practices, such as drainage and watershed management; fisheries management; and technologies for lifting, storing, and conveying water. One of the actual problems now a day is optimal management of water resources in agriculture, which mainly considers selection of optimal parameters of irrigation regime in order to get regular and sustainable yield (Irakli, 2016).

Arabica coffee accounts for more than 62% of the world coffee production (Dias *et al.,* 2007) and 90% of the world coffee market (Worku and Astatkie, 2010). However, its production system is traditional till now, where coffee productivity is severely affected by water shortage especially during critical stage of flowering and fruit set (Tadesse, 2019). Coffee irrigation is a promising technique to increase yield and expansion of coffee plantations in areas considered unsuitable due to the occurrence of water shortage (Silva *et al.,* 2008).

Generally, it's important to identify the best morphological and physiological characteristics of different coffee cultivars against soil moisture stress for selection of potential coffee genotypes for better coffee production. Moreover determination of optimal irrigation scheduling for coffee Arabica is important because it is a viable solution technique for systematically determining the time and quantity of irrigation in individual fields where there is water shortage. Too little water causes unnecessary water stress and can result in yield reductions. Too much water can cause water logging, leaching, and may also result in loss of yield. Hence, there is an urgent need to identify and adopt effective irrigation water management by determining Crop Water Requirement, and Irrigation water requirement of crops.

Impact of Soil Moisture stress on Coffee Accessions at Seedling stage

To cope with the drought, resistant/tolerant plants initiate defense strategies against water deficit, which are categorized as morphological and physiochemical/ biochemical mechanisms (Omprakash *et al.,* 2017). Different research on drought tolerance in coffee has been reported using pot-grown seedlings under greenhouse conditions. Coffee is a highly environmentally-dependent crop and an increase of a few degrees of average temperature and/or short periods of drought in coffee-growing regions can substantially decrease yields of quality coffees. From study conducted at Jimma agricultural research center, the authors described that, hararge coffee genotypes showed sensitivity to water stress imposed under rain shelter at

seedling on total dry matter yield, root to shoot ratio, relative leaf water content and leaf thickness. Accordingly Accession H-915/98 and H-929/98 exhibited significantly higher mean stress score value whereas, H-857/98 and H-981/98 showed lower value (Robel *et al.,* 2018). Drought resistant coffee genotypes tends to increase their root lengths to uptake deep soil moisture water through their deep root system and reduce their leaf area for improving plant water status (Tesfaye *et al.,* 2019). Much deeper root system of the tolerant genotypes enabled them to gain greater access to water towards the bottom of the pots and, therefore, to maintain a more favorable internal water status longer than in drought-sensitive clones (Cheserek and Gichimu, 2012) For cultivated plants, tolerance to drought is generally considered as the potential for a particular species or variety to yield more in comparison to others under limited soil water conditions (Pinheiro, 2004). Similar work was reported for Coffee genotype in which Seedling survival in drought prone environments may depend upon the species ability to compensate for the negative effect of low water potentials in the atmosphere by adjusting root and shoot morphological and physiological patterns (Tesfaye, 2005; Tesfaye, 2018). In Ethiopia coffee seedlings are normally raised in nurseries during the dry, hot period, and transplanted to the field at the beginning of the wet season. Therefore, the practice of deficit irrigation is effective water saving methods in different crops to mitigate drastic reductions in growth and yield of crops in areas of recurrent water scarcity as well as long drought periods.

Optimal irrigation scheduling for coffee

The knowledge of the onset and the evolution of water stress is essential in order to design an optimal irrigation scheduling oriented to maximize water use efficiency (Efthimios *et al.,* 2020). To achieve effective planning on irrigation water management, accurate information is needed for crop water requirement (Tadesse, 2019). In arid and semi-arid climates agricultural water scarcity is the most critical constraint for the development of agriculture.

Improvement of irrigation systems and the introduction of low cost water saving irrigation technologies important. Among those technologies, proper irrigation scheduling, by which the precise timing and amount of irrigation are determined, has long been advocated as an improved water management technique (Howell, 1996). Hence, effective use of available water with appropriate irrigation scheduling has a significant implication on irrigated agriculture. (García *et al.,* 2020) concluded that technical training and willingness to accept irrigation schedules is needed for stakeholder's. Hence, irrigation advisory services (public or private) can play a key role in this water management technology adaptation.

Optimization of soil moisture depletion level is a major limiting factor in coffee production systems. The scheduling of irrigation for coffee is based on FAO recommendation and requires adjustment to local condition. Hence, effective use of available water with appropriate irrigation scheduling has a significant implication on irrigated agriculture. FAO allowable soil moisture depletion factor should be validated to determining appropriate optimal soil moisture depletion level for coffee crop. From experiment conducted at Gera south west Ethiopia, the irrigation water was applied based on allowable soil moisture depletion for coffee which is 40%, accordingly, in Jimma zone Gera woreda, the maximum and minimum yield were obtained from the 120% and FAO recommended soil moisture depletion level, respectively. The sharp reduction of yield was observed at 60% ASMDL as compared to 120 % ASMDL treatment (Tilahun *et al.,* 2021). Robel *et al.,* (2019) reported that Over-irrigation decreased seed yield by 24.3% when irrigated at 60% soil moisture depletion. This may be due to frequent application of water that leaches out important plant nutrients from the roots. The reduction of coffee yield beyond 120% ASMDL treatment may be due induction of soil moisture stress and consequently leads to plants stressed. Different authors reported that reducing and increasing the amount water application interval significantly affected yield of different crops (Yaziz and Tefera; Muktar and Yigezu, 2016). Again, Robel *et al.,* (2019) on maize concluded that the higher or lower soil moisture depletion level can reduce crop yield.

The coffee ETc for Jimma zone is a good indicator and benefits to the coffee growers to help in planning the water resources of the area for best agricultural water management practices (Taddese, 2019). As coffee is a perennial crop, optimum Crop and Irrigation Water Requirement is important, because climate variability is among the major problems affecting the production and productivity of coffee Arabica (Etefa, 2019). Similar works was reported by (Farg *et al.,* 2012) which states that, Grain yield is affected by both the magnitude of water deficit and the stage of growth subjected to the deficit (Insufficient water supply) caused by prolonging irrigation intervals, and decreasing the available moisture in the soil clearly inhibits plant growth.

Recommendation

This review enabled better understanding of the different ways in which coffee adapts to drought. Water deficit, optimal soil moisture depletion level, water requirement and irrigation requirements, which will guide the ongoing and future trials direction.

In case of screening Hararge coffee genotype for drought tolerances, in addition to morphological and physiological parameters, the study should include leaf stomatal conductance during the study because drought avoidance consists of mechanisms that reduce water loss from plants, due to stomatal control of transpiration. In other way leaf NPK analysis should be done because those nutrients associated with increase in leaf area, carboxylases, increased root density, proliferation and chlorophyll content may affect different coffee genotypes differently. In determination of optimal irrigation scheduling for coffee further study should be conducted to identify appropriate soil moisture depletion levels at different location and soil type for verification of the effectiveness of the finding or allowable soil moisture depletion level, since it is one of the most important limiting factors for irrigation water managements.

References

Admasu, Robel, Addisu Asefa, and Minda Tadesse. "Effect of Growth Stage Moisture Stress on Common Bean (*Phaseolus vulgaris* L.) Yield and Water Productivity at Jimma, Ethiopia." International Journal of Environmental Sciences & Natural Resources 16.1 (2019): 25-32.

Admasu, Robel, *et al.*, "Growth response of hararghie coffee accessions to soil moisture stress at seedling stage at jimma, south west Ethiopia." International Journal of Development Research 8.06 (2018): 20913-20920.

Bidinger, F. R., V. Mahalakshmi, and G. Durga Prasada Rao. "Assessment of drought resistance in pearl millet [*Pennisetum americanum* (L.) Leeke]. I. Factors affecting yields under stress." Australian Journal of Agricultural Research 38, no. 1 (1987): 37-48.

Cheserek, J. J., and Bernard M. Gichimu. "Drought and heat tolerance in coffee: a review." (2012).

Dancer J (1963). The response of seedling-arabica coffee to moisture deficit. Euphotic, 12: 294-298.

Dias P C, Araujo W L, Moraes G A B K, Barros R S, DaMatta F M (2007). Morphological and physiological responses of two coffee progenies to soil water availability. J. Plant. Physiol., 164: 1639-1647.

Etefa Tilahun Ashine, "Determination of Crop Water Requirement and Irrigation Water Requirement for Coffee Arabica (*Coffea arabica* L.): Case Study of Somodo Watershed" Inte Journal of Research Studies in Agricultural Sciences (IJRSAS), 2019; 5(6), pp. 1-8, http://dx.doi.org/10.20431/2454-6224.0506001

Farg, E., S. M. Arafat, M. S. Abd El-Wahed, and A. M. El-Gindy. "Estimation of evapotranspiration ETc and crop coefficient Kc of wheat, in south Nile Delta of Egypt using integrated FAO-56 approach and remote sensing data." The Egyptian Journal of Remote Sensing and Space Science 15, no. 1 (2012): 83-89.

García, I. F., Lecina, S., Ruiz-Sánchez, M. C., Vera, J., Conejero, W., Conesa, M. R., Domínguez, A., Pardo, J. J., Léllis, B. C., & Montesinos, P. (2020). Trends and challenges in irrigation scheduling in the semi-arid area of Spain. *Water (Switzerland)*, *12*(3), 1–26.

Hale M. G. and Orcutt D. M. (1987) The Physiology of Plants Under Stress, New York: John Wiley & Sons. Ham J. M., Heilman J. L. and Lascano R. J. (1991) Soil and canopy balances of a row crop at partial cover. Agronomy Journal

Howell, T. A. (1996). Irrigation scheduling research and its impact on water use. American Society of Agricultural Engineers, Proceeding(Nov.3-6),21–33.

Irakli Kruashvili, Konstantine Bziava, Irma Inashvili, Maia Lomishvili (2016). Determination of optimal irrigation rates of agricultural crops under consideration of soil properties and climatic conditions. Georgian Technical University, 68, Kostava Str., Tbilisi, 0175, Georgia. irrigation levels. Thai J Agric Sci 32: 549-354.

ITC (International Trade Centre) (2010). Climate Change and the Coffee Industry, Kasterine A., Scholer M, Hilten HJ (ed.), Geneva, Netherland.

Medrano H, Chaves M M, Porqueddu C and Caredda S (1998) Improving forage crops for semi-arid areas. Out Agric 27:89-94

Muktar B Y, Yigezu T T (2016). Determination of Optimal Irrigation Scheduling for Maize (*Zea mays* L.) at Teppi, Southwest of Ethiopia. Irrigation Drainage Systems Engineering 5(3): 173.

Omprakash, R. Gobu1, Prashant Bisen, Murlimanohar Baghel and Kumar Nishant Chourasia. 2017. Resistance/Tolerance Mechanism under Water Deficit (Drought) Condition in Plants. Int.J.Curr.Microbiol.App.Sci. 6(4): 66-78. doi:

Pinheiro, H. A., F. M. Da Matta, A. R. M. Chaves, M. E. Loureiro and C. Ducatti, 2005. Drought tolerance is associated with rooting depth and stomatal control of water use in clones of *Coffea canephora*. Annals Bot., 96: 101-108.

Pugnaire F I, Serrano L, Pardos J (1999) Constraints by water stress on plant growth. In: Pessarakli M (ed) Hand book of plant and crop stress, 2nd edn. Marcel Dekker, Inc., New York, pp 271–283

Robel A, Addisu A, Minda T. Determination of Optimal Irrigation Scheduling for Soybean (*Glycine max* L.) Yield and Water Productivity at Jimma, South West Ethiopia. Agri Res& Tech: Open Access J. 2019; 19(4)

Santana Júnior, Edvaldo B., Eugênio F. Coelho, Karoline S. Gonçalves, and Jailson L. Cruz. "Physiological and vegetative behavior of banana cultivars under irrigation water salinity." Revista Brasileira de Engenharia Agrícola e Ambiental 24 (2019): 82-88.

Savva, A. P. and K. Frenken (2002). Crop water requirements and irrigation scheduling. FAO Sub-Regional Office for East and Southern Africa, Harare. Zimbabwe. 132p.

Scheel, G. L. *et al.,* Environmental stress evaluation of *Coffea arabica* L. leaves from spectrophotometric fingerprints by PCA and OSC–PLS–DA. Arabian Journal of Chemistry (2016), http://dx.doi.org/10.1016/j.arabjc.2016.05.014)

Tadesse Bedane, Minda., 2019. Spatial and temporal variability of coffee (*Coffea arebica* L.) Water and irrigation requirement mapping for Jimma zone, Hawassa University.

Tefera, Tesfaye, Beniam Yaziz, and Tesfaye Shimbir. "Response of Coffee Genotypes (*Coffea arabica*) for Moisture Stress Condition at Tepi, South West of Ethiopia."

Tesfaye S G, 2005. Growth, water relations, yield and crop quality of Arabica coffee in response to water stress and deficit irrigation. PhD Dissertation, University Putra Malaysia, Malaysia.

Tesfaye Shimbir, I. M. Razi and M. Maziah (2008). Effects of deficit irrigation and partial root zone drying on growth, dry matter partitioning and water use efficiency in young coffee plants. Journal of Food, Agriculture and Environment 6: 312-317.

Tesfaye, S. G., Mohd Razi Ismail, H. Kausar, M. Marziah, and M. F. Ramlan. "Plant Water Relations, Crop Yield and Quality of Arabica Coffee (*Coffea arabica*) as Affected by Supplemental Deficit Irrigation." International Journal of Agriculture & Biology 15, no. 4 (2013).

Tilahun, Etafa, Minda Tadesse, Addisu Asefa, Robel Admasu, and Tesfaye Shimbir. "Determination of Optimal Irrigation Scheduling for Coffee (*Coffee arabica* L.) at Gera, South West of Ethiopia." International Journal of Research Studies in Agricultural Sciences 7, no. 1 (2021): 37-42.

Worku M, Astatkie T (2010). Growth responses of arabica coffee (*Coffea arabica* L.) varieties to soil moisture deficit at the seedling stage at Jimma, Southwest Ethiopia. J. Food, Agric. Envir.; 8(1):195 - 200.

Yaziz, B. and Tefera, T. 2016. Determination of Optimal Irrigation Scheduling for Maize (*Zea mays*) at Teppi, Southwest of Ethiopia. Irrigation & Drainage Systems Engineering, 5(3).

How to cite this article:

Addisu Asefa. 2023. Impact of Water Stress and Irrigation Scheduling on *Coffee arabica* at Jimma, South West Ethiopia: A Review. *Int.J.Curr.Res.Aca.Rev*. 11(08), 20-24. doi: https://doi.org/10.20546/ijcrar.2023.1108.003