Optimizing Fruit Production: A Review of Sensor-Based Approaches in Orchard Management

ABSTRACT

Fruit crops produce higher yields per hectare than other horticultural crops. Fruits are also a rich source of vitamins, minerals, and antioxidants. It is necessary to monitor and maintain the orchard properly to increase both production and quality of fruits. However, maintaining large orchards is quite difficult. The application of different sensors in fruit crops helps in precise orchard management and, therefore, helps in sustainable production in the long run. Remote sensing tools are useful in gathering data on factors necessary and act as a constraint for increasing the yield potential of fruit crops. An increase in the cost incurred in maintaining the orchards resulted in a low benefit cost ratio in the production of fruits. The application of sensors for the continuous monitoring of orchard facilitates in increased water use efficiency and precise orchard management strategies. This article reviews the use of sensors in various aspects related to fruits crops management.

Keywords: Sensors, Fruit crop, Remote sensing, irrigation

INTRODUCTION

Dependance on rainfed agriculture is not appropriate most of the times due to different climatic conditions or different fruit crop growth requirements. Most of the fruit crops need irrigation for maximizing the yield when rainfall is not sufficient for the growth cycle of fruit crops.

Though deficit irrigation helps in improving water productivity (Costa *et al*., 2007; Chai *et al*., 2016) by utilizing deficit irrigation strategies like regulated deficit irrigation, which increases water use effeciency for achieving higher yields, and partial root-zone drying, which involves supplying water to half of the root zone. While the former was proven to be successful in fruits and vegetable crops, later showed similar results in orange trees as that of full irrigation (Consoli *et al*., 2017).

Estimation of water status in stem is a good measure of a crop reaction to scarcity of water (Kramer, 1988; Boyer, 1989), as compared to that of root water. Stem water potential is the most reliable indicator of plant water status compared to leaf water potential, as leaf water status will be under the control of stomata. (Ψstem) (Shackel *et al*., 1997).

Plant-based sensors like to contact, and non-contact sensors are useful for calculating the plant water status data, which can be further used for irrigation management in fruit crops [16-18]. Drip irrigation supplies water to the root of trees and there by saves water. Analysis of plant water before drip irrigation helps in achieving increased water use effeciency [19,20]. The use of plant-based sensors help in the precise scheduling of irrigation as per the requirements of fruit crops.

Leaf adapted sensors

Estimation of water status in leaves is difficult due to their fragile nature. Some leaf adapted sensors were tested by scientists to understand the water relations of plant and leaves, although the water status of leaves does not represent the whole plant waters status. Abaxial leaf mounted sensors were studied for monitoring of plants.

Leaf thickness sensors

Changes in leaf thickness over a period helps in knowing the water deficit. Changes in the leaf thickness happens due to water exchange from the atmosphere to the plant and vice versa.

Leaf thermal sensing

Thermal imaging at the ground and from the top helps in knowing the canopy temperature (Tc) as an index of water stress. When water deficit exists in plant stomata closes,,, transpiration decreases, which increases canopy temperature and, thus, increases canopy temperature; thus, canopy temperature is measured.

Sensors mounted on stem

The amount of water in fruit trees is related to moisture availability in the soil and climate. Stems and shoots are the medium through which water will be exchanged between soil and atmosphere. Without destroying the stem and shoots stem, water can be measured with the help of this sensors, thereby estimating water amounts in soil and plants.

Stem dendrometers

The change in the elasicity of stem tissues is related to diffusion and exchange of water in tissues of phloem. Changes in the water status of the plant will lead to changes in the stem diameter. It's usage is not complicated, and the use of low cost stem dendrometers helps in achieving precise irrigation scheduling for fruit orchards. But stem, stem dendrometer estimations do not show accurate water status in leaf and fruit. Even in young plants, stem dendrometers cannot give accurate results, and also growth of new plants might not give correct data.

Fruit mounted sensors

Fruit water relations are very important in achieving production and quality. Fruit volume depends up onthe exchange of water between the tissues of the fruit and the atmosphere through the skin of the fruit. During the day, due to fluctuations in temperature, transpiration of the fruit increases, and changes in the fruit volume will be seen, and during nighttime, transpiration of the fruit decreases. Nevertheless, sensors attached to fruit may not accurately estimate water status in the stem. Therefore, an integration of data of fruit mounted sensors supported by data of water status acquired by sensors attached to leaves and stem are more useful.

REMOTE SENSING IN FRUIT CROPS

Remote sensing is the technique of gathering, processing, and interpreting data of any object on earth by detecting the radiation emitting from the object with the help of different contact and contact less sensors. Sensors record the energy of the target object and thereafter, it transmits, receives, processes, and further does interpretation and analysis. Remote sensing operates through different platforms like ground based, air borne, and space borne. The principle behind remote sensing is that tools of remote sensing receives energy of the target object in the form of the electromagnetic spectrum, which will be interpreted and analysed. Different sensors like active and passive sensors, vegetation indices, satellites, drone with digital cameras, thermal imagery, global positioning system (GPS), etc., are different components of remote sensing.

Applications:

1. Mapping of orchards.

The mapping of orchards is a useful strategy for estimating yields, efficient input use efficiency and thereby planning for effective management of the orchard for sustainable yields. Remote sensing tools are efficient in providing mapping of data. In Punjab different orchards were mapped in the Abohar Tehsil using Sentinel-2 satellite data. Kinnow orange orchard was identified from other orchards (like guava, orange, malta and ber) and also area under trees is estimated (Digra *et al.*, 2022). With remote sensing, vegetation, water stress, and diseases in citrus orchards at any time of the year can be controlled. Spectral images will be used in remote sensing to make several segmentations of trees or rows based on size, vegetation and water stress.

2. Fertilizer application and nutrient estimation

Site-specific orchard management by variable rate delivery of inputs such as fertilizers on a tree size basis could improve profitability and environmental protection. Mahajan *et al*. (2021) checked the foliar nutrients status of mango using hyperspectral imagery at India. The experiment involved normalized difference spectral index (NDSI), ratio spectral index (RSI) with multiple machine learning (ML) tools and models for prediction, calibration and validation of various nutrients in leaf of mango from 400 samples of 40 orchards. The reason might be that NDSI and RSI are highly based on radiation emits through vegetation of a crop, and nutrients status highly influence the plant vegetation, which ultimately leads to better management.

3. Detection of water stress

Remote-sensing tools identifies water stress of fruit trees using leaf transpiration and temperature. Initially, data of soil and air moisture levels can be taken, and difference can be used for calculating and estimating water stress. When water stress condition exists leaf temperature increases as transpiration activity will be decreases due closure of stomata (Gates, 1964). Technologies using infrared methods have efficiency in achieving good view of orchards and also helps in gathering information about trees canopy temperature. (Lu *et al*., 2020). Zhou *et al*. (2022) used Red Green Blue images based on infrared radiation emitted by grape vines to assess water stress. So, temperature of the canopy of fruit trees can be taken as important criteria for monitoring water stress in orchards. Use of thermal camera in citrus and persimmon trees for measuring canopy temperature to detect water stress was studied by Ballester *et al*. (2013a & b). The irrigation requirement can also be calculated with remote sensing by estimating crop evapotranspiration using the normalized difference vegetation index.

4. Detection of disease incidence

Precision farming uses remote sensing tools for increasing effeciency in managing the input supply to orchards, and also remote sensing tools are capable of monitoring the trees precisely by estimating physiological stress in trees as stress affects photosynthesis of the tree canopy and thereby affects the intake of light energy and further results in changes if reflecting patterns. Remote sensing interprets & analyses satellite and aerial images for gathering information about the spatial distribution of trees, their acreage, and different characteristics of trees. This can be decoded either manually or through machines for assessment. Detection of malady among trees is possible through this assessment. Detection of citrus greening was done with the help of vegetation indices like Normalized difference vegetation index in Texas, USA (Chang *et al*., 2020). Ye *et al*. (2021) applied remote sensing for detecting and managing banana wilt in China with vegetation indices like NDVI etc. and were able to monitor banana wilt with the help of high-resolution imagery.

CONCLUSION

The major aim of farming and scientific community is to maximize yields with efficient utilization of resources and for sustainable production patterns. Though lot of sensors have been in use for maximizing the management of orchard and input use, estimation of the water status of the plant with a single reliable method is not there for proper irrigation scheduling. With the help of remote sensing tools orchards can be monitored regularly with vegetation indices with spatial resolution which further helps in site specific management. However, cost of sensors and their vulnerability to damage made them less accessible to broad spectrum of farming community. Also, high resolution images are needed but the spectral images provided by some satellites don't have a very high resolution so it is difficult to get a good result in overcrowded orchard. In addition, the deep learning algorithms need huge data for more precision.TRe

References

1. Ballester, C., Castel, J., Jimenez-Bello, M.A., Castel, J.R., Intrigliolo, D.S. (2013a). Thermographic measurement of canopy temperature is a useful tool for predicting water deficit effects on fruit weight in citrus trees. *Agric Water Manag*, 122:1–6.

2. Ballester, C., Jimenez-Bello, M.A., Castel, J.R., Intrigliolo, D.S. (2013b). Usefulness of thermography for water stress detection in citrus and persimmon trees. *Agric For Meteorol*, 168:120–129.

3. Boyer, J.S., 1989. Water potential and plant metabolism: comments on Dr PJ Kramer's article 'Changing concepts regarding plant water relations', 11, Number 7, pp. 565–568, and Dr JB Passioura's Response, pp. 569–571. *Plant Cell Environ*, 12(2): 213-216.

4. Chai, Q., Gan, Y., Zhao, C., Xu, H.L., Waskom, R.M., Niu, Y. and Siddique, K.H., 2016. Regulated deficit irrigation for crop production under drought stress. *A review. Agron Sustain Dev*, 36(1): 3.

5. Chang, A., Yeom, J., Jung, J. and Landivar, J. (2020). Comparison of canopy shape and vegetation indices of citrus trees derived from UAV multispectral images for characterization of citrus greening disease. *Remote Sensing*, 12(24), 4122.

6. Consoli, S., Stagno, F., Vanella, D., Boaga, J., Cassiani, G. and Roccuzzo, G., 2017. Partial root-zone

drying irrigation in orange orchards*:* Effects on water use and crop production characteristics. *Eur J Agron*, 82: 190-202.

7. Costa, J.M., Ortuno, M.F. and Chaves, M.M., 2007. Deficit irrigation as a strategy to save water: physiology and potential application to horticulture. *J Integr Plant Biol*, 49(10): 1421-1434.

8. Digra, A., Nijjar, C. S., Setia, R., Gupta, S.K., Pateriya, B. Mapping Orchards and Crops Using Sentinel-2 Imagery In book: Artificial Intelligence and Machine Learning in Satellite Data Processing and Services, pp.117-122.

9. Kramer, P.J., 1988. Changing concepts regarding plant water relations. *Plant Cell Environ*, 11(7): 565-568.

10. Lu, B., Dao, P.D., Liu, J., He, Y., Shang, J. Recent Advances of Hyperspectral Imaging Technology and Applications in Agriculture. *Remote Sens.* **2020**, *12*, 2659.

11. Mahajan, G. R., Das, B., Murgaokar, D., Herrmann, I., Berger, K., Sahoo, R. N., Patel, K., Desai, A., Morajkar, S. and Kulkarni, R. M. 2021. Monitoring the foliar nutrients status of mango using spectroscopy-based spectral indices and PLSR combined machine learning models. *Remote Sensing*, 13(4), 641.

12. Shackel, K.A., Ahmadi, H., Biasi, W., Buchner, R., Goldhamer, D., Gurusinghe, S., Hasey, J., Kester, D., Kruegner, B., Lampinen, B. and Mcgourty, G., 1997. Plant water status as an index of irrigation need in deciduous fruit trees. *HortTechnology*, 7(1): 23-29.

13. Ye, H., Huang, W., Huang, S., Nie, C., Guo, J. and Cui, B. (2021). Application of UAV remote sensing in monitoring banana fusarium wilt. In: Marghany, M. (Ed.), Remote Sensing. Intech Open Limited, London, 1-16.

14. Zaman, QU, Schumann, AW and Miller WM. 2005. Variable rate nitrogen application in florida citrus based on ultrasonically-sensed tree size. *Am. Soc. Agril. Engineers*, 21(3):331-335.

15. Zhou, Z., Diverres, G., Kang, C., Thapa, S., Karkee, M., Zhang, Q., Keller, M. 2022. Ground-Based Thermal Imaging for Assessing Crop Water Status in Grapevines over a Growing Season. *Agronomy*,12(2):322.

16. Pujar DU, Pujar UU, Shruthi CR, Wadagave A, Chulaki M. Remote sensing in fruit crops. Journal of Pharmacognosy and Phytochemistry. 2017;6(5):2479-84.
17. Longchamps L, Tisseyre B, Taylor J, Sagoo L, Momin A, Fountas S, Manfrini L, Ampatzidis Y, Schueller JK, Khosla R. Yield sensing technologies for perennial and annual horticultural crops: A review. Precision Agriculture. 2022 Dec;23(6):2407-48.
18. Panda SS, Hoogenboom G, Paz JO. Remote sensing and geospatial technological applications for site-specific management of fruit and nut crops: A review. Remote Sensing. 2010 Aug 23;2(8):1973-97.
19. Jafarbiglu H, Pourreza A. A comprehensive review of remote sensing platforms, sensors, and applications in nut crops. Computers and Electronics in Agriculture. 2022 Jun 1;197:106844.
20. Scalisi A, Bresilla K, Simões Grilo F. Continuous determination of fruit tree water-status by plant-based sensors. Italus Hortus. 2017;24(2):39-50.