**Use of Soil Moisture Sensor for Efficient irrigation in Smart Agriculture**

**Abstract:**

The demand for water is gradually increasing to quench the agricultural thirst. The uncertainty of timely rainfall, irrigation has become the important source of adding water to the soil to grow crop . Conventional methods of water application incur poor irrigation efficiency and high wastage of this precious natural resource. The study was carried out to evaluate the use of soil moisture sensors (SMS) for efficient irrigation in smart agriculture. It was observed that 5.53 times more water requirement for flood method without SMS whereas it was only 3.51 times more water required for SMS-enabled plot than its basic irrigation water requirement (3246l/p). The flood method deployed without SMS, the irrigation efficiency was very poor (25.10%) whereas drip method with SMS resulted the highest IE (89.94%). Considerable amount (50-85%) of water was saved from wastage when SMS was used to determine the water content of the soil. The SMS-enabled plot produced good average weight of each guava. The fruits harvested from the plants with SMS were priced higher than the others. Considering the cost of devices including sensors, water carrying channels and others, the benefit-cost ratio increased with the SMS and modern irrigation techniques. The drip irrigation with SMS demonstrated the highest B-C ratio (2.41). The findings suggested that the sensor enabled irrigation system saved wastage of water and led to the efficient uses of water for better crop production.

**Key Words**: Smart Agriculture, Soil Moisture Sensor, Irrigation Efficiency, precision agriculture, precision irrigation

**Introduction**

Water is a precious natural resource that sustains the lives on the earth. In the world, 97% water is brackish in nature and only 3% water is sweet water (Ahuja, 2009). Most interestingly, out of this 3%, 2.4 % water remains as snow and ice. International Water Management Institute (IWMI) assessment projected that India’s total water demand will increase 32% by 2050 and ground water will contribute 51 % of the total demand. Plants require fresh water for their physiological functions such as photosynthesis, nutrient absorption, translocation, biomolecule synthesis etc. Agricultural crops are having different water requirement for their growth and development. Crops are irrigated to mitigate the water deficiency in soil. The application methods of water are being practiced by the different crop growers depending upon the source of water, soil properties, land situation, types of crop grown, climate etc (Shen, et al., 2013; Yang et al., 2010). The main sources of water in soil are rainfall, irrigation, groundwater, condensation of water vapour and melting of ice. In India, monsoon brings 80% of rainfall during kharif season. The uncertainty of monsoon the Indian agriculture is facing the great challenges to grow crops properly. As a consequence, irrigation is the prime source of soil water to nourish the crops. The main source of irrigation water in the country are wells and tube wells (55-62%), canals (24-32 %) and tanks (5-6%). The fresh water is declining due to overuse and unscientific management of water. Because of the scarcity of fresh water for irrigation, agriculture land will lose its acreage and there will be a big challenge to meet the basic demand of food, fodder, fuel, fibre and other essential commodities for the raising population. To sustain the agriculture, precision farming through smart agriculture can be adopted for better irrigation efficiency and proficient use of water in order to harvest good crops. As a part of smart agriculture soil moisture sensors (SMS) have been used to forecast irrigation requirements and scheduling with exact quantity at specific crop locations (Shah & Das, 2012). While the modern techniques utilize soil resistivity sensor, tensiometers, soil moisture sensors, micro-electro mechanical systems and optical techniques (Blonquist, et al., 2006; Susha Lekshmi, et al., 2014). To strengthen the irrigation system various methods of irrigation systems are combined with different technologies and it resulted in less manual intervention, decreased crop diseases, less water usage, less power consumption and increased cultivation (Raheman, et al., 2018). Wireless sensors were used to sense some parameters like soil moisture, soil temperature, and weather condition in order to irrigate efficient amount of water in field (Montesano et al., 2018, Hardie, 2020, Vera et al., 2021, Lloret et al., 2021). The present study was designed to evaluate the use of soil moisture sensor for efficient irrigation in smart agriculture.

**Materials and Methods**

The study was conducted during the winter season (2024-25) at the Guava (*Psidium guajava L*) Farm, Baruipur, South 24 Parganas, West Bengal, India. The plants are four years old and the experiment was laid out in Randomized Block Design with eight treatments and three replications. A capacitive soil moisture sensor (v2.0) was installed and calibrated. Irrigation was done manually on the basis of reading of SMS. The treatments constituted of T1 : No SMS + Flood Irrigation, T2 : No SMS + Furrow Irrigation, T3: No SMS + Sprinkler Irrigation, T4: No SMS + Drip Irrigation, T5 : SMS + Flood Irrigation, T6 :SMS + Furrow Irrigation, T7: SMS + Sprinkler Irrigation, T8: SMS + Drip Irrigation. The plot size for each treatment and replication was 5m x 4m with plant spacing 2.5m x 2m. Guava grows in tropical and sub-tropical climate with wide adaptability of weather and soil features. The variety of guava was Allahabad Safeda. The study location belongs to sub-tropical climate and new alluvial soil. The soil is loamy. During the study, data were recorded and analysed through the formulas by using Microsoft excel.

**Result and Discussion**

The source of irrigation for the experiment plots was shallow tube well. The water was lifted by the pump. Basic physiological water requirement of guava plant (4 years old) is 18 litre per day. For the entire winter season (October - March) for 182 days, the total water requirement for each plant 3276 litre. For 2 plants in 20 m2 area, the total water requirement is 6552 litre for the entire season. The dew accumulated at the rate of 0.23 l m-2 day-1 and contributed 4.6 l per day for the 20 m2 area. Ground water through capillary action and winter rainfall also contributed 4 % of water requirement. Therefore, irrigable water required for the two plants was 3246 litre in 20 m2 area.

The study showed that in T1 water amount for single irrigation was very high (1503.33 l) where as T8 required least amount of water (73.33). Water requirement significantly decreased by the intensifying irrigation method with devices. Soil moisture sensor (SMS) reduced the quantity of irrigation water irrespective of application methods (Tab-1). The SMS widened the interval of irrigation. In T1 the interval was 15.33 days but, T5 it was increased to 19.67 days. Frequency of watering also decreased from T1 to T5, T2 to T6, T3 to T7, and T4 to T8 because of use of sensor which detected the water deficiency at right time at exact location. The huge amount of water was unnecessarily applied to the plot where sensor was not installed. It was observed that 553 times more water requirement for flood method without SMS whereas it was only 1.027 times more water required for drip method with SMS than its basic irrigation water requirement (Fig.1).

Table -1: Calculation of irrigation water of the treatments

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Water amount per irrigation per 20 m2 area (l) | Interval (days) | No. of Irrigation for six months | Water irrigated  (l / plot) |
| T1 | 1503.33 | 15.33 | 11.95 | 17964.79 |
| T2 | 1233.33 | 13.33 | 13.67 | 16859.62 |
| T3 | 743.33 | 8.67 | 21.47 | 15959.30 |
| T4 | 149.33 | 3.00 | 60.67 | 9059.85 |
| T5 | 1226.67 | 19.67 | 9.29 | 11395.76 |
| T6 | 1001.33 | 15.00 | 12.17 | 12186.19 |
| T7 | 439.33 | 11.00 | 16.64 | 7310.45 |
| T8 | 73.33 | 4.00 | 45.50 | 3336.52 |
| SEM | 19.74485 | 0.648564 | 0.980495 | 767.589 |
| CD 0.05 | 59.89577 | 1.96741 | 2.974321 | 2328.472 |

Fig.1: Irrigation intervals and frequency of different treatments

During irrigation of plots water was lost due to run-off, percolation etc. The loss of water depends on the water carrying canals. Here earthen canals were made to deliver water to the plots of guava. Water conveyance improved with the utility of modern devices. In case of drip irrigation system with SMS showed the highest conveyance efficiency (95.33%) and also field application efficiency (94.33%) because of slow discharge of water and as per estimated water deficiency of the soil (Tab.2). In case of T1 where flood method was deployed without SMS, the irrigation efficiency was very poor (25.10%) whereas drip method with SMS resulted the highest IE (89.94%). Considerable amount (50-85%) of water was saved from wastage when SMS was used to determine the water content of the soil (Fig.2).

Table -2: Irrigation efficiency and water saving of different treatments

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Conveyance efficiency (%) | Field application efficiency (%) | Irrigation Efficiency (%) | Water Saving (%) |
| T1 | 60.67 | 41.33 | 25.10 | - |
| T2 | 69.67 | 50.67 | 35.33 | - |
| T3 | 80.67 | 64.33 | 51.93 | - |
| T4 | 86.33 | 74.67 | 64.47 | - |
| T5 | 61.00 | 54.33 | 33.18 | 36.56613 |
| T6 | 69.00 | 65.33 | 45.11 | 27.71969 |
| T7 | 84.00 | 82.33 | 69.18 | 54.19314 |
| T8 | 95.33 | 94.33 | 89.94 | 63.17252 |
| SEM | 1.521669 | 1.716516 | 1.925561 |  |
| CD 0.05 | 4.615964 | 5.207032 | 7.163817 |  |

Fig.2: CE , FAC and IE of different treatments

Timely watering in adequate amount improves the fruit qualities. Water stress and decontrolled supply promote thick texture and deep colour. It was observed that sufficient and timely application of water to the plant by using SMS, gave the good colour i., e. mint green, light green and crisp and tender texture which induce good market demand and price (Tab.3). The SMS-enabled plot produced good average weight of each guava. T8 plot showed the highest average weight of a single fruit (195.33 g) and also yield was the best (48.17 kg) among other Treatments.

Table -3**: Fruit appearance, average weight and yield of guava in treatments**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Fruit Colour | Fruit firmness | Fruit average weight (g) | Fruit yield (Kg /plant) |
| T1 | India Green | hard | 85.33 | 8.10 |
| T2 | Forest Green | firm | 91.33 | 13.17 |
| T3 | Lime Green | firm | 96.33 | 19.20 |
| T4 | Lawn Green | crisp | 107.33 | 26.37 |
| T5 | Lime Green | firm | 111.67 | 21.57 |
| T6 | Lawn green | firm | 127.00 | 31.47 |
| T7 | Mint Green | crisp | 158.33 | 41.43 |
| T8 | Light Green | tender | 195.33 | 48.17 |
| SEM |  |  | 2.5382 | 0.750066 |
| CD 0.05 |  |  | 7.6996 | 2.275317 |

Right quantity of water at right time enhances the quality of fruit by inducing nutrient availability, promoting photosynthesis process, bio molecules synthesis etc. Market price depends on the quality and size of the fruits. The fruits harvested from the plants whose water application were monitored by SMS were priced higher than the others. Considering the cost of devices including sensors, water carrying channels and others, the benefit- cost ratio increased with the SMS and modern irrigation techniques (Tab.4). The T8 demonstrated the highest B: C ratio (2.41)

**Table -4 : Calculation of B:C ratio for the different Treatments**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Price rate of guava  (Rs. /kg) | Gross return  (Rs./ ha) | Net return  (Rs./ ha) | B: C Ratio |
| T1 | 40 | 324000 | 144000 | 1.80 |
| T2 | 50 | 658500 | 313500 | 1.91 |
| T3 | 55 | 1056000 | 436000 | 1.70 |
| T4 | 60 | 1582200 | 756600 | 1.92 |
| T5 | 60 | 1294200 | 444200 | 1.52 |
| T6 | 70 | 2202900 | 852900 | 1.63 |
| T7 | 80 | 3314400 | 1674400 | 2.02 |
| T8 | 100 | 4817000 | 2817000 | 2.41 |
|  |  |  |  |  |

**Conclusion**

Water is the most valuable resource that is limited in nature. Water required for crop cultivation is quenched through the irrigation. Traditional methods of watering implicated the more wastage of water and application cost. Smart devices like soil moist sensors restricted the water loss and improved the yield with better quality considering the expenses incurred for procurement of devices and accessories.

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1.

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**References**

1. Ahuja, S. (2009). Handbook of Water Quality and Purity, Elsevier Inc.
2. D.L. Bjorneberg, "IRRIGATION Methods", Elsevier Inc., (2013).J.M. Blonquist, S.B. Jones, D.A.
3. Hardie M. (2020). Review of novel and emerging proximal soil moisture sensors for use in agriculture Sensors, 20(23), p. 6934,
4. Lloret, J. , Sendra, S. ,  Garcia, L. , Jimenez, J.M.  (2021). A wireless sensor network deployment for soil moisture monitoring in precision agriculture. Sensors, 21(21),7243.
5. Montesano FF, van Iersel MW, Boari F, Cantore V, D Amato G, et al. (2018) Sensor-based irrigation management of soilless basil using a new smart irrigation system: Effects of set-point on plant physiological responses and crop performance. Agricultural Water Management 203: 20-29.
6. M. Nagarajapandian, U. Ram Prasanth, G. Selva Kumar, S. Tamil Selvan, "Automatic irrigation system on sensing soil moisture content", IJIREEICE. 3 (2015) 96–98.
7. N. G. Shah and I. Das, “Precision Irrigation Sensor Network Based Irrigation, Problems, Perspectives and Challenges of Agricultural Water Management", IIT Bombay, India, pp. 217–232, (2012).
8. Raheman A, Rao MK, Vamsi Reddy B, Ravi Kumar T (2018) IoT based self-tracking solar powered smart irrigation system. International Journal of Engineering & Technology 7(7): 390-393.
9. Rao VP, Suneetha KB and Hemalatha. (2010). Irrigation water management. Department of Agronomy, College of Agriculture, Rajendranagar, Hyderabad (p 148).
10. Robinson, "Precise irrigation scheduling for turfgrass using a subsurface electromagnetic soil moisture sensor", Agric. Water Manag. 84 (2006) 153–165
11. S.U. Susha Lekshmi, D.N. Singh, M. Shojaei Baghini, "A critical review of soil moisture measurement", Measurement. 54 (2014) 92– 105.
12. Vera, J.,  Conejero, W.,  Mira-García, A.B.,  Conesa, M.R. and Ruiz-Sánchez, M.C. (2021).Towards irrigation automation based on dielectric soil sensors, J. Hortic. Sci. Biotechnol , 96 (6),696-707.
13. Willardson LS, Allen RG, Frederiksen HD. (1994). Elimination of irrigation efficiencies. In Acta 13th Tech. Conf. USCID. Denver, CO, EEUU 19 (pp. 19-22).
14. Y. Shen, S. Li, Y. Chen, Y. Qi, S. Zhang, "Estimation of regional irrigation water requirement and water supply risk in the arid region of Northwestern China 1989-2010", Agric. Water Manag. 128 (2013) 55– 64.
15. Y. Yang, Y. Yang, J.P. Moiwo, Y. Hu, "Estimation of irrigation requirement for sustainable water resources reallocation in North China", Agric. Water Manag. 97 (2010) 1711–1721