__Original Research Article__

WSN BASED IRRIGATION MANAGEMENT IN BEANS

Abstract

Wireless sensor network is an important technology in agriculture to enhance the efficiency, productivity and profitability of farming with minimal use of inputs. Maintaining uniformity of soil moisture throughout the crop growth is of greater importance to achieve maximum yield. Hence, a field experiment entitled "WSN based irrigation management in beans" was conducted at ZARS, GKVK, Bengaluru during *kharif* 2021. This study was aimed to know the effect of sensor based irrigation management on the performance of beans, water saving and water use efficiency (WUE). For the sensor based irrigation treatment, irrigation was provided when available moisture in the soil was depleted for about 25-30 per cent. Results indicated that, sensor based irrigation recorded significantly higher beans yield (6972 kg ha^{-1}) which enhanced crop yield by 18.87 per cent and saved water to the tune of 26.66 per cent over conventional method of irrigation. This could help farming community to boost income.

Key words: *Beans, Irrigation, Sensor, WUE* and *WSN*

Introduction

Wireless Sensor Network (WSN) is a technology which utilizes advanced techniques *viz*., Wi-fi, computer-based irrigation control systems and sensors in monitoring real-time data of the crop in the field. In agriculture, water is a limited resource wherein judicious use of available water has prime importance (Levido *et al.*, 2014). Soil moisture measurement is key information for managing optimum water requirements for the crops (Schroder, 2006). There is need to develop new technologies for the precision management. Sensors measure the water content at the root zone depth regularly in irrigation scheduling through proper water management with calculated water distribution. It is very productive to measure soil moisture with sensors (Clarke *et al*., 2008 and Scherer *et al*., 2013).

Beans is one of the most important legume crop botanically called as *Phaseolus vulgaris* L., belongs to the family Fabaceae. It has high mineral variability and antioxidant activities which could be useful for higher nutrition value. Beans also contain higher amounts of proteins, carbohydrates and vitamins. The green pods are consumed as fresh vegetable and dried seeds are used for seed purposes, while the foliage is used as fodder for animals as well as to restore soil fertility.

Beans can be grown in a wide range of soils but thrives best in loamy, silty loam and clay loam soils having soil pH range 5.5-6.0 with a cool climatic condition. It performs better within the ideal temperature range of 20-25^{0}C but can be grown in temperatures ranging 14 to 32^{0}C. However, French beans mature faster in warmer climatic condition, yield reduction due to high temperature and water loss during stages of crop has been noticed (Rosales *et al*., 2012). Apart from these, irrigation and nutrition are the other prime factors to improve the productivity. Maintaining soil moisture during the crop growth stages is of greater importance to achieve maximum yield. Depletion of soil water beyond the minimum balance leads to yield losses. Hence, care should be taken such that water in the crop root zone retains minimum level of water. Therefore, with the above facts, the current study on WSN based irrigation management in beans was carried out in the field to know the influence of sensor based automated drip irrigation on yield, water requirement and water use efficiency of beans.

Literature Survey

In a study conducted by Blonquist et al. (2006), the use of a sprinkler system in conjunction with the Acclima Digital Time Domain Transmission Soil Moisture Sensor was found to result in a 16% reduction in water application compared to evapotranspiration estimates from a weather station and a 53% reduction in water application using a fixed irrigation rate of 50mm per week (7.14 mm day-1). These findings demonstrate the potential for significant water savings through the use of soil moisture sensor systems, which can result in cost savings of up to US$100.00 per month for a 1000 m^2 irrigated turfgrass plot based on average water prices in the US.

According to a study by Thompson et al. (2007), the use of soil moisture sensors for the estimation of water content allows for real-time, in situ measurements at a cost-effective price point. These sensors have the potential to improve irrigation practices by allowing for irrigation tailored to the specific needs of a particular crop in a specific field. Additionally, these sensors can be used in a variety of ways, including as a standalone method, in conjunction with the FAO method, or as a complementary tool to supplement irrigation management based on experience.

In a study by Vellidis et al. (2008), an array of Watermark wireless smart sensors was used to measure soil moisture and temperature in a cotton field located at the Tifton Campus of the University of Georgia. The system consisted of multiple sensors installed throughout the field, which transmitted data wirelessly to a central receiver for collection and analysis.

Dukes et al. (2010) summarized the results of research on the reduction of irrigation water requirements for various types of crops in the Florida region. They found that using tensiometers to measure soil moisture, the irrigation requirements of tomato crops were reduced by 40-50%. Specifically they reported 73% reduction of water use at 0.15 bar pressure. However, the use of tensiometers also had some drawbacks, including the need for frequent maintenance and the potential for clogging due to algae growth.

In a study by Perea et al. (2013), three types of tensiometers and resistance block sensors were evaluated for use in measuring soil moisture in an onion field with sandy loam, sandy clay, and clay loam soil textures (light, medium, and heavy). The sensors were installed at 15 and 30 cm soil depths. The study found that the sensors performed poorly at the 15 cm depth due to management and maintenance issues. The sensors installed in sandy clay soil performed better than those in the other two soil types. The authors recommended that sensors installed at deeper depths performed better throughout the entire growing season. However, it was found that the moisture content was underestimated by both types of sensors. Additionally, it was noted that sensors installed close to the soil surface may be affected by soil wetting and drying phases, poor maintenance and installation.

According to a study by Zaier et al. (2015), a soil moisture probe sensor is inserted into the ground, ideally in a horizontal position at the root level. This sensor is characterized by its small size, durability, waterproofing, and low power consumption. Additionally, the study found that the sensor is insensitive to the salinity of water and does not corrode over time.

In a study by Chate and Rana (2016), a smart irrigation system was developed for use on an agricultural farm using a Raspberry Pi and the Python programming language for automation purposes. The system included live streaming of crop imagery via Android phones and an automatic motor ON/OFF system. Additionally, the system featured the capability to capture live crop images over Wi-Fi and a moisture sensor was employed to measure the moisture content of the soil.

In a study by Vories et al. (2017), two irrigation timings based on management allowed depletion (MAD) were evaluated. The MAD1 treatment involved 10 mm of water application at a 12 mm estimated soil water deficit (SWD) and MAD2 treatment involved 15 mm application at a 19 mm estimated SWD. Three variable rate of irrigation settings, 75%, 100%, and 125% of the target application, were used for each MAD treatment. The results showed that for rice, the irrigation water use efficiency was significantly greater than the field average for only one treatment combination (MAD1 – 100%) and significantly lower for two (MAD2– 75, 100%). Two of the treatment combinations were found to have a significantly greater irrigation water use efficiency than the field average (MAD1 – 75%, MAD2 – 75%) while two were found to have a significantly lower efficiency (MAD1 – 125%, MAD2 – 125%).

In a study by Shamshiri et al. (2021), it was found that the Internet of Things (IoT) based real-time acquisition system deployed in berry orchards, the soil moisture sensor played a crucial role in the real-time and accurate measurement of soil moisture status, providing accurate soil moisture information for microclimate monitoring.

Methodology

The field experiment was conducted at Integrated farming system (IFS) demo unit, L block, ZARS, GKVK, Bengaluru-65. Geographically situated in the Eastern Dry Zone (Zone-V) of Karnataka. The experimental site (GKVK, Bengaluru) is located between 13°08' N Latitude and 77°58' E Longitude at an altitude of 930 m above mean sea level (MSL).

The experimental site of the soil samples was collected at a depth of 0-20 cm by following specified technique. The methodologies adopted for analyzing soil physical, chemical parameters as well as values obtained are furnished in Table 1.

The soil of the experimental site was red sandy loam. The moisture content at field capacity was 25.94 per cent with a bulk density of 1.45 g cc^{-1}. The soil of the experimental site was slightly acidic in nature (pH 5.87) with medium electrical conductivity (0.37 dS m^{-1}) and organic carbon content was low (0.48%). Soil had low available nitrogen (264.2 kg ha^{-1}), high phosphorous (59.3 kg ha^{-1}) and medium potassium (201.5 kg ha^{-1}).

Table 1: Soil physical and chemical properties of the experimental site before sowing

Sl. No.	Particulars	Values	Methods employed

Physical properties (%)			
1	Sand	60.92	International pipette method (Piper, 1966)
2	Silt	26.06	
3	Clay	14.02	
4	Textural class	Sandy loam	
5	Field capacity (%)	25.94	Keen's cup method
6	Permanent wilting point (%)	7.51	(Piper, 1966)
7	Bulk density (g cc^{-1})	1.45	Core sampler method (Dastane, 1967)
Chemical properties			
1	Soil pH (1:2.5)	5.87	Potentiometric method (Piper, 1966)
2	Electrical conductivity (dS m^{-1})	0.37	Conductivity bridge (Jackson, 1973)
3	Organic carbon (%)	0.48	Walkely and Black (wet oxidation method) (Jackson, 1973)
4	Available nitrogen (kg ha^{-1})	264.2	Alkaline permanganate method (Subbiah and Asija, 1956)
5	Available phosphorus (kg ha^{-1})	59.3	Bray's method (Jackson, 1973)
6	Available potassium (kg ha^{-1})	201.5	Flame photometer method (Jackson, 1973)

Drip system installation

Drip system consisting of pump, filter units on main line and laterals with drippers for each plot were laid. Water was drawn through 7.5 HP motor from borewell followed to the main field using 90 mm PVC pipes after filtering *via* sand and screen filters. Water from the mains was delivered to the submains of 63mm diameter PVC pipes followed by 12 mm laterals which were fixed at 50 cm apart. Inline laterals with emitters were fixed at 40 cm with discharge rate of 4 lph.

The crop was raised by following University of Agricultural Sciences, Bangalore Package of Practices whereas, irrigation was provided as per the treatments. The experiment was conducted with two irrigation techniques *viz*., I_1: Irrigation as per conventional technique and I_2: Sensor based Irrigation. Later irrigation was managed by imposing the treatments as specified.

Sensor installation

Sensors were inserted at the soil depth of 15 cm and the setup is as follows

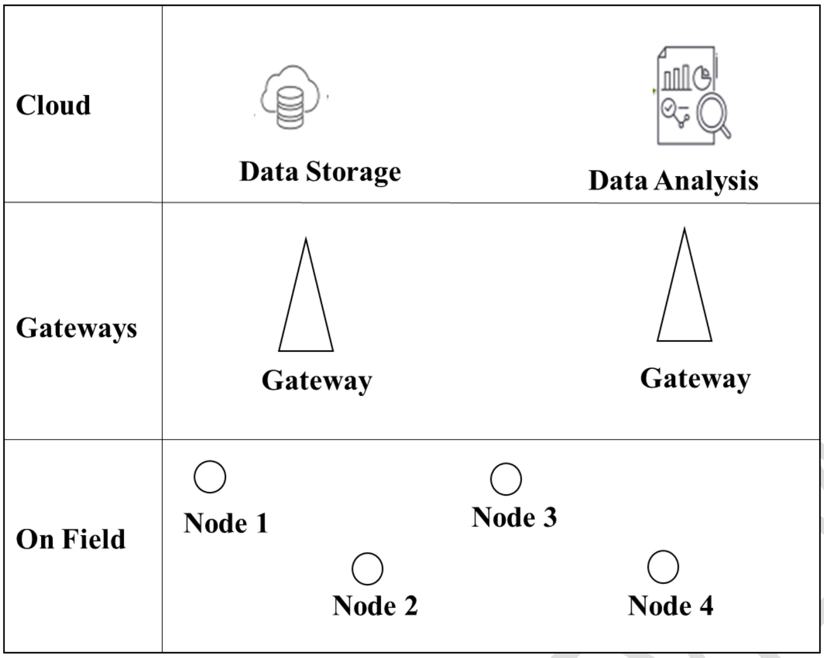


Fig. 1: Flow diagram showing set up of WSN system in the field

The operational Procedure of the set up;

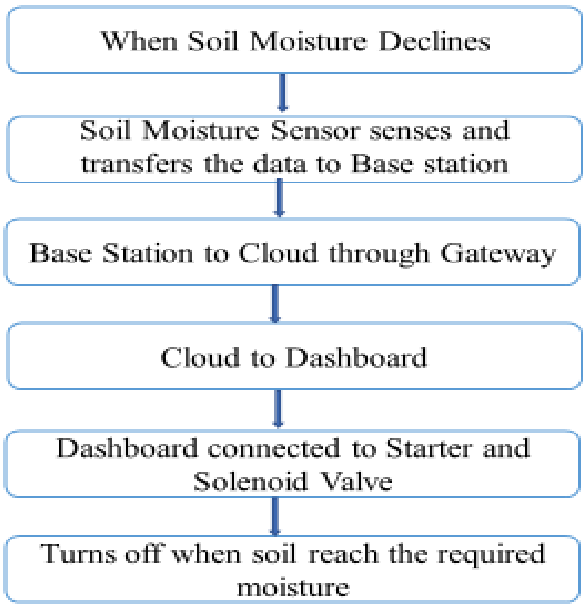


Fig. 2: Diagrammatic representation of operational procedure of sensors and automation system

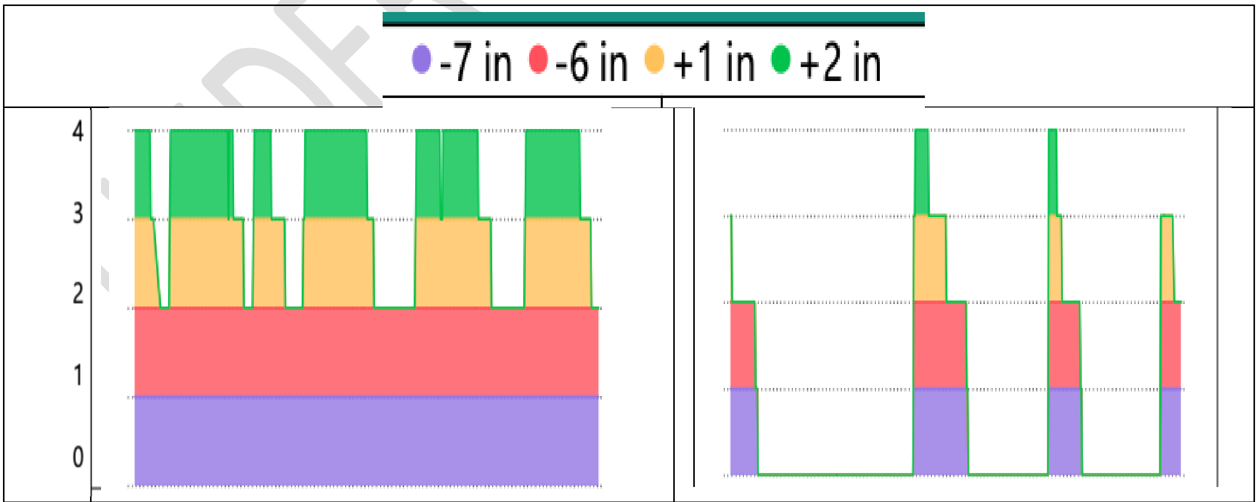
The crop performance was observed by following standard procedures. Water use efficiency (WUE) indicates the yield per unit water used and it was calculated from the yield of beans and the amount of water used by following the procedure outlined by Viets, (1972) and it is expressed in kg ha-cm^{-1}.

$$\textbf{Irrigation WUE} = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Irrigation water (ha-cm)}}$$

Results and discussion

Weather data prevailed during the period of crop growth had direct effect on growth and development of beans. Actual climatic conditions observed during the crop growth period were ranged from 25.9 - 28.4°C of average maximum temperature and average minimum temperature was ranged from 17.3-19.1°C. The normal mean sunshine hours varied from 4.4 to 9.6 hours and normal mean monthly relative humidity ranged from 77 to 89 per cent. The mean maximum and minimum wind speed were recorded in July and October months (6.7 and 3.5 km hr^{-1}, respectively). The open pan evaporation was maximum during July (4.4 mm) and minimum during September (3.1 mm). The weather prevailed during the experimental period was normal. Hence, more yield and quality crop was observed.

Amount of water used in both conventional and sensor based irrigation techniques are quantified along with the effective rainfall and which is presented in the Table 2 and real time moisture content in the soil is depicted in Fig.3.



	I_2- Sensor based irrigation	I_1- Conventional irrigation

Fig. 3: Soil Moisture content in real time

Table 2: Depletion of Available Soil Moisture (%) before irrigation and Water Irrigated (litres/200 sqmt)

Date of Irrigation	Sensor Based Irrigation through Drip		Date of Irrigation	Conventional Irrigation as per PoP	
	Soil Moisture before irrigation (%)	Water irrigated (lts/200 sq mt)		Soil Moisture before irrigation (%)	Water irrigated (lts/200 sq mt)
09/07/2021	12.40	3357	09/07/2021	12.40	3353
13/07/2021	24.52	2272	15/07/2021	16.56	4873
23/07/2021	23.92	2293	24/07/2021	15.12	4972
30/07/2021	22.44	2258	02/08/2021	15.36	4893
03/08/2021	21.38	2269	13/08/2021	14.92	5213
12/08/2021	21.40	2261	26/08/2021	15.12	4736
16/08/2021	22.18	2267	02/09/2021	15.26	4782
22/08/2021	22.54	2308	13/09/2021	15.22	4678
01/09/2021	22.51	2138	23/09/2021	13.28	5218
10/09/2021	23.33	2252	05/10/2021	14.10	4634
18/09/2021	22.97	2292	-	-	-
01/10/2021	23.14	1283	-	-	-
Total Water irrigated		**27250**			**47352**
Effective rainfall received in (Ha-cm)		**24.07**			**24.07**
Total Water Used in Ha-cm		**37.695**			**47.746**

Data pertaining to yield of beans, total water used, water use efficiency and water saved are presented in table 3.

Table 3: Yield, water used, Water use efficiency (kg ha-cm^{-1}) and water saved (%) as influenced by sensor based irrigation management in beans

Main plot	Yield (kg /ha)	Total water used (ha-cm)	WUE (kg ha-cm^{-1})	Water saved (%)
- Conventional irrigation	5865	47.746	122.83	-
- Sensor based irrigation	6972	37.695	184.96	26.66

Results indicated that, sensor based irrigation recorded significantly higher beans yield (6972 kg ha^{-1}) over conventional method of irrigation (5865 kg ha^{-1}). Adoption of sensor based irrigation enhanced crop yield by 18.87 per cent over conventional method.

This higher yield with sensor based irrigation was mainly due to maintenance of uniform moisture in the soil throughout the crop growth period by providing water at required time and quantity which helped in enhancing consistent cell division and expansion of leaf area. For prolonged photosynthetic activity persistence of assimilatory surface area is prerequisite. Similar results were noticed by Kalaydjieva*et al*. (2015) that optimum irrigation by the maintenance of "pre irrigation soil moisture" over 80 per cent of the field capacity (FC) (100% moisture) enhanced leaf area index over other treatments in french bean.

Bhattarai *et al*. (2005) found that aerated irrigation improved the root activity and root zone microbial activity which speeds up the absorption and utilization of soil nutrients thereby, enhances the growth of above ground part of crop. Proper irrigation can continuously enhance the accumulation of dry matter. Chaitra (2020) observed that sensor based irrigation at 25 per cent Depletion of Available Soil Moisture (DASM) in maize recorded significantly higher dry matter accumulation. Sensor based drip irrigation at 25 per cent depletion maintained adequate moisture and aeration throughout the crop growth which enhanced the yield attributing characters. The beans yield obtained were in accordance with Tajima (1995).

Conclusion

Total water used and water use efficiency gives relation between the assimilation, plant productivity per unit water used. Irrigation as per existing practice recorded higher usage of water (47.746 ha-cm) whereas, sensor based irrigation used lesser quantity (37.695 ha-cm). Similarly, sensor based irrigation recorded higher WUE (184.96 kg ha-cm^{-1}) over existing conventional method which recorded least WUE (122.83 kg ha-cm^{-1}). Due to the increase of the aerobic respiration level of the roots, the improvement of the water and fertilizer uptake efficiency of the rice was observed (Heuberger et al., 2001 and Nakano, 2007).

Adoption of sensor based irrigation helped in enhancing crop yield by 18.87 per cent apart saving water to the tune of 26.66 per cent over conventional method of irrigation.

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