J. Indian Soc. Coastal Agric. Res. 43(1):61-72(2025) https://doi.org/10.54894/JISCAR.43.1.2025.164509

Performance of Cost-effective Mini Pan Evaporimeter for Scientific Irrigation Scheduling

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Received: 05.02.2025 Accepted: 11.05.2025

Extensive research has been done to standardise the United States Weather Bureau (USWB) class A pan evaporation based irrigation scheduling in different crops worldwide.However, using the Class A pan evaporimeter for on-farm irrigation scheduling has certain drawbacks, such as its big size, high cost, and maintenance challenges. Additionally, the scarcity of Class A pan evaporation data jeopardises the adoption of this irrigation scheduling technique in farmers' fields. Keeping this in mind, a low cost, handy and simple mini evaporimeterwas developed and tested for irrigation scheduling in different crops at ICAR-Indian Institute Water Management, Bhubaneswar. Evaporation datafrom mini pan evaporimeters developed using galvanized iron (GI) sheet and PVC pipes with diameters of 10 cm, 20 cm, and 30 cm, and a height of 25 cm, were compared with Class A pan evaporation data. It was observed that the 30 cm GI mini pan had the highest coefficient of determination (R^2: 0.86-0.89) with the Class A pan, followed by the 20 cm GI mini pan evaporimeter (R^2: 0.80-0.87).Consequently, the performance of mini pan evaporimeters (30 cm and 20 cm GI mini pans) was evaluated for irrigation scheduling in summer (maize), *Kharif* (rice), and *Rabi* (tomato) seasons at Bhubaneswar, Odisha. The results revealed that the yield and yield attributes of the crops (maize, rice, and tomato) were not significantly (P>0.05) different under irrigation scheduling using mini pan and Class A pan. Mini pan evaporimeter with a diameter of 30 cm and a height of 25 cm may be recommended for on-farm irrigation scheduling in place of the USWB Class A pan evaporimeter.

(***Key words:*** *Irrigation scheduling, Maize, Mini pan evaporimeter, Rice, Tomato, USWB class A pan, Yield)*

Agriculture is a major consumer of global freshwater resources, accounting for approximately 70% of the world's freshwater withdrawals, primarily for crop irrigation (Ingrao *et al.,* 2023). Enhancing water-use efficiency in agriculture is essential to balance agricultural production, industrial and municipal demands and ecosystem functionality. Irrigation becomes indispensable when precipitation and/or stored soil moisture are insufficient to meet crop water demand. In India, per capita surface water availability was 2309 m³ in 1991 and 1902 m³ in 2001. These figures are projected to decrease further to 1401 m³ by 2025 and 1191 m³ by 2050 (Kumar *et al.,* 2005). To ensure future food and nutritional security, it is critical to develop strategies for increasing food production through more water-efficient techniques on the available land. In this context, scientific irrigation scheduling plays a pivotal role in helping farmers to utilize water resources effectively.

Irrigation scheduling involves determining the optimal timing and quantity of water to be applied to crops to enhance growth and productivity, while minimizing water usage. Several methods are available for irrigation scheduling, and the choice of the most suitable method depends on factors such as crop type, soil characteristics, climate, and the available resources and technology. Common methods of irrigation scheduling include soil moisture-based, weather-based, water budgeting (field water balance) approach and remote sensing (using satellite imagery, aerial imagery, and drones) approach (Gu *et al.,* 2020). Among different methods, USWB pan evaporation has been extensively used for standardising irrigation scheduling in different crops, due to the simplicity and easiness of data

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collection involved in this approach (Singh *et al.,* 2000; Yazar *et al.,* 2002; Panigrahi *et al,* 2010a; Pradhan *et al.,* 2013; Sharma *et al.,* 2021; Pejić *et al.,* 2021; Sharma *et al.,* 2023). However, due to certain drawbacks, such as its bigger size, higher cost, and maintenance challenges, the adoption of USWB pan has been limited in famers' fields (Torres, 1998). Moreover, the scarcity of Class A pan evaporation data for different locations led to the abandonment of this technique for irrigation scheduling by farmers. Further, ease of use and affordability of any technology are crucial from the perspective of small-scale farmers. Therefore, simple, handy and low cost devices have more scope for adoption in irrigation scheduling in farmers' fields, which may result in substantial water saving and higher water productivity compared with the present traditional irrigation scheduling in crops.

In recent past, research has been done to develop and evaluate evaporimeters for irrigation scheduling in different crops. Farias *et al.* (1994) evaluated a reduced pan (20 cm diameter and 25 cm height) for a plastic greenhouse in Brazil and found a strong correlation between evaporation from the reduced pan and both the Class A pan and Penman equation values. They concluded that the reduced pan could replace the larger and more expensive Class A pan. Liu and Costa (1998) compared evaporation from the 20 cm pan with reference evapotranspiration (ETo) calculated using the FAO Penman-Monteith method for the North China Plain. They reported that while daily pan evaporation was not sufficiently sensitive to rapid climatic changes, the results were acceptable when averaged over periods of 5, 7, or 10 days. Another study in China by Liu and Kang (2007) on irrigation scheduling for winter wheat using a small pan (20 cm diameter and 11 cm depth) reported that pan evaporation (Epan) was highly correlated with actual evapotranspiration (ET) measured using weighing lysimeters. The 20 cm pan has also been successfully used in specialized research, including drip irrigation scheduling for tomatoes in a greenhouse with non-controlled climatic conditions (Yuan *et al.,* 2001), potatoes in a rain-shelter house (Yuan *et al.,* 2003), and strawberries in plastic greenhouses (Yuan *et al.,* 2004). Oladele *et al.* (2020) utilized a small pan evaporimeter (24.5 cm diameter and 11 cm height) to measure evaporation in the hot tropical region of southwest Nigeria. They found that the inexpensive small pan could complement conventional pans, empirical ETo models, remote sensing, and other methods for quantifying evapotranspiration. Overall, the studies had revealed that the small pan evaporimeter has the scope to be used in irrigation scheduling. However, limited information is available on development and evaluation of mini evaporimeters for irrigation scheduling in a sub-humid tropical climate. Keeping this in mind, a study was conducted to design and develop a low cost, simple and handy evaporimeter for irrigation scheduling in different crops under a sub-humid tropical climate of India.

Accurate measurement of evaporation is essential for effective water management, particularly in agriculture. The USWB Class A pan is a widely accepted standard for measuring evaporation; however, its large size and high cost often limit its use in small-scale studies and resource-constrained regions. To address this, mini pan evaporimeters of varying sizes were developed using galvanized iron (GI) sheets and PVC pipes with diameters of 10 cm, 20 cm, and 30 cm, and a height of 25 cm at the Indian Council of Agricultural Research (ICAR)-Indian Institute of Water Management (IIWM), Bhubaneswar, Odisha, India. These mini pan evaporimeters were installed at the ICAR-IIWM research farm in Bhubaneswar, Odisha, and evaporation data were recorded across the summer, *Kharif*, and *Rabi* seasons. The performance of these mini pan evaporimeters was evaluated by comparing their evaporation data with that of the standard USWB Class A pan. Regression analysis revealed that among the mini pans tested, the 30 cm GI mini pan exhibited the highest correlation coefficient (0.86-0.89) with the Class A pan, indicating strong agreement, followed by the 20 cm GI mini pan (0.80-0.87) (Manikandan *et al.,* 2020).

However, using a mini pan evaporimeter without its proper validation in irrigation scheduling under field conditions may lead to inaccurate results.The present experiment was therefore conducted to evaluate the performance of the mini pan evaporimeter for irrigation scheduling in maize (summer), rice (*Kharif*), and tomato (*Rabi*) in comparison to class A pan evaporation-based irrigation scheduling in the crops under a sub-humid tropical climate of eastern India. The hypothesis of the experiment points that there will be an insignificant difference in water use, soil moisture storage and yield of the crops under irrigation scheduling based on the developed mini pan evaporimeter and the USWB Class A pan evaporimeter.

MATERIALS AND METHODS

The detail of design, development and calibration of mini evaporimeter is available in Manikandan *et al.* (2020). The study was conducted to develop a low-cost, easy-to-use, small-sized evaporation pan for on-farm irrigation scheduling. Mini pans made of GI and PVC with diameters of 30 cm, 20 cm, and 10 cm (height 25 cm) were evaluated. Regression analysis showed that GI mini pans of 30 cm and 20 cm diameter had the closest agreement with the USWB Class A pan. Significant differences were observed between PVC and GI pans due to their thermal and radiative properties. Evaporation measured at 3-day intervals showed no significant difference from daily values, making it suitable for practical use in irrigation scheduling. Based on the conclusion of Manikandan *et al.* (2020), mini pan evaporimeters with diameters of 30 cm and 20 cm were selected for irrigation scheduling in maize, rice and tomato at research farm of ICAR-IIWM, Bhubaneswar during the summer, *Kharif* and *Rabi* of 2020-21, respectively.

The pH and electrical conductivity (EC) of the initial soil samples of the experimental field were determined using potentiometric methods. Soil organic carbon was measured by the Walkley-Black chromic acid wet oxidation method. Available nitrogen (N) was estimated using the alkaline potassium permanganate method, while available phosphorus (P) was determined using Bray's method. Available potassium (K) was measured by the flame emission method. Bulk density was determined using the core method, and soil texture by Bouyoucos hydrometer method. During the experimental period, periodic soil moisture was measured using the gravimetric method through soil sampling at different depths. The soil at the site is classified as sandy clay loam (*Aeric Haplaquepts*) in texture. The soil is slightly acidic, with a pH range of 5.12-5.69, and non-saline, with an EC range of 0.037-0.069 dSm^{-1}.The basic soil properties of the experimental site are presented in Table 1.

Irrigation scheduling and cultural operations for Maize

The effects of irrigation scheduling based on mini pan evaporation and Class A pan evaporation on crop yield was studied in maize, rice and tomato during summer, *Kharif* and *Rabi*, respectively. The maize crop [cv. Nilesh (NMH 51)] was planted during the summer season in 5 m × 5 m plots with a spacing of 60 cm × 30 cm. The fertilizer dose applied in maize was 150:60:60 ($N:P_2O_5:K_2O$). Nitrogen fertilizer was applied in three splits: 50% at basal, 25% four weeks after sowing, and 25% at the flowering stage. Phosphorus (P) and potassium (K) fertilizers were applied as a basal dose at planting. The sources of N, P, and K fertilizers were urea, Single Super Phosphate, and Muriate of Potash, respectively.

Table 1. *Basic soil properties of experimental site*

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH (1:2.5)	EC (dS m^{-1})	Organic carbon (OC, %)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Bulk density (Mg m^{-3})
0-15	56.5	19	24.5	Sandy Clay Loam	5.12	0.066	0.597	212.16	12.6	127.4	1.56
15-30	58.5	17	24.5	Sandy Clay Loam	5.24	0.069	0.483	188.74	8.77	118.1	1.61
30-60	53.5	16	30.5	Sandy Clay Loam	5.46	0.043	0.341	168.47	2.19	90.0	1.70
60-90	43.5	16	40.5	Clay	5.69	0.037	0.256	154.86	1.53	61.94	1.74

The treatments (T_1: Irrigation scheduling based on a 30 cm mini pan; T_2: Irrigation scheduling based on a 20 cm mini pan; T_3: Irrigation scheduling based on the USWB Class-A pan) were arranged in a randomized complete block design with seven replications. To determine the leaf area index (LAI) of maize, a 5 × 5 cm² leaf sample was cut from representative plants, oven-dried, and weighed to calculate the specific leaf area, which was used to compute the total leaf area. The remaining leaves were also oven-dried and weighed. The leaf area on a hectare basis was derived from the plant population, and LAI was calculated by dividing the total leaf area by the land area. The cob yield and stover yield were recorded following standard procedures. All other management practices were carried out as per the recommendations for the site.

Irrigation scheduling for maize was performed at IW/CPE value of 1.0, as recommended by Mohapatra *et al.* (2016). For treatments T_1 and T_2, conversion factors of 1.30 and 1.58 (for the summer season) were used to calculate the cumulative pan evaporation values in 30 cm and 20 cm mini pan evaporimeters, respectively. The conversion factor was calculated on a daily basis by dividing the evaporation measured from the USWB Class A pan evaporimeter by the evaporation recorded from the mini pan evaporimeters (30 cm and 20 cm diameter). Subsequently, the seasonal average values of the conversion factor were computed for *Kharif*, *Rabi*, and summer seasons (Table 2). For the T_3 treatment, an IW/CPE ratio of 1.0 and irrigation water of 50 mm were used, whereas irrigation in T_1 and T_2 was scheduled when the cumulative pan evaporation values reached 65 mm and 79 mm, respectively. The volume of water required for each plot was calculated by multiplying area (m^2) of the plot with depth (m) of irrigation. The quantity of water applied to each plot was regulated by measuring the discharge of pump from time to time and determining time of irrigation.

Table 2. *Conversion factors from mini pan evaporimeter to USWB Class A Pan for different seasons)*

Diameter of mini-pan	*Kharif*	*Rabi*	Summer
20 cm	1.60	1.67	1.30
30 cm	2.10	2.20	1.58

Irrigation scheduling and cultural operations for Rice during *Kharif* season

During *Kharif* season, the rice crop (cv. Pooja and Swarna) was transplanted in 5 m × 5 m plots with a spacing of 20 cm × 15 cm. The treatments [T_1: Irrigation scheduling based on a 30 cm mini pan; T_2: Irrigation scheduling based on a 20 cm mini pan; T_3: Irrigation scheduling based on the USWB Class-A pan; T_4: Irrigation scheduling based on 3 days after the disappearance of ponded water (DAD) as suggested by Thakur *et al.* (2010); and T_5: Control (rainfed)] were laid out in a randomized complete block design with four replications. Recommended management practices were followed for raising the crop in the field. The fertilizer dose applied was 80:40:40 ($N:P_2O_5:K_2O$). Nitrogen fertilizer was applied in three splits: 50% at land preparation, 25% at the tillering stage, and 25% at the flowering stage. Phosphorus (P) and potassium (K) fertilizers were applied as a basal dose at transplanting. The sources of N, P, and K fertilizers were urea, Single Super Phosphate, and Muriate of Potash, respectively. The residual soil moisture storage for the depth of 0–60 cm was determined using the gravimetric method at harvest. All plants in a 5 m × 5 m area for each replicate (excluding the border rows) were harvested to determine yield per unit area, and grain yield was adjusted to 14.5% seed moisture content. All other management practices followed were as per the recommendations for the site. Irrigation scheduling for treatments from T_1 to T_3 was performed using the IW/CPE ratio of 3 (Haindavi *et al.,* 2018). The value of irrigation water (IW) was set at 60 mm, and irrigation for the T_3 treatment was provided when the cumulative pan evaporation value reached 20 mm in the Class-A pan. For treatments T_1 and T_2, conversion factors of 1.60 and 2.10 (for the *Kharif* season) were used to calculate the cumulative Class-A pan evaporation values equivalent to 32 mm and 42 mm for 30 cm and 20 cm mini pan evaporimeters, respectively. For treatment T_4, an initial 70 mm of water was applied to the respective plots, followed by irrigation 3 days after the disappearance of ponded water from the field.

Irrigation scheduling and cultural operations for tomato during *Rabi* season

During *Rabi* season, tomato crop (cv. Swaraksha) was transplanted in the plots of size 10 m × 4 m with a spacing of 75 cm × 50 cm. The treatments [T_1: Irrigation scheduling based on a 30 cm mini pan; T_2: Irrigation scheduling based on a 20 cm mini pan; T_3: Irrigation scheduling based on the USWB Class-A pan] were laid out in a randomized complete block design with seven replications. Farmyard manure (FYM) was applied at the rate of 25 t ha^{-1}. The fertilizer dose applied was 200:50:100 ($N:P_2O_5:K_2O$). All other management practices were followed as per the recommendations for site. Irrigation scheduling was conducted at an IW/CPE ratio of 1 with an irrigation water depth of 50 mm (Panigrahi *et al.,* 2010b). For the USWB Class-A pan evaporimeter, the cumulative pan evaporation was 50 mm. For the 30 cm and 20 cm mini pan evaporimeters, the cumulative pan evaporation values were 84 mm and 110 mm, respectively, with conversion factors of 1.67 and 2.20 for the *Rabi* season.

The residual soil moisture storage for the 0-60 cm depth was determined through gravimetric sampling at harvest. A net plot area of 25 m^2 for each replicate was harvested (excluding the border rows) to determine yield per unit area in rice and maize crops. Grain yield was adjusted to 14.5% seed moisture content for both the crops. Soil moisture sampling in the root zone (0-60 cm) was conducted at frequent intervals using the gravimetric method to evaluate the effects of irrigation treatments on soil moisture storage. Plant height, the number of branches and fruits per plant, and tomato yield were recorded.

All data were analyzed statistically using analysis of variance (ANOVA). The effects of the treatments were determined using F-test, and least significant differences (LSD) between the means of treatments at the 5% probability level were calculated.

RESULTS AND DISCUSSION

Irrigation scheduling effects in maize during summer season

All three treatments (T_1-T_3) of the maize crop were irrigated four times during the growing period. The leaf area index (LAI) of maize varied from 2.49 to and 2.55 in different treatments (Fig. 1). Similarly, maize cob yield and above-ground biomass ranged from 4.06 to 4.08 t ha^{-1} and from 6.93 to 7.35 t ha^{-1}, respectively (Fig. 2). The LAI, cob yield, and above-ground biomass of maize were not significantly affected by irrigation scheduling based on the IW/CPE ratios of the three pan evaporimeters. Profile soil moisture storage (0-90 cm) at different growth stages was monitored and is presented in Fig. 3. The profile moisture storage in treatments T_1, T_2, and T_3 ranged from 100.44 to 217.62 mm, 104.63 to 188.71 mm, and 103.23 to 197.47 mm, respectively, within the 90 cm soil depth. The profile moisture storage was not significantly ($p \geq 0.05$) different among the treatments (Fig. 3). This may be attributed to the equal amounts of water applied and, consequently, similar plant growth across the treatments.The results revealed that the performance of the maize crop under irrigation scheduling using mini pan evaporimeters was comparable to that of the USWB Class A pan. The study conducted by Torres (1998) in Colombia clearly indicated that three irrigations applied to sugarcane using a small-sized pan evaporimeter (30 cm diameter and 40 cm height) resulted in higher cane yield (147 t ha^{-1}) and sugar yield (16.7 t ha^{-1}), which were at par with the yields obtained under daily and bi-weekly water balance–based irrigation scheduling using the USWB pan. Oladele *et al.,* (2020) also successfully employed mini pan evaporimeter (24.5 cm diameter and 11 cm height) in Nigeria for scheduling irrigation in maize and tomato crops, and emphasized the usefulness of this evaporimeter over conventional USWB class A pan. This substitution was attributed to the similar influence of maximum temperature and mean relative humidity on evaporation rates. In our study, comparable evaporation rates were observed between the mini pan evaporimeters and the USWB Class A pan. This consistency in evaporation rates resulted in equivalent water usage across irrigation schedules determined by the different evaporimeters, ultimately leading to similar LAI values and maize yields.

Irrigation scheduling effects in rice during *Kharif* season

During the *Kharif* season, in both the varieties, six irrigations of 60 mm each was applied in T_1, T_2, and T_3, whereas in T_4, six irrigations of 70 mm depth was applied. The highest water use was 928 mm in Pooja and 998 mm in Swarna under T_4 treatment, whereas the lowest water use (508 mm) was found in T_5 (control, rainfed) treatment. The water use under T_1, T_2, and T_3 was 868 mm. The yield attributes (panicles m^{-2}, panicle length, grains per panicle, and 1000-grain weight) along with the yield of the two rice

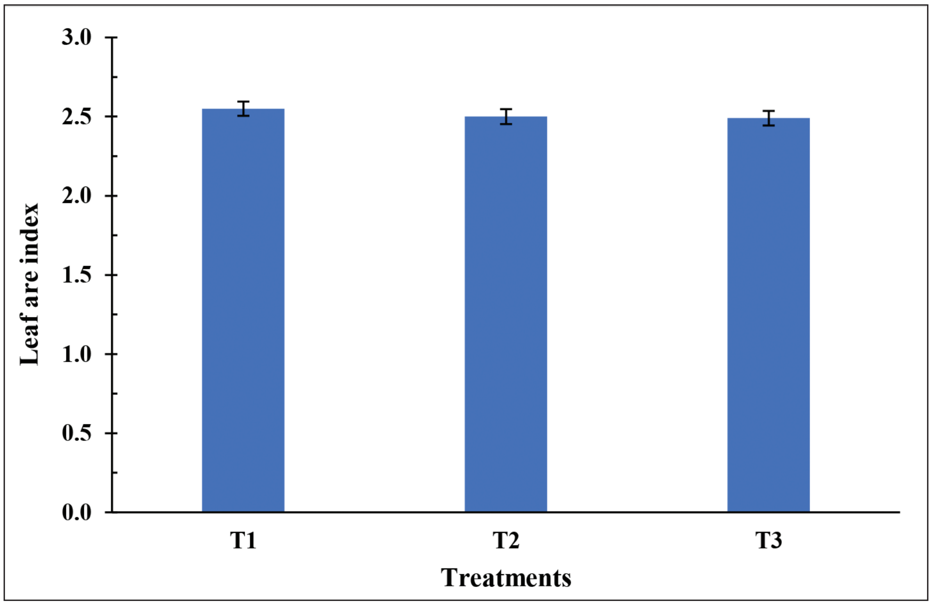

Fig.1. LAI of maize at flowering stage under different irrigation treatments (T_1: Irrigation scheduling based on 30 cm mini pan; T_2: Irrigation scheduling based on 20 cm mini pan and T_3: Irrigation scheduling based on USWB Class-A pan)

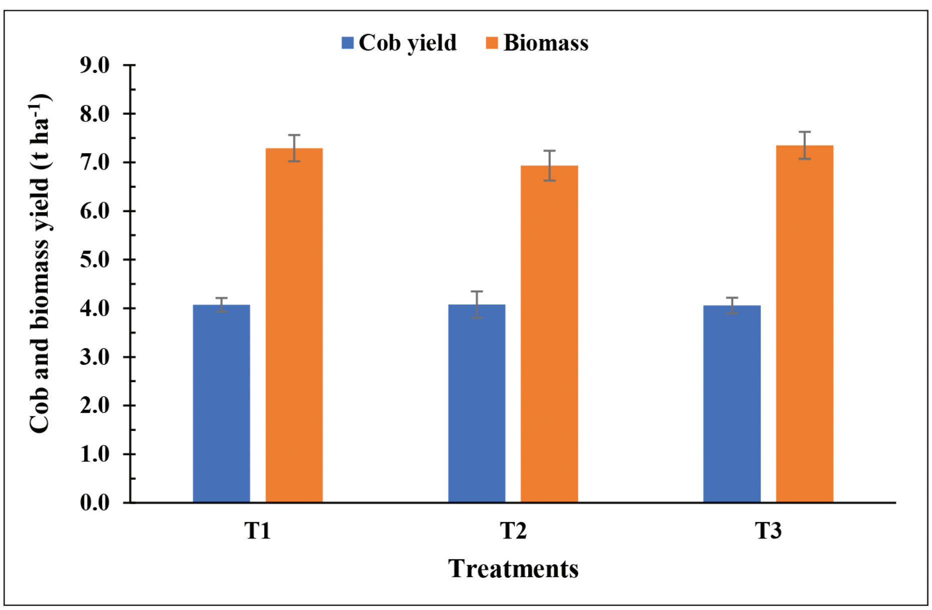

Fig.2. Above ground biomass and cob yield of maize under different irrigation treatments (T_1: Irrigation scheduling based on 30 cm mini pan; T_2: Irrigation scheduling based on 20 cm mini pan and T_3: Irrigation scheduling based on USWB Class-A pan)

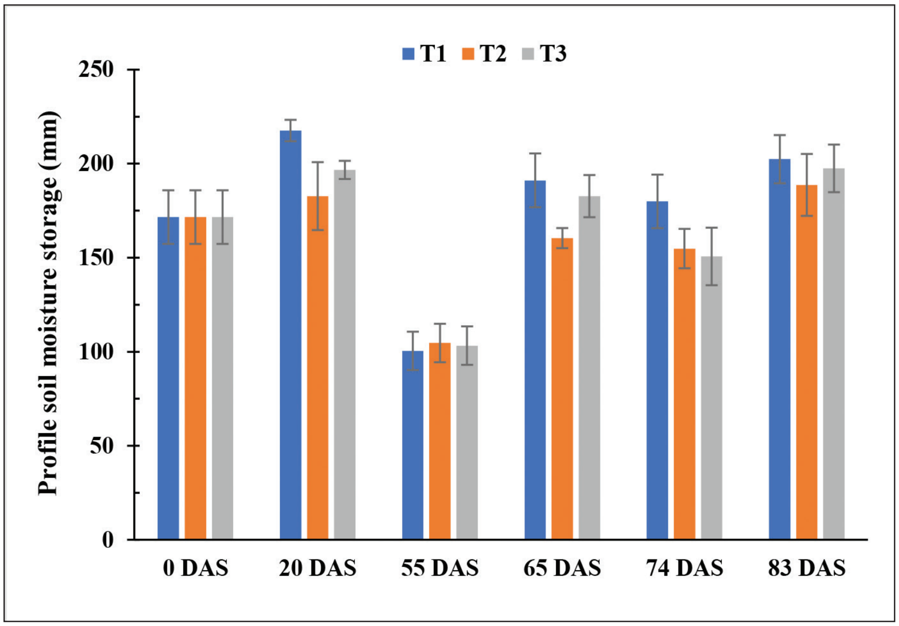

Fig.3. Profile soil moisture in maize under different irrigation treatments (T_1: Irrigation scheduling based on 30 cm mini pan; T_2: Irrigation scheduling based on 20 cm mini pan and T_3: Irrigation scheduling basedon USWB Class-A pan)

cultivars are presented in Table 3. For Pooja, the rice grain yield varied between 2.70 t ha^{-1} (T_5) and 4.83 t ha^{-1} (T_1), and the straw yield varied between 5.40 t ha^{-1} (T_5) and 8.03 t ha^{-1} (T_3). For Swarna, the rice grain yield varied between 2.93 t ha^{-1} (T_5) and 5.35 t ha^{-1} (T_1), and the straw yield varied between 5.73 t ha^{-1} (T_5) and 8.90 t ha^{-1}(T_3).

The yield and yield attributes of Pooja and Swarna rice varieties were statistically at par among the irrigation treatments based on different pan evaporimeters (T_1 to T_3) and 3 DAD (T_4). This can be attributed to the nearly equal amount of water applied under different treatments from T_1 to T_4. However, the T_5 treatment (control or rainfed) showed significantly ($P < 0.05$) lower yields and yield attributes compared to the other treatments. The lower yield was attributed to shorter panicles with fewer grains, poor grain filling, and a significant decrease in grain weight of rice in the T_5 treatment.

The residual soil moisture storage (0-60 cm depth) taken at harvest varied from 139.50 to 178.60 mm and from 135.80 to 191.60 mm among the treatments under Pooja and Swarna cultivars, respectively (Fig. 4). The soil moisture storage in the T_5 treatment was significantly lower compared to all other treatments under both the cultivars. However, among the treatments from T_1 to T_4, the residual soil moisture storage was statistically at par in Pooja and Swarna cultivars. Hence, the results clearly indicated that the yield and yield parameters of the rice crop did not vary significantly between irrigation schedules based on mini pan evaporimeters and the USWB Class A pan. Studies conducted to compare the performance of pan evaporimeter (10.3 cm diameter and 14 cm height) with Class A pan evaporimeter in wheat crop at New Delhi (Sharma and Dastane, 1969) and in rice crop (during summer and monsoon seasons) at Coimbatore (Iruthayaraj and Morachan, 1978) concluded that the growth and yield performance of the crops under both the methods of irrigation were statistically at par. Liu and Kang (2007) used mini pan evaporimeterof 20 cm diameter for winter wheat irrigation scheduling (sprinkler) in China and reported that this pan was handy and effortlessly used for irrigation scheduling.

Irrigation scheduling effects in tomato during *Rabi* season

During *Rabi* season, tomato crop was irrigated five times under all three treatments (T_1-T_3). The plant height varied from 64.23 to 68.64 cm in different treatments (Fig. 5). Similarly, the tomato yield varied from 17.80 to 20.12 t ha^{-1} in different treatments (Fig. 6). Both the plant

Table 3. *Yield and yield parameters of Pooja and Swarna variety of rice under different treatments*

Yield attributes	Irrigation based on 30 cm mini pan		Irrigation based on 20 cm mini pan		Irrigation based on USWB Class A pan		Irrigation based on 3 DAD		Control	
	Pooja	Swarna	Pooja	Swarna	Pooja	Swarna	Pooja	Swarna	Pooja	Swarna
Panicles m^{-2}	375a	380A	370a	377A	365a	371A	359a	367A	259b	264B
Panicle length (cm)	23.3a	24.3A	22.7a	23.7A	23.0a	25.0A	22.3a	23.3A	21.2b	21.6B
Grains per panicle	85a	89A	79a	84A	80a	85A	79a	86A	62b	68B
1000 grains weight (g)	19.2a	21.2A	18.9a	20.7A	19.1a	20.8A	18.8a	20.6A	17.1b	18.3B
Grain yield (t ha^{-1})	4.83a	5.35A	4.73a	5.20A	4.78a	5.28A	4.55a	5.05A	2.70b	2.93B
Straw yield (t ha^{-1})	7.95a	8.80A	7.93a	8.68A	8.03a	8.90A	7.48a	8.33A	5.40b	5.73B
Water used (mm)	868	928	868	928	868	928	928	998	508	508

Rows marked by small letters are not significantly different at $p > 0.05$ in Pooja
Rows marked by capital letters are not significantly different at $p > 0.05$ in Swarna

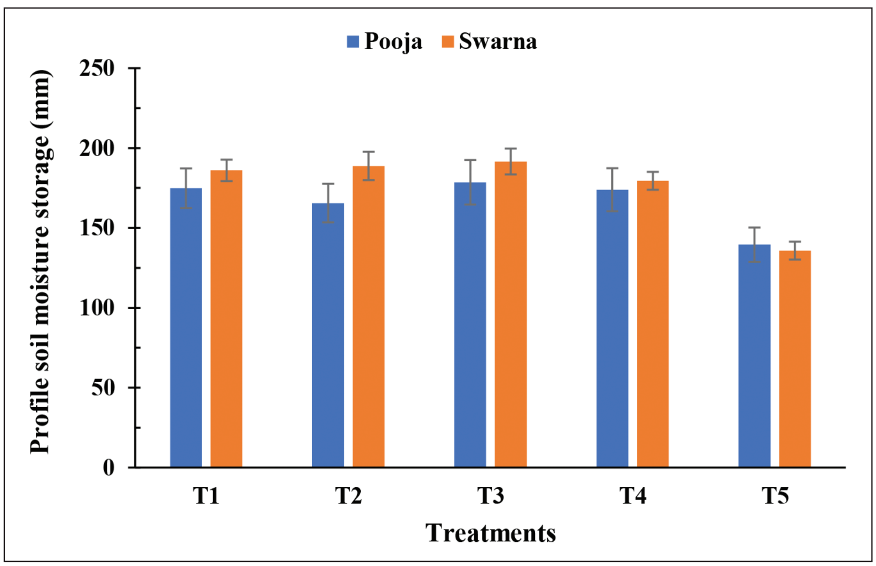

Fig. 4. Residual profile soilmoisture of Pooja and Swarna under different irrigation treatments [T_1: Irrigation scheduling based on 30 cm mini pan; T_2: Irrigation scheduling based on 20 cm mini pan; T_3: Irrigation scheduling based on USWB Class-A pan; T_4: Irrigation scheduling based on 3 days after disappearance of ponded water (DAD) and T_5: Control (Rainfed)]

height and yield of tomato were statistically at par under the three treatments. The profile soil moisture values in T_1, T_2, and T_3 were 154.26-188.81 mm, 158.84-184.05 mm and 160.80-200.97 mm, respectively, within the 60 cm soil depth. The profile soil moisture data was not significantly different ($p \geq 0.05$) among the treatments (Fig. 7). This can be attributed to equal amount of water application, keeping other factors constant, which resulted in similar plant growth in the treatments. Earlier, the 20 cm mini pan has been satisfactorily used for the estimation of ET with locally calibrated pan coefficients and for irrigation scheduling of tomato crops in unheated

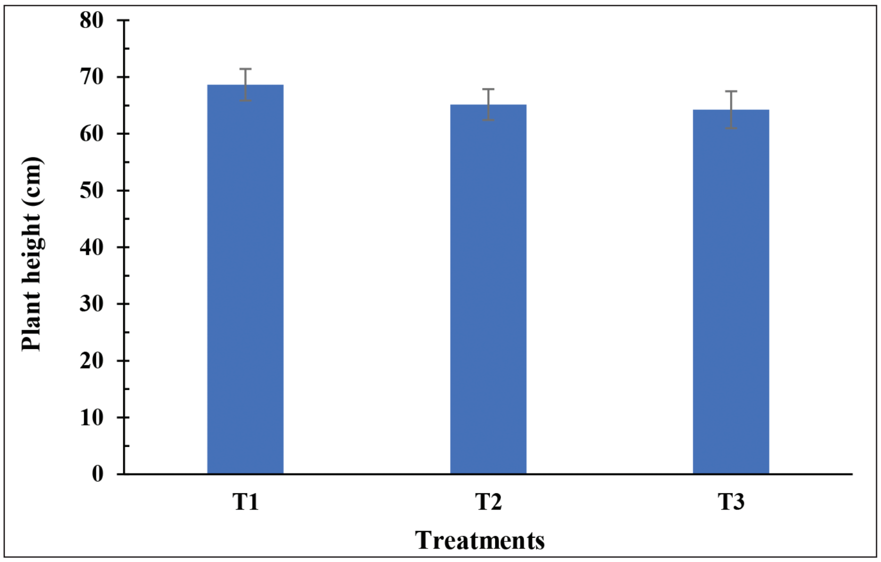

Fig. 5. Plant height of tomato plants as affected by different irrigation treatments (T_1: Irrigation scheduling based on 30 cm mini pan; T_2: Irrigation scheduling based on 20 cm mini pan; T_3: Irrigation scheduling based on USWB Class-A pan)

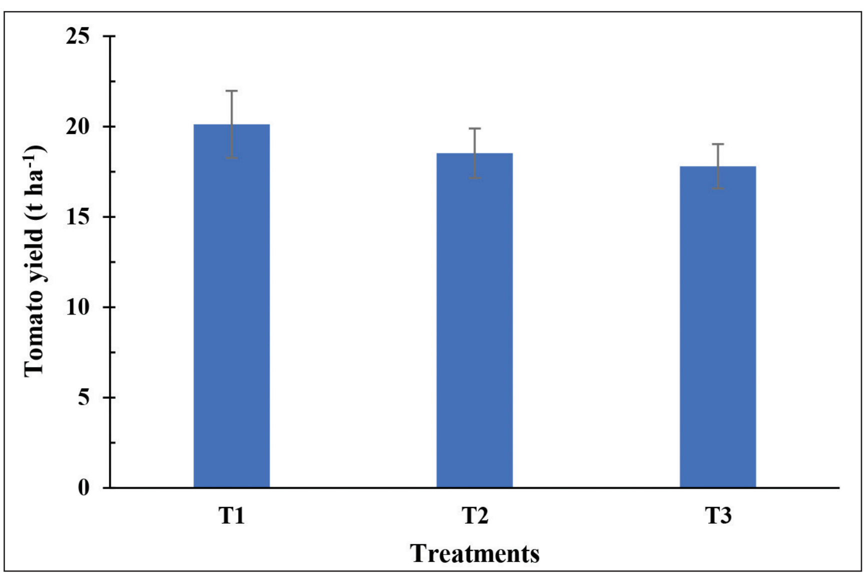

Fig. 6. Tomato yield as affected by different irrigation treatments (T_1: Irrigation scheduling based on 30 cm mini pan; T_2: Irrigation scheduling based on 20 cm mini pan; T_3: Irrigation scheduling based on USWB Class-A pan)

greenhouses (Yuan *et al.,* 2001) and solar greenhouses (Liu *et al.,* 2013). Similarly, Oladele *et al.* (2020) used small pan evaporimeters (24.5 cm in diameter and 11 cm in height) for the estimation of ET and irrigation scheduling of tomato crops under poly-covered houses and open-field conditions. Our results also revealed that the performance of the tomato crop under the IW/CPE irrigation schedule with mini pan evaporimeters was at par with that under the USWB Class A pan.

CONCLUSION

The study revealed that the yield and yield attributes of maize, rice, and tomato crops grown in different seasons of the year were not significantly different with irrigation scheduling under mini pan evaporimeters compared to the USWB Class A pan evaporimeter. Due to higher efficacy, low cost, handy and simplicity in use, the mini evaporimeter made up of galvanised iron sheet (20 gauge thickness) with 25 cm height and 30 cm diameter can be used effectively in irrigation scheduling of the crops. This will guide the on-farm management of irrigation water more precisely, resulting in substantial water saving, higher yield and improved water productivity compared to traditional irrigation scheduling in farmers' fields.

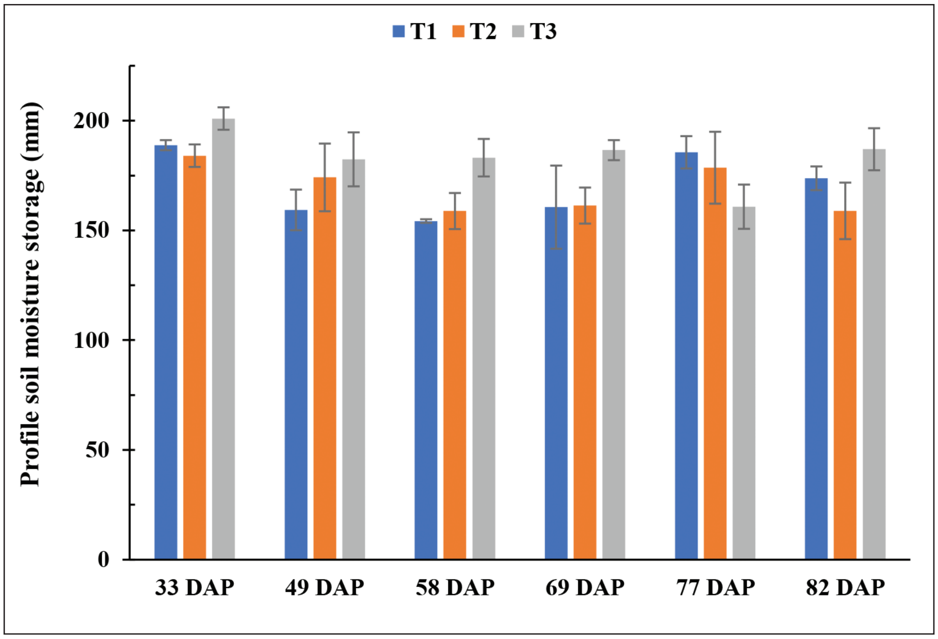

Fig.7. Profile soil moisture in tomato under different treatments (T_1: Irrigation scheduling based on 30 cm mini pan; T_2: Irrigation scheduling based on 20 cm mini pan; T_3: Irrigation scheduling based on USWB Class-A pan)

ACKNOWLEDGEMENT

The authors sincerely thank the ICAR for providing the financial support necessary to conduct this experiment. We also extend our gratitude to the field and laboratory staff for their invaluable assistance in collecting observations.

CONFLICTS OF INTEREST

This research was funded by ICAR, but the funder had no role in the design of the study, data collection, analysis, interpretation, or writing of the manuscript. The authors declare no other conflicts of interest.

Data availability

The data supporting the findings of this study are not publicly available due to proprietary restrictions.

However, they can be accessed from the corresponding author upon reasonable request, subject to approval.

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