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Estimation of Crop Water Requirement of Pineapple (*Ananas comosus* (L.) Merr.) for Drip Fertigation

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ABSTRACT

The experiment was conducted at the research farm of ICAR- Central Coastal Agricultural Research Institute, Goa, India during 2016–2019 to estimate the crop water requirement (CWR) of pineapple during different growth stages and compare the pineapple crop performance and economic viability at different irrigation systems. Crop water requirement of pineapple was calculated based on the consolidated weather data of 14 years and crop evapotranspiration (ET_c) of pineapple at different growth stages using Penman-Montieth equation using CROPWAT 8.0 software. In the experiemtal location, maximum crop evapotranspiration was found in the month of May (81 mm month^{-1}) and the minimum was in the month of July (25 mm month^{-1}). Crop water requirement was the highest in April (0.67 litre day^{-1} plant^{-1}). During the period of monsoon, irrigation was withdrawn due to sufficienct soil moisture situation. Performance of pineapple crop under different systems of irrigation viz., surface irrigation, drip irrigation and drip fertigation was studied and found that the highest plant height (76.90 cm), D leaf width (5.45 cm), number of leaves (43), D leaf weight (150.3 g) and fruit weight (2.35 kg) were in drip fertigation. An estimated yield of 96.80 t ha^{-1} was recorded under drip fertigation treatment followed by drip irrigation (90.99 t ha^{-1}) and surface irrigation (76.45 t ha^{-1}) treatments. The cost economics analysis of pineapple production under different treatments revealed that the highest gross returns (₹ 14.5 lakhs), net returns (₹ 7.9 lakhs) and B:C ratio (1.2) were in drip fertigation treatment. Adoption of drip fertigation system in pineapple crop under west coast agro-climatic conditions of Goa is helpful to enhance the crop growth and yield of pineapple and fetch good economic returns.

KEYWORDS: CWR, pineapple, surface irrigation, drip irrigation, fertigation

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Pineapple (*Ananas comosus* L. Merr.) is a tropical fruit crop with xerophytic adaptations. India is the fifth largest producer of pineapple with 0.11 mha hectares area and 17.99 mt production with a productivity of 16.8 t ha^{-1} (Anonymous, 2020). The largest area under pineapple production is in Assam (0.017 mha) followed by Manipur (0.014 mha). The highest production is in West Bengal (0.32 mt) followed by Assam (0.300 mt). The highest productivity of pineapple is in Karnataka (58.9 t ha^{-1}) followed by West Bengal (29.5 t ha^{-1}). North-eastern hills and west-coast plains are the important pineapple growing tracts of India. It is one of the best intercrop in coconut and arecanut based multitier cropping systems of west coast of India (Priya Devi et al., 2013). Pineapple is planted in May-June and mainly cultivated as a rainfed crop in India. An average rainfall of 3000 mm is obtained in Goa during south-west monsoon which is followed by water scarcity period from November to May. Hence irrigation is recommended to pineapple during summer months. Minimum precipitation of 1000 to 1500 mm year^{-1} (Huang and Lee, 1969) or 80 to 100 mm month^{-1} (Py et al., 1987) is required for pineapple during the growth and development stages. Though it has several drought tolerant mechanisam, such as sunken stomata, wax coated spiny leaves and deep root systems, irrigation is required in pineapple beyond five per cent or less soil moisture level (Shiroma, 1971). Neild and Boshell (1976) recommended irrigation to pineapple in areas with rainfall less than 500 mm year^{-1}. According to de Almeida and Reinhardt (1999), irrigation in rainfed pineapple crops is required when the rain is consecutively less than 15 mm for three months or less than 25 mm for four months or less than 40 mm for five months. Minimum monthly rainfall required by pineapple is 80 to100 mm and if, annual rainfall is less than 500 mm, irrigation is necessary (de Almeida et al., 2002). For the maximum growth of pineapple, evenly distributed rainfall (or irrigation) of 600 mm per year is essential (Evans et al., 2002). Irrigation water quantity, quality (Guimaraes et al., 2016; Brito et al., 2017) and method of irrigation influences the photosynthetic efficiency of pineapple (Souza et al., 2012; Maia et al., 2016). The high photosynthetic efficiency of pineapple is due to the Crassulacean Acid Metabolism (CAM) (Zhang et al., 2014; Couto et al., 2016).

Micro-irrigation with driplines, sprinklers or microjets can save water and avoid soil erosion in slopes where pineapple is grown usually. In water scares regions; drip irrigation, micro- jets or overhead sprinklers can be advised for pineapple production (Carr, 2012). According to Ojeda et al. (2012), drip irrigation in pineapple enhances growth in pineapple and reduces the cost of weed management and fertilizer application. Fertigation can overcome the limitations of sprinkler and such as weed management and manual fertilizer application. This method improves absorption of nutrients, reduces leaching losses, increase nutrient accumulation (Amaral et al., 2014) and enhance nutrient use efficiency (Rajan et al., 2014; Santos et al., 2015; Mota et al., 2016). In pineapple, N and K fertilizers have great effect in improving growth and yield (Pereira et al., 2012; Alves et al., 2013). To schedule N and K fertigation, water requirement during the growth period must be calculated. Thus, this study aimed to estimate the crop water requirement of pineapple during different growth stages and compare the pineapple crop performance and economic viability under various irrigation systems in Goa.

2. MATERIALS AND METHODS

2.1. *Crop water requirement of pineapple*

Crop evapotranspiration of pineapple was calculated by Penman-Montieth equation using CROPWAT 8.0 software developed by Food and Agricultural Organization (FAO). Fourteen years of weather data from 2003 to 2016 of the meteorological observatory of ICAR CCARI, Goa was used to calculate the evapotranspiration (ET_0) of the experimental plot (Figure 1). The crop evapotranspiration was calculated by the formula provided below.

$ETc = ET_0 \times Kc$

where:

ETc=Crop evapotranspiration (mm)

ET_0=Reference evapotranspiration (mm)

Kc=Crop coefficient (Kc_{ini} pineapple =0.5; Kc_{mid} pineapple =0.3, Kc_{late} pineapple=0.3 (Allen et al., 1998)

2.2. *Effective rainfall*

In this study, the USDA method approach available in the CROPWAT 8.0 model was used to estimate daily and monthly rainfall. Rainfall of the study area ranged from 0.5 to 224 mm. The mean monthly rainfall and effective rainfall of the experimental location is shown in Figure 2.

The volume of water applied per plant was calculated using the formula provided below.

$V=(ET_c - Er) \times r^2/e$

where:

V-Volume of water applied per plant (litres); ETc -Crop evapotranspiration (mm); Er -Effective rainfall (mm); r -wetted radius (m); Wetted area (A) = r^2 (r=30 cm; half of spacing of the crop); e-Efficiency of irrigation system (Surface Irrigation-40% and drip system-90% (Sivanappan et al., 1998).

2.3. *Total water requirement of the field*

The total irrigation water requirement of the pineapple field through the drip system was calculated by multiplying the

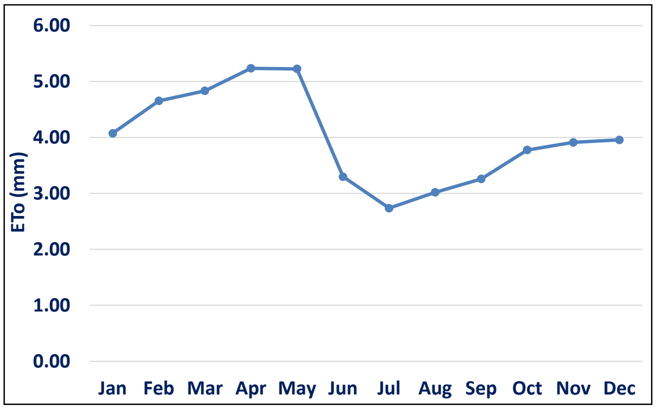

Figure 1: Consolidated mean monthly evapotranspiration of the study area (ET_0)

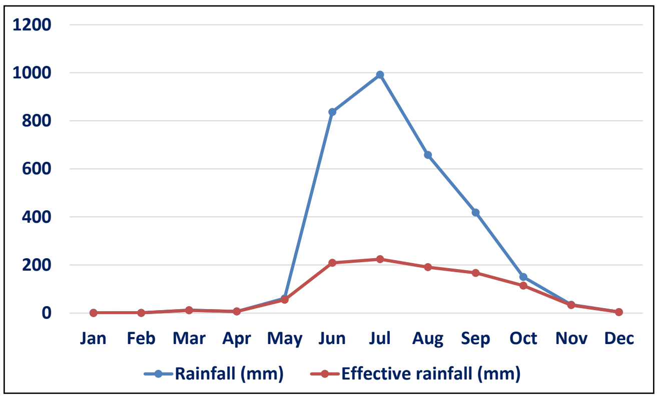

Figure 2: Consolidated mean monthly rainfall and effective rainfall of the study area

total number of emitters per line with the discharge rate of the emitters (4 lph). It was expressed in litre per day.

2.4. Time of irrigation

The time of operation of the drip system was calculated from the following formula.

Time of irrigation (minutes)=(Total water requirement ×60/ Total discharge)×Drip efficiency (90%)

2.5. Details of the experimental field

The experiment was conducted at the research farm of ICAR-CCARI, Goa, India during 2016–2019, which represents the low altitude and very high rainfall zone of the Western Ghats region. Planting was done in December, 2016 and first harvest was in June, 2018. The ratoon crop was harvested in June, 2019. The experimental site is at 15° 48'58" North latitude and 73° 92'29" East longitude and 18.60 m above mean sea level. The study area has a warm tropical climate with an average annual temperature of 27.9°C. The soil temperature regime is hyperthermic. The average rainfall of the site is 2900 mm. The south-west monsoon contributes to a significant part of rainfall, with 122 mean rainfall events. The mean annual total evaporation of the area was 1473 mm. The soil of the experimental site was lateritic type with gravelly clay loam and gravelly clay texture with moderately low water holding capacity. A popular pineapple variety of smooth cayenne group 'Giant Kew' was planted in trench method (90×60×45 cm) with a planting density of 41152 plants ha^{-1}.

2.6. Details of the field experiment

The experiment consisted of three treatments viz., T_1-Surface irrigation, T_2-Drip irrigation and T_3-Drip fertigation. The experiment was laid out in RBD with three replications.

2.6.1. Surface irrigation

In surface irrigated pineapple plants, irrigation was provided with one inch hose pipes (flow rate of 40 litre minute^{-1}). Every day, 1.33 l plant^{-1} have been irrigated with 20 PSI pressure.

2.6.2. Drip irrigation

The source of irrigation water was an open well in the field. A sand filter of 25 m^3 hr^{-1} capacity was provided for filtration, along with a disc filter.The motor pump capacity was 10 HP. The mainline diameter was 63 mm, and the sub mainline was 40 mm PVC pipe. Laterals were made of 16 mm LDPE pipelines. Lateral spacing was 60 cm, and inline emitters were spaced at a distance of 60 cm. The discharge rate of emitters was four litres per hour, and for drip fertigation, a separate valve with a venturi system was provided.

2.6.3. Fertigation

Nutrient requirement of pineapple at various stages of growth was calculated according to Malezieux and Bartholomew (2003), and a weekly fertigation schedule was formulated with a recommended dose of fertilizers (12:4:12 g NPK plant^{-1} cycle^{-1}). For surface irrigation (T_1) and drip irrigation (T_2), recommended dose conventional straight fertilizers viz., Urea (46% N), Rock phosphate (18% P_2O_5) and Muriate of potash (60% K_2O) were applied as basal dose and top dressing at 3rd and 6th months after planting. Saturated fertilizer solutions of N and K were prepared by dissolving the required quantity of fertilizers and supplied through venturi system in drip fertigation (T_3) weekly.

2.7. Statistical analysis

The data was analyzed in ANOVA with 0.05 probabilities using the statistical software WASP-2.0 developed by ICAR-CCARI, Old Goa.

2.8. Production economics

Total cost of cultivation included the fixed costs, operational costs under different irrigation systems and returns were calculated based on the market price of pineapple. Profitability was calculated in terms of B:C ratio.

3. RESULTS AND DISCUSSION

3.1. Crop water requirement

The reference evapotranspiration (ET_0) of the study area ranged from 2.7 to 5.2 mm day^{-1} with the maximum in April and May whereas the minimum in July. Crop evapotranspiration (ET_c) of pineapple throughout the growth period ranged from 25.46 mm $month^{-1}$ (July) to 81.01 mm $month^{-1}$ (May). In Goa, the adequate rainfall is higher than the crop evapotranspiration of pineapple from June to October, ranging from 114 to 224 mm. Hence, the actual irrigation requirement was zero during this period. Cahyono et al., 2016 reported that there is no need for intensive irrigation for pineapple if the adequate rainfall is surplus of water requirement. However, the daily water requirement ranged from 1.06 mm to 2.4 mm day^{-1} during the remaining months. Hanafi et al., 2010 also reported a water requirement of 2.43 mm day^{-1} during the initial stage and 1.55 mm day^{-1} during the ripening stage of pineapple in BRIS soils of Malaysia. Allen et al. (1998)recommended a crop coefficient of 0.50 in the initial stage; 0.30 in mid-season and 0.30 in the end-season of pineapple growth in Hawaii conditions. According to de Azevedo et al. (2007) the mean Kc value of pineapple in Brazil was 0.88±0.06, and the highest Kc value was during the vegetative stage (0.91±0.07) with the water requirement of 1423.6 mm. The maximum Kc was 0.51 in the initial pineapple stage, followed by 0.37 in development stage, 0.33 in the mid-stage, and a minimum of 0.30 during the ripening stage in BRIS soils of Malaysia (Hanafi et al., 2010).

According to Py (1965), pineapple requires 1.3–5.0 mm water day^{-1} depending on the crop stage and the soil water conditions. The actual irrigation requirement of pineapple during non-monsoon months ranged from 26 to 72 mm $month^{-1}$. Hepton (2003) reported that pineapple requires 5.00 cm water $month^{-1}$ from rain or irrigation for average growth. In the case of water stress, reduced growth rate, lengthy crop cycle, and reduction in average fruit weight were observed. The water requirement in terms of litres per day per plant ranged from 0.30 to 0.67 litres, with a maximum in April during Stage I and a minimum in December during Stage III. The pineapple plant has a meagre transpiration rate as it closes the stomata during the daytime and opens during the night. In this experiment, the total irrigation water requirement of the entire field ranged from 58.97 litres to 168.09 litres per day during non-monsoon months. The duration of irrigating the whole area under the drip irrigation system ranged from 11 minutes to 33 minutes (Table 1).

3.2. Fertigation schedule

Nitrogen is the integral component of amino acids and proteins required for cell growth, elongation, and development. Photosynthetic pigment chlorophyll and plant growth-promoting enzymes are synthesized with the help of nitrogen (Maathuis, 2009); hence its requirement is high in the early stages of the growth of pineapple. But during the fruit development and ripening stage, the nitrogen supply should be reduced as it affects the quality of fruits by increasing acidity and reducing sugar content. Potassium is essential to balance salt concentration and stomatal movement. Ramos et al. (2009) reported that the deficiencies of N and K reduced fresh and dry weight, length, width and area of D leaves at nine and 12 months after planting. The effect of K on vegetative growth might be linked to its impact on the synthesis of proteins in meristematic tissues and on cellular elongation (Kirkby, 2005). Potassium isconsidered a quality nutrient since it helps translocate nutrients during ripening and fruit development.A proper supply of potassium ensures good quality of pineapple fruits. Rock phosphate (18% P_2O_5) (22.22 g $plant^{-1}$) was provided as the basal dose and the weekly fertigation schedule for pineapple was calculated based on the rops stage. In stage I (early vegetative stage), 40% N and 30% was given to the crop using urea (46% N) and Muriate of potash (60% K_2O). In stage II (late vegetative stage), 30% N and 30% K, In Stage III (flowering stage), 20% N and 20% K, and in Stage IV (fruit development stage), 10% N and 20% K was given through fertigation. In stage V (fruit maturation stage), no nutrients were provided.

3.3. Growth and yield

Plant growth and yield parameters of pineapple were compared between the three irrigation treatments. The results revealed that crop growth and yield of fertigated plants were higher than surface irrigated and drip-irrigated plants. The highest plant height (76.90 cm), D leaf width (5.45 cm), number of leaves (43), D leaf weight (150.3 g) and fruit weight (2.35 kg) was recorded in drip fertigated plants (Figure 3). An increase in vegetative growth and fruit yield in tropical fruit crops such as banana (Mahalakshmi et al., 2001) and papaya (Sadarunnisa et al., 2010) by drip fertigation was reported earlier. The maximum yield of 96.80 t ha^{-1} was recorded under drip fertigated plants, followed by drip irrigated (90.96 t ha^{-1}) and surface washed (76.45 t ha^{-1}) plants (Table 2). According to Patra et al. (2015), drip irrigation was superior to micro-sprinklers and sub-surface irrigation in a pineapple under Gangetic alluvial plains of West Bengal. Fontes et al. (2000) also reported that, the application of N, P and K through drip fertigation might have increased the yield by maximizing the mobility of nutrients around the root zone. It is also possible that optimum water and nutrients at different levels might have activated the physiological processes for the absorption and

Table 1: Crop stage wise water requirement in pineapple

Crop stage	Month	ET_0 (mm day^{-1})	ET_0 (mm month^{-1})	ETc (mm month^{-1})	ER (mm)	AIR (mm month^{-1})	CWR (l day^{-1} plant^{-1})	Total water required (l day^{-1})	Time of drip irrigation (minutes)
Stage I									
	January	4.1	126.3	63.17	0.9	62.3	0.56	140.60	28.23
	February	4.7	130.3	65.17	0.5	64.7	0.65	161.66	32.46
	March	4.8	149.8	74.92	11.5	63.4	0.57	143.20	28.75
	April	5.2	157.1	78.54	6.5	72.0	0.67	168.09	33.75
	May	5.2	162.0	81.01	54.9	26.1	0.24	58.97	11.84
	June	3.3	99.0	49.49	208.7	0.0	0.00	0.00	0.00
Stage II									
	July	2.7	84.9	25.46	224.2	0.0	0.00	0.00	0.00
	August	3.0	93.6	28.07	190.8	0.0	0.00	0.00	0.00
	September	3.3	97.8	29.33	166.8	0.0	0.00	0.00	0.00
	October	3.8	117.1	35.12	113.9	0.0	0.00	0.00	0.00
Stage III	November	3.9	117.4	35.21	32.7	2.5	0.02	0.00	0.00
	December	4.0	122.6	36.79	4.0	32.8	0.30	74.04	14.87
	January	4.1	126.3	37.90	0.9	37.0	0.33	83.55	16.78
Stage IV	February	4.7	130.3	39.10	0.5	38.6	0.39	96.50	19.38
	March	4.8	149.8	44.95	11.5	33.5	0.36	85.53	17.17
	April	5.2	157.1	47.12	6.5	40.6	0.38	94.79	19.03
Stage V	May	5.2	162.0	48.61	54.9	0.0	0.00	0.00	0.00
	June	3.3	99.0	29.69	208.7	0.0	0.00	0.00	0.00

Early vegetative stage (Stage I); Late vegetative stage (Stage II); Flowering stage (Stage III); Fruit development stage (Stage IV); Fruit maturation stage (Stage V); ET_0: Evapotranspiration ETc: Crop Evapotranspiration; ER: Effective rainfall; AIR: Actual Irrigation Requirement; CWR: Crop water requirement

utilization of nutrients for the primary metabolic processes. In Goa's agro climatic and crop production system of Goa, fertigation is helpful to enhance the yield of pineapple. The plant growth and yield parameters under different irrigation treatments are depicted in Figure 3.

3.4. Cost economics of pineapple production

The cost of cultivation of pineapple under surface irrigation (T_1), drip irrigation (T_2) and drip fertigation (T_3) was calculated. Water source for all three treatments was an open well in the field with a 3 HP pump. The cost of establishing the drip system was ₹ 311373 ha^{-1}. Interest on establishment cost was assessed as 10% of the total establishment cost. The total fixed cost was ₹ 1500 for T_1 and ₹ 45092 for T_2 and T_3 treatments. Cost of repair and maintenance of drip was 2% of establishment cost (₹ 6228) in T_2 and T_3. The total cost of planting material (suckers) was ₹ 205760 @ ₹ 5 per sucker for a hectare area (41152 plants ha^{-1}, spacing – 90×60×45 cm^3). Farmyard manure, 10 t ha^{-1}, was applied to all the treatments, and the cost was ₹ 9990 @ ₹ 999/ t. The total fertilizer cost was ₹ 29756. Manpower @ ₹ 600/- per person, including all cultural operations including harvest, was ₹ 600000 for T_1 as the fertilizer application and irrigation takes more man-days (100 man-days). In T_2, 70 man-days were involved, and in T_3, it was 60 person-days. The total cost of cultivation in surface irrigation was ₹ 850106, whereas, in drip irrigation and drip fertigation, it was ₹ 719926 and ₹ 659926 yield ha^{-1} was estimated, and gross and net returns were calculated by considering unit price as ₹ 15 kg^{-1} fruit. The highest gross and net returns and B:C ratio was in T_3 (₹ 1451980, ₹ 792054, and 1.2, respectively) since the cost of production was lesser than the T_1 and T_2 treatments. The cost of cultivation of pineapple under different irrigation systems is provided in Table 2.

Table 2: Cost of cultivation of pineapple under different irrigation systems

Sl. No.	Particulars	Cost (₹)		
		Surface irrigation (T_1)	Drip irrigation (T_2)	Drip fertigation (T_3)
Fixed costs				
A.	Water source (well)+ motor charges (₹ 75000) with 2% depreciation	1500	1500	1500
B.	Cost of establishment of drip system (₹ 311373.00) with 4% depreciation	0	12454	12455
C.	Interest cost-10 % of establishment cost	0	31137	31137
D.	Total fixed costs (A+B+C)	1500	45092	45092
Operating costs				
E.	Cost of repair and maintenance of drip - 2% of establishment cost	0	6227	6228
F.	Cost of panting material @ ₹ 5/- 41152 plants ha^{-1} (90×60×45 cm^3)	205760	205760	205760
G.	Farm yard manure @ ₹ 999/t -10 t ha^{-1}	9990	9990	9990
H.	Fertilizers	29756	29756	29756
I.	Plant protection chemicals	100	100	100
J.	Transportation	2000	2000	2000
K.	Miscellaneous	1000	1000	1000
L.	Man power @ ₹ 600/- person including all cultural operations including harvest)	600000	420000	360000
M.	Total operating cost (E+F+G+H+I+J+K+L)	848606	674834	614834
N.	Total cost of cultivation (D+M)	850106	719926	659926
O.	Yield (kg ha^{-1})	76451	90992	96799
P.	Gross returns @ ₹ 15 kg^{-1}	1146769	1364875	1451980
Q.	Net returns	296663	644949	792054
R.	B: C ratio	0.3	0.9	1.2

1US$= INR 67.84

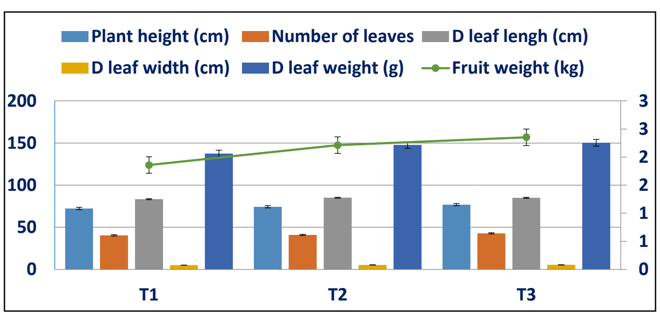

Figure 3: Plant growth and yield parameters under different irrigation treatments

4. CONCLUSION

The actual irrigation requirement of pineapple during non-monsoon season ranged from 0.24 to 0.67 mm plant^{-1} month^{-1}. Growth and yield of drip fertigated plants were higher than surface irrigated and drip irrigated plants. The highest net returns and B:C ratio was also recorded in drip fertigated pineapple plants in the agro climatic conditions of Goa.

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