DOI : 10.5958/0974-0112.2022.00010.X

Indian J. Hortic. 79(1), March 2022: 62-68

Response of pineapple to fertigation and flower induction in red laterite soil

Maneesha S. R*, S. Priya Devi[1], R. M. Vijayakumar[2], K. Soorianathasundaram[2], D. Selvi[2] and P. Jeyakumar[2]

ICAR-Central Coastal Agricultural Research Institute, Ela, Goa - 403402, India.

ABSTRACT

The present study was conducted to standardize fertigation level and flower induction treatment in pineapple variety 'Giant Kew' under red laterite soil conditions of Goa. Six main plot treatments viz., F0- Surface irrigation + conventional soil application of 100% RDN (Recommended Dose of Nutrients), F1- Drip irrigation + conventional soil application of 100% RDN, F2- Fertigation with 125% RDN, F3- Fertigation with 100 % RDN, F4- Fertigation with 75% RDN, F5- Fertigation with 50% RDN and three subplot treatments viz., T1-Ethephon 25 ppm + urea 2% + sodium carbonate 0.04%, T2 - NAA 25 ppm and T0 - water were applied to the experimental field in maincrop as well as ratoon crop. Fertigation with 125 % RDN improved the vegetative growth, photosynthetic pigment content, yield and leaf nutrient status. Ethephon treatment enhanced flowering and reduced crop duration of pineapple. The earliest flowering was recorded in F2T1 (47.55 days), and the latest was in F0T0 (59.22 days). Ethephon treated plants were harvested early after flower induction(156.41 days) over the control (168.50 days). F2 resulted in the highest fruit weight and total fruit yield (2.21 kg and 90.70 t/ ha), which was at par with F3 (2.20 kg and 90.62 t/ ha), but nutrient use efficiency was the highest in the F5 treatment. Fertigation with 100 % RDN and ethephon flower induction treatment resulted in a better yield of 'Gaint Kew' pineapple in Goa at a reduced rate of water and nutrients.

Keywords: Pineapple, Fertigation, Flower induction, Yield, Nutrient use efficiency

INTRODUCTION

Pineapple is one of the major tropical fruit crops of India with a total annual production of 17.99 million tons from 0.11 million ha area having productivity of 16.80 t/ ha (Indiastat, 12). It is a hardy, herbaceous plant with xerophytic adaptations and Crassulacean Acid Metabolism (CAM) (Zhang *et al.,* 21). Pineapple is mostly cultivated as a rainfed crop in sloppy hills of North East and West coast regions of India. In West coast region of India, including Goa, heavy rainfall during south-west monsoons causes top soil erosion and nutrient depletion in slopes, followed by an acute water shortage till next monsoon.

According to Carr (4), micro irrigation with drip, micro jets or overhead sprinkler is a viable option to provide irrigation to pineapple. Natural flowering is non uniform and will lead to staggered harvest in pineapple. Uniform flowering and year round production of pineapple is possible by staggered planting and flower induction (forcing) by external application of plant bioregulators. So, keeping in view the problems of irregular flowering and limited water availability, the present study was made to optimize the pineapple production through the interventions of fertigation and chemical manipulations in pineapple variety 'Giant Kew' in peninsular red lateritic soil.

*Corresponding author: Maneesha.sr@icar.gov.in
[1]ICAR-IIHR, Bengaluru- 560 089 , Karnataka, India.
[2]Dept.of Fruit Crops, HC&RI, TNAU, Coimbatore- 641 003,Tamil Nadu, India

MATERIALS AND METHODS

The experimental site at ICAR-CCARI, Old Goa had red lateritic soil with acidic pH (6.34) and normal Ec (0.34 dSm^{1}). The soil organic carbon (1.22 %) and organic matter (2.10%) was high while available nitrogen (143.17 kg/ ha) was low. Soil available phosphorus (33.43 kg/ ha) was high and available potassium (244.79 kg/ ha) was medium. The experiemtal site had 7 % slope with terraces, where a popular pineapple variety 'Giant Kew' was planted in double rows in trenches with a population density of 41152 plants/ ha with a spacing of 90 × 60 × 45 cm. The plot size was 1000 m^2 with 4115 plants. The field experiment was conducted from 2016-2019 in split plot design with six main plot treatments and three subplot treatments with three replications in both main crop and ratoon crop (Table 1).

Water soluble straight fertilizers (urea - 46% N and muriate of potash - 60% K_2O) were used to fertigate the pineapple plants. Full dose of P was given in the form of rock phosphate (18% P_2O_5) as basal dose to all plants. In conventioanal soil application treatments (F_0 and F_1), 1/4th doseof N and K were applied as basal and remaining quantity was given in three equal splits at three months interval. Irrigation water requirement of pineapple at different growth stages were calculated using the Kc values of pineapple (Allen *et al.,* 1) and consolidated

Table 1. Treatment details of the experiment

	Main plot treatments
F_0	Surface irrigation + conventional soil application of 100% RDN (12:4:12 g NPK/ plant/ cycle)
F_1	Drip irrigation + conventional soil application of 100% RDN (12:4:12 g NPK/ plant/ cycle)
F_2	Fertigation with 125% RDN (15: 5:15 g NPK/ plant/ cycle)
F_3	Fertigation with 100 % RDN (12:4:12 g NPK/ plant/ cycle)
F_4	Fertigation with 75 % RDN (9:3:9 g NPK/ plant/ cycle)
F_5	Fertigation with 50 % RDN (6:2:6 g NPK/ plant/ cycle)
	Subplot treatments
T_0	Water
T_1	Ethephon 25 ppm+ urea 2%+ sodium carbonate (0.04%) (Dass *et al.,* 8)
T_2	NAA 25 ppm (Das, 7)

weather data of 14 years (2003-2016) obtained from the meteorological observatory of ICAR- CCARI, Ela, Old Goa as per the method of Cahyono *et al.*(3). Fertilizer amount was calculated as per the nutrient requirement of pineapple at various stages of growth (Malezieux and Bartholomew, 14). During early vegetative stage (0-24 weeks); 40% N and 30% K; late vegetative stage (25-41 weeks), 30% N and 30% K; flowering stage (20% N and 20% K) and in fruit development stage (10% N and 20% K) were given through weekly fertigation. When the plants attained physiological maturity (35-40 leaf stage), flower induction treatments were applied. Flower induction treatment solutions were prepared using Ethrel 39% SL (Ethephon) and Planofix 4.5% (NAA) and 50 ml treatment solution was poured into the central core at the time of stomal opening i.e., evening hours. Observations on plant growth and yield were recorded and photosynthetic pigment contents (Arnon, 2) and D leaf nutrient contents (Humphries, 11; Jackson, 13) and nutrient use efficiency (Dobermann, 9) were estimated in both main crop and ratoon crop . The pooled data were sstatistically analyzed in ANOVA at 0.05 probability using WASP 2.0 software of ICAR-CCARI, Goa.

RESULTS AND DISCUSSION

Nitrogen (N) and potassium (K) are the critical nutrients required for growth of pineapple crop. Plant biometric characters of 'Gaint Kew' pineapple variety were significantly affected by fertigation with elevated level of N and K. Fertigation with 125 % RDN (F_2) resulted in the highest plant height (87.38 cm), base girth (38.11 cm) and number of leaves per plant (43.97) (Table 2). Plant spread was not significantly affected by the fertigation levels. D leaf

Table 2. Effect of fertigation levels and flower induction treatments on growth of pineapple variety 'Giant Kew'

Treatments	Plant height (cm)	Plant spread (cm)	Base girth (cm)	Number of leaves	D leaf length (cm)	D leaf width (cm)	D leaf weight (g)	D leaf thickness (mm)
F_0	77.77	94.67	33.48	40.67	75.11	4.38	137.50	1.56
F_2	87.38	107.72	38.11	43.97	82.66	5.10	180.76	1.77
SE(d)	3.18	4.57	1.70	1.28	3.84	0.26	16.58	0.08
$CD_{(0.05)}$	1.86	12.00	1.10	1.29	5.53	0.23	9.26	0.16
T_0	80.35	99.90	33.74	41.93	75.32	4.67	150.90	1.64
T_1	82.97	99.99	36.44	42.27	76.18	4.85	151.54	1.72
SE(d)	1.33	0.85	1.35	0.19	0.72	0.09	0.69	0.04
$CD_{(0.05)}$	1.50	2.84	0.95	0.96	2.61	0.17	5.43	0.12
F_0T_0	75.65	95.09	32.18	41.12	71.94	4.40	131.48	1.50
F_2T_1	90.47	108.97	39.77	44.33	86.42	5.38	181.78	1.85
SE(d)	3.29	4.72	2.01	1.33	3.85	0.26	16.38	0.10
$CD_{(0.05)}$	3.67	6.97	2.34	2.36	6.39	0.41	13.29	0.30

length (82.66 cm), D leaf width (5.10 cm) and D leaf weight (180.76 g) were also the highest in F_2 treatment (Table 2). Nitrogen is the basic component of proteins and amino acids required for cell growth and cell enlargement and hence application of high level of N enhances the vegetative growth of the crop. Potassium maintains salt balance, regulates opening and closing of stomata, promotes cellular elongation and indirectly enhances the photosynthetic efficiency of the crop. Application of N and K at right proportion to the root zone through drip may possibly have increased the availability of nutrients and reduced the nutrient loss in red laterite soil. Slow release of fertilizers also might have helped in better uptake and assimilation of nutrients. Spironello *et al.* (19) also reported vigorous pineapple plant growth by high dose of nitrogen.Flower induction treatments and interaction between fertigation levels and flower induction treatments didn't affect plant growth parameters significantly.

F_2 treatment resulted the highest chlorophyll 'a', Chlorophyll 'b' and total chlorophyll content content (2.16 mg/ 100g, 1.06 mg/ 100 g and 3.22 mg/ 100 g, respectively) among the fertigation levels, while among the flower induction treatments, T_1 recorded the same (1.96 mg/100g, 0.84 mg/100 g and 2.80 mg/100 g, respectively) (Figure 1). Application of high nitrogen content increased the chlorophyll content since it is a structural component of chlorophyll molecule. Ferigation with 125 % RDN had high level of N fertilizers and this resulted in high chlorophyll content of pineapple. Flower induction treatments also had resulted in significant effect on chlorophyll content of pineapple leaves. Ethephon releases ethylene gas in treated pineapple plants and cause floral bud differentiation and the plants tries to increase photosynthetic efficiency by producing high chlorophyll content. Though ethylene is known for its chlorophyll degradation capacity, it promotes chlorophyll synthesis in young and non senesense leaves (Ceusters and Poel, 5). The interaction between fertigation levels and flower induction treatments was significant only in chlorophyll 'b' content and recorded the highest in F_2T_1 (1.26 mg/100 g).

F_2 treated plants took the least duration to initiate flowering (52.38 days) and F_0 treatment had the longest duration (55.85 days) among the fertigation levels. Among the flower induction treatments, the similar response was noted with T_1(50.60 days) and T_0 treatment took 58.16 days to flower. The ineraction between fertigation levels and flower induction treatments was also significant and F_2T_1 (47.55 days) treatment had the shortest duration and F_0T_0 (59.22 days) had the longest duration. Fertigation with high nutrient content helped the plants to attain physiological maturity fast and ethephon treatment encourages fast flower induction in pineapple crop.

Optimum plant growth with sufficient nutrient supply at regular interval along with irrigation water might have enhanced the physiological activity of the plant and ethephon treated plants had released ethylene gas to change the vegetative apex to the floral primodia. The time gap between main crop and ratoon crop harvests was 330.9 days in Ethephon treated plants and 333.78 days in NAA treated plants over control (342.5 days). Total duration of the main crop was 16-17 months, it was 12 months in ratoon crop. The optimum plant growth with sufficient nutrient

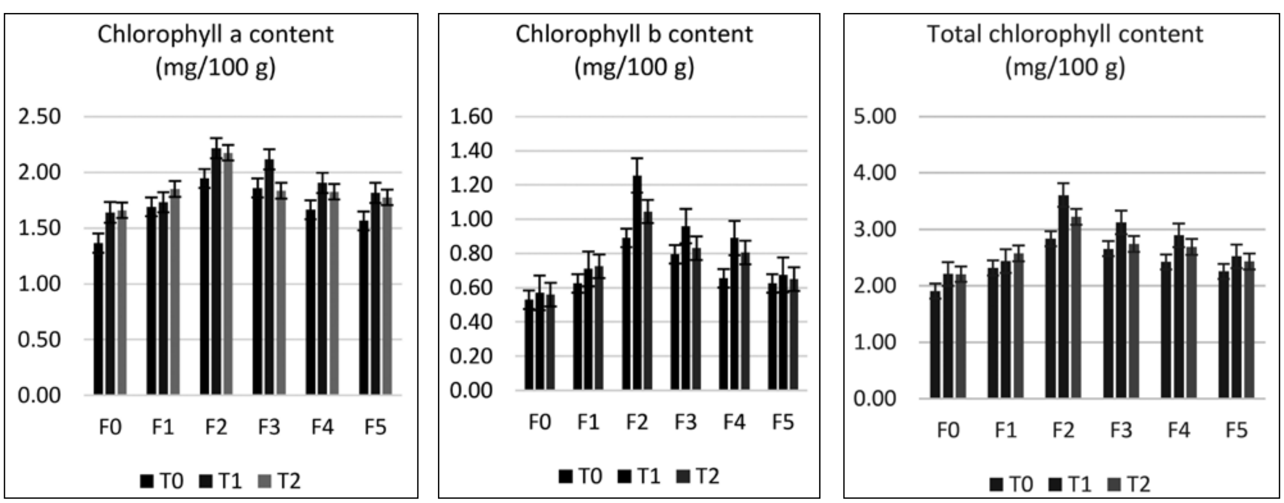


Fig. 1. Effect of fertigation levels and flower induction treatments on chlorophyll content of pineapple variety 'Giant Kew'

supply at regular interval along with irrigation water might have enhanced the physiological activity of the plant and ethephon treatment had released ethylene gas to change the vegetative apex to the floral primordia. Early and enhanced flowering in ethephon treated pineapple plants was reported earlier by Cunha (6).

The highest D leaf nitrogen (1.42%), phosphorus (0.30%) and potassium (1.39%) contents were in F_2 treatment (Table 3). Plant nutrient status is a good indicator of the physiological activity of the plant and here,constant and ready supply of high dose of nutrients to the root zone might have helped in the efficient absorption of nutrients and accumulation in the leaf tissues. In this experiment, maximum yield was obtained when D leaf nutrient content was 1.14-1.46% N, 0.22 - 0.33 % P and 1.22-1.44 % K, which is in concomitant with the findings of Ramos *et al.* (17) and Sema *et al.* (18)

Flower induction treatments significantly influenced the taken from flower induction treatment to harvest the main and ratoon crops of pineapple variety 'Giant Kew'. The minimum number of days taken from flower induction treatment to harvest was recorded in T_2 (156.41 days) and the longest duration from flower induction to harvest was noted in T_0 (168.50 days). Fertigation levels and the interaction between fertigation levels and flower induction treatments, failed to exert any significant effect on days taken from flower induction to harvest. Ethephon treatment enhances flowering and fastens fruit maturity in pineapple crop.

Table 3. Effect of fertigation levels and flower induction treatments on D leaf nutrient content of pineapple variety 'Giant Kew' at flowering stage

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)
F_0	1.21	0.26	1.27
F_2	1.42	0.30	1.39
SE(d)	0.07	0.03	0.05
CD $_{(0.05)}$	0.04	0.02	0.05
P value	<0.001	<0.001	0.001
T_0	1.28	0.26	1.31
T_1	1.30	0.26	1.31
SE(d)	0.01	0.00	0.01
CD $_{(0.05)}$	0.03	0.02	0.04
F_0T_0	1.14	0.25	1.22
F_2T_1	1.44	0.33	1.44
SE(d)	0.08	0.03	0.05
CD $_{(0.05)}$	0.08	0.05	0.09

Among the fertigation treatments, F_2 resulted the highest fruit weight and total yield (2.21 kg and 90.70 t/ ha) which was at par with F_3 (2.20 kg and 90.62 t/ ha) (Table 4). In this study, high N and low K (40: 30) dose was applied in the early vegetative growth stages; equal dose (30:30) at late vegetative growth and flowering stage (20:20) and low N high K (10:20) dose was given in fruit development stage for proper utilization of these nutrients foreffective growth and physiological development. Pegoraro (16) also suggested that, N and K should be applied prior to flowering since maximum uptake was observed prior to and at flowering in pineapple. According to Fontes *et al.* (10), application of N and K through drip irrigation increased the yield by increasing the mobility of nutrients in the root zone. High amount of potassium applied might have increased the yield by enhancing the plant metabolism and translocation of metabolites to the fruits. Fruit weight of pineapple was higher in drip irrigated pineapple plants than microsprinkler irrigated plants in gangetic alluvial plains (Patra *et al*., 15) due to the efficiecnt use of water and nutrients. Spironello *et al.* (19) and Teixeira *et al.* (20) also reported enhanced yield by enhanced potassium fertilizer doses in pineapple. Among the flower induction treatments, T_1 had the highest fruit weight (1.93 kg) while it was the least in

Table 4. Effect of fertigation and flower induction treatments on crop duration and yield of pineapple variety 'Giant Kew'

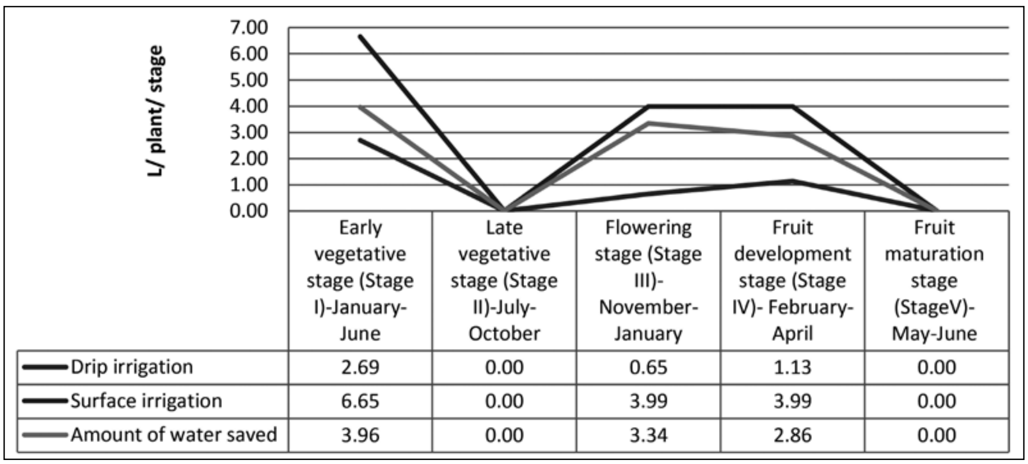
Treatments	Days taken for flower induction	Days taken for fruit harvest	Fruit weight (kg)	Total yield (t/ ha)
F_0	55.85	169.92	1.57	64.65
F_2	52.38	159.38	2.21	90.70
F_3	52.88	156.67	2.20	90.62
F_4	53.51	160.38	2.06	84.87
F_5	55.13	160.72	1.74	71.54
SE(d)	1.34	4.49	0.27	11.01
CD $_{(0.05)}$	1.58	8.45	0.04	1.78
T_0	58.16	168.50	1.88	77.30
T_1	50.60	156.41	1.97	81.13
T_2	53.15	159.11	1.93	79.50
SE(d)	3.85	6.35	0.05	1.92
CD $_{(0.05)}$	0.81	2.40	0.06	2.35
F_2T_1	47.55	153.23	2.31	95.13
F_3T_1	47.90	152.53	2.26	93.07
SE(d)	3.59	7.01	0.25	10.44
CD $_{(0.05)}$	1.99	5.89	0.14	5.75

T_0(1.88kg). T_1 also registered the highest estimated total yield (81.13 t/ ha) in this experiment.

Surface irrigated pineapple plants were irrigated by one inch hose pipes with a flow rate of 40 litre/ minute and approximately, 1.33 litre/ plant have been irrigated every day with 20 PSI pressure. Irrigation water requirement of drip irrigated plants ranged from 0.00- 0.67 litre/ plant/ day during the growth cycle (Figure 2). At early vegetative stage, a total of 6.65 litre water was applied per plant in surface irrigated plants (F_0) against 2.69 litre in drip irrigated plants with a saving of 3.96 litre water per plant. During late vegetative stage, there was sufficient rainfall and irrigation was ceased.During flowering stage, 3.34 litre and fruit development stage 2.86 litre water per plant was saved by drip irrigation.

Drip fertigation treatments had high nutrient use efficiency than the conventional soil application treatments (Figure 3). There was no significant difference in nutrient use efficiency of F_0 and F_1. F_5 had the highest N, P and K use efficiency (138 %, 163.06 and 181.00 %, respectively. The higher fertilizer use efficiency of drip fertigation was due to the reduced evaporation or run off, application of water to the root zone. In case of all the three nutrients, F_2 treatment had lesser nutrient use efficiency than F_3 treatment. Application of higher level of fertilizers in red laterite soils with low water and nutrient holding capacity is not effective to increase the production. Efficiency of nutrient uptake and nutrient utilization can be enhanced by fertigation and conventional water soluble fertilizers.

In red laterite soil of Goa, fertigation with 125 % RDN treatment improved plant growth, leaf nutrient status, fruit weight and total yield in pineapple. But fertigation with 100 % RDN along with ethephon



	Early vegetative stage (Stage I)-January-June	Late vegetative stage (Stage II)-July-October	Flowering stage (Stage III)-November-January	Fruit development stage (Stage IV)- February-April	Fruit maturation stage (StageV)-May-June
Drip irrigation	2.69	0.00	0.65	1.13	0.00
Surface irrigation	6.65	0.00	3.99	3.99	0.00
Amount of water saved	3.96	0.00	3.34	2.86	0.00

Fig. 2. Water requirement of pineapple at different stages of growth in surface irrigation and drip irrigation

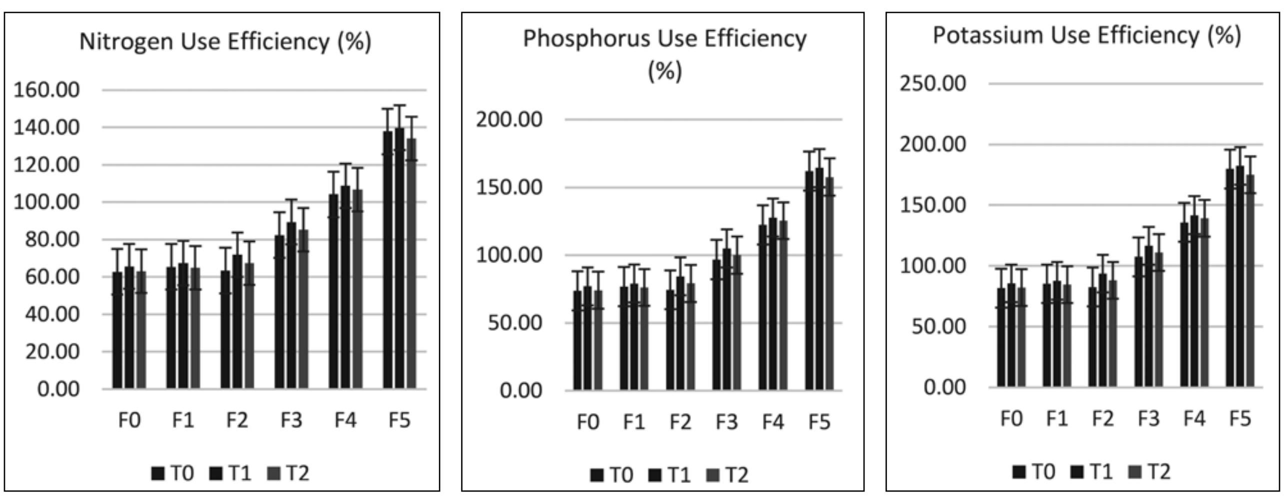


Fig. 3. Effect of fertigation levels and flower induction treatments on nitrogen, phosphorus and potassium Use efficiency of pineapple variety 'Giant Kew'

flower induction treatmentis recommended since it has at par result in fruit weight and total yield with reduced rate of water and fertilizers.

AUTHORS' CONTRIBUTION

Conceptualization of research (MSR, SPD, RMV, KS), Designing of the experiments (MSR, KS), Contribution of experimental materials (SPD), execution of field experiments/ lab analysis, data collection (MSR, SPD), Analysis of data and interpretation (MSR, SPD, RMV, KS, DS, JJ); Preparation of the manuscript (MSR, SPD).

DECLARATION

The authors declare no conflict of interest.

ACKNOWLEDGEMENT

We are thankful to former Directors of ICAR-CCARI, Dr. N.P. Singh; Dr. E.B. Chakurkar and present Director, Dr. Parveen Kumar for providing necessary facilities for conducting this research work and supporting. Ms. Deepika Shetgaonkar, Ms. Vidula Pitre and Ms. Madhavi Khapare, Young professionalshad helped profusely in field experimentsand laboratory analysis. All the staff of ICAR-CCARI, Old Goa and TNAU, Coimbatore had directly or indirectly supported in the successful completion of this study.

REFERENCES

1. Allen, R. G., Pereira, L.S., Raes, D. and Smith, M. 1998. Crop evapotranspiration: guidelines for computing crop water requirements*. Food and Agricultural Organization of the United Nations, Irrigation and Drainage Rome, Italy*. p. 56.
2. Arnon, D. I. 1949. Copper enzymes in isolated chloroplasts polyphenol oxidase in Beta vulgaris. *Plant Physiol*. **24** (1): 1-15
3. Cahyono, P., Astuti, N.K. and Rahmat, A. 2016. Analysis of water balance to determine water requirement of pineapple (*Ananas comusus* L. Merr.) in pineapple plantation Lampung, Indonesia. *Pro. Int. Conf. Climate Change*: 255-57.
4. Carr, M. K. V. 2012. The water relations and irrigation requirements of pineapple (*Ananascomosus var. comosus*): *A review. Exp. Agric.* **48:**1-14.
5. Ceusters, J. and Poel, B.V.2018. Ethylene Exerts Species-Specific and Age-Dependent Control of Photosynthesis. *Plant Physiol.***176**: 2601-12.
6. Cunha, G. A. P. 2005. Applied aspects of pineapple flowering. *Bragantia, Campinas* **64:** 499-516.
7. Das, N. 1964. Studies on the action of NAA on the flowering and fruiting of pineapple. *Ind. J. Agric. Sci.* **34**(1): 38-45.
8. Dass H. C., Randhawa, G. S. and Negi,S.P. 1975. Flowering in pineapple as influenced by ethephon and its combinations with urea and calcium carbonate. *Sci. Hortic.* **3**(3):231-38.
9. Dobermann, A. 2007. Nutrient use efficiency – measurement and management. **In** "IFA International Workshop on Fertilizer Best Management Practices", Brussels, Belgium, p 1-28.
10. Fontes, P. C. R., Sampaio, R.A. and Finger, F.L. 2000. Fruit size, mineral composition and quality of trickle irrigated tomatoes as affected by potassium rates. *Pesq. Agropec. Bras.* **35**: 21-25.
11. Humphries, E. C. 1956. Mineral components and ash analysis. In: *Modern methods of plant Analysis*. Paech, K., M. V. Tracey (Eds). Springer, Berlin, Heidelberg. **1**:468-502.
12. Indiastat. 2020. Indiastat database. Retrieved from http:// www. *indiastat.com database*. on 29th June, 2020.
13. Jackson, M. L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi. pp.1-498.
14. Malezieux, E. and Bartholomew, D. P. 2003. Plant Nutrition. Chapter 5. **In:** *The Pineapple, Botany, Production and Uses*. D. P. Bartholomew, R. E. Pauli and K. G. Rohrbach (Eds.). Wallingford, UK: CAB International. pp.143-66.
15. Patra, S. K., Pramanik, S. and Saha, S. 2015. Techno- economic feasibility of microirrigation in pineapple under the Gangetic alluvial plain of West Bengal. *Indian J. Hort.***72:** 329-33.
16. Pegoraro, R. F., de Souza, B.A.M., Maia,V. M., da Silva, D.F., Medeiros, A.C. andSampaio, R.A. 2014. *Rev. Bras. Ci. Solo*. **38:** 896-904.
17. Ramos, M.J.M., Monnerat, P.H., da R. Pinho, L. G., de A. Pinto, J.L. 2009. Growth and Flowering of 'Imperial' Pineapple Plants under

Macronutrient and Boron Deficiency. *Acta Hortic.* **822:**139-46.

18. Sema, A., Maiti, C.S., Singh, A.K. and Bendangsengla, A. 2010. DRIS nutrient norms for pineapple on alfisols of India. *J. Plant Nutr.***33:** 1384-99.

19. Spironello, A., Quaggio, J. A., Teixeira, L. A. J., Furlani, P. R. and Sigrist, J. M. M. 2004. Pineapple yield and fruit quality effected by NPK fertilization in a tropical soil. *Rev. Bar. Frutic. Jaboticabal.,***26**: 155-59.

20. Teixeira, L. A. J., Quaggio, J.A., Cantarella, H. and Mellis, E.V. 2011. Potassium fertilization for pineapple: effects on plant growth and fruit yield. *Rev. Bras. Frutic., Jaboticabal* SP. **33:**618-26.

21. Zhang, J., Liu, J. Ming, R. 2014. Genomic analysis of CAM plant pineapple. *J. Exp. Bot.* **65:** 3395-3404.

Received : July, 2020; Revised : February, 2022;
Accepted : March, 2022