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Effect of calcium nutrition on yield and quality of pineapple (*Ananas comosus* var. Mauritius) in the humid tropical climate of Kerala

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Abstract
Fertilizer type, dosage, time and method of application plays a significant role in the yield and postharvest quality of pineapple. To study the effects of calcium on yield and quality of pineapple (*Ananas comosus* var. Mauritius) foliar spray of calcium nitrate 0.5% at 70 days after flowering (DAF) and soil application of Ayar @ 40g plant^{-1} at different growth stages were imposed in this field experiment. The yield performance, vegetative characters and physico-chemical qualities were appraised. Treatments expressed no significant difference in vegetative characteristics of the plant but significant differences were observed in fruit yield. Combined application of Ayar @ 40g plant $^{-1}$ at the fourth month after planting and foliar spray of calcium nitrate 0.5% at 70 DAF recorded the highest fruit yield with 58.38 t ha^{-1}.

Keywords: *Ananas comosus* var. Mauritius, ayar, calcium nitrate, fruit yield, vazhakulam pineapple

1. Introduction
India is the sixth largest producer of pineapple (*Ananas comosus* (L.) Merr.) in the world with a production of 17,11,000 t (FAO, 2019) [3]. In India, it is grown in the states of Karnataka, Meghalaya, West Bengal, Kerala, Assam, Manipur, Tripura, Arunachal Pradesh, Mizoram, and Nagaland (NHB, 2018) [9]. Pineapple is the second most important cultivated crop in Kerala. Kerala produces more than 2,75,000 t pineapple from an area of 9,152.55 ha (GOK, 2020) [4]. The annual value of pineapple produced in Kerala is about ₹600 crores.

Ernakulam is the major pineapple producing district of Kerala, accounting for 63% of total pineapple production in Kerala (GOK, 2020) [4]. In Ernakulam district, pineapple cultivation is more concentrated in and around Vazhakulam, the 'Pineapple City'. Mauritius cultivar 'Vazhakulam Pineapple' which is registered under Agricultural-Horticultural product at the GI Registry, Chennai as Geographical Indication (GI) No. 130 is the dominant cultivar in the district. 'Vazhakulam Pineapple' with its unique aroma, crispy golden yellow flesh, slightly conical shape and deeply placed fruit 'eyes' with an average fruit weight is 1200-1400g is an excellent variety suited for table purposes and distant marketing. It yields sweet juice with 14-16°Brix and 0.50 - 0.70 percent acidity.

Planting density and crop nutrient absorption efficiency are the main factors affecting the yield of pineapple. Pineapple plants have a large nutrient uptake demand, especially for potassium, followed by nitrogen, calcium, magnesium, sulphur, and phosphorus (Souza and Reinhardt, 2007) [2]. Incessant rains in Kerala state have caused severe soil acidity and deficiency of many plant nutrients which are essential for good yield. The soil samples taken from 14 districts in Kerala showed that there was a very high deficiency of magnesium, boron and calcium: around 80% of soil samples recorded magnesium deficiency, 70% had boron deficiency and 50% had calcium deficiency and 88% of the soil is acidic in nature. The effect of application of secondary nutrients in pineapple in Kerala is not assessed so far. Hence the effect of calcium nutrition on yield enhancement and the quality of pineapple was studied.

2. Materials and Methods
2.1 Location
Experiment was laid out at Vazhakulam (9°56'01.7"N 76°38'45.1"E) situated 40 m above mean sea level with humid tropical climate receiving an average annual rainfall of 2115 mm.

2.2 Source of Nutrients

Fertilizers used for the experiment were Urea (46%N), Muriate of Potash (60% K_2O), Rajphos (20% P_2O_5), Calcium nitrate (Gromax-N – 18.8% Ca, 15.5% N), Potassium nitrate (Gromax-N – 45% K, 13% N). Ayar (Ca 15%, Mg 5%, S 10%, Zn 0.5% and B 0.5%) from Kerala Agricultural University was used as source of calcium for soil application. MicroRich of Indus valley fertilizers (Mg 8.5%, Ca 0.5%, S 11%, Zn 0.5%, Fe 0.50%, Mn 0.50%, Mo 0.02%, Cu 0.25% and B 1%) was used for foliar application.

2.3 Experimental Design

The experiment was laid out in a randomized complete block design, with 9 treatments, replicated 3 times; with 30 plants in each treatment. The treatment details are given in Table 1.

Table 1: Treatment details

Treatment	Details
T1	PoP [(Basal 20 g Raj Phos + 100 g FYM) + 2:2 NK (2 MAP, 4 MAP, 6 MAP)]
T2	PoP+ Ayar 20 g/plant (3 MAP) + Ayar 20 g/plant (5 MAP)
T3	PoP + Ayar 40 g/plant (3 MAP)
T4	Foliar application of fertilizers at monthly interval Urea: Potash: Microrich in 2 : 1.5 : 0.5
T5	PoP + $CaNO_3$ spray (70 DAF)
T6	PoP+ KNO_3 spray (70 DAF)
T7	PoP + Ayar 40 g/plant (4 MAP) + $CaNO_3$ spray (70 DAF)
T8	PoP + Ayar 40 g/plant (4 MAP) + KNO_3 spray (70 DAF)
T9	PoP + Ayar 40 g/plant (4MAP)

2.4 Planting and aftercare

Suckers of 'Mauritius Pineapple' weighing 500-750 g were planted in small pits of 10 cm depth in paired rows, in triangular method so that the plants in two adjacent rows are not opposite to each other. Spacing of 30 cm X 45 cm X 150 cm was adopted to get a plant population of 40,000 plants ha^{-1}. Entire dose of Farm Yard Manure (16 t ha^{-1}) and P_2O_5 (160 kg ha^{-1}) was applied in pits prepared for planting suckers. Nitrogen and K_2O each at the rate 320 kg ha^{-1} was applied in four equal split doses after planting; 50 days after planting (DAP), 110 DAP, 170 DAP, and 60 days after flower induction. Plants were earthed up along with first top dressing. Hand weeding was followed for weed management and irrigation was provided during January to March at two weeks interval. Plants were artificially induced to flower with Ethrel 25 ppm + urea 2%+ calcium carbonate 0.04% at 7 months after planting (MAP).

2.5 Observations

Soil samples collected from the experimental plot before planting was analysed for physical and chemical properties. Twenty plants from each replication were chosen randomly at 7 MAP and recorded vegetative growth characteristics *viz*. plant height and number of leaves. Fruits were harvested when the skin colour of the basal one eye turned yellow. Six fruits from each plot were selected randomly and fruit weight with crown (g) and fruit firmness (kg cm^{-2}) were recorded. Pure juice extracted from the fully ripe fruit was used to determine the pH and total soluble solids (TSS). Fruit firmness was checked using Digital penetrometer (G- Tech GY-4) with a probe radius 4 mm. Total soluble solids in fruit juice was measured using hand refractometer (ERMA) of range 0-32°Brix and pH measured using Elico digital pH meter. Data were statistically analyzed by one-way analysis of variance (ANOVA) and when found significant, the treatments were compared using Duncan's multiple range test (DMRT).

3. Result

Analysis of physico-chemical properties of soil collected from the experimental field prior to the start of the experiment (Table 2) indicated that soil was extremely acidic and showed a deficiency of available Calcium (169.7 mg kg^{-1}) and Magnesium (43.9 mg kg^{-1}) necessitating either soil or foliar application to correct deficiencies of essential plant nutrients. The effect of application of Calcium on growth and yield of pineapple was assessed in the present investigation. Vegetative growth characteristics *viz.*, plant height, leaf length, leaf width and number showed no significant difference among treatments. Plant height varied from 113.22cm to114.37 cm in the experimental plants and leaf number from 45 to 46 (Table 3).

The highest fruit yield (1459.43g) was recorded in T7 where both soil application of Ayar 40g $plant^{-1}$ at 4MAP and $Ca(NO_3)_2$ 0. 5% spray at 70 DAF was given. The estimated yield of T7 (58.38t ha^{-1}) recorded an increase of 6.48 % over the control plot yield of 54.82t ha^{-1} (Figure 1). T7 was on par with $Ca(NO_3)_2$ (0. 5%) spray given at 70 DAF (T5) with an individual fruit weight of 1436.36 g (Table 4). A perusal of data reveals that increased availability of calcium to the plants may have contributed to higher fruit yield in T7 and T5. It can also be inferred that a single application or quantity may not be sufficient to correct calcium deficiency prevalent in acidic soil.

Calcium is considered as one of the most important minerals determining the quality of fruits since it is required for cell elongation and cell division (Rizzi and Abruzzese, 1990) [10]. T7 might have increased calcium availability to plants during active vegetative growth stages and the initial fruit development phase hence performing the best. Herath, Bandara & Banda (2003) [6] reported that basal lime application of 150 kg followed by a 100 kg lime top dressing, significantly reduced internal browning, increased fruit TSS and ascorbic acid levels and reduced fruit weight loss in Mauritius pineapple after storage.

Similarly, Herath, Bandara & Banda (2000) [5] also reported a beneficial effect of the pre-harvest application of calcium (CaO) in pineapple. Foliar spray of nitrogen in combination with calcium significantly increased the fruit firmness (8.64 kg cm^{-2}) in apples (Kuchay, Mallikarjuna & Ali, 2018) [8] and the application of 2% calcium nitrate spray resulted in increased fruit size, fruit length, fruit weight in pomegranate (Korkmaz and Aşkın, 2013) [7]. Bibi *et al.* (2019) [1] observed that $Ca(NO_3)_2$ was a better option than $CaCl_2$ to improve yield and quality in mango.

Fruit firmness, pH, and Brix: acid ratio were not affected by different treatments (Table 4).

Table 2: Soil physicochemical properties of experimental plot before planting

Parameters	Quantity	Remarks
pH	4.1	Extremely acid
Electrical Conductivity (ds m^{-1})	0.06	Normal
Organic Carbon (%)	1.66	High
Available Phosphorus (kg ha^{-1})	68.70	High
Available Potassium (kg ha^{-1})	283.6	High
Available Calcium (mg kg^{-1})	169.7	Deficient
Available Magnesium (mg kg^{-1})	43.9	Deficient
Available Sulphur (mg kg^{-1})	9.24	Sufficient
Available Iron (mg kg^{-1})	51.07	Sufficient
Available Manganese (mg kg^{-1})	43.52	Sufficient
Available Zinc (mg kg^{-1})	3.38	Sufficient
Available Copper (mg kg^{-1})	5.46	Sufficient
Available Boron (mg kg^{-1})	1.35	Sufficient

Table 3: Effect of treatments on vegetative growth characteristics of pineapple cultivar 'Mauritius' in laterite soils of tropical humid climate

Treatment	1 MAP		2.5 MAP		4 MAP		5 MAP		6 MAP	
	*Height of plant	*No. of leaves	*Height of plant	*No. of leaves	*Height of plant	*No. of leaves	*Height of plant	*No. of leaves	*Height of plant	*No. of leaves
T1	71.67	25.22	84.11	32.67	102.33	37.44	108.11	42.00	114.33	45.11
T2	71.67	23.78	85.44	32.78	103.44	37.22	107.44	41.44	114.37	45.11
T3	71.89	24.78	82.33	33.56	104.11	38.78	108.33	41.22	114.33	45.00
T4	72.00	25.89	82.00	32.89	103.67	38.33	108.56	42.78	113.22	45.22
T5	71.11	25.89	84.44	34.44	103.67	39.56	108.33	42.22	114.82	45.78
T6	71.78	24.56	83.44	33.78	103.11	37.33	108.67	42.00	113.67	46.11
T7	70.56	24.22	82.44	32.22	102.44	37.78	108.22	42.67	113.55	45.00
T8	71.67	23.44	84.67	33.89	102.56	38.67	108.22	42.78	114.00	46.44
T9	70.56	24.11	82.44	34.22	102.67	38.67	108.44	42.56	113.55	45.33

* Non-Significant at 5% level

Table 4: Effect of treatments on fruit yield and quality of pineapple cultivar 'Mauritius' in laterite soils of tropical humid climate

Treatments	Fruit weight (g)	*Fruit firmness (Kg cm^{-2})	*pH	*TSS (in °Brix)
T1	1370.62 $^{(c)}$	5.24	3.68	14.66
T2	1399.61 $^{(bc)}$	5.82	3.82	14.76
T3	1284.29 $^{(d)}$	5.45	3.65	15.23
T4	1403.47 $^{(bc)}$	5.36	3.65	14.46
T5	1436.36 $^{(ab)}$	6.03	3.79	15.2
T6	1358.92 $^{(c)}$	5.73	3.71	16.13
T7	1459.43 $^{(a)}$	6.80	3.64	14.6
T8	1366.2 $^{(c)}$	6.83	3.83	14.47
T9	1377.72 $^{(c)}$	5.98	3.72	14.21

The values with different superscripts differ significantly at 1% and 5% level; * non-Significant at 5% level

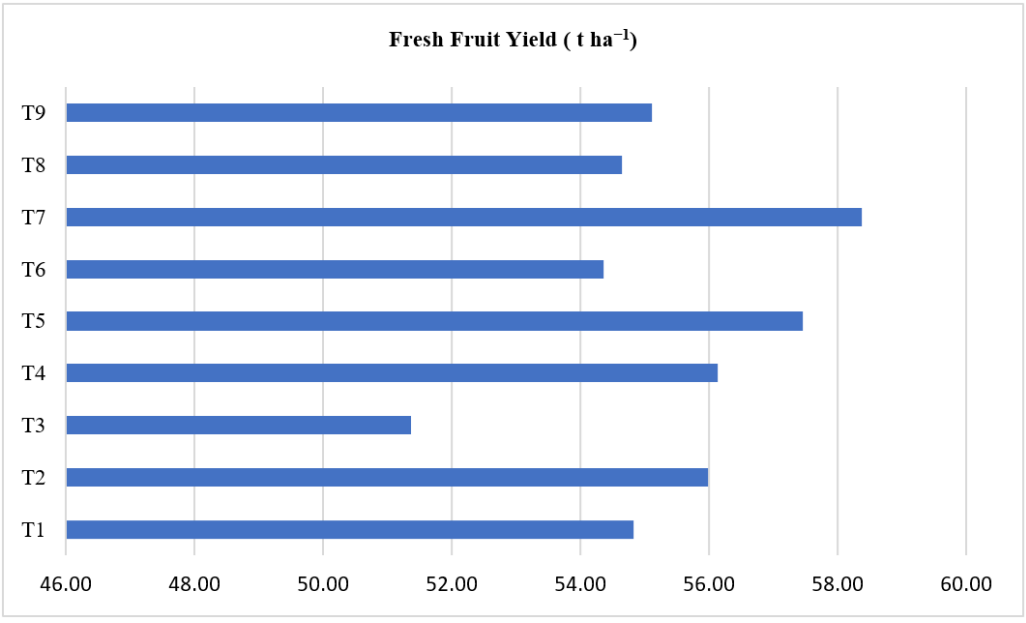

Fig 1: Effect of treatments on estimated fruit yield of pineapple cultivar 'Mauritius' in laterite soils of tropical humid climate

4. Conclusion

The present study showed that the combined application of Ayar, the secondary micronutrient mixture and foliar spray of $Ca(NO_3)_2$ was effective in achieving yield enhancement in Mauritius pineapple. As deficiency of calcium is reported in almost all the pineapple growing belts in Kerala, the source, method, frequency and time of application of calcium in pineapple has to be standardised of Mauritius pineapple.

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