NUTRIENT MANAGEMENT FOR PINEAPPLE (*Ananas comosus* L.) cv. AMRITHA

by

POOJA SHREE S.
(2017-12-029)

THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Faculty of Agriculture
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DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE
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DECLARATION

I, hereby declare that this thesis entitled **"Nutrient management for pineapple (*Ananas comosus* L.) cv. Amritha"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, associateship, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara,
Date: 20.08.2019

Pooja Shree S.
(2017-12-029)

CERTIFICATE

Certified that this thesis entitled **"Nutrient management for pineapple (*Ananas comosus* L.) cv. Amritha"** is a record of research work done independently by **Ms. Pooja Shree S. (2017-12-029)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

20/08/19

Dr. K. Ajith Kumar
(Chairperson, Advisory committee)
Associate Director of Research
Regional Agricultural Research Station
Ambalavayal, Wayanad
and
Special Officer
College of Agriculture,
Ambalavayal, Wayanad

Vellanikkara
Date: 20/08/2019

CERTIFICATE

We, the undersigned members of advisory committee of **Ms. Pooja Shree S. (2017-12-029),** a candidate for the degree of **Master of Science in Horticulture** with major in **Fruit Science**, agree that the thesis entitled **"Nutrient management for pineapple (*Ananas comosus* L.) cv. Amritha"** may be submitted by **Ms. Pooja Shree S. (2017-12-029),** in partial fulfilment of the requirement for the degree.

20/08/19

Dr. K. Ajith Kumar
(Chairperson, Advisory committee)
Associate Director of Research
Regional Agricultural Research Station
Ambalavayal, Wayanad
and
Special Officer
College of Agriculture,
Ambalavayal, Wayanad

20/08/19

Dr. Jyothi Bhaskar
Professor and Head
Department of Fruit Science
College of Horticulture
Vellanikkara

20/08/19

Dr. Sureshkumar P.
Professor and Head
Radio Tracer Laboratory
Vellanikkara

Dr. Shobhana A.S
Professor and Head
Fruits Crops Research Station
Vellanikkara

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Introduction

1. INTRODUCTION

Pineapple (*Ananas comosus* L.) is a wonderful tropical fruit having exceptional juiciness, vibrant tropical flavour and immense health benefits. It is an important monocot plant and is the only plant which produces edible fruits in the family Bromeliaceae. This family is divided into 3 sub-categories *i.e.,* Pitcarnioideae, Tillandsioideae and Bromelioideae. Pineapple belong to the sub-family Bromelioideae, genus *Ananas* and species *comosus* (Bartholomew *et al.*, 2003). The family Bromeliaceae consists of about 56 genera and 2794 species that have adapted to wide range of habitat, ranging from terrestrial to epiphytic, shady to full sun and from hot humid tropics to cold dry tropics. The plants can grow under moist to extreme dry conditions as well as at varying altitudes starting from mean sea level to alpine condition (Bartholomew *et al.*, 2003). Plants of the family are characterized by short stem, narrow stiff leaves arranged in a circular cluster, with terminal inflorescence (racemes or panicle) containing actinomorphic hermaphrodite flowers. Pineapple flowers fuse together with the central stem. It is one of the most important commercial fruit in the world. Pineapple contains considerable amount of calcium, potassium, fibre and vitamin C.

Globally, pineapple is grown extensively in an area of 10,98,705 ha with a production of 2,74,02,956 MT of pineapple (FAO, 2018). It dominates the world trade in tropical fruits, accounting for 51% of the global fruit market (FAO, 2018). Thailand ranks first both in area and production of pineapple in the world followed by Philippines and China. In India, it is cultivated under an area of 1,10,000 ha and production of 17,06,000 MT in the year 2017 (FAO, 2018). The most popular commercial variety in India is Giant Kew. Other important varieties are Queen, Kew, Mauritius, Charlotte Rothchild, Jaldhup, Lakhat *etc*. Kew and Mauritius are the important pineapple varieties cultivated commercially in Kerala. Majority of the cultivated area is covered by these two varieties. Pineapple is widely grown in states like West Bengal, Assam, Kerala and Karnataka.

In Kerala, pineapple is grown mainly as an intercrop in the rubber and coconut plantations, as pure crop in garden land and in converted paddy fields. Pineapple fruits are produced round the year in Kerala. During 2017, Kerala state recorded production of 3,05,640 MT from an area of 17,290 ha with a productivity

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of 17.6 t ha^{-1}. More than 60 per cent of the area is concentrated in Vazhakulam town in Ernakulam district. Pineapple industry can bring about a much needed employment opportunity in the region with not only its cultivation but also with setting up of more processing and semi-processing units in the state.

Amritha, a hybrid of pineapple has been released from the Pineapple Research Centre, Vellanikkara, Kerala Agricultural University in the year 2004. This new table variety was developed with the objective of improving the quality of fruit in the commercial variety Kew. Amritha is obtained by crossing Kew with Ripley Queen. Fruit yield and shape are comparable with that of female parent, Kew. Fruit quality attributes like flesh colour, flavour and sweetness are comparable with male parent Ripley Queen. Amritha fruits are harvested 13-15 months after planting. Crop sustains to less pest and disease incidence. The cylindrical fruits are tapering slightly towards the base, weighing 1.5-2 kg and crown weighing 80-100 g. They are green when unripe and changes to yellow during ripening. The taste is good with high TSS (18.3 °Brix) and low acidity (0.2%) (Dhillon, 2013).

Amritha when grown under the existing POP recommendation of KAU the fruit weight was varying from 0.5-1 kg per plant. The observations and trials conducted at Pineapple Research Station, Vellanikkara showed better response to higher levels of N, P and K with respect to yield. There is a need to develop optimum nutrient doses for ensuring high productivity of pineapple cv. Amritha. Therefore the present study was conducted with objective to standardise the nutrient requirement of pineapple (*Ananas comosus* L.) cv, Amritha for maximum production.

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Review of Literature

2. REVIEW OF LITERATURE

In this chapter, relevant literature pertaining to the objectives of the experiment are reviewed and presented in the order of vegetative growth, flowering, yield and fruit quality based on nutrition.

2.1. Response of crops to different levels of nutrients

2.1.1. Vegetative characters

Tay (1975) observed that there was positive response in plant height when potassium was applied up to 896 kg K_2O ha^{-1} in pineapple cv. Singapore Spanish.

A nutritional study was conducted on pineapple variety Queen with three levels of N (4, 8 and 16 g $plant^{-1}$) and three levels of K_2O (4, 8 and 16 g $plant^{-1}$) revealed that number of leaves increased significantly only to nitrogen but not to the changes in levels of phosphorous and potassium (Chadha *et al.*, 1976).

Vilela- Morales *et al.* (1977) studied the response of pineapple cv. 'Pernambuco' on different levels of N, P and K growing in Savanna soils of Brazil. Results revealed that plant height, production of slips and suckers increased with the increased levels of N and K, but there was no effect of P.

Medhi and Barooah (1978) conducted a study where N was applied 0, 110 and 220 kg ha^{-1}, P_2O_5 at 0, 75 and 150 kg ha^{-1} and K_2O at 0, 100 and 200 kg ha^{-1} concluded that average plant height and leaf numbers at flowering were greatest with the highest rate of each nutrient.

Mukherjee *et al.* (1981) carried out a nutritional study on cv. Kew with three mixed fertilizer treatments of N, P and K which resulted that the highest dose of fertilizer (16:8:16 g of N P and K) gave best result in plant height, number of leaves, leaf area, sucker and slip production.

Obiefuna *et al.* (1987) conducted an experiment to study the optimal fertilizer rates for maximum production of Smooth Cayenne pineapple and revealed that plants which received NPK fertilizers at 200-50-200 kg ha^{-1} produced the highest yield and best quality fruits.

Bhugaloo *et al.* (1999) found that as the rate of nitrogen fertilizer was increased from 0 to 420 kg N ha^{-1} it resulted in an increase in mean length of D leaf.

Singh *et al.* (2002) conducted an experiment to study the effect of different levels of N, P and K in pineapple cv. Queen in Andaman. It was observed that levels of N significantly influenced leaf number.

Amez *et al.* (2005) conducted a study with four levels of nitrogen (0, 2, 4 and 6 g $plant^{-1}$) in pineapple cv. Samba. It was observed that increasing nitrogen rates had a significant increase in the number of leaves per plant, plant height and the weight of the 'D' leaf.

Pereira da Silva *et al.* (2012) reported that increasing N doses increased length of D leaf in pineapple cv. Victoria.

A study was conducted to determine the effects of nitrogen fertilizers on pineapple and it was concluded that N fertilizer application up to 200 kg N ha^{-1} significantly increased the number of leaves, D - length and leaf area of the crop (Omotoso and Akinrinde, 2013).

Sakimin *et al.* (2017) conducted an experiment to evaluate the effects of two types of fertilizers on growth of MD-2 pineapple. Results showed that application of NPK fertilizers increased plant height, width and leaf length.

Experiment conducted to study the effects of N and K fertilization on growth of D leaf in cv. Imperial revealed that N dose of 285 kg ha^{-1} and K

dose of 410.4 kg ha^{-1} favored the increase in length, basal width, fresh and dry mass of D leaf (Rios *et al.*, 2018).

2.1.2. Flowering

Dass *et al.* (1975) reported that ethephon at a concentration as low as 25 ppm in combination with urea (2 %) and calcium carbonate (0.04 %) could induce more than 90 % flowering after 50 days of treatment. They also concluded that addition of either urea or calcium carbonate increased the effectiveness of ethephon for induction of flowering.

Mukherjee *et al.* (1981) reported that percentage of flowering was best in pineapple cv. Kew on application of 16:8:16 g of N P K per plant.

Experiment was carried out to find out the effect of N and P along with constant levels of K on pineapple cv. Queen revealed that it significantly influenced the days taken for flowering (Singh *et al.*, 2002)

Malip (2010) reported that application of 240 mg L^{-1} ethephon and 2 per cent urea showed optimum percentage of flowering in 'Maspine' pineapple with good fruit characteristics and quality required for canning.

2.1.3. Yield

Experiment conducted to evaluate the effect of N fertilizer levels on pineapple cv. Red Spanish revealed increased yield of fruits with the application of 168 pounds of N $acre^{-1}$ (Samuels *et al.*, 1955).

Samuels *et al.* (1956) reported that maximum quantity of 56 pounds of P_2O_5 $acre^{-1}$ can be used for increasing the yield of pineapple.

Evans (1957) studied the influence of fertilizers on pineapple replant areas and revealed that nitrogen when applied at a rate of 2,000 lb $acre^{-1}$ in

the form of sulphate of ammonia increased the yield of pineapple (10.5 t acre^{-1}).

Samuels and Diaz (1960) obtained higher yield acre^{-1} and mean weight per fruit fertilized with potassium sulfate than those which received potassium chloride.

Samuels and Gandia- Diaz (1960) studied nutritional requirement and yield comparison in pineapple cultivars *viz.,* Red Spanish and Smooth Cayenne where different levels of N (ammonium sulphate), P (superphosphate) and K (potassium chloride) were given to both the varieties in three applications among the different levels of N application, 200 lb of N acre^{-1} increased yield of both varieties.

A study was conducted in pineapple cv. Kew to know the responses of N, P and K revealed that pineapple did not have any response on application of P and K but a dose 2 g of N was enough to obtain better results under Basti conditions in India (Teotia and Pandey, 1964).

Mitchell and Nicholson (1965) reported maximum yield of pineapple on increased application of nitrogen up to 352 pounds acre^{-1} year^{-1} after flowering.

Cibes and Tejera (1966) reported that increments of potassium significantly increased the mean fruit weight of fruit in cv. Red Spanish from 1842 g to 2355 g in the 351 ppm K treatment carried out in gravel culture.

Kwong *et al.* (1966) obtained highest fruiting percentage and fruit weight with application of nitrogen at 16 g plant^{-1}. Studies also revealed that application of 20 g plant^{-1} of N and above reduced the plant growth.

Dodgson (1968) reported that 400 lb N $acre^{-1}$ $crop^{-1}$ increased the yield over 200 lb N by increasing fruit size in mother crop, and by increasing fruit size and set in ratoon crop.

Tay (1972) obtained increased yield of pineapple by 46 per cent on application of nitrogen, phosphorous and potassium to pineapple growing in peat soils of Malaysia.

Abutiate and Eyeson (1973) studied the NPK fertilizer responses for the pineapple cv. Smooth Cayenne and reported that N and K addition showed significant increase in yield and mean fruit weight whereas P had a depressing effect on yield but its effect on mean fruit was inconsistent.

A study was carried out to determine the response of pineapple cv. Singapore Spanish at five levels of nitrogen (0-672 kg N ha^{-1}) and six levels of potassium (0-1,120 kg K_2O ha^{-1}) and revealed that increased application of N up to 672 kg N ha^{-1} resulted in increase in the mean fruit weight but had a negative effect on fruit quality. Application of potassium up to 1120 kg K_2O ha^{-1} had a positive effect both on mean fruit weight and quality (Tay, 1975).

A fertilizer dose of 16:0:25 g of N, P_2O_5 and K_2O applied in 4 equal splits, at quarterly intervals, was found to increase fruit yield without reducing the quality of Kew pineapple grown with irrigation facility (Chadha *et al.*, 1976).

Singh *et al.* (1977) reported increase in number of leaves $plant^{-1}$, weight of 'D' leaf, average fruit weight, fruit size, fruit yield, number of slips and suckers $plant^{-1}$ with the increased application of nitrogen in pineapple cv. Kew.

Vilela-Morales *et al.* (1977) reported that fruit weight of pineapple cv.'Pernambuco' increased with increased levels of N and K.

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Medhi and Barooah (1978) conducted a study where N was applied at 0, 110 or 220 kg ha^{-1}, P_2O_5 at 0, 75 or 150 kg ha^{-1} and K_2O at 0, 100 or 200 kg ha^{-1} and concluded that yield was highest with N and P at the highest rate and K_2O at 100 kg ha^{-1}.

Webster and Keetch (1973) obtained increased size and yields of pineapple by the application of nitrogen in pineapple cv. Smooth Cayenne.

Khatua *et al.* (1980) obtained highest yield with 16 g N, 4 g P_2O_5 and 16 g K_2O $plant^{-1}$, which indicated that K:P ratio in the leaf at the flowering stage was 202:1.

Choairy and Fernandes (1986) studied the effect of phosphate fertilizers on pineapple cv. "Smooth Cayenne" and the dose involved 0, 1, 2, 3, 4 and 5 g $plant^{-1}$. Results showed that average weight of the fruit increased with 3 and 5 g of P_2O_5 per $plant^{-1}$, 5 g dose also increased the diameter of the fruit.

Asoewgu (1988) studied the effect of fertilization with four levels of nitrogen (0, 100, 150 and 200 kg ha^{-1}) and four potassium levels (0, 100, 150 and 200 kg ha^{-1}) on Smooth Cayenne pineapple where he observed that fruit weight was highest at N, 150 kg ha^{-1} and K, 200 kg ha^{-1}.

Mustaffa (1989) reported that application of phosphorous to Kew pineapple significantly increased the yield and fruit parameters in 2^{nd} and 3^{rd} cycles of crop.

Botrel *et al.* (1991) conducted an experiment to study the influence of different levels of phosphate fertilizers on pineapple crop. Results revealed that the use of 3.0 g of P_2O_5 per plant led to higher yield.

De Paula *et al.* (1991) reported that potassium fertilization increased production of pineapple up to 29 t ha^{-1} when 936 kg ha^{-1} of K_2O was added.

A study was carried out to evaluate the effect of foliar applications of N, P and Mg on the yield of cv. Red Spanish resulted in significant increase in fruit yield on application of 392 kg ha^{-1} of K and 224 kg ha^{-1} of Mg (Velez-Ramos and Borges, 1995).

Guoug *et al.* (1995) studied the effect of P and K on pineapple yield in cultivars 'Queen' and 'Smooth Cayenne'. Results revealed that important role was played by phosphorous in increasing yield from 35.5 t ha^{-1} to 44.7 t ha^{-1} for Queen. Application of 5 g P_2O_5 $plant^{-1}$ resulted highest yield for Queen and 7 g P_2O_5 for Smooth Cayenne. Application of 12 g K_2O $plant^{-1}$ also resulted in highest fruit yield.

A study was conducted to reveal the relationship between level of nitrogen fertilizers and quality of pineapple fruits of cv. Queen Victoria. The results indicated an increase of mean fruit length, mean fruit weight and mean fruit to crown ratio with increase in rate of nitrogen fertilizer from 0 to 420 kg ha^{-1} (Bhugaloo *et al.,* 1999).

Chundawat (2001) studied that nitrogen at the rate of 12 g plant applied to pineapple cv. Kew was found ideal for high fruit yields.

Razzaque and Hanafi (2001) reported that application of K_2O at 266 kg ha^{-1} resulted highest fruit weight in cv. Gandul pineapple.

Experiment conducted in pineapple cv. Perola to study the effect of different levels of nitrogen and potassium revealed that diameter and length of the fruit increased with potassium doses and also increased fruit yield of pineapple (79 t ha^{-1}) (Veloso *et al.,* 2001).

An attempt has been made by Singh and Singh (2004) to determine the effect of N (0, 8, 10, 12, 14 and 16 g $plant^{-1}$) and P fertilizers (0, 3, 6 and 9 g $plant^{-1}$) on the growth, yield and fruit quality of pineapple cv. Kew. The

application of 14 g N, 6 g P and 12 g K plant^{-1} is best for the sustainable growth and maximum yield of good quality pineapple.

Amez *et al.* (2005) observed that increasing N rates had a significant increase in pineapple fruit weight with or without the crown.

Hartinee *et al.* (2010) conducted an experiment to study the effect of nitrogen (N) and potassium (K_2O) on fruit yield of 'Maspine' pineapple and revealed that the highest average fruit weight of 1.88 kg was obtained with 200 kg N and 200 or 400 kg ha^{-1} K_2O.

Guarconi and Ventura (2011) studied the effect of fertilization with N and K on pineapple cv. MD-2 and found that highest productivity and fruit mass were obtained with the application of 650.6 kg ha^{-1} of N and 735.9 kg ha^{-1} of K_2O respectively.

Experiment was carried out in pineapple cv. Smooth Cayenne with the objective of investigating the effect of rates and sources of potassium fertilizer on plant growth and fruit yield revealed that fruit yield increased with potassium fertilization (Teixeira *et al.,* 2011).

A study was carried out to find out the effect of nitrogen on growth and yield of pineapple grown in BRIS soil where seven different rates of nitrogen fertilizer (0, 200, 400, 600, 800, 1,000 and 1,200 kg ha^{-1}) were applied in four equal split doses. Results showed increase in crown weight, mean fruit weight, mean fruit to crown ratio as the level of nitrogen was increased from 0 – 600 kg N ha^{-1} (Arshad and Armanto, 2012).

Hassan and Sahrin (2012) developed a mathematical model to determine the optimum rate of mixed fertilizers and they found that the combination of fertilizer N 75 kg ha^{-1}, P 57 kg ha^{-1} and K 89 kg ha^{-1} produced a high yield in pineapple.

A study conducted to know the effects of increasing doses of N on fruit yield and quality of the pineapple cv. 'Victoria' revealed that individual fruit weight and total yield increased with increasing N doses, as maximum values of 1.0 kg and 37.9 t ha^{-1} were seen at doses of 409 and 439 kg ha^{-1} N, respectively (Pereira da Silva *et al.,* 2012).

Wei-qi *et al.* (2012) reported that application of nitrogen two split doses helped in achieving higher yields (more than 10%) in case of pineapple cv. Yellow Mauritius.

Experiment was conducted in pineapple cv. "Victoria" with an objective to determine the effect of N, P_2O_5 and K_2O on fruit mass and productivity. The crop was provided with five levels of N (0, 214, 428, 642 and 856 kg ha^{-1}), five levels of P_2O_5 (0, 75, 150, 225 and 300 kg ha^{-1}) and five levels of K_2O (0, 150, 300, 450 and 600 kg ha^{-1}). Results revealed that the productivity and the average mass of fruit with crown had reached the maximum values of 65.0 t ha^{-1} with 647 kg N ha^{-1} and 1,247 g with 660 kg N ha^{-1} respectively (Caetano *et al.,* 2013).

A study was conducted in pineapple cv. Smooth Cayenne to determine the effect of N, P and K fertilizers on yield and revealed that the application of nitrogen (N), phosphorous (P_2O_5) and potassium (K_2O) fertilizers separately increased the yields by 15, 4.8 and 12.6 t ha^{-1}) and the yield increasing rates are 16.8%, 4.5% and 13.1% respectively (Ma *et al.,* 2013).

Omotoso and Akinrinde (2013) reported that fruit yield components such as fruit length, fruit diameter and core diameter increased with increased application of N fertilizers up to 200 kg N ha^{-1}.

Yanan *et al.* (2013) obtained significantly higher yield of 96.76 t/hectometre^2 (25.24%) in Bali pineapple in Leizhou Peninsula region with the application of nitrogen at a rate of 300 kg/ hectometre^2.

Rios *et al.* (2018) reported increased productivity (23.36 t ha^{-1}) of pineapple cv. Imperial with application of higher doses of N and K.

Rodriguez *et al.* (2018) reported that replacement of potassium chloride with K_2SO_4 significantly increased the fruit weight (1.66 kg) in pineapple var. MD-2.

Experiment was conducted to evaluate the effect of different rates of inorganic N and P fertilizers on fruit yield of pineapple cv. Smooth Cayenne revealed fruit yield increased up to 20.19 % and 68.22 % when 281 kg ha^{-1} of nitrogen and 134.8 kg ha^{-1} were applied respectively (Tewodros *et al.,* 2018).

2.1.4. Fruit quality

Cannon (1957) observed decrease in sugar and acid content with the application of nitrogen. Total soluble solid content significantly reduced with addition of nitrogen, but N x P interaction was significant for acidity per fruit. It was also reported that at lower levels of P and increasing levels of N juice acidity was lowering. But at the higher levels of P juice acidity was increasing.

A study conducted to determine the effect of various potassium levels on the quality of Red Spanish pineapple revealed that highest °Brix value of 12.53 for the 526 ppm of K was obtained in gravel culture (Cibes and Tejera., 1966)

Gaillard (1970) reported increased fruit quality and reduction in fruit acids with increased application of nitrogen.

Experiment was conducted in Smooth Cayenne cultivar to determine the effect of phosphate fertilization on fruit quality and it was revealed that the total acidity was not affected, but the brix to total acidity ratio was higher with higher phosphorous levels (Choairy and Fernandes, 1986).

A study was carried out to evaluate the effects of 4 levels of phosphorous (0, 2, 4 and 6 g plant^{-1} year^{-1}) in pineapple cv. Kew and the results indicated decreased acidity and total sugars but increased ascorbic acid which was significant in all the three crops of pineapple (Mustaffa, 1989).

Botrel *et al.* (1991) studied influence of phosphate fertilization on pineapple fruit and concluded that phosphate fertilization produced higher average fruit weight with crown.

An experiment was carried out to study the effect of potassium and nitrogen on quality of pineapple fruit and found that the °Brix content of the fruits increased with increased doses of K and the acidity decreased with the application of N (De Paula *et al.*, 1991).

A study was carried out to evaluate the suitable N: K_2O ratio required to recognize the optimum level of economic fertilizer for cv. Smooth Cayenne where nitrogen at two levels (224 and 336 kg N ha^{-1}) were combined with different levels of K_2O to give N: K_2O ratios of 1:15, 1.2 and 1:2.5 at 336 kg N ha^{-1} and reported a significant increase in acidity and °Brix contents of pineapple fruit juice (Owusu-Bennoah *et al.*, 1995).

Veloso *et al.* (2001) reported decreasing trends of fruit acidity with increased doses of potassium in pineapple cv. Perola.

Spironello *et al.* (2004) conducted an experiment to evaluate the effects of N, P and K on yield and fruit quality on pineapple cv. 'Smooth Cayenne'. Results showed that effect of N rates was negative on total soluble solids and total acidity while the opposite trend occurred with K, which also increased the content of vitamin C.

Hartinee *et al.* (2010) studied the effect of different levels of nitrogen (N) and potassium (K_2O) on quality of pineapple cv. 'Maspine' which

resulted in highest fruit total soluble solids (TSS) ranging from 11-18 °Brix at 200 kg N and 200 or 400 kg K_2O.

A study was carried out to evaluate the effect of nitrogen split application in pineapple cv. Yellow Mauritius and the results revealed that less than two split doses of N application was necessary to maintain good fruit quality (Wei-qi *et al.*, 2012).

Ma *et al.* (2013) reported that the application of P (100 kg ha^{-1}) K (500 kg ha^{-1}) decreased the vitamin C and total titratable acidity contents of fruits, whereas the soluble sugar contents of the fruits increased. Phosphate fertilizer application had less effects on the quality of fruit.

An experiment was carried out to determine the effect of different rates of nitrogen fertilizer on growth and fruit quality of pineapple. It was observed that fruit quality [total soluble sugars (TSS), percentage acidity and vitamin C] decreased with increasing rates of N application (Omotoso and Akinride, 2013).

A study was conducted in Bali pineapple to determine the effect of different levels of nitrogen application on quality of fruits. Results showed that with the increased rate of nitrogen application, the titrable acidity and vitamin - C content of pineapple fruit decreased (Yanan *et al.*, 2013).

Pengrin *et al.* (2014) reported increased fruit flesh weight, fruit size, translucent flesh and total soluble solids (TSS) on application of 5 -15 g of potassium for pineapple cv. Smooth Cayenne.

Oliveira *et al.* (2015) studied the influence of N and K fertilizers on fruit quality of pineapple cv. 'BRS Imperial' and reported that the N doses reduced titrable acidity (TA) and soluble solids (SS) with 17.9 °Brix at 550 kg

ha^{-1} N and the K_2O doses increased TA and SS with increased TSS (19.4 ^{o}Brix) at 600 kg ha^{-1} K_2O.

A study was conducted in pineapple var. MD-2 to study the effects of replacement of KCl with K_2SO_4 on fruit quality. It resulted in higher fruit total soluble solids (13.4 ^{o}Brix) with application of K_2SO_4 (Rodriguez *et al.*, 2018).

Experiment conducted in pineapple variety 'Comte de paris' to determine the effects of boron (B) on quality of fruit showed that boron had positive effect on fruit weight, TSS, the ratio of TSS to acidity and vitamin C content. But it had no effect on the content of sugars and titratable acidity (Wei *et al.*, 2018).

Materials and Methods

3. MATERIAL AND METHODS

The experiment aimed to standardize the nutrient requirement of pineapple (*Ananas comusus* L.) cv. Amritha. The procedures followed are detailed below.

3.1. Experimental site

The experiment was conducted at Fruits Crops Research Station (FCRS), Vellanikkara, Thrissur, Kerala.

3.1.1. Season

The experiment was conducted from April 2018 to May 2019.

3.1.2. Date of planting

The date of planting was done on 13 April 2018.

3.2. Materials

3.2.1. Variety

Pineapple cv. Amritha was used for this experiment. It is a hybrid developed by crossing Kew and Ripley Queen at Pineapple Research Centre, Vellanikkara, under Kerala Agricultural University, now renamed as Fruits Crops Research Station. Fruits are golden yellow colour with non- fibrous flesh. It has rich aroma, high TSS and low acidity. Suckers for planting were also collected from Fruits Crops Research Station, Vellanikkara, Thrissur, Kerala.

3.3. Methods

3.3.1. Design of the experiment

Design of the experiment was Randomized Block Design (RBD) with six treatments. The six treatments were laid out in RBD with four replications.

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3.3.2. Treatments

Treatments consisted of different levels of nutrients in six different treatments based on soil test results. Farmyard manure (FYM), urea, muriate of Potash (MOP) and rock Phosphate were used as source of nutrients.

Table 1. Treatment combinations

Notations	Treatment combinations	Urea (g plant^{-1})	Rock Phosphate (g plant^{-1})	MOP (g plant^{-1})
T_1	POP recommendation of KAU (8:4:8 N, P_2O_5, K_2O g plant^{-1})	17.30	20.00	13.33
T_2	Modified based on soil test results	9.39	11.45	11.36
T_3	25% higher than the modified POP based on soil test results	11.70	14.31	14.31
T_4	50% higher than the modified POP based on soil test results	14.08	17.17	17.03
T_5	75% higher than the modified POP based on soil test results	16.40	20.03	19.13
T_6	Adhoc Organic POP	0	0	0

Adhoc Organic POP- FYM @ 500 g plant $^{-1}$, phosphate @ 20 g plant $^{-1}$, bone meal @ 50 g plant $^{-1}$ at the time of planting, 250 g cowdung, 50 g neem cake, 50 g groundnut cake, 1g Azospirillum and 1 g Phosphobacter or PGPR mix 1 applied six weeks after planting. Apply 1.5 g of SOP in liquid form along with cowdung solution at an interval of 6, 10, 14, 18, 22 and 30 weeks after planting for each plant (KAU, 2013).

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Plate 1a. Experimental Field

Plate 1b. Experimental Field

Plate 2. Ploughing of land

Plate 3. Soil sample collection

4a

4b

4c

4d

Plate 4a, 4b, 4c & 4d. Application of lime

5a

5b

Plate 5a & 5b. Layout of Experiment

6a

6b

Plate 6a & 6b. Trench Preparation

7a

7b

7c

7d

Plate 7a, 7b, 7c & 7d. Application of FYM and inorganic fertilizers

8a

8b

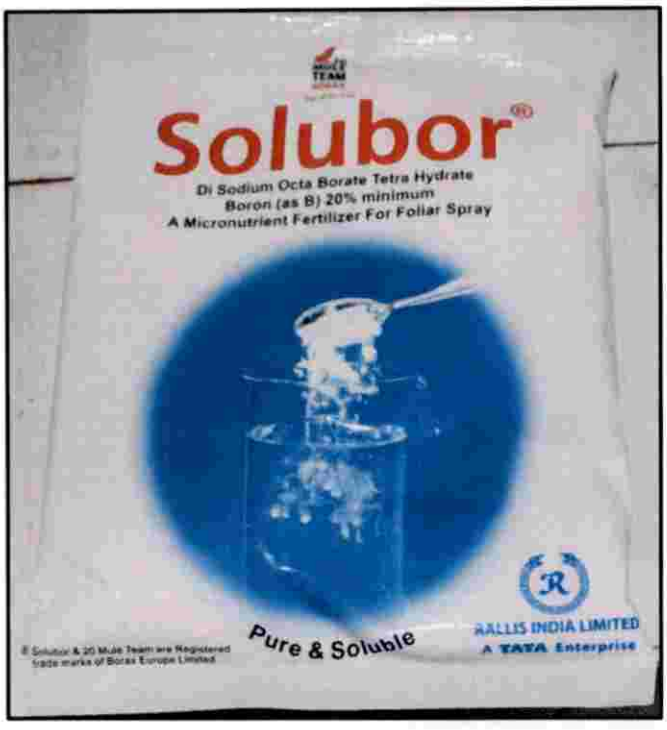
Plate 8a & 8b. Planting material

9a

9b

9c

Plate 9a, 9b & 9c. Planting of suckers



10a

Plate 10b. Foliar application of Boron

11a

11b

Plate 11a & 11b. Ethrel Application

12a

12b

Plate 12a & 12b. Initiation of flower

13a

13b

Plate 13a & 13b. Flowering

14a

14b

Plate 14a & 14b . Fruiting

15a

15b

15c

15d

15e

15f

Plate 15 (a, b, c, d, e & f). Treatment Plots

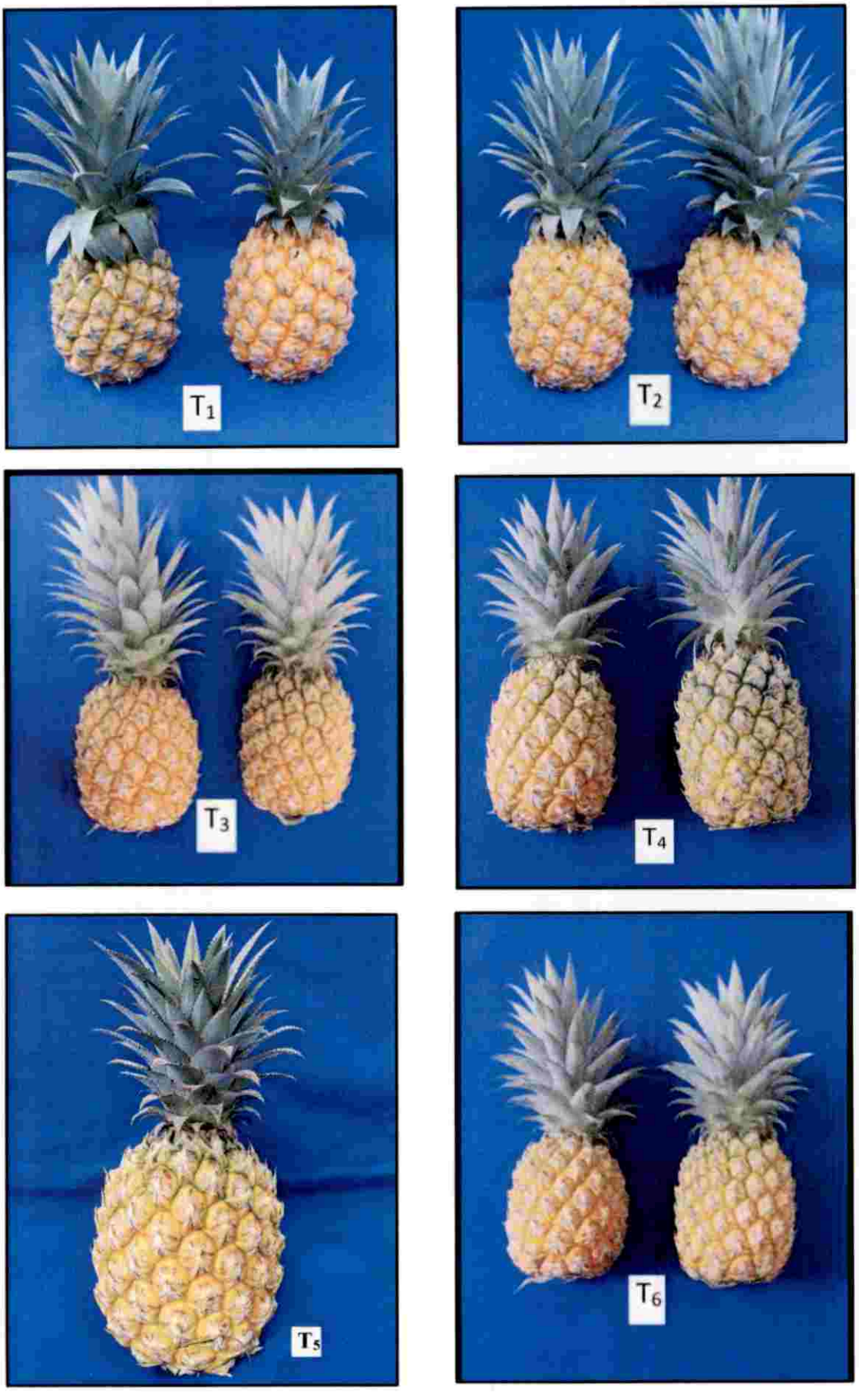


Plate 16. Pineapple fruits harvested from different treatments

3.3.3. Preparation of land

Land was ploughed thoroughly and was made free of weeds and clumps of soil. Incorporation of lime at 331 kg $acre^{-1}$ was done and again land was ploughed thoroughly after 10 days. Land was leveled properly and trenches of size 3m x 1m were taken.

3.3.4. Fertilizer application

Organic manure (FYM) was incorporated into soil during planting time at the rate of 50 tonnes ha^{-1}. Full dose of P_2O_5 was applied at the time of planting. Nitrogen and K_2O applied in 3 split doses, at the time of planting, August - September and in March of the second year. Foliar spray of boron (solubar) 4 g $litre^{-1}$ was done at monthly intervals.

3.3.5. Planting

Twenty four number of trenches/ plots of size 3 m x 1 m size with 15-30 cm depth were taken with a spacing of 90 cm between the beds. Double row triangular method of planting was done with a spacing of 45 cm x 30 cm.

Healthy suckers (500 g) were planted twenty number in each trench/ plot by hand in early morning hours.

3.3.6. After cultivation

Weeding was done in trenches/ plots as and when required. Irrigation was given especially during active vegetative growth and flowering.

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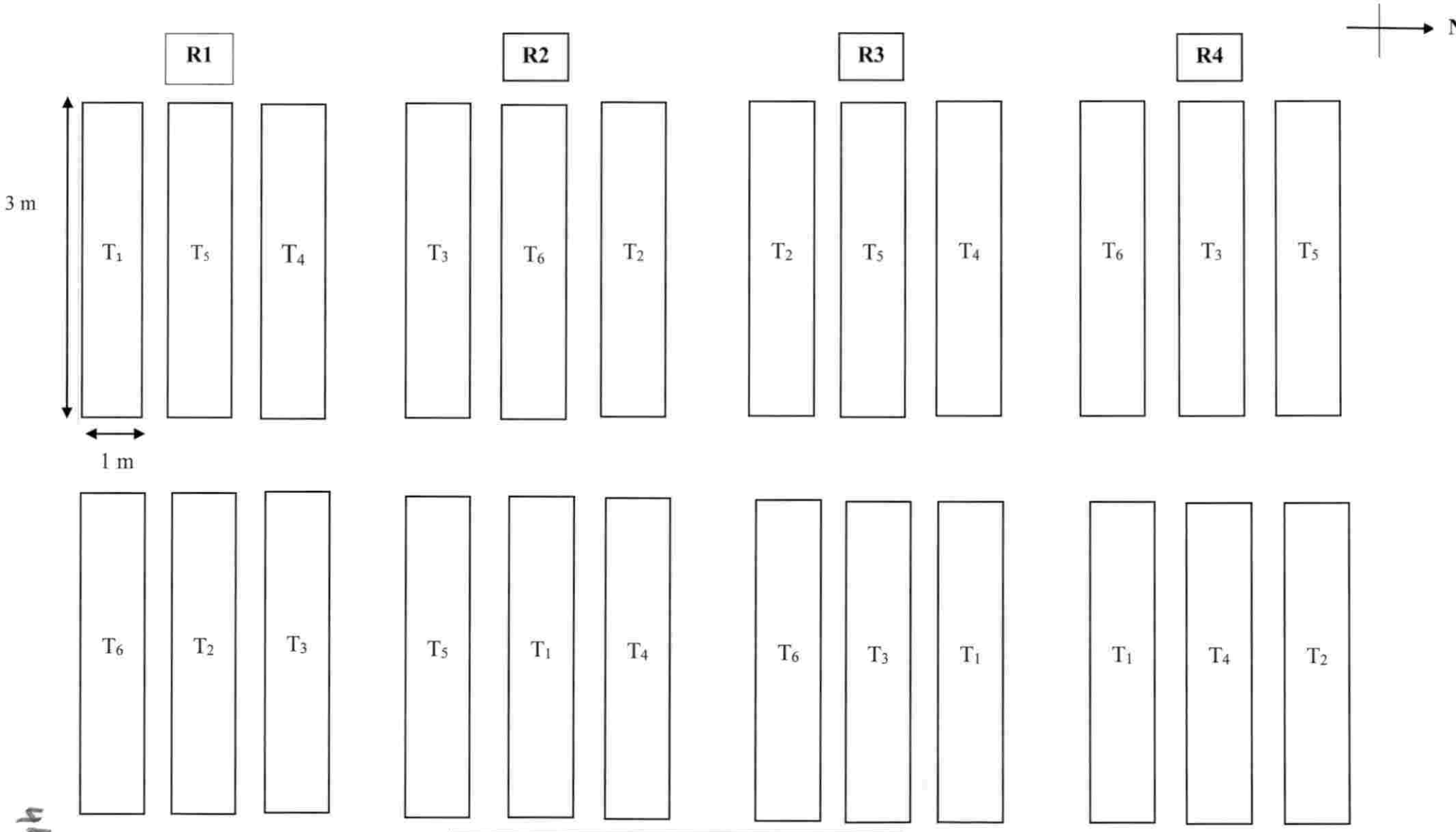

Fig. 1 Plan and Layout of the experiment

3.4. Main items of observations

Observations were recorded from individual plots. The observations on various growth parameters were taken at monthly intervals. Five plants per treatment were randomly selected for recording various growth, flowering and yield attributes.

3.4.1. Vegetative characters (Monthly intervals)

3.4.1.1. Plant height

The height of the plant from the ground level to the tip of the longest leaf was measured at monthly intervals and also at the time of application of ethrel and expressed in centimetres.

3.4.1.2. No. of leaves per plant

The total number of leaves was recorded at monthly intervals and at the time of ethrel application.

3.4.1.3. Length of 'D' leaf

The 'D' leaf was taken out and the length was recorded at monthly intervals and expressed in centimetres.

3.4.1.4. Breadth of 'D' leaf

The 'D' leaf was taken out and the breadth was recorded at monthly intervals and expressed in centimetres.

3.4.1.5. 'D' leaf area

The 'D' leaf area was worked out using the formula suggested by Balakrishnan *et al*. (1978) and expressed in centimetre square.

$$LA = L \times B \times 0.725$$

Where LA= Leaf area in cm^2, L= length of 'D' leaf in cm, B= breadth of 'D' leaf in cm and 0.725 is the constant.

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3.4.1.6. Leaf Area Index (LAI)

Leaf area index was worked out from the formula suggested by Watson (1952).

$$LAI = \frac{\text{Total leaf area per plant } (cm^2)}{\text{Total land area occupied per plant } (cm^2)}$$

3.4.1.7. Leaf production rate

The mean number of leaves produced per month up to flowering was recorded.

3.4.1.8. No. of suckers per plant

The mean number of suckers produced per plant was recorded after harvest of the crop.

3.4.1.9. Position of suckers

Suckers were found in three positions with respect to the mother plant, *viz.,* low (within 5 cm from the ground level), medium (Between 5-15 cm from the ground level) and high (more than 15 cm from the ground level). The number of suckers per plant in each position was recorded and expressed as percentage.

3.4.2. Flowering characters

3.4.2.1. Days to attain physiological maturity

The time taken from planting to attain 39-42 leaf stage in each treatment was recorded.

3.4.2.2. Days for initiation of flowering

The mean number of days taken from ethrel application to the appearance of reddish colour at the centre of the plant was recorded.

3.4.2.3. Days for 50 per cent flowering

The mean number of days taken from ethrel application to emergence of inflorescence in 50 per cent of the plants in each treatment was recorded.

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3.4.3. Fruit and yield characters

3.4.3.1. Fruit weight

The weight of fruits, with crown intact and without crown, was recorded immediately after harvest and expressed in kilograms.

3.4.3.2. Length of the fruit

The length of fruit was recorded immediately after harvest and the values were expressed in centimetres.

3.4.3.3. Girth of the fruit

The girth of the fruit in the middle portion was recorded and expressed in centimetres.

3.4.3.4. Breadth of the fruit

The breadth of the fruit at three portions, namely top three-fourth, middle and bottom one-fourth were recorded. The mean fruit breadth was calculated and expressed in centimetres.

3.4.3.5. Crown weight

The weight of crown was recorded immediately after removing from harvested fruits and expressed in kilograms.

3.4.3.6. Length / breadth ratio (L/B ratio)

L/B ratio was worked out using the formula suggested by Pantastico (1975).

$$\text{L/B ratio} = \frac{\text{Fruit length (cm)}}{\text{Mean fruit breadth (cm)}}$$

3.4.3.7. Taper ratio

The taper ratio of the fruit was arrived at using the formula

$$\text{Taper ratio} = \frac{\text{Breadth at top } ¾}{\text{Breadth at bottom } ¼}$$

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3.4.3.8. Yield per hectare

The mean fruit yield per hectare was worked out from the fruit weight and expressed as tonnes per hectare.

3.4.3.9. Days for maturity

The mean number of days taken from emergence of inflorescence to harvest was worked out for each treatment.

3.4.3.10. Crop duration

The mean number of days taken from planting to harvest was worked out.

3.4.3.11. Peel weight

Peeling of fruits was done carefully and peel weight was noted down and recorded in grams.

3.4.3.12. Pulp weight

After removing the peel and central core, the weight of the pulp in kilogram was recorded for each fruit.

3.4.3.13. Pulp percentage

Pulp percentage was worked out from the above observation as

$$\text{Pulp percentage} = \frac{\text{Pulp weight}}{\text{Weight of fruit without crown}} \times 100$$

3.4.3.14. Harvest Index

Harvest index was calculated using the formula of Donald (1962).

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Total biological yield}} \times 100$$

3.4.3.15. Root: Shoot ratio

Root:shoot ratio is the ratio of the average dry weight of the root to the average dry weight of the shoot.

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3.4.3.16. Shelf life

The shelf-life of pineapple fruit was observed until 10 percent of the fruit surface discolouration was considered as the end of shelf-life which was worked out for each treatment and expressed in days.

3.4.4. Qualitative analysis of fruits

3.4.4.1. TSS

Total soluble solids was found out using a digital refractometer and expressed as degree °Brix.

3.4.4.2. Titratable acidity

Ten grams of macerated fruit sample was mixed with distilled water and made up to a known volume. An aliquot of the filtered solution was titrated against 0.1N sodium hydroxide using phenolphthalein as indicator. The acidity was calculated using the formula and expressed as percentage of citric acid (AOAC, 1998).

$$\text{Acidity (\%)} = \frac{\text{Titre value} \times \text{Normality of alkali} \times \text{Volume made up} \times \text{Equivalent weight of acid} \times 100}{\text{Volume of sample taken for estimation} \times \text{Weight / volume of sample taken} \times 1000}$$

3.4.4.3. Total sugars

Fifty millilitres of the filtrate used in the estimation of reducing sugars was taken into a 100 ml volumetric flask and 5 ml of concentrated HCl was added for hydrolyzing the sample. Then the hydrolysed solution was neutralized with 20 per cent NaOH by using one or two drops of phenolphthalein indicator. Diluted HCl was added till it became colourless. Finally, the volume was made up to 100 ml and it was titrated against standard Fehlings solution using methylene blue as an indicator (Ranganna, 1997). The total sugars were calculated as given below.

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$$\text{Total sugars (\%)} = \frac{\text{Factor} \times \text{Dilution} \times 100}{\text{Titre value} \times \text{Volume of filtrate} \times \text{Weight of sample taken}}$$

3.4.4.4. Reducing sugars

Ten grams of macerated fruit sample was mixed with distilled water and then transferred to 250 ml volumetric flask to which added 2 ml lead acetate 45 % then after 10 min, added 2 ml potassium oxalate 22 % then shaken well and volume is made up to 250 ml by adding distilled water. Later filtered solution and supernatant solution have to be taken in a burette and titrated against 5 ml each of Fehling solution A and B mixture taken in the conical flask. With given heat to the conical flask solution by adding 2 drops of methylene blue as indicator at the time of titration. The titration had been done till up to colour changes to brick red colour. The reducing sugar was calculated using the formula and expressed as percentage (AOAC, 1998).

$$\text{Reducing sugars (\%)} = \frac{\text{Factor} \times \text{Dilution} \times 100}{\text{Titre value} \times \text{Weight of sample taken}}$$

3.4.4.5. Non reducing sugars

Non-reducing sugars were calculated by subtracting the amount of reducing sugars from the total sugars. The Non-reducing sugar was calculated using the formula and expressed as percentage (AOAC, 1998).

Non reducing sugars (%) = Total sugars (%) – Reducing sugars (%)

3.4.4.6. Sugar/acid ratio

Sugar/acid ratio was worked out by dividing the value of total sugars by the value of titratable acidity.

3.4.4.7. Fibre

The fibre content was estimated by acid alkali method as suggested by Chopra and Kanwar (1978). Two grams of dried and powdered sample was boiled with 200 ml of 1.25 per cent sulphuric acid for thirty minutes. It was filtered through a muslin cloth and washed with boiling water. The residue was again boiled with 200 ml of 1.25 per cent sodium hydroxide for 30 minutes. Repeated the filtration and the residue was washed with 1.25 per cent sulphuric acid, water,

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and alcohol. The residue was transferred to a pre weighed ashing dish, dried, cooled and weighed and ignited in a muffle furnace at 600 °C for 30 minutes, cooled in a desiccator and weighed. The crude fibre content of the sample was calculated from the loss in weight on ignition and expressed in percentage on fresh weight basis.

3.4.4.8. Ascorbic acid

Ascorbic acid content was estimated by volumetric method (Sadasivam and Manickam, 1992). Dye solution was prepared using (42 mg of sodium bicarbonate and 52 mg of 2, 6, dichloro phenol indophenols dye in 200 ml of distilled water). Then about 100 mg of pure dry crystalline vitamin-C was taken and made up to 100 ml using 4 % oxalic acid to get the stock solution. The working standard solution (100 ml) was prepared by diluting 10 ml stock solution using 4 % oxalic acid. After that 5 ml each of working standard solution and 4 % oxalic acid was pipetted into a conical flask and titrated against the dye solution. The result point was the appearance of pale pink colour which was observed for a few minutes. The titration was repeated for 3 times to get the accurate value. The amount of dye consumed (V_1) was equal to the amount of vitamin-C present in the working standard solution. The sample was made into pulp and 10 ml pulp (V_s) was taken and made up to 100 ml with 4 % oxalic acid solution. Then 5 ml of the made up solution was pipette into a conical flask and was titrated against the dye (V_2). The quantity of vitamin-C (mg) present in 100 g of sample was calculated as follows

$$\text{Ascorbic acid (mg/100 g)} = \frac{0.5 \times V_2 \times 100}{V_1 \times 5 \times Vs} \times 100$$

3.5. Organoleptic evaluation

Organoleptic evaluation of ripe fruits was conducted based on nine point hedonic scale for taste, flavour, colour, texture, sweetness and appearance.

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3.6. Soil and plant analysis

3.6.1. Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The composite samples from the experimental site prior to experiment were analysed for mechanical and chemical composition. After the experiment composite samples were collected from each plot, air dried, powdered and passed through a 2 mm sieve and analysed for pH, EC, organic carbon, available N, P and K as per the standard methodology given in Table 2.

Table 2. Soil analysis methodology

Parameter	Method	Reference
Soil pH	Soil water suspension of 1:25 and read pH meter	Jackson, 1958
Electrical conductivity	Soil water suspension of 1:25 and read electrical conductivity by meter	Jackson, 1958
Organic carbon	Walkley and Black method	Walkley and Black, 1934
Available Nitrogen	Alkaline permanganate method	Subbiah and Asija, 1956
Available phosphorous	Ascorbic acid reduced molybdophosphoric blue colour method	Watanabe and Olsen, 1965
Available potassium	Neutral normal ammonium acetate using photometry	Jackson, 1958

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3.6.2. Plant analysis

Plant samples collected from each plot at harvest were analysed for N, P and K.

3.6.2.1. Total nitrogen

Total nitrogen was determined by Micro Kjeldhal method (Piper, 1942). In this method, all forms of nitrogen in the sample were converted into sulphate of ammonia by digestion with sulphuric and salicylic acid in the presence of sodium sulphate as the electrolyte and selenium as catalyst. The digest was made up to a known volume with distilled water. An aliquot of the resulting solution was distilled with excess of alkali and the distillate was collected in 4 per cent boric acid indicator mixture. The amount of ammonia evolved was determined by titration with standard sulphuric acid.

The analysis of other nutrients *viz.,* P and K was done after diacid digestion of the plant sample. In diacid digestion, the acid mixture was prepared by mixing the nitric and perchloric acid in 9: 4 ratio. The dried plant sample (0.5 g) was taken in a 50 ml conical flask and 20 ml of diacid was added for predigestion. After the predigestion, samples were heated on a hot plate for digestion until a clear solution was obtained. The digest was transferred to a 25 ml volumetric flask. The digestion flask was washed 2 to 3 times with double distilled water and volume was made up to 25 ml. Aliquots from this solution were taken for the analysis of the nutrient elements.

3.6.2.2. Total phosphorous

Five milligrams of plant digest was pipetted out into a 50 ml volumetric flask. Barton's reagent 5 ml was added in to this, shaken well and the volume was made up. This was allowed to stand for 30 minutes for yellow colour development. Then the intensity of the colour was read at 420 nm in spectrophotometer (Piper, 1942). The absorbance value was plotted in the standard graph to obtain the concentration of P in the colour solution.

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3.6.2.3. Total potassium

Five millilitre of the plant digest was pipetted out into a 25 ml volumetric flask and diluted to 25 ml with distilled water. The standards were aspirated followed by the sample and the meter reading was noted and K content was calculated by referring to the standard curve prepared (Piper, 1942).

3.7. Economic analysis

For economic analysis, total revenue (TR) and total cost (TC) were estimated in pineapple cv. Amritha production. Total variable cost was calculated by the addition of cost incurred on land preparation, labour charges, planting material, weeding and harvesting. Total returns was calculated by the yield obtained after the final harvest. Later, Benefit cost ratio (BCR) was obtained by dividing total revenue (TR) with total cost (TC) (Khan *et al.,* 2017).

3.8. Statistical analysis

The data regarding growth parameters and floral characters were subjected to statistical analysis by using the technique of analysis of variance (ANOVA) for Randomized Block Design (Panse and Sukhatme, 1985).

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Results

4. RESULTS

The results of the experiment regarding to nutrient requirement of pineapple (*Ananas comusus* L.) cv. Amritha are presented in this chapter. The influence of various treatments of N, P and K on the morphological, floral, yield and quality attributes of pineapple were studied. The results are presented under the following heads.

1. Vegetative characters
2. Flowering characters
3. Fruit and yield characters
4. Quality parameters
5. Soil, plant and fruit nutrient analysis
6. Economic analysis

4.1. Vegetative characters

Different observations on growth parameters *viz.,* plant height, number of leaves per plant, length and breadth of 'D' leaf, 'D' leaf area, leaf area index, leaf production rate, number of suckers per plant, position of suckers are recorded and presented in Tables 3 to 9.

4.1.1. Plant height

The effect of different treatment combinations on plant height are presented in Table 3.

Application of different levels of nutrients had no significant effect on plant height.

4.1.2. Number of leaves per plant

The effect of different treatment combinations on number of leaves per plant are presented in Table 4.

Application of different levels of nutrients had no significant effect on number of leaves per plant.

Table 3. Effect of different levels of nutrients on plant height of pineapple cv. Amritha

Treatments	Plant height (cm)											
	Months after planting (MAP)											
	1	2	3	4	5	6	7	8	9	10	11	12
T_1	35.8	36.2	39.4	49.7	54.3	56.0	57.4	59.3	59.2	59.9	61.3	63.5
T_2	38.8	41.3	45.1	49.5	53.1	56.0	58.2	60.3	61.4	62.6	64.5	66.8
T_3	37.5	39.0	43.8	49.2	53.1	56.3	57.9	59.7	60.5	62.1	64.0	66.7
T_4	37.1	39.2	44.2	50.2	54.7	57.4	59.9	62.3	62.8	64.5	66.1	68.4
T_5	39.1	41.8	44.7	51.5	55.1	58.9	62.0	63.9	64.4	66.1	67.7	70.0
T_6	39.2	41.2	48.1	50.9	52.9	54.6	56.1	57.4	58.8	60.8	63.0	65.3
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

Table 4. Effect of different levels of nutrients on number of leaves per plant of pineapple cv. Amritha

Treatments	No. of leaves											
	Months after planting (MAP)											
	1	2	3	4	5	6	7	8	9	10	11	12
T_1	18.5	22.8	25.6	25.7	25.9	29.6	29.6	31.1	32.0	32.2	32.7	33.7
T_2	20.0	24.1	26.6	26.5	27.0	30.1	30.1	32.9	33.2	34.4	35.3	35.6
T_3	22.0	22.1	25.1	26.4	27.3	30.5	30.5	32.2	33.9	33.9	34.3	34.6
T_4	19.7	24.1	27.0	27.8	28.6	32.6	32.6	34.7	36.0	36.5	37.1	37.3
T_5	19.2	23.2	26.8	27.3	27.9	31.0	31.0	33.2	35.0	35.5	36.1	36.2
T_6	18.4	21.8	25.4	25.9	24.7	29.2	29.2	32.4	33.0	34.7	35.2	36.4
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

Table 5. Effect of different levels of nutrients on length of 'D' leaf of pineapple cv. Amritha

Treatments	Length of 'D' leaf (cm)											
	Months after planting (MAP)											
	1	2	3	4	5	6	7	8	9	10	11	12
T_1	27.8	29.6	34.5	39.8	43.5	45.7	44.2	41.1	41.1	41.6	42.9	43.7
T_2	27.9	30.7	32.7	40.3	45.7	46.3	42.6	39.3	40.2	40.9	42.1	42.9
T_3	28.2	29.9	30.6	39.3	44.2	43.6	41.8	38.9	40.5	40.5	41.8	42.8
T_4	29.1	30.0	32.3	40.0	43.9	45.9	38.2	38.5	39.5	40.2	41.3	42.2
T_5	28.8	30.2	30.3	39.5	46.0	46.5	41.0	40.9	41.9	43.1	44.0	45.1
T_6	30.2	32.6	32.7	39.1	42.6	42.9	43.1	44.3	46.0	47.6	49.8	51.4
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	3.549	3.137	3.386	3.018	3.187

NS – Non significant

Table 6. Effect of different levels of nutrients on breadth of 'D' leaf of pineapple cv. Amritha

Treatments	Breadth of 'D' leaf (cm)											
	Months after planting (MAP)											
	1	2	3	4	5	6	7	8	9	10	11	12
T_1	1.82	2.02	2.05	2.35	2.77	2.75	2.80	2.82	3.05	3.30	3.66	3.66
T_2	1.80	2.03	1.85	2.21	2.57	2.70	2.70	2.65	3.09	3.34	3.58	3.58
T_3	1.77	1.69	1.73	2.20	2.75	2.82	2.62	2.60	2.97	3.36	3.60	3.60
T_4	1.94	2.14	1.94	2.27	2.65	2.85	2.77	2.80	3.08	3.33	3.60	3.60
T_5	1.94	2.14	1.95	2.22	2.65	2.77	2.75	2.77	2.98	3.27	3.54	3.54
T_6	1.78	1.99	2.04	2.55	2.82	2.82	2.65	2.67	2.98	3.27	3.55	3.55
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

Table 7. Effect of different levels of nutrients on 'D' leaf area of pineapple cv. Amritha

Treatments	'D' leaf area (cm^2)											
	Months after planting (MAP)											
	1	2	3	4	5	6	7	8	9	10	11	12
T_1	36.85	43.38	52.04	52.04	88.26	91.95	90.42	84.65	91.24	99.51	114.1	125.6
T_2	36.48	45.41	44.65	44.65	85.40	90.94	83.57	75.56	90.23	99.35	109.4	125.0
T_3	36.19	36.78	39.00	39.00	88.81	89.42	79.13	73.41	87.28	98.63	108.9	123.0
T_4	41.12	46.78	45.66	45.66	84.91	94.80	76.95	78.26	88.33	97.51	107.8	124.3
T_5	40.69	47.15	42.75	42.75	89.48	94.34	81.82	82.30	90.69	102.76	113.1	135.6
T_6	38.99	47.00	48.34	48.34	87.63	88.09	83.31	86.43	99.78	113.77	128.7	155.2
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	10.561	10.937

NS – Non significant

Table 8. Effects of different levels of nutrients on leaf area index of pineapple cv. Amritha

Treatments	Leaf area index											
	Months after planting (MAP)											
	1	2	3	4	5	6	7	8	9	10	11	12
T_1	0.53	0.63	0.73	0.83	0.93	1.03	1.23	1.33	1.43	1.73	2.03	2.33
T_2	0.55	0.65	0.75	0.85	0.95	1.05	1.25	1.35	1.45	1.75	2.05	2.35
T_3	0.55	0.65	0.75	0.85	0.95	1.05	1.25	1.35	1.45	1.75	2.05	2.35
T_4	0.52	0.62	0.72	0.82	0.92	1.02	1.22	1.32	1.42	1.72	2.02	2.32
T_5	0.61	0.71	0.81	0.91	1.01	1.11	1.31	1.41	1.51	1.81	2.11	2.41
T_6	0.64	0.74	0.84	0.94	1.04	1.14	1.34	1.44	1.54	1.84	2.14	2.44
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

4.1.3. Length and breadth of 'D' leaf

Data showing the effect of different treatments on average length and breadth of 'D' leaf at monthly intervals are presented in Tables 5 and 6.

Data indicated that there was no significant difference among the treatments up to seven months after planting with regard to length of the 'D' leaf.

However, after eight months after planting, T_6 recorded the maximum length of 44.3 cm and was on par with T_1 and T_5. The minimum length was recorded in T_4 (38.55 cm) and it was on par with T_2 and T_3. Similar trend in length of the 'D' leaf was observed during ninth, tenth, eleventh and twelfth month after planting.

The treatments did not show significant difference for width of 'D' leaf.

4.1.4. 'D' leaf area

Data pertaining to 'D' leaf area, as influenced by the different treatments are furnished in Table 7.

As per recorded data, the treatments had no significant effect on the 'D' leaf area up to ten months after planting.

On the other hand, at eleven months after planting, T_6 recorded the maximum 'D' leaf area (128.17 cm^2) which significantly different from all other treatments. The minimum 'D' leaf area was recorded by T_4 (107.87 cm^2) and it was on par with T_3, T_2, T_5 and T_1.

At twelve months after planting, T_6 recorded maximum 'D' leaf area (155.24 cm^2) which showed significantly superior when compared to other treatments. The treatment T_3 recorded the minimum value of 123.06 cm^2 and it was on par with T_4.

4.1.5. Leaf area index

The effect of different treatment combinations on leaf area index are presented in Table 8.

Application of different levels of nutrients on cv. Amritha had no significant effect on leaf area index.

4.1.6. Leaf production rate

Data on the monthly leaf production rate as influenced by the different treatments are given in Table 9.

The data showed that no significant difference was observed by the different treatments with respect to leaf production rate.

4.1.7. Number of suckers per plant

There was no production of suckers observed during the period of experiment.

4.1.8. Position of suckers

Data on the position of suckers was not observed due to no production of suckers during the period of experiment.

4.2. Flowering characters

Different observations on flowering attributes *viz.*, days to attain physiological maturity, days for initiation of flowering, days for 50 per cent flowering of pineapple under various nutrient combinations were recorded and the results are presented below.

4.2.1. Days to attain physiological maturity

Treatments T_5 and T_6 attained physiological maturity for flowering (39-42 leaf stage) within a period of 6 $^1/_2$ months after planting, whereas the treatments T_1, T_2, T_3 and T_4 attained physiological maturity within a period of 7 months after planting.

4.2.2. Days for initiation of flowering

Data on the days for initiation of flowering as influenced by different treatments are furnished in Table 10.

The treatment T_5 recorded the minimum time for initiation of flowering (39.2 days). The treatment T_1 took maximum time for initiation of flowering (43.7 days), where T_3 was on par with T_1.

4.2.3. Days for 50 per cent flowering

Data on the effect of different treatments on the days of flowering of 50 per cent of the plants are presented in Table 10.

The treatment T_5 recorded minimum number of days for 50 per cent flowering (47.2 days) and was significantly superior. T_2 recorded the maximum days (52.2 days) which was on par with T_3, T_6, T_1 and T_4.

Table 9. Effect of different levels of nutrients on leaf production rate of pineapple cv. Amritha

Treatments	Leaf production rate (monthly)
T_1	1.6
T_2	1.4
T_3	1.8
T_4	1.7
T_5	1.7
T_6	1.8
CD (0.05)	NS

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Table 10. Effect of different levels of nutrients on flowering characters of pineapple cv. Amritha

Treatments	Days to attain physiological maturity (months)	Days for initiation of flowering	Days for 50 per cent flowering
T_1	7	43.7	51.1
T_2	7	42.3	52.2
T_3	7	43.0	51.9
T_4	7	41.5	49.4
T_5	6.5	39.2	47.2
T_6	6.5	42.2	51.6
CD (0.05)	-	1.273	2.25

Table 11. Effect of different levels of nutrients on fruit weight, length, girth and breadth of the fruit

Treatments	Fruit weight (kg)	Length of the fruit (cm)	Girth of the fruit (cm)	Breadth of the fruit (cm)
T_1	0.554	12.10	27.04	26.41
T_2	0.669	11.92	27.49	26.72
T_3	0.712	12.32	27.89	27.32
T_4	0.858	12.85	29.26	28.77
T_5	0.985	14.15	30.79	30.33
T_6	0.749	13.74	28.29	27.83
CD (0.05)	0.101	0.693	1.307	1.333

Table 12. Effect of different treatments on L/B ratio, taper ratio, yield per hectare and days for fruit maturity

Treatments	L/B ratio	Taper ratio	Yield per hectare (t/ha)	Days for fruit maturity	Crop duration (days)
T_1	0.44	1.021	32.33	96.50	370
T_2	0.43	1.040	38.58	96.00	370
T_3	0.44	1.041	34.24	95.75	371
T_4	0.44	1.024	39.58	95.50	371
T_5	0.48	1.025	51.99	96.00	369
T_6	0.46	1.023	42.57	97.50	374
CD (0.05)	0.033	0.013	4.144	NS	NS

NS – Non significant

4.3. Fruit and yield characters

Various observations on fruit and yield characters *viz.,* fruit weight, length of the fruit, girth of the fruit, breadth of the fruit, L/B ratio, taper ratio, yield per hectare, days for fruit maturity, crop duration, peel weight, pulp weight, peel/pulp ratio, pulp percentage, harvest index, root: shoot ratio, crown weight and shelf life of pineapple with respect to different nutrient combinations were recorded, analyzed and the results are presented.

4.3.1. Fruit weight

Data on the effect of different treatments on fruit weight with crown are given in Table 11.

The maximum weight of fruit was observed in T_5 (0.985 kg) which was significantly superior to other treatments which is followed by T_4 (0.858 kg) and the minimum weight of fruit was obtained from T_1 (0.554 kg).

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4.3.2. Length of the fruit

Data on fruit length as affected by the different treatments are tabulated in Table 11.

The maximum length of fruits was observed in T_5 (14.15 cm) which was on par with treatment T_6 (13.74 cm). The lowest value for fruit length was recorded in T_2 (11.92 cm) and it was on par with T_1 (12.10 cm).

4.3.3. Girth of the fruit

Data relating to the fruit girth as influenced by the treatments are given in Table 11.

The treatment T_5 produced maximum girth of fruits (30.79 cm) and was significantly different from all other treatments. The minimum girth of fruits was observed in T_1 (27.04 cm) which was on par with T_2 (27.49 cm) and T_3 (27.89 cm).

4.3.4. Breadth of the fruit

Data pertaining to the breadth of the fruit of various treatments are presented Table 11.

With regard to fruit breadth, maximum value recorded in T_5 (30.33 cm), which was significantly superior to all other treatments and followed by T_4 (28.77 cm). The minimum value was obtained in T_1 (26.41 cm).

4.3.5. Length/breadth ratio (L/B ratio)

Data on the influence of various treatments on the L/B ratio are tabulated in Table 12.

Treatment T_5 (0.48) recorded the highest L/B ratio and it was on par with T_6 (0.46 cm). The lowest L/B ratio was observed in T_2 (0.43) and it was on par with T_1 (0.44), T_3 (0.44) and T_4 (0.44).

4.3.6. Taper ratio

Data relating to the taper ratio as affected by the different treatments are presented in Table 12.

Higher values of taper ratio were recorded by T_3 (1.041) and T_2 (1.040). The lowest value was observed in T_1 (1.021).

4.3.7. Yield per hectare

Data relating to the yield per hectare are presented in Table 12.

With respect to the yield per hectare, maximum value was recorded by T_5 (51.99 t/ha) which was significantly superior when compared with other treatments followed by T_6 (42.57 t/ha), T_4 (39.58 t/ha) and T_2 (38.58 t/ha). Minimum value was recorded in T_1 (32.22 t/ha) which was on par with T_3 (32.33 t/ha).

4.3.8. Days for fruit maturity

Data pertaining to the number of days taken from inflorescence emergence to fruit maturity are presented in Table 12.

With respect to the days for fruit maturity, there was no significant difference between the treatments.

4.3.9. Crop duration

Data relating to the crop duration as affected by the different treatments are presented in Table 12.

The data indicated that there was no significant difference among the treatments with respect to crop duration.

4.3.10. Peel weight

Data on the influence of different levels of nutrients on peel weight are given in Table 13.

The maximum value of peel weight was recorded in treatment T_5 (105.74 g) and it was on par with T_6 (101.10 g). The minimum value of peel weight recorded by T_2 (92.64 g).

4.3.11. Pulp weight

Data depicting the pulp weight as affected by the different treatments are presented in Table 13.

The highest value of pulp weight was recorded in treatment T_5 (0.402 kg) and it was on par with T_6 (0.332 kg). The minimum value of peel weight recorded in T_2 (0.255 kg).

4.3.12. Peel/pulp ratio

Data on the influence of various treatments on the peel/ pulp ratio are given in Table 13.

The minimum peel/ pulp ratio was observed in T_5 (0.26) which was on par with treatment T_6 (0.30). The highest value was recorded in T_1 (0.37) and it was on par with T_2 (0.36) and T_3 (0.33).

4.3.13. Pulp percentage

Data relating to the pulp percentage as influenced by the treatments are given in Table 13.

The data indicated that there was no significant difference among the treatments with respect to pulp percentage.

4.3.14. Harvest index

Data relating to harvest index of different levels of nutrientss are presented in Table 13.

There was no significant difference on harvest index with different levels of nutrients.

4.3.15. Root:shoot ratio

Data relating to root:shoot ratio of different levels of nutrients are presented in Table 13.

With respect to root:shoot ratio, there was no significant difference between the treatments.

4.3.16. Crown weight

Data pertaining to the crown weight of fruits are presented in Table 13.

From the data it is seen that the treatment T_5 recorded the maximum crown weight (118.54 g) which was significantly superior when compared with other treatments. Treatment T_1 (99.49 g) was on par with T_2 (102.47 g), T_3 (106.72 g), T_4 (106.50 g) and T_6 (102.75 g).

4.3.17. Shelf life

The effect of different treatments on shelf life of pineapple fruits are presented in Table 13.

There was no significant difference on shelf life of pineapple fruits with application of different treatments. Average shelf life of 4 days was observed when the fruits were stored under the ambient temperature after harvest.

Table 13. Effect of different levels of nutrients on fruit characters of pineapple cv. Amritha

Treatments	Peel weight (g)	Pulp weight (kg)	Peel/ pulp ratio	Pulp percentage (%)	Harvest index	Root:shoot ratio	Crown weight (g)	Shelf life (days)
T_1	96.10	0.259	0.37	46.83	28.7	0.02	99.49	4
T_2	92.64	0.255	0.36	38.26	29.7	0.03	102.47	4
T_3	94.94	0.283	0.33	39.99	29.6	0.02	106.72	3
T_4	99.84	0.315	0.31	37.31	29.1	0.02	106.50	4
T_5	105.74	0.402	0.26	41.05	30.4	0.03	118.54	4
T_6	101.10	0.332	0.30	44.38	29.3	0.02	102.75	5
CD (0.05)	5.521	0.037	0.044	NS	NS	NS	9.577	NS

NS – Non significant

Table 14. Effect of different levels of nutrients on fruit quality of pineapple cv. Amritha

Treatments	TSS (°Brix)	Titrable acidity (%)	Total sugars (%)	Reducing sugars (%)	Non reducing sugars (%)	Sugar/acid ratio	Fibre (%)	Ascorbic acid (mg 100 g^{-1})
T_1	12.30	0.87	11.86	4.18	11.86	13.64	1.92	23.07
T_2	12.80	0.90	13.11	4.31	13.11	14.73	2.29	22.30
T_3	13.00	0.95	12.77	3.98	12.77	13.67	2.03	22.30
T_4	14.60	0.89	12.46	3.88	12.46	14.07	1.99	23.33
T_5	15.30	0.81	12.52	3.72	12.52	15.45	2.02	21.79
T_6	14.10	0.90	12.78	3.93	12.78	14.18	1.80	21.02
CD (0.05)	0.944	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

4.4. Quality parameters

Various observations on quality attributes *viz.*, total soluble solids (TSS), titratable acidity, total sugars, reducing sugars, non reducing sugars, sugar/acid ratio, fibre, ascorbic acid of pineapple plants grown under different nutrient combinations were recorded and the results are presented below.

4.4.1. TSS

Data pertaining to the total soluble solids as influenced by the treatments are given in Table 14.

The data revealed that the highest TSS was observed in T_5 (15.30 °Brix) and it was on par with T_4 (14.60 °Brix). Among the treatments T_1 (12.30 °Brix) had the lowest TSS value which was on par with T_2 (12.80 °Brix) and T_3 (13.00 °Brix).

4.4.2. Titratable acidity

Application of different treatments had no significant effect on titratable acidity of the fruits as shown in Table 14.

4.4.3. Total sugars

There was no significant effect on total sugar content of fruits due to the application of different treatments as shown in Table 14.

4.4.4. Reducing sugars

Applications of various treatments had no effect on reducing sugar content of the fruits as shown in Table 14.

4.4.5. Non reducing sugars

Applications of various treatments had no effect on reducing sugar content of the fruits as shown in Table 14.

4.4.6. Sugar/ Acid ratio

There was no significant effect on sugar/acid ratio content of the fruits on application of different treatments as shown in Table 14.

4.4.7. Fibre

There was no significant effect on fibre content of the fruits on application of different treatments as shown in Table 14.

4.4.8. Ascorbic acid

Applications of various treatments had no effect on ascorbic acid content of the fruits as shown in Table 14.

4.5. Organoleptic evaluation

Data corresponding to the sensory evaluation of pineapple fruits grown under different nutrient combinations are presented in Table 15.

In pineapple, colour, taste, flavour and texture contribute to the fruit quality. Hence for the assessment of quality, sensory evaluation was carried out on a nine point hedonic scale using score card for eight attributes namely appearance, colour, texture, flavour, odour, taste, after taste and overall acceptability. Sensory evaluation was conducted on the same day of harvest. Among the nine treatments, the highest score for appearance was recorded by T_6 (8.80) and the lowest was recorded by T_1 (7.17). The highest score for colour was recorded by T_6 (8.55) and the lowest by T_1 (7.45). For flavour, T_6 (8.35) recorded the maximum score and minimum was recorded by T_2 (7.20). In case of texture, highest score was recorded by T_6 (8.45) and minimum was recorded by T_1 (6.55). For odour, T_6 (8.45) recorded the highest score and the lowest was recorded by T_1 (6.80). For taste, T_6 (8.91) recorded the highest value and lowest value by T_1 (7.35). The highest score for after taste for recorded by T_6 (8.95) and the lowest scored by T_3 (7.30). Finally in case of overall acceptability, T_6 (8.72) was found to have the highest score and T_3 (6.00) recorded the lowest.

Table 15. Sensory evaluation of pineapple fruits from different treatments

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T_1	7.17 (1.10)	7.45 (1.90)	7.57 (3.65)	6.55 (1.45)	6.80 (2.20)	7.35 (2.35)	7.47 (2.35)	7.32 (3.10)	57.68
T_2	8.42 (3.90)	8.07 (4.00)	7.20 (2.40)	7.17 (2.65)	7.75 (4.30)	7.67 (2.95)	7.55 (3.40)	7.55 (3.40)	61.38
T_3	7.87 (2.35)	7.70 (2.65)	7.32 (2.75)	7.27 (2.65)	6.87 (1.65)	7.72 (3.15)	7.30 (1.85)	6.00 (1.00)	58.05
T_4	8.47 (4.00)	7.77 (3.00)	7.22 (2.65)	7.92 (4.65)	7.15 (2.75)	7.45 (2.55)	7.87 (3.55)	7.12 (2.65)	60.97
T_5	8.47 (4.05)	8.00 (3.90)	7.52 (3.55)	7.77 (3.80)	7.72 (4.10)	8.05 (4.30)	8.22 (4.65)	8.42 (5.20)	64.12
T_6	8.80 (5.60)	8.55 (5.55)	8.35 (6.00)	8.45 (5.80)	8.45 (6.00)	8.91 (6.00)	8.95 (6.00)	8.72 (5.65)	69.18
Kendal's W	0.75	0.48	0.52	0.72	0.77	0.63	0.75	0.86	

4.6. Soil, plant and fruit nutrient analysis

4.6.1. Soil pH

Soil samples were collected from the experimental site before planting of the crop and it recorded a pH of 4.20 (Table 16). After the final harvest, T_1 recorded the highest pH of 5.56 which was followed by T_3 (5.42), T_2 (5.40), T_4 (5.30), T_6 (5.28) and T_1 (5.19) (Table 17).

4.6.2. Soil EC

Before planting, the EC recorded was 0.05 dSm^{-1} (Table 16) and after the final harvest EC was noted for T_2 and T_5 (0.07 dSm^{-1}) which was followed by T_1 (0.06 dSm^{-1}), T_3 (0.06 dSm^{-1}), T_4 (0.06 dSm^{-1}) and T_6 (0.04 dSm^{-1}) (Table 17).

4.6.3. Organic carbon

Before planting, the organic carbon content of the soil was 1.84 % (Table 17). After the final harvest, the highest organic carbon content was recorded in T_6 (3.72 %), which was followed by T_5 (3.49 %), T_3 (3.51 %), T_4 (3.18 %), T_1 (2.30 %) and T_2 (2.17 %) (Table 17).

4.6.4. Available Nitrogen

After the final harvest, the highest N content was in T_5 (261.52 kg ha^{-1}), which was followed by T_3 (260.42 kg ha^{-1}), T_4 (239.61 kg ha^{-1}), T_6 (205.72 kg ha^{-1}), T_2 (171.69 kg ha^{-1}) and T_1 (180.45 kg ha^{-1}) as given in Table 17.

4.6.5. Available Phosphorous

Before planting, the available phosphorous content of the soil was 80 kg ha^{-1} (Table 16). After the final harvest, the highest available P content was in T_6 (146.96 kg ha^{-1}), which was followed by T_5 (95.14 kg ha^{-1}), T_4 (93.95 kg ha^{-1}), T_3 (88.97 kg ha^{-1}), T_1 (86.67 kg ha^{-1}) and T_2 (84.26 kg ha^{-1}) (Table 17).

4.6.6. Available Potassium

Available potassium content of 214.90 kg ha^{-1} was recorded before planting. After the final harvest, the highest available K content was recorded in T_5 (391.44 kg ha^{-1}),

which was followed by, T_4 (383.04 kg ha^{-1}), T_2 (376.88 kg ha^{-1}), T_3 (374.08 kg ha^{-1}), T_6 (246.68 kg ha^{-1}) and T_1 (206.36 kg ha^{-1}).

Table 16. Physio - chemical properties of soil at the experiment site before planting

Parameters	Content in the soil
Soil pH	4.20
Soil EC (dSm^{-1})	0.05
Organic carbon (%)	1.84
Available P content (kg/ha)	80
Available K content (kg/ha)	214.90

Table 17. Physio - chemical properties of soil at the experiment site after the harvest

Treatments	pH	EC (dSm^{-1})	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1	5.56	0.06	2.30	180.45	86.67	206.36
T_2	5.40	0.07	2.17	171.69	84.26	376.88
T_3	5.42	0.06	3.51	260.42	88.97	374.08
T_4	5.30	0.06	3.18	239.61	93.95	383.04
T_5	5.19	0.07	3.49	261.52	95.14	391.44
T_6	5.28	0.04	3.72	205.72	146.96	246.68

4.6.7. Plant analysis

The effects of treatments on the plant N, P, K are presented in Table 18.

4.6.7.1. Nitrogen

Application of various treatments had no significant effect on plant N content.

4.6.7.2. Phosphorous

Application of various treatments had no significant effect on plant P content.

4.6.7.3. Potassium

Application of different treatments had no effect on plant K content.

4.6.8. Fruit analysis

The effect of treatments on the fruit N, P, K are presented in Table 19.

4.6.8.1. Nitrogen

Application of various treatments had no significant effect on fruit N content.

4.6.8.2. Phosphorous

Application of different treatments was not significant on fruit P content.

4.6.8.3. Potassium

Application of different treatments had no effect on fruit K content.

Table 18. N, P and K Content (%) in D leaf of pineapple cv. "Amritha"

Treatments	N	P	K
T_1	1.245	0.078	0.599
T_2	1.226	0.062	0.429
T_3	1.262	0.093	0.457
T_4	1.259	0.069	0.492
T_5	1.257	0.078	0.380
T_6	1.244	0.086	0.427
CD (0.05)	NS	NS	NS

NS – Non significant

Table 19. N, P and K Content (%) in fruits of pineapple cv. "Amritha"

Treatments	N	P	K
T_1	1.060	0.001	0.669
T_2	1.195	0.001	1.010
T_3	0.890	0.001	0.874
T_4	0.916	0.001	0.941
T_5	1.000	0.001	0.692
T_6	0.925	0.006	0.619
CD (0.05)	NS	NS	NS

NS – Non significant

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4.7. Economic analysis

Benefit cost ratio was worked out (Table 20). It was calculated by taking account the cost of inputs and raw materials required for the cultivation of pineapple cv. Amritha which was accounted for total cost. So by the calculation of total cost and total returns, benefit cost ratio was worked out. The highest B:C ratio was recorded in T_5 (4.59) followed by T_2 (3.83). The lowest B:C ratio was recorded in T_6 (2.26).

Table 20. Benefit cost ratio of growing one hectare pineapple cv. Amritha s under different levels of nutrients

Treatments	Total cost (Rs/ha)	Total returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
T_1	443333	1293200	849867	2.92
T_2	403333	1543200	1139867	3.83
T_3	423333	1369600	946267	3.24
T_4	436666	1583200	1146534	3.63
T_5	453333	2079600	1626267	4.59
T_6	753333	1702800	949467	2.26

Discussion

5. DISCUSSION

An experiment entitled 'Nutrient management for pineapple (*Ananas comosus* L.) cv. Amritha' was conducted to study the effect of major nutrients *viz.*, N, P_2O_5 and K_2O on the growth and yield characters of pineapple. The results of the experiment are discussed as follows; vegetative characters, flowering characters, fruit and yield characters, quality parameters, soil, plant and fruit nutrient analysis, economic analysis.

5.1. Vegetative characters

The plant height was not significantly influenced by different levels of nutrients. This was a deviation from the finding of Tay (1975), Vilela- Morales *et al.* (1977) where there was an increase in plant height with application N, P and K (Fig 2).

Application of different treatments on number of leaves per plants had no significant effect. Razzaque and Hanafi (2001) reported negative influence on growth parameters upon application of higher rates of potassium. It is contradictory from the findings of Chadha *et al.* (1976), where they found out that there was increase in number of leaves per plant with increased levels of nitrogen (Fig 3).

The length of 'D' leaf was not influenced by different treatments up to seven months after planting. However, eight months after planting, T_6, T_5 and T_1 were on par and was superior over T_4 which was on par with T_2 and T_3 and similar trend was seen up to twelfth MAP (Fig 4). Similar trend was reported where, increased application of N doses increased the D- leaf length of pineapple cv. Victoria (Pereira da Silva *et al.*, 2012).

However, the breadth of 'D' leaf was not influenced significantly by application of different levels of nutrients (Fig 5).

In case of 'D' leaf area, there was no significant effect up to ten months after planting (Fig 6). But eleven months after planting, application of different

Fig 2. Plant height (cm) of pineapple cv. Amritha under different levels of nutrients

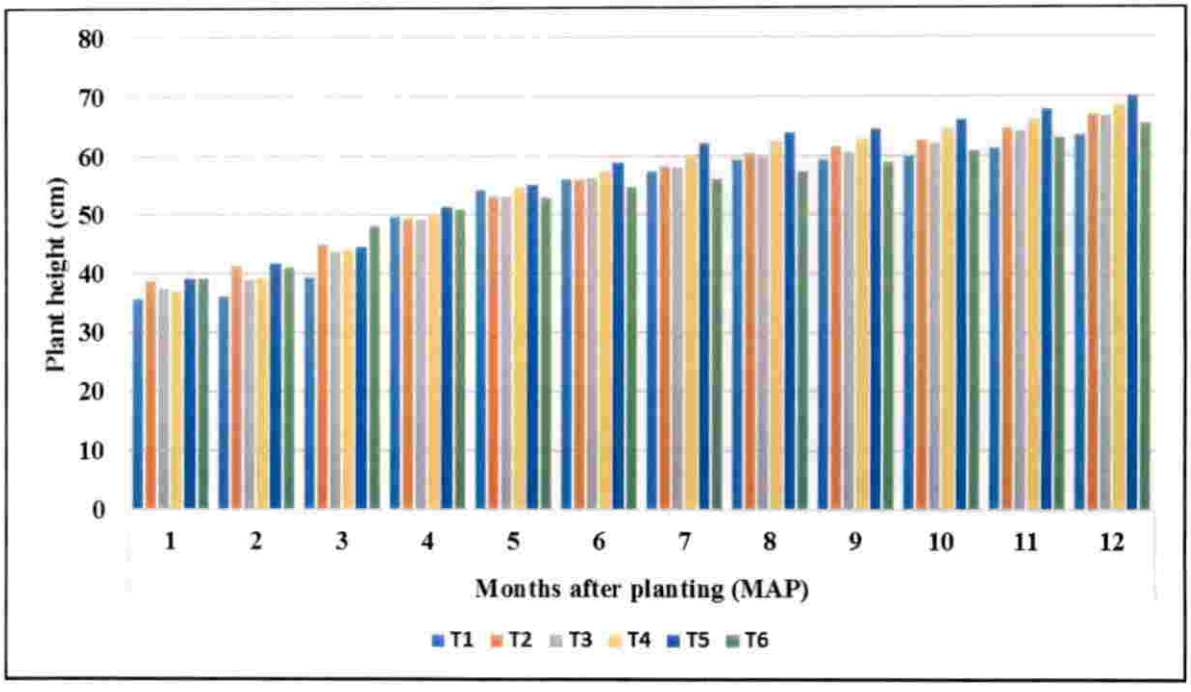


Fig 3. No. of leaves per plant of pineapple cv. Amritha under different levels of nutrients

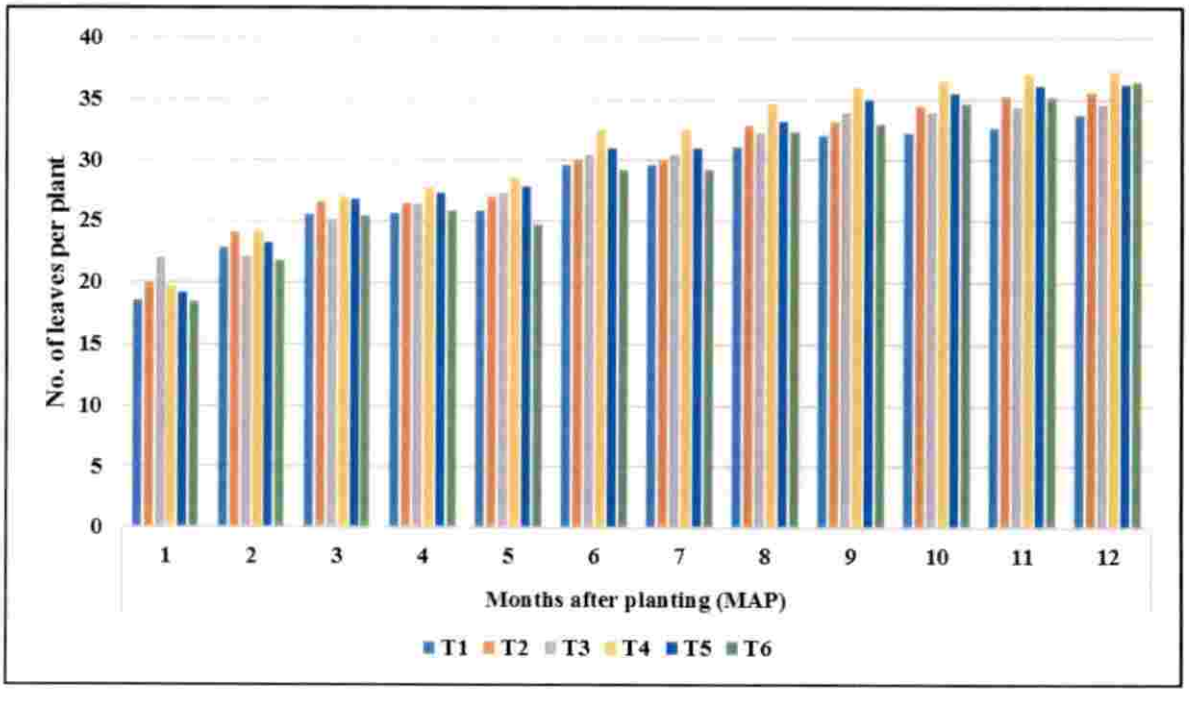


Fig 4. Length of 'D' leaf (cm) of pineapple cv. Amritha under different levels of nutrients

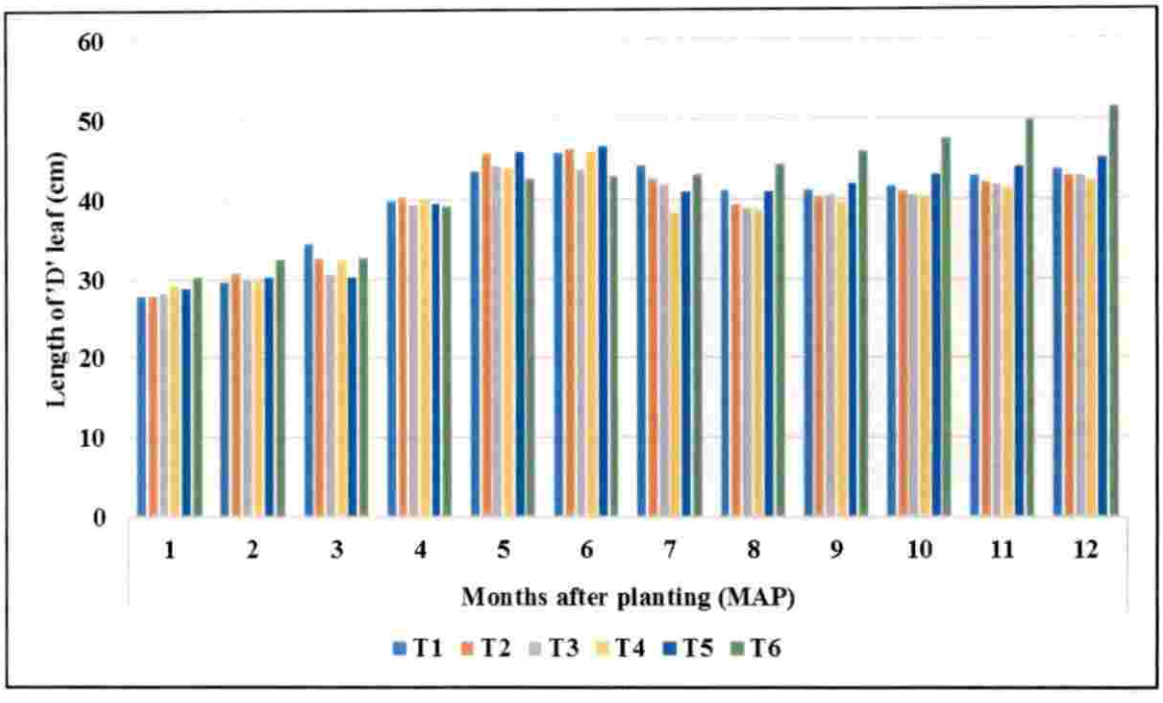


Fig 5. Breadth of 'D' leaf (cm) of pineapple cv. Amritha under different levels of nutrients

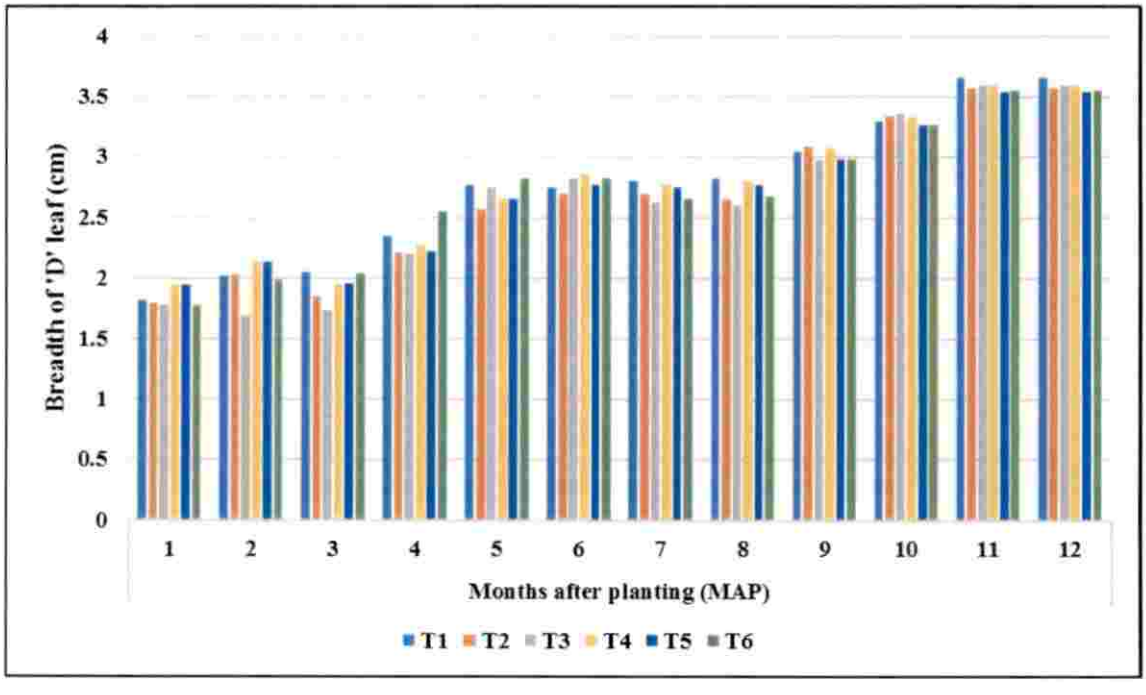


Fig 6. 'D' leaf area (cm^2) of pineapple cv. Amritha under different levels of nutrients

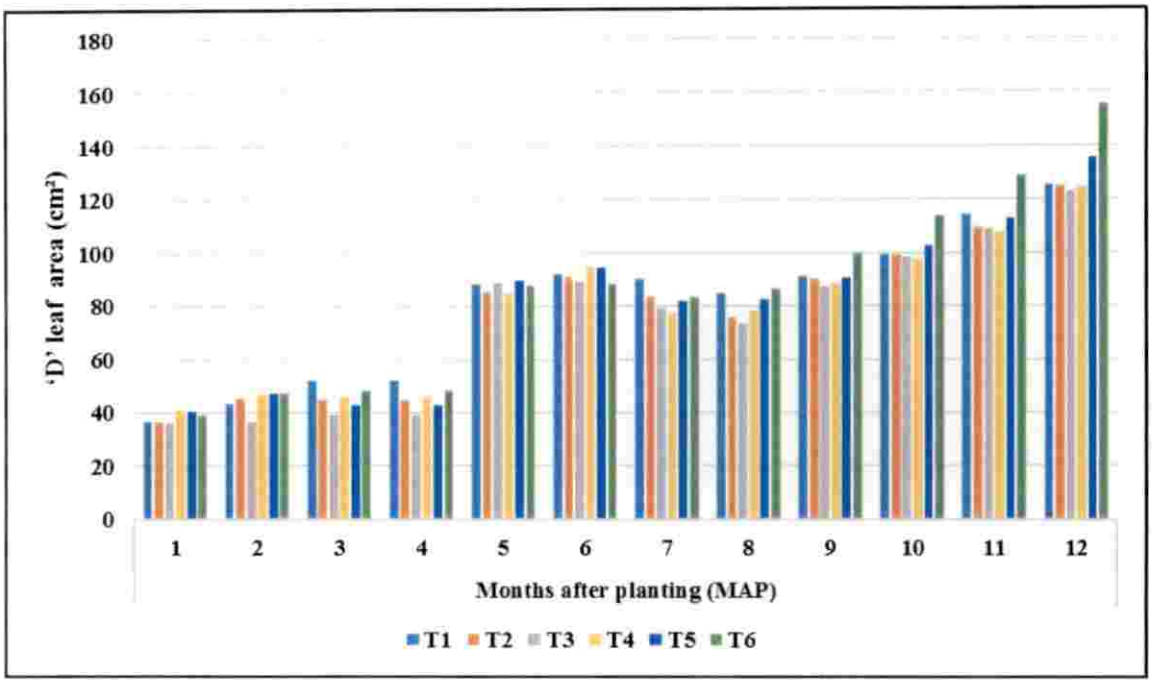
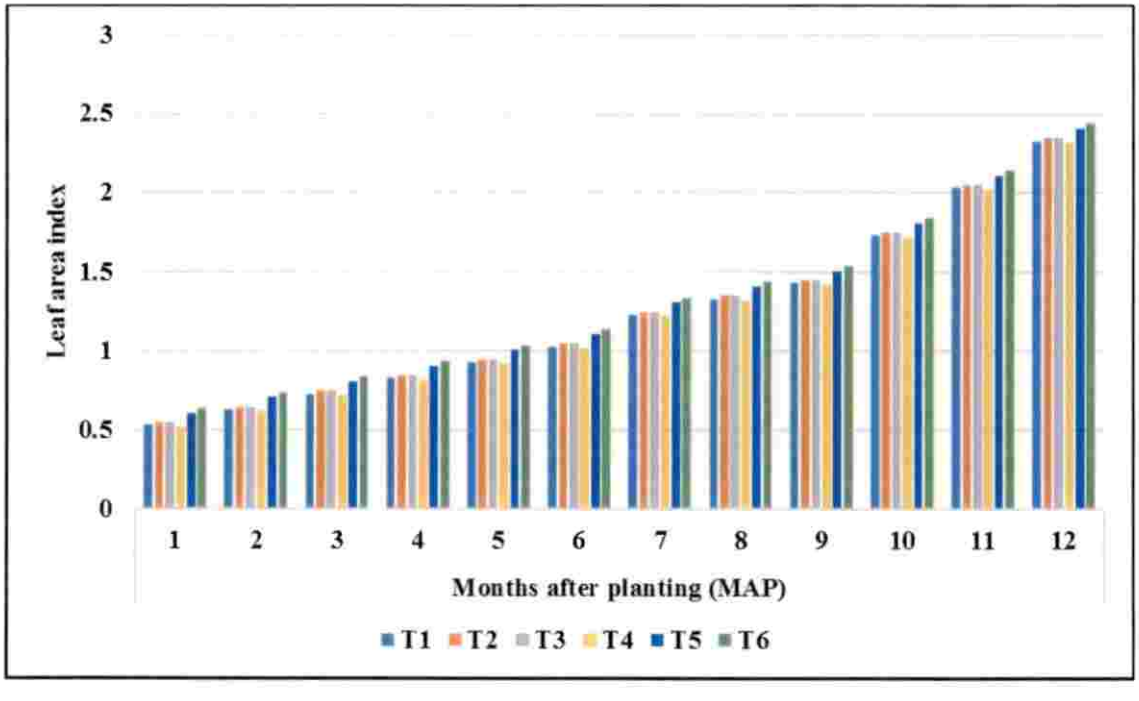


Fig 7. Leaf area index of pineapple cv. Amritha under different levels of nutrients



levels of nutrients had a significant effect on 'D' leaf area. Increase in length of 'D' leaf after eight months after planting could be attributed to significant increase in 'D' leaf area after eleven months after planting (MAP). This could be attributed to application of higher rates of nitrogen (Omotoso and Akinrinde, 2013).

Application of different levels of nutrients did not have any significant effect on leaf area index (Fig 7) and leaf production rate. This might be due to the fact that the application of different level of nutrients did not produce any significant effect on length, breadth and number of leaves per plant at any stage of the plant growth.

Experiment was conducted for a duration of one year and within this duration production of suckers was not observed.

5.2. Flowering characters

In this study, application of different level of nutrients was found to have notable effect on the flowering characters.

Attainment of physiological maturity of the plant is usually indicated by the presence of 39-42 leaves, which is considered as the optimum stage for induction of flowering using ethrel in pineapple. In the present study, T_5 (6.5 months) and T_6 (6.5 months) attained earlier physiological maturity when compared to other treatments. Treatment, T_5 recorded minimum days (39.2 days) for initiation of flowering (Fig 8). It concludes that application of urea increases the efficacy of ethephon to induce flowering (Dass *et al.,* 1975). Increased application of N, P and K in cv. Kew gave best percentage of flowering (Mukherjee *et al.,* 1981).

In the present study, application of different nutrients influenced the time taken by the plants to attain 50 percent flowering was in T_5 which took minimum days (47.2 days) and T_2 was observed to take maximum days (52.2 days) (Fig 8). Use of N and P along with constant levels of K had a significant effect on days taken for flowering in pineapple as reported in the cv. Queen (Singh *et al.,* 2002).

Fig 8. Flowering characters pineapple cv. Amritha under different levels of nutrients

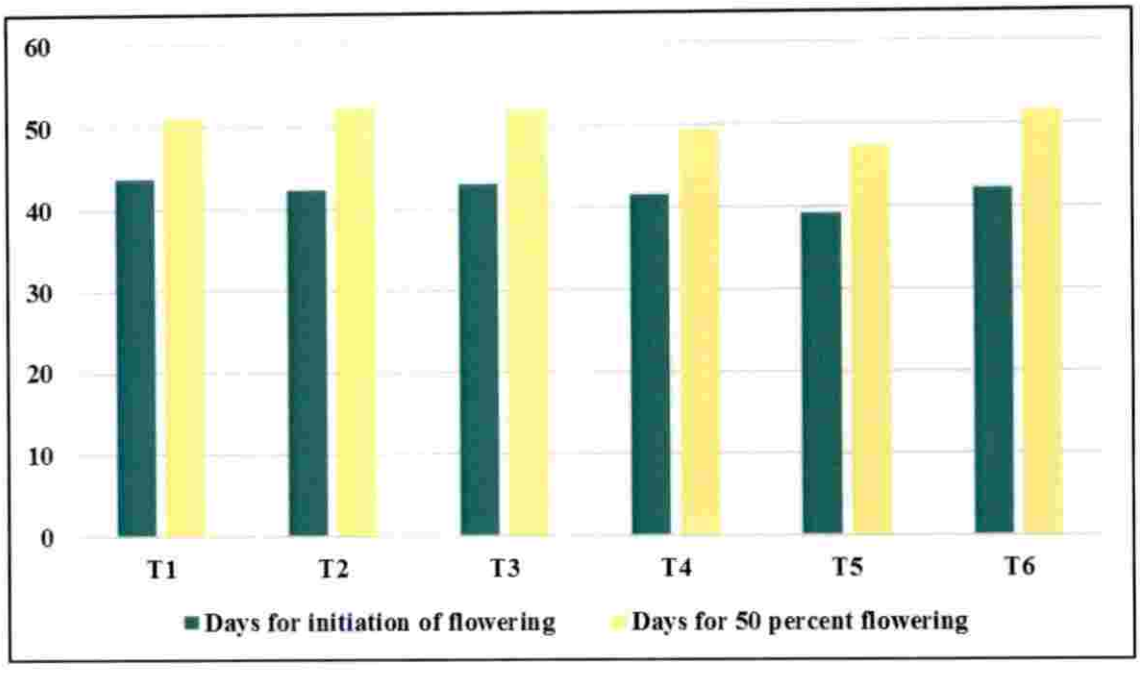


Fig 9. Fruit weight (kg) of pineapple cv. Amritha under different levels of nutrients

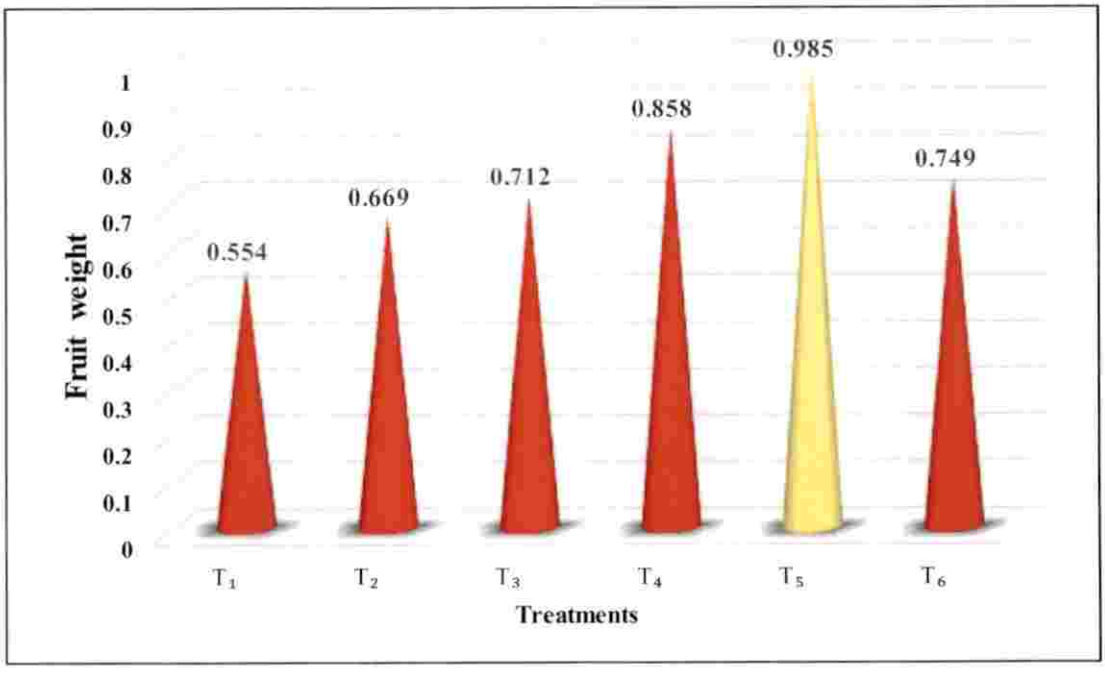


Fig 10. Length of the fruit (cm) under different levels of nutrients

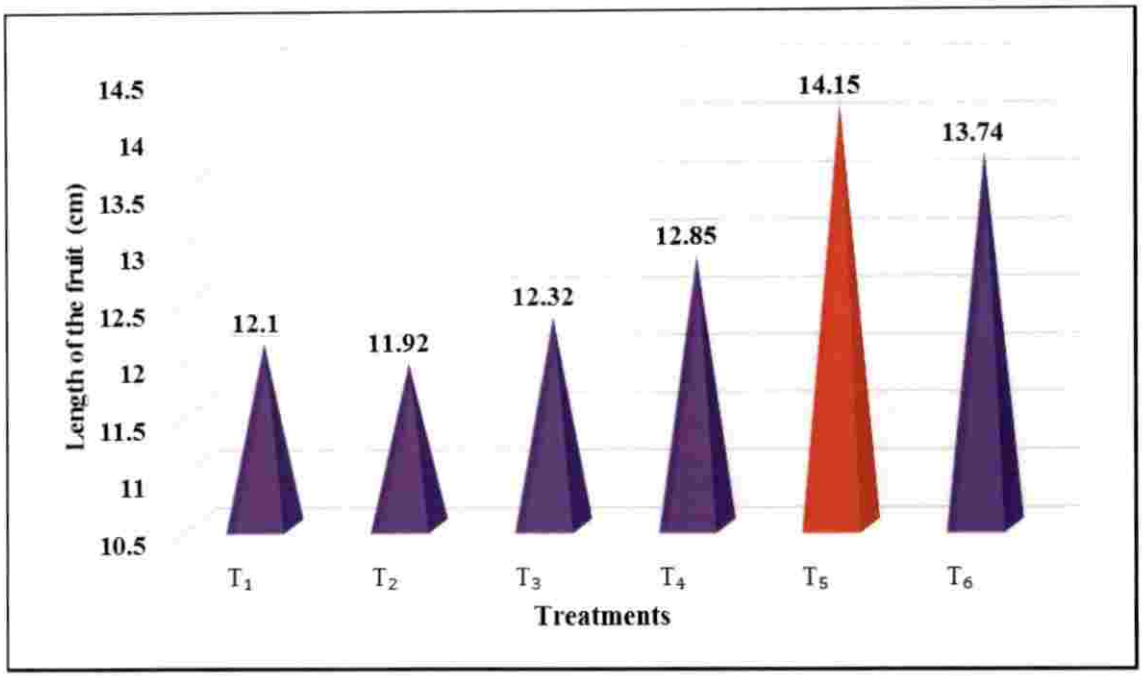
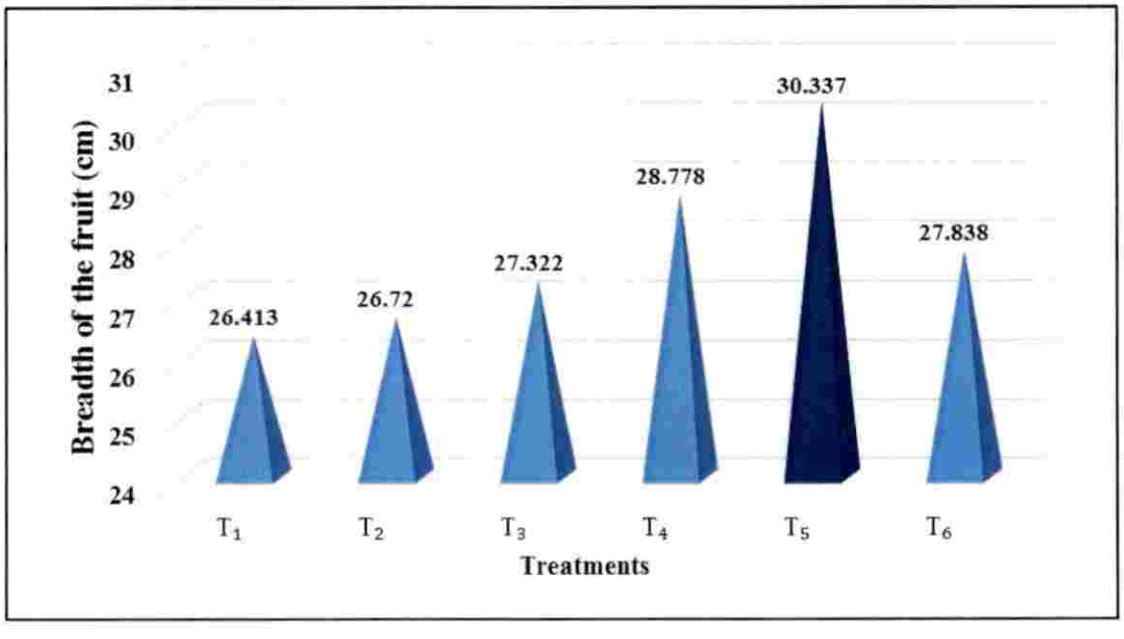


Fig 11. Breadth of the fruit (cm) under different levels of nutrients



5.3. Fruit and yield characters

The fruit is the economically important part, the primary objective of any experiment is to improve the size, yield and quality of the fruit.

The results showed that the mean fruit weight was significantly influenced by the application of different level of nutrients (Fig 9). Here treatment T_5 recorded the maximum weight of fruit (0.985 kg) which was significantly superior. It indicate that increased application of N, P_2O and K_2O increased the average fruit weight as observed by Abutiate and Eyeson (1973). Similar trends was also reported in pineapple cv. Kew (Singh *et al.,* 1977) and cv. Pernambuco (Vilela-Morales *et al.,* 1977). It was also reported there was significant effect on fruit weight with increased application of N rates in pineapple var. Samba (Amez *et al.,* 2005). Pineapple fruit size was usually increased by application of N fertilizers (De Paula *et al.,* 1991). The favourable effect of N and K fertilizers on fruit size and quality was also reported by Cunha *et al.* (1999) and Sossa *et al.* (2017). Botrel *et al.* (1991) reported higher average fruit size was influenced by application of phosphate fertilizers.

The present investigation have clearly shown that the fruit length (Fig 10) and breadth (Fig 11) increased with the increased application of different level of nutrients. The maximum length, breadth and girth of the fruit (Fig 12) was recorded in treatment T_5. The reason for this may be due to increased level of nitrogen application (Omotoso and Akinrinde, 2013). It was also reported that application of phosphorous influenced fruit weight and length (Buzzetti *et al.,* 1986).

The L/B ratio (Fig 13) and taper ratio are also important as far as the fruits are used for canning purpose. The application of different levels of nutrients influenced these attributes. This could be attributed to the greater fruit length observed in case of application of increased dose of nutrients (Arshad and Armanto, 2012).

The yield per hectare was significantly influenced by the application of different level of nutrients (Fig 14). Results revealed that T_5 recorded the highest yield (51.99 t/ha) and was significantly superior when compared with the other

treatments. This may due to application of higher doses of N, P and K. Teixeira *et al.* (2011) reported that application of potassium fertilizers increased the fruit yield. Singh *et al.* (1977) observed increased fruit yield with the increased application of nitrogen in pineapple cv. Kew. Similar result was also observed in pineapple cv. Smooth Cayenne by Webster and Keetch, (1978). The present results are in conformity with these findings.

The fruit characters in terms of peel weight (Fig 15), pulp weight (Fig 16) and peel/pulp ratio (Fig 17) were affected significantly by application of different level of nutrients. This may be due to high fruit weight acquired by the application of increased levels of N, P_2O_5 and K_2O (Caetano *et al.*, 2013).

The pulp percentage, harvest index and root:shoot ratio were not influenced significantly by application of different levels of nutrients.

The fruit crown weight had a significant influence with application of different levels of nutrients (Fig 18). It may be due to application of increased levels of nitrogen (Arshad and Armanto, 2012). Similar trend was also observed by Bhugaloo *et al.* (1999) in pineapple cv. Queen with application of higher doses of nitrogen.

However, application of different level of nutrients did not significantly influence the time taken for fruit maturity and crop duration.

The shelf life of pineapple fruits ranged from 4-5 days and was found to be non-significant with respect to the application of different level of nutrients. The storage temperature and relative humidity were found to play a major role in determining the shelf life than the nutrients applied.

5.4. Quality parameters

The total soluble solids ranged from 12.30 °Brix to 15.30 °Brix and was significant among the treatments (Fig 19) due to application of higher levels of N, P and K as reported by Oliveira *et al.* (2015) and Pengrin *et al.* (2014).

However, other quality attributes like titratable acidity, total sugars, reducing sugars, non reducing sugars, sugar/acid ratio, fibre content and ascorbic acid content had no significant effect with application of different levels of nutrients.

Fig 12. Girth of the fruit (cm) under different levels of nutrients

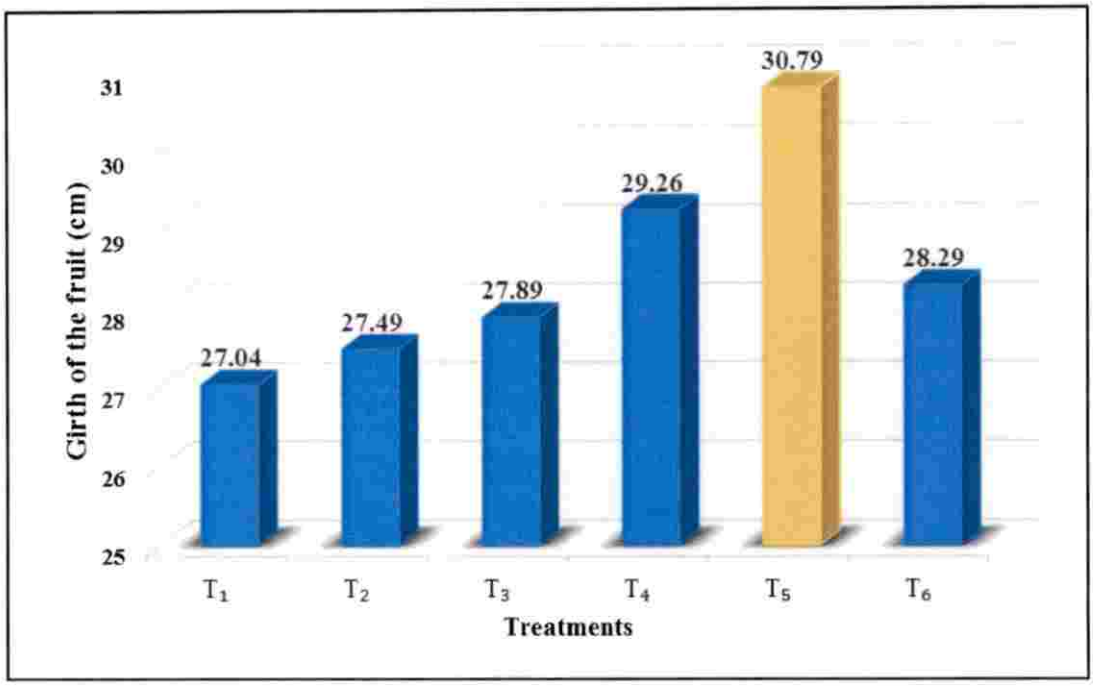


Fig 13. Length / breadth ratio under different levels of nutrients

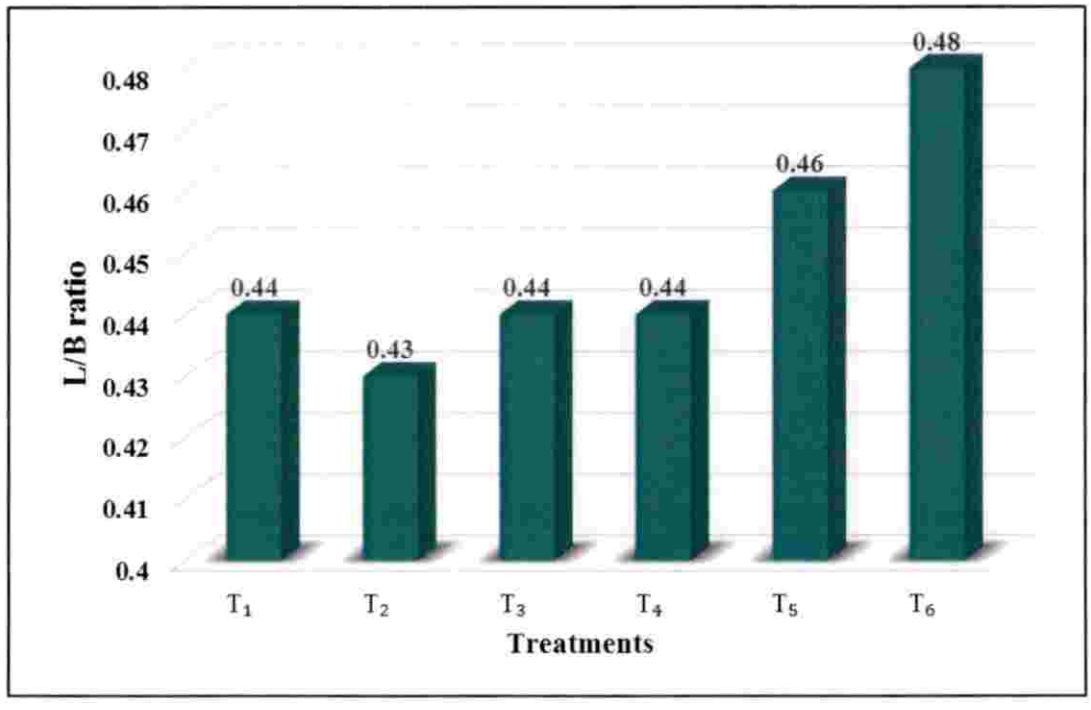


Fig 14. Yield per hectare (t/ha) of pineapple cv. Amritha under different levels of nutrients

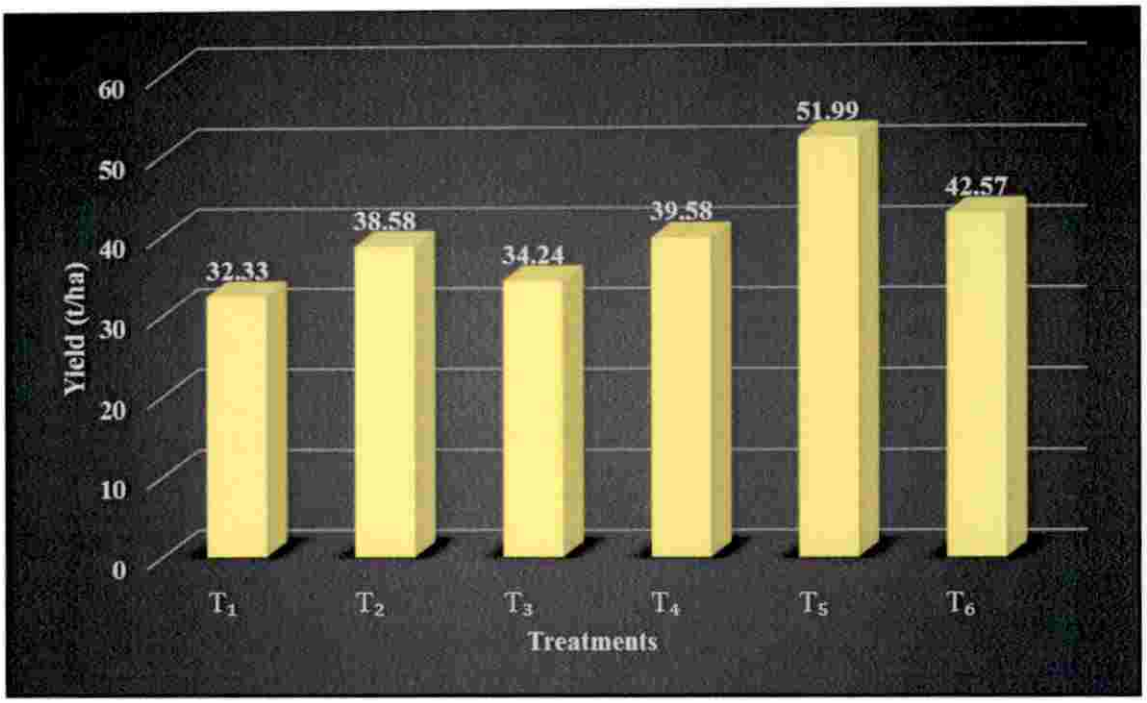
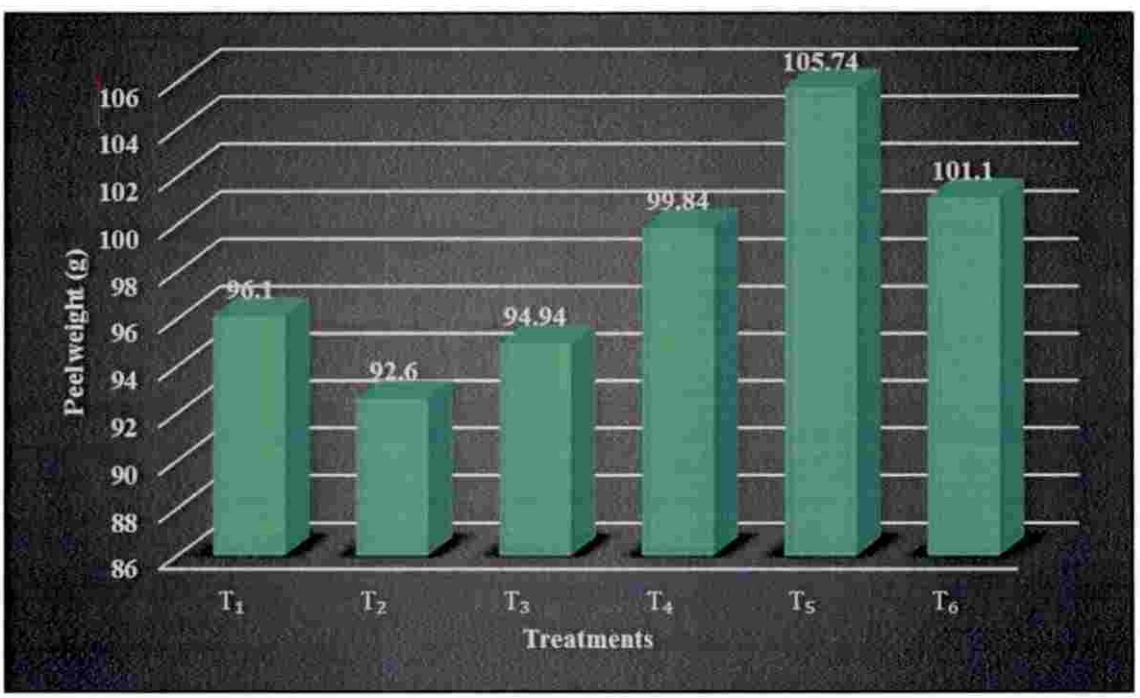


Fig 15. Peel weight (g) of pineapple cv. Amritha under different levels of nutrients



5.5. Organoleptic evaluation

Sensory qualities are very important from the consumer's point of view. It depends on characters like appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability.

The highest score for all the sensory evaluation characters was recorded by T_6. Finally in case of overall acceptability, 8.72 score was the highest score recorded by T_6 found to have the highest score. So T_6 can be considered as the best treatment with regard to sensory characters.

5.6. Soil and plant analysis

5.6.1. Soil analysis

5.6.1.1. Soil pH

Initially, a pH of 4.20 was recorded for the soil sample collected from the site before planting of the crop. After the final harvest, pH content increased in all the treatments and T_1 recorded the highest pH content of 5.56 which is higher than the initial pH before planting. The increase in pH may be due to the addition of lime at 331 kg $acre^{-1}$.

5.6.1.2. Soil EC

Before planting, the EC recorded was 0.05 dSm^{-1} for the soil sample collected from the experimental area. After the final harvest, the highest EC was noted for T_5 and T_2 (0.07 dSm^{-1}). A slight increase was noted than the initial soil EC this may be attributed to the application of N, P and K fertilizers influencing the ionic concentration in the soil.

5.6.1.3. Organic carbon

The initial organic carbon content of the soil was 1.76 per cent. After the final harvest, the highest organic carbon content of 3.27 % was recorded in T_6. It was noted that the organic carbon content increased after planting and it may be due to addition of more organic nutrients and FYM.

5.6.1.4. Available N content

The available N content was found to be highest in T_5 (261.52 kg ha^{-1}) after the final harvest, which may be attributed to application of higher levels of N to the soil.

Fig 16. Pulp weight (kg) of pineapple cv. Amritha under different levels of nutrients

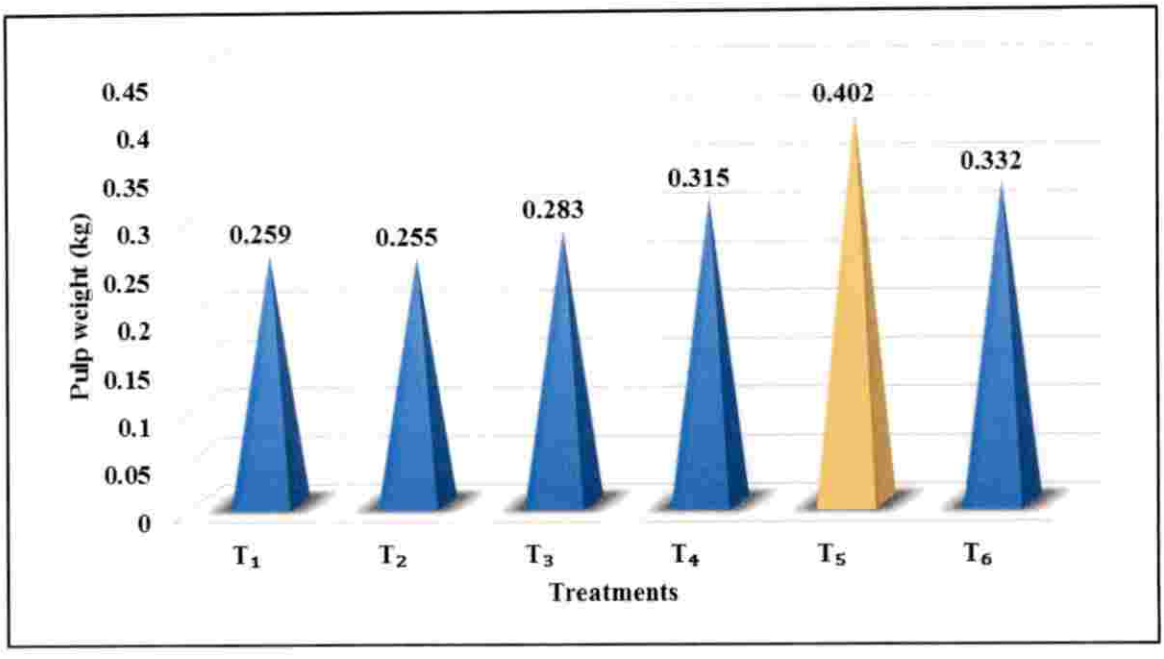


Fig 17. Pulp/peel ratio of pineapple cv. Amritha under different levels of nutrients

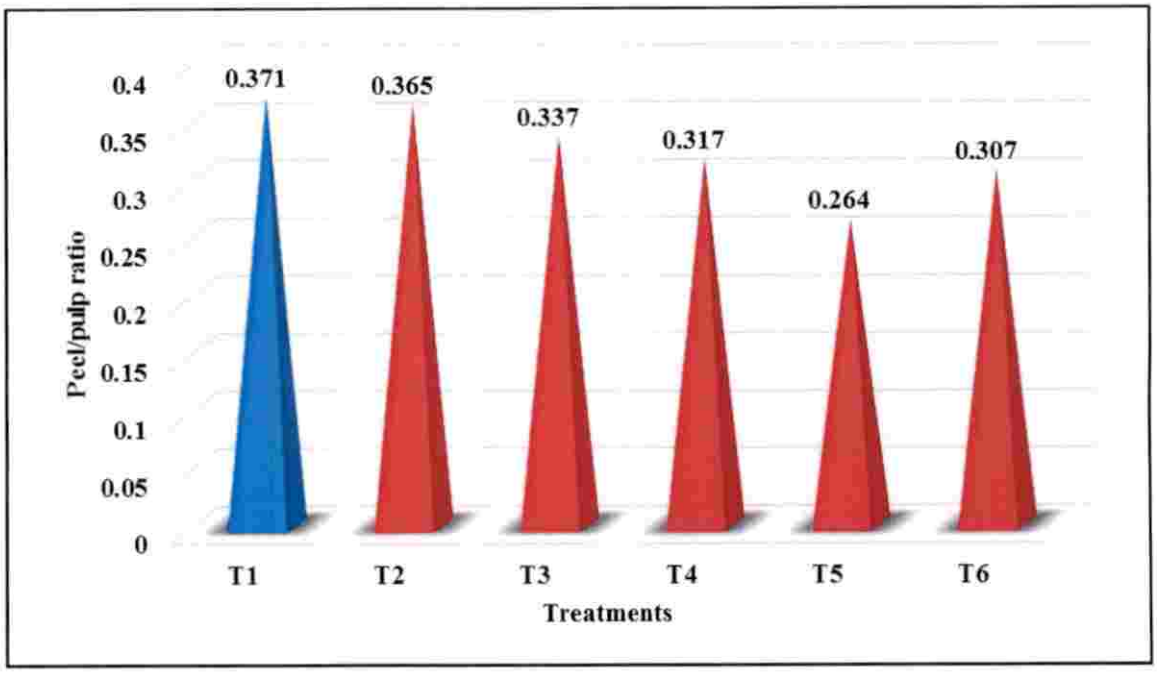


Fig 18. Crown weight (g) of pineapple cv. Amritha under different levels of nutrients

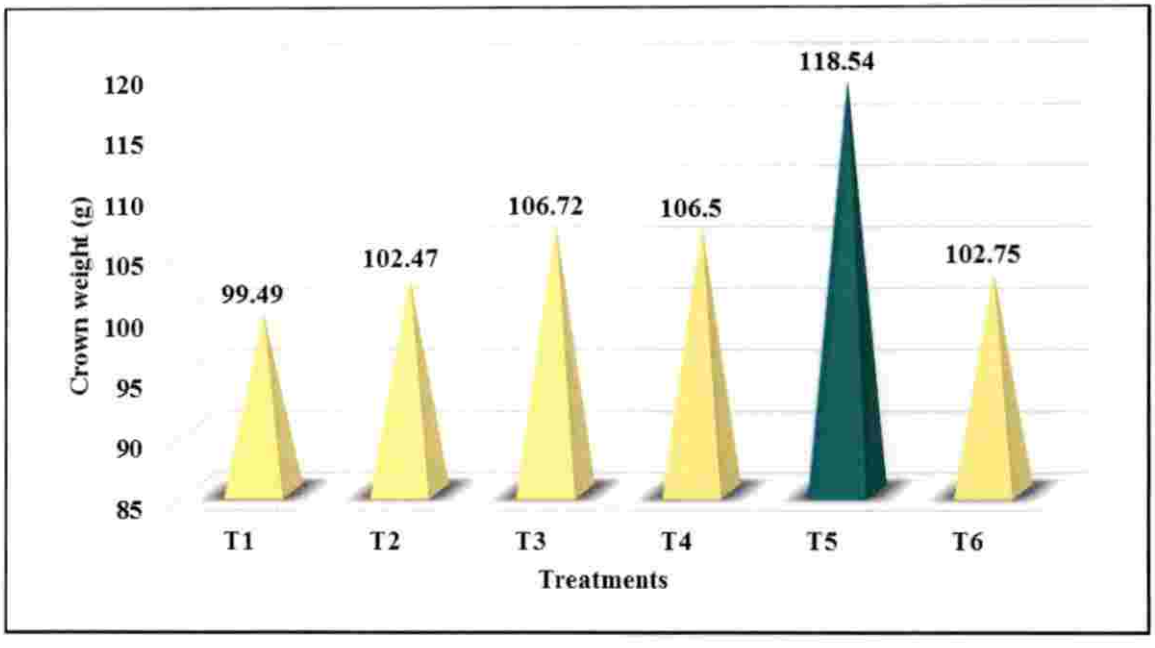
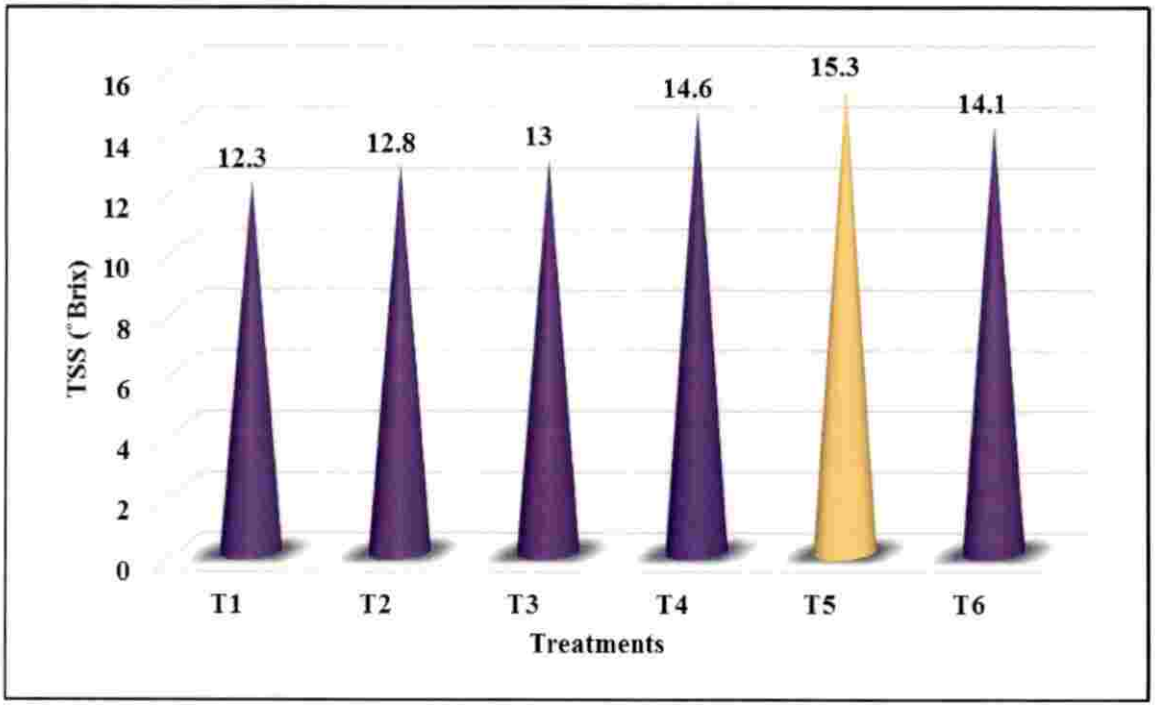


Fig 19. TSS (°Brix) of pineapple cv. Amritha under different levels of nutrients



5.6.1.5. Available P content

The initial available P content of soil was 80 kg ha^{-1}. After the final harvest, T6 recorded the highest available P content of 146.96 kg ha^{-1}, which may due to application of higher levels of P in various forms.

5.6.1.6. Available K content

Before planting, the available K content of the soil was 214 kg ha^{-1}. After the final harvest, T_5 recorded the highest available K content of 391.44 kg ha^{-1} which may be attributed to the application of higher level of potassium.

5.6.2. Plant analysis

The plant N content was not significantly influenced by various treatments.

Application of different level of nutrients did not influence the plant P content significantly.

Effect of application of different levels of nutrients had no significant effect on plant K content.

5.6.3. Fruit analysis

Similar trend as plant analysis, fruit N, P and K content was not significantly influenced by different level of nutrients.

5.7. Economic analysis

Benefit cost ratio is an important and ultimate factor which decides the optimum levels of various inputs to be used for maximization of production and returns from any crop. The different inputs and operations in pineapple cultivation were identified and the cost and benefit were worked out. The analysis revealed that T_5 was having the maximum benefit cost ratio of 4.59 followed by T_2 (3.83). The maximum benefit cost ratio obtained for T_5 can be attributed to the higher returns compared to total costs.

Summary

6. SUMMARY

The present experiment "Nutrient management for pineapple (*Ananas comosus* L.) cv. Amritha" was conducted to standardize an appropriate recommendation of major nutrients (N, P_2O_5 and K_2O) for the optimum growth and yield of pineapple cv. Amritha. The study was undertaken at Fruits Crops Research Station, Vellanikkara during the year 2018-2019. Suckers weighing 500 g of pineapple cv. Amritha was utilized for the investigation. Time of planting was second week of April. The experiment was laid out in Randomised Block Design (RBD) with six treatments and four replications. Treatments comprised of POP recommendation of KAU (8:4:8 N, P_2O_5, K_2O g plant^{-1}), Modified based on soil test results (9.39:11.45:11.36 N, P_2O_5, K_2O g plant^{-1}), 25 per cent higher than the modified POP based on soil test results (11.7:14.31:14.31 N, P_2O_5, K_2O g plant^{-1}), 50 per cent higher than the modified POP based on soil test results (14.08: 17.17: 17.03 N, P_2O_5, K_2O g plant^{-1}), 75 per cent higher than the modified POP based on soil test results (16.4:20.03:19.13 N, P_2O_5, K_2O g plant^{-1}), and adhoc organic POP (FYM @ 500 g plant $^{-1}$, phosphate @ 20 g plant $^{-1}$, bone meal @ 50 g plant $^{-1}$ at the time of planting, 250 g cowdung, 50 g neem cake, 50 g groundnut cake, 1g Azospirillum and 1 g PGPR mix 1 applied six weeks after planting. Apply 1.5 g of SOP in liquid form along with cowdung solution at an interval of 6, 10, 14, 18, 22 and 30 weeks after planting for each plant).

The effect of different level of nutrients on growth, flowering, yield, quality, soil analysis, plant and fruit analysis, organoleptic evaluation and economic analysis were studied in detail and important findings are summarized below.

Application of different levels of nutrients had no significant effect on plant height, number of leaves per plant, breadth of 'D' leaf, leaf area index and leaf production rate.

Length of 'D' leaf showed significant difference among the treatments after eight months of planting. T_6 recorded the maximum length of 'D' leaf (44.3 cm) and was on par with T_1 (41.1 cm) and T_5 (40.9 cm). Similar trend was observed during ninth, tenth, eleventh and twelfth months after planting.

Significant difference was observed in 'D' leaf area among the treatments after ten months of planting. T_6 recorded the maximum 'D' leaf area at eleventh (128.70 cm^2) and twelfth (155.20 cm^2) months after planting and was significantly superior over other treatments.

Treatments, T_5 and T_6 took 6 $^1/_2$ months after planting to attain physiological maturity whereas, other treatments T_1, T_2, T_3 and T_4 attained physiological maturity at a period of seven months after planting.

Days for initiation of flowering was minimum in T_5 (39.2 days) and was significantly superior to other treatments. The treatment T_1 took maximum time for initiation of flowering (43.7 days), where T_3 (43.0) was on par with T_1.

In case of days for 50 percent flowering, T_5 recorded the minimum value (47.2 days) and was on par with T_4 (49.4 days). Treatment T_3 recorded the maximum days to attain 50 percent flowering (51.9 days) and it was on par with T_1, T_2, T_3 and T_6.

Application of different level of nutrients influenced fruit weight, T_5 (16.4:20.03:19.13 N, P_2O_5, K_2O g $plant^{-1}$) recorded the maximum weight of 0.985 kg and it was superior over other treatments. The minimum weight of fruit was obtained from T_1 (0.554 kg).

In case of length of the fruit, maximum value was recorded by T_5 (14.15 cm) and it was on par with T_6 (13.74 cm). The minimum value for fruit length was recorded in T_2 (11.92 cm) and it was on par with T_1 (12.10 cm). Girth of the fruit was highest in T_5 (30.79 cm) and was significantly different from all other treatments. The lowest value for girth of the fruit was observed in T_1 (27.04 cm) which was on par with T_2 (27.49 cm) and T_3 (27.89 cm). Breadth of the fruit was maximum in T_5 (30.33 cm), which was significantly superior. The minimum value was recorded in T_1 (26.41 cm), and it was on par with T_2 and T_3.

Length/breadth ratio was recorded highest for T_5 (0.48) and it was on par with T_6 (0.46). The lowest L/B ratio was observed in T_2 (0.43) and it was on par with all other treatments. In case of taper ratio, higher values were recorded by T_3 (1.041) and T_2 (1.040). The lowest value was observed in T_1 (1.021) and it was on par with T_4, T_5 and T_6.

In case of yield per hectare, maximum value was recorded by T_5 (51.99 t/ha) which was significantly superior when compared to other treatments. The minimum value for yield per hectare was recorded by T_1 (32.22 t/ha).

Days for fruit maturity and crop duration was not found to be influenced significantly by the application of different levels of nutrients.

Peel weight was maximum for T_5 (105.74 g) and it was on par with T_6 (101.10 g). The minimum value was recorded by T_2 (92.64 g) and it was on par with T_3 and T_1. Pulp weight was recorded maximum in by T_5 (0.402 kg) which was significantly superior and the minimum value was recorded in T_2 (0.255 kg).

The minimum peel/pulp ratio was observed in T_5 (0.26) and it was on par with T_6 (0.30). The highest value was observed in T_1 (0.37) which was on par with treatment T_2 and T_3.

Application of different levels of treatments had no significant influence on pulp percentage, harvest index, root:shoot ratio and shelf life.

Crown weight had a significant effect on the treatments, T_5 recorded the maximum crown weight (118.54 g) which was significantly superior when compared with other treatments. The minimum weight of crown was recorded from T_1 (99.49 g) and it was on par with T_2, T_3, T_4 and T_6.

Biochemical characters including titratable acidity, total sugars, reducing sugars, non-reducing sugars, sugar/acid ratio, fibre content and ascorbic acid content were not significantly influenced by the application of different levels of nutrients whereas in case of TSS, T_5 recorded the highest value of 15.3 °Brix and was found to be significantly superior from all other treatments. T_1 recorded the lowest value of 12.3 °Brix and it was on par with T_2 and T_3.

The overall sensory score was found to be highest in T_6 (69.18) and it was followed by T_5 (64.12).

Soil analysis after the harvest of the crop revealed that the values for soil pH (5.42), soil EC (0.07 dSm^{-1}), organic carbon (3.72 %), available N (261.52 kg ha^{-1}), available P (95.14 kg ha^{-1}) and available K (391.44 kg ha^{-1}) was found to be elevated than the initial values before planting.

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N, P and K content in the plant and fruit were not significantly affected by application of different levels of nutrients.

Hence it was conclude that among the different treatments evaluated, treatment T_5 - 75 per cent higher than the modified POP based on soil test results (16.4:20.03:19.13 N, P_2O_5, K_2O g $plant^{-1}$) with a B:C ratio of 4.59 can be recommended for ensuring high productivity of pineapple cv. Amritha.

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Appendix

Appendix- I

Score card for organoleptic evaluation

Name of the judge:

Date:

Characteristics	Scores					
	T_1	T_2	T_3	T_4	T_5	T_6
Appearance						
Colour						
Flavour						
Texture						
Odour						
Taste						
After taste						
Overall acceptability						

9 point Hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature

List of symbols and abbreviations

Symbols	Abbreviations
%	Percent
@	At
C. D.	Critical difference
cm	Centimeter
cv.	Cultivar
et al.	and other
g	Gram
i.e.	That is
kg	Kilogram
mg	Milligram
ml	Milliliter
viz.	As follows
TSS	Total soluble solids
MAP	Month after planting

NUTRIENT MANAGEMENT FOR PINEAPPLE (*Ananas comosus* L.) cv. AMRITHA

by

POOJA SHREE S.

(2017-12-029)

ABSTRACT OF THE THESIS

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DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR – 680 656
KERALA, INDIA

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ABSTRACT

Amritha, is the pineapple hybrid released from the Pineapple Research Centre, Vellanikkara, under KAU. The present study entitled "Nutrient management for pineapple (*Ananas comosus* L.) cv. Amritha" was conducted for standardizing the optimum nutrient doses for ensuring high productivity. When grown under the existing POP recommendation of KAU the fruit weight was varying from 0.5 - 1 kg per plant. Therefore, there is a need to develop optimum nutrient doses for ensuring higher productivity of pineapple cv. Amritha. Experiment was conducted with six treatments *viz.*, T_1 - POP recommendation of KAU (8:4:8 N, P2O5, K2O g plant^{-1}), T_2 - Modified based on soil test results (9.39:11.45:11.36 N, P_2O_5, K_2O g plant^{-1}), T_3 - 25 per cent higher than the modified POP based on soil test results (11.7:14.31:14.31 N, P_2O_5, K_2O g plant^{-1}), T_4 - 50 per cent higher than the modified POP based on soil test results (14.08: 17.17: 17.03 N, P_2O_5, K_2O g plant^{-1}), T_5 - 75 per cent higher than the modified POP based on soil test results (16.4:20.03:19.13 N, P_2O_5, K_2O g plant^{-1}), and T_6 - adhoc organic POP.

Length of 'D' leaf showed significant difference among the treatments after eight months of planting. T_6 recorded the maximum length of 'D' leaf (44.3 cm) and was on par with T_1 (41.1 cm) and T_5 (40.9 cm). This was continued in ninth, tenth, eleventh and twelfth months after planting. Significant difference was observed in 'D' leaf area among the treatments after nine months of planting. T_6 recorded the maximum 'D' leaf area at tenth (113.77 cm^2), eleventh (128.70 cm^2) and twelfth (155.20 cm^2) months after planting and was significantly superior over other treatments. Application of different levels of nutrients had no significant effect on plant height, number of leaves per plant, breadth of 'D' leaf, leaf area index and leaf production rate.

Treatments, T_5 and T_6 took 6 $^1/_2$ months after planting to attain physiological maturity whereas, other treatments attained physiological maturity at a period of seven months after planting. Days for initiation of flowering was minimum in T_5 (39.2 days) and was significantly different from other treatments.

In case of days for 50 per cent flowering, T_5 recorded the minimum value (47.2 days) and was on par with T4 (49.4 days).

Significant difference was observed among the treatments for fruit weight and was highest in T_5 (0.985 kg). The maximum length, girth and breadth of fruit was recorded in T_5 (14.15 cm), (30.79 cm) and (30.33 cm) respectively. In case of length/breadth ratio T_5 (0.48) recorded the highest value which was on par with T6 (0.46). Higher taper ratio values were recorded by T_3 (1.041) and T_2 (1.040). With respect to the yield per hectare, maximum value (51.99 t/ha) was recorded by T_5 which was significantly superior. T_5 recorded the highest peel weight (105.74 g), pulp weight (0.402 kg) and crown weight (118.54 g). The minimum peel/pulp ratio was observed in T_5 (0.26). There was no significant difference among treatments for days for fruit maturity, harvest index, root:shoot ratio, crop duration and shelf life.

On evaluating the quality parameters of fruits, TSS was found to be highest in T_5 (15.30 °Brix) and was on par with T_4 (14.60 °Brix). In case of other parameters like titratable acidity, total sugars, reducing sugars, non reducing sugars, sugar/acid ratio, fibre content and ascorbic acid content, the treatments were found to be non significant. The overall sensory score was found to be highest in T_6 (69.18) and was followed by T_5 (64.12). The highest B:C ratio was calculated for T_5 (4.59).

Analysis of soil after the harvest of the crop revealed that the values for soil pH, soil EC, organic carbon, available N, P and K were found to be elevated. N, P and K content in the plant and fruit had no significant difference.

In the present study early flowering was observed in T_5 (75 per cent higher than the modified POP based on soil test results) which in turn resulted in early fruit set and harvesting in the treatment. Highest fruit weight T_5 (0.98 kg) and yield per hectare (51.99 t/ha) was also recorded in T_5 (75 per cent higher than the modified POP based on soil test results). On sensory evaluation, Adhoc organic POP (T_6) was found to be superior and was followed by T_5.