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Research Article

Taro (*Colocasia Esculenta* (L.) Schott Var *Esculenta*) Cultivation in Trinidad

Walter Faamatuainu* and Falaniko Amosa

The University of the South Pacific, Alafua, Samoa, West Indies

Abstract

Information relating to taro cultivation in Trinidad is limited. Therefore, a survey was conducted to determine taro cultivation practices in Trinidad. The findings from the survey showed that the majority of taro farmers are at least thirty years old and all are commercial farmers. Taro cultivars grown by Trinidad farmers are locally known as the 'Blue' and 'White', which are propagated using their suckers. Moreover, taro plants are cultivated year round for three to nine months for their leaves and corms. Utilizing the inputs from taro farmers, a greenhouse experiment was conducted to evaluate the influence of varying nitrogen rates on taro yields. Except for Petioles Yield (PY), interactions between taro cultivars and nitrogen rates for leaf Blades Yield (LY) and Corms Yield (CY) were statistically significant ($P<0.05$). It seems that the application of 100 kg/ha of nitrogen enhances the yields of taro plants. Further, the polymer coated urea and calcium nitrate released the highest ammonium and nitrate concentrations respectively. Overall, cultivation practices used by taro farmers in Trinidad were identified from the survey and the application of nitrogen fertilizers improved the yields of taro plants in Trinidad.

Keywords: Cultivation; Fertilization; Nitrogen; Taro; Trinidad

Introduction

The transfer of knowledge from researchers and extension officers to farmers is widely recognised as the weak link that limits the contribution of science and technology towards the improvement of the agricultural sector [1]. Further, difficulties in accessing information also restrict the development of agriculture in Trinidad and Tobago (TnT). Information generated from research is essential for improving farming systems in TnT [1]. Therefore, the main objective of the survey is to determine cultivation and management practices used in the production of taro in Trinidad.

***Corresponding author:** Walter Faamatuainu, The University of the South Pacific, Alafua, Samoa, West Indies, E-mail: walterfaamatuainu@gmail.com

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The cost of taro has gradually increased over the past few years because of the continuous increase in the prices of imported foods, there are suggestions, that increasing the domestic agricultural production will provide food security for the locals as well as reducing their reliance on imported foods. Moreover, having a competition between local and imported foods will reduce the prices of food which is essential in reducing the food import bill in TnT [2]. Records have shown that taro covered 393 hectares in 2014, which is a drop of 16.4% from a decade earlier in 2004 [3] Meanwhile the contribution of agriculture to the GDP (Gross Domestic Product) of Trinidad and Tobago in 1990, 1997 and 2006 was 2.5, 1.8 and 0.4% respectively. The decline in the contribution of agriculture to the country's GDP coincided with the reduction in agricultural lands from 13.8 to 10.5% during the same period [4]. It was reported that the annual food import bill in TnT is at least US$150 million and is still increasing to half a billion dollars [2].

This is unfortunate because it was proposed in agricultural plans fifty years earlier to reduce the importation of foods and encourage the domestic production of foods [5]. There is also a scarcity of information regarding the response of taro plants in Trinidad to the application of nitrogen fertilizers. Therefore, the greenhouse experiment was implemented to determine the yields of taro plant applied with varying nitrogen rates. Literature suggests that taro production is improved by nitrogen fertilization [6,7]. Optimum nitrogen supply improves crop growth, biological production and yield.

Nitrate (NO_3^-) is the predominant nitrogen form in well aerated non-acidic soils, due to the activities of nitrifying bacterial, however; ammonium (NH_4^+) is found in higher concentrations in flooded soils whereby the activity of nitrifying bacteria is limited. Hence, when plants absorbed NO_3^-, the rhizosphere is alkalinized while the absorption of NH_4^+ leads to the acidification of the rhizosphere. Changes in soil pH as a result of NH_4^+ and NO_3^- inputs is known to influence microbial and pathogenic activities in the soil [8]. Differences in the growth of taro plants due to the application of nitrates and ammonium based nitrogen fertilizers are not well known. Previous studies have reported that NO_3^- increased the dry matter of taro plants [8]. The controlled release nitrogen fertilizers such as polymer coated urea allow water to move in and dissolve urea leading to the diffusion of nitrogen out of the porous polymer membrane. Polymer coated urea is beneficial because it reduces split nitrogen applications and nitrogen leaching [9]. A review of literature revealed that the nitrogen release patterns of polymer coated urea in upland soils have not been reported.

Materials and Methods

Survey

The survey was implemented using questionnaires containing open and close ended questions which were distributed to forty taro farmers in Trinidad. The questionnaires were used in this study because of the speed of data collection, low cost requirements, efficient and higher level of objectivity compared to other methods of data collection. The IBM SPSS 20 Statistics software was used to analyse the data collected.

Greenhouse experiment

A factorial design was used to implement the greenhouse experiment with two local taro cultivars identified from the survey (Blue and White) and three nitrogen rates (0, 100 and 200 kg/ha) as experimental factors. The experiment was setup in a Randomised Complete Block Design (RCBD) with four replications at the UWI field station (North 10°38'17.16, 61°25'40.8 West) in Trinidad, comprised of the River Estate soil series (fluventic eutropepts). Taro suckers (uniform size) from local farmers were used as planting material. Nitrogen was applied as urea (46% nitrogen) in three split application during the first five weeks of planting. Taro plants were kept free from weeds by hand weeding and were irrigated up to field capacity on a daily basis. Taro plants were harvested six months after planting and washed to remove soil. Afterwards, the plants were divided into leaf blades, petioles and corms then; their fresh weights were recorded. Analyses of variances (ANOVA) were performed on the data collected using the IBM SPSS 20 statistical software.

Nitrogen release experiment

The experiment was setup in a RCBD factorial design, consisting of four nitrogen treatments (Polymer Coated Urea (PCU), urea, calcium nitrate, and the control) and six sampling intervals (1 day, 7, 14, 60, 120 and 180 days after the fertilizer application (DAA)) with two replications. Polythene containers were filled with 250 g of air dried soil and the nitrogen source fertilizers at 100 kg/ha were then incorporated into the containers. Soil samples were collected for ammonium and nitrate analysis at 1, 7, 14, 60, 120 and 180 DAA. The setup followed the procedures used by [10]. At each sampling intervals, available nitrogen was measured by determining ammonium and nitrate in the soil samples using Kjedahl methods whereby ammonium and nitrate were determined by steam distillation with MgO and Devarda's Alloy respectively. Distillations were followed by titrations with sulphuric acid.

Results and Discussion

Survey results

Farmer's age, gender and farm size

All the farmers surveyed were at least thirty years old and were mostly males. When grouping the farmers by age and gender, it was observed that nine males and one female were more than forty-six years old while the rest were between thirty-one and forty-five years old. Results from a survey conducted by CARDI on agricultural farmers in Trinidad revealed that 57% of the respondents were females and 73.2% of the total farmers had access to tertiary level education. According to the researchers, their results implied that there are renewed interests in agriculture which was caused by the developments in the 1980s whereby the local economy was not performing to expectations and the threat to food security was inevitable.

Food security is an important issue in TnT because the FAO estimated that 13% of the total population are undernourished [11]. CARDI also revealed in their study that young people are taking up farming and are willing to adopt and implement new technologies in their farms [1]. With regards to the size of taro farms, we found out that most of the taro farms are around two acres; the largest farm is sixteen acres while the smallest farm is 0.125 acres. All the farmers surveyed are commercial farmers. There were no statistically significant associations and relationships between the size of taro farms and gender, age and employment. The government of TnT has proposed that 2,812 hectares (13.4% of the total arable lands) should be designated for the cultivation of pulses, tubers (taro, sweet potato, yams etc) and roots [12]. The decline in agricultural lands from 13.8 to 10.5% probably influenced the lands available for taro cultivation and the size of taro farms [13,14].

Table 1 shows that the White and Blue taro cultivars are commonly cultivated by farmers, and according to the literature reviewed, these are the two main taro cultivars in TnT. Taro is mainly grown in TnT for its corms and leaves for consumption. Taro suckers (85%) and mother plants (15%) are the planting materials used by Trinidad farmers to expand or replant their taro farms. It is important to note that using suckers as a propagation (vegetative) method is recommended as they limit the spread of diseases and viruses. Further, using suckers as planting materials to expand taro cultivation is important because suckers provide more uniformity in terms of yield production. According to the Ministry of Agriculture, Land and Fisheries, suckers are the recommended planting materials for taro in TnT [15]. Moreover, it was suggested that using suckers as planting materials in the Caribbean leads to quality corm yields which are suitable for export [16].

Variables		Planting Materials Mother Plants and Suckers	Suckers only	Total
Cultivar	Blue only	1	9	10
		5	18	23
	Blue and White	0	7	7
	Total	6	34	40

Table 1: Taro planting materials and cultivars.

With regards to the planting time, we found out that taro is grown all year round, during the dry (December to May) and wet (June to November) seasons. These practices ensure the sustainable supply of taro to local markets as well as providing food security throughout the year. The influence of planting time might have an impact on management practices such as irrigation which will be vital during the dry season. However, the unpredictable weather patterns are other factors to consider. Pesticides application is also affected since some pests are more prevalent in the dry than during the wet season and vice versa, while fertilizer applications are affected by excessive rainfall (loss through runoff and leaching) and drought (less solubility in the soil and limited nutrient availability for the plants). The time of the year or season to plant taro varies from country to country; however, planting taro in the rainy or wet season seems to produce higher yields [17-20].

Management practices (fertilizers, irrigation and pesticides)

All farmers applied fertilizers to their taro farms, whereby 25% uses 50 kg/ha and 27.5% uses 100 kg/ha as fertilizer rates, only seven farmers used rates which exceeded 100 kg/ha. This information indicated that farmers manage and control their fertilizer application in such a way that careful consideration and calculation is required before fertilizers are applied to their taro farms. Hence, future recommendations through extension with regards to fertilizer management will be easily implemented in these farms since farmers already had experience in fertilizer application using different fertilizer sources and rates. The result above also shows that farmers had positive feedback regarding fertilizer application in such a way that taro yield increased after the application of fertilizers. The positive influence of fertilization on the yields of taro plants was also reported by other taro researchers [7,21].

The application of water through irrigation is essential for the growth and development of taro plants and this reflected by the majority of farmers (75%) irrigating their taro farms. Similar to fertilizer application, farmers indicated that irrigation application improves the yield of taro plants. Ten farmers (25%) relied on rainfall (rain-fed) to irrigate their farms which is cheaper than installing irrigation systems. Irrigation is one of the oldest and most effective management practices used around the world to improve taro yield [22]. Thirty-nine farmers used pesticides as management practices to improve taro production. Different types of herbicides were used by farmers to control weeds which indicate that weeds are one of the major taro pests in Trinidad. Fungicides were often used by farmers to control fungus in their taro farms. Pesticides used was found to be dependent on the cultivars and yields variables, after running the chi-square tests, all the relationships were statistically significant ($P < 0.05$). Therefore, our results suggest that pesticides used by farmers who grow taro for leaves production are different from pesticides used by farmers who specialised in corm production. The relationship between taro cultivars and yields discussed earlier is also highlighted in the dependence of taro cultivars and pesticides used. Hence, pesticide application depends on the taro cultivar and its yield. The Blue and White cultivars are mainly grown for their corms and leaves respectively. The pesticides retailers in TnT, reported that the most frequently purchased brands of pesticides are gramozone, swiper and fastac [12].

Apart from the widely used management practices such as fertilizer, irrigation and pesticide applications, farmers were also asked to identify their own specific ('cultural or traditional') management practices implemented in their farms. Their responses revealed a wide range of techniques and soil amendments which enable farmers to produce marketable taro yield. It is important to note that some farmers applied both mineral fertilizers and organic amendments such as poultry manure. Different methods and sources of fertilizer applications supply nutrient to the soil and provides structural stability. As a result, soil physical and chemical properties are favourable for taro production. The utilization of bio-stimulants is encouraging due to the fact it is one of widely available, cheap and environmentally friendly ways to replenish soil fertility. Traditional farming practices such as moulding and tillage have been practices by taro farmers since ancient times. Consequently, sustainable taro production and minimal impact on the environment are guaranteed [23-27].

The time spent to cultivate taro in Trinidad ranged from three to nine months, Table 2. Nineteen farmers responded that they harvest their taro plant between three and four months. Biotic and abiotic factors such as pests, diseases, and climate and soil characteristics affect the timing of taro harvest. However, understanding the growth and development patterns of the taro cultivars under consideration is an essential perquisite for determining the time of harvest [25,28]. Leaves harvest is limited by the regeneration of leaves; therefore the time or frequency of harvesting can be set at weekly or monthly intervals [29]. The majority (97.5%) of taro in Trinidad are sold in local markets and only one farmer export taro. The literature review suggested that taro production in Trinidad is not enough for the local markets, hence; taro imports from other Caribbean countries are brought into the country to satisfy the domestic demand. This might explain the above results whereby taro export is almost neglected because taro cultivation in Trinidad is not able to meet the local demand. As a result, little is left for export. Despite the fact that taro export in Trinidad is very small, taro export in other Caribbean countries like Dominica, Jamaica and St Vincent and Grenadine is growing with markets in the US and the UK [2,3,16].

Variables	Yields Farmers harvesting corms		Farmers harvesting leaves	Total
Harvest time (months)	3	0	13	13
	4	0	6	6
	6	3	0	3
	7	8	0	8
	9	9	1	10
Total	20		20	40

Table 2: Harvest times and yields.

Factors affecting taro production

Trinidad farmers indicated that access to land and availability of labour, are major constraints to improving taro production in Trinidad. Moreover, having access to overseas markets and better prices (subsidies included) are an also important factor which needs to be addressed for the betterment of taro production in Trinidad. The literature review indicated that Trinidad imports more taro than taro produced locally to satisfy local demands. However, the farmers surveyed identified these practices as having a negative impact on their productivity. This is an important point to consider because there seems to be a breakdown in communication between farmers and other stakeholders such as the government, wholesalers and consumers.

Greenhouse results

Table 3 shows the Leaf Yield (LY), Petiole Yield (PY) and Corm Yield (CY) of two taro cultivars after six months of growth under varying nitrogen rates. Optimal or highest leaf yield was obtained from using nitrogen at the rate of 100 kg/ha for the Blue and White taro cultivars. The White taro cultivar LY was higher than that of Blue taro cultivar. The Blue taro cultivar was also found in previous studies to produce optimum yields after the application of nitrogen fertilizers [29,30]. Results from this experiment are similar to those reported from Samoa where increasing the nitrogen rate to at least 100 kg/ha increased the vegetative yields of taro plants [6]. The White taro petiole yield was higher than the Blue cultivar at 100 kg/ha of nitrogen. Reports suggested that applying nitrogen at 100 kg/ha increased the above-ground biomass of taro plants in PNG by 16.5% [7]. Applying nitrogen at the rate of 100 kg/ha also produced optimum corm yield for the two taro cultivars. Corm yield of the White taro cultivar was higher than the Blue taro cultivar. The literature also suggested that applying nitrogen fertilizers to taro plants enhances their CY [7].

Laboratory experiment results

It was noted that ammonium (NH_4^+) concentrations increased from 1 to 14 DAA before declining at 60, 120 and 180 DAA, Figure 1. The nitrate (NO_3^-) concentrations decreased at 7 DAA before increasing at 14, 60 and 120 DAA. The results show that NH_4^+ concentration was significantly higher than NO_3^- concentration. Since polymer coated urea is an ammonium based nitrogen fertilizer, higher ammonium levels were expected. It is important to note that as NH_4^+ concentration declined, NO_3^- concentration increased. Conversion from ammonium to nitrate might be the reason of this observation. Figure 2 shows that there was a sharp increased in NH_4^+ from 1 to 7 DAA. Afterwards, NH_4^+ concentration gradually declined from 14 to 180 DAA. NO_3^- concentration declined at 7 DAA before increasing at 14, 60, 120 and 180 DAA. The results show that NH_4^+ concentration was significantly higher than NO_3^- concentration. Since urea is an ammonium based nitrogen fertilizer, higher ammonium levels were expected. A noticeable sharp increase in NH_4^+ concentration at 7 DAA indicates the instant nitrogen supply by FR nitrogen fertilizers. Afterwards, NH_4^+ concentration starts to decline. Volatilization might be the reason for the reduction in NH_4^+ concentration. Nitrate concentration experienced little changes during the experiment, which suggest that nitrification in the soil was minimal [30,31].

Nitrogen rate (kg/ha)	LY		PY		CY	
	Blue	White	Blue	White	Blue	White
0	0.44a	0.61a	2.38a	2.82a	2.56a	3.33a
100	0.52b	0.72b	2.51b	2.93b	2.61b	3.48b
200	0.49c	0.65c	2.46c	2.88c	2.60c	3.42c

Table 3: Taro plants leaf blades, petioles, corms and total yields (tonne/ha).

Means in the same column with the same letter are not significantly different.

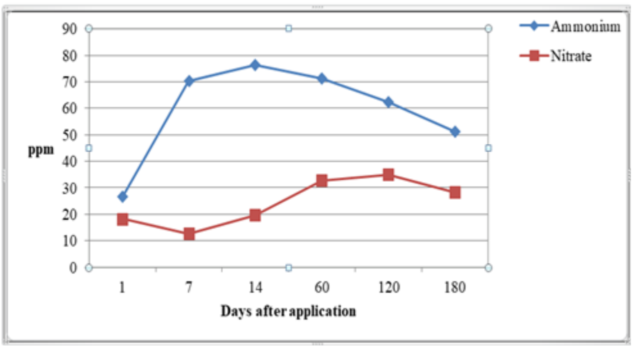

Figure 1: Polymer coated urea, nitrogen release pattern in the River Estate soil.

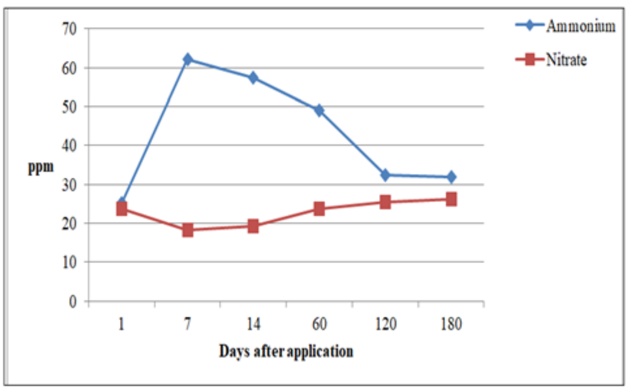

Figure 2: Urea, nitrogen release pattern in the River Estate soil.

Meanwhile Figure 3 shows that there was a drop in the NO_3^- concentration from 1 to 7 DAA. Afterwards, NO_3^-concentration decreased from 14 to 180 DAA. NH_4^+ release pattern increased from 1 to 7 DAA, before slowly declining from 7 to 180 DAA. The NH_4^+ concentration increased from 1 to 7 DAA before declining at 14, 60, 120 and 120 DAA. The results show that NO_3^- concentrations were significantly higher than NH_4^+concentration which is probably due to the fact that calcium nitrate is nitrate based fertilizer. We also noted NO_3^- concentration declined overtime while NH_4^+concentration increased from 1 to 7 DAA. Thereafter, NH_4^+concentration gradual declined overtime. It seems that denitrification and emissions of nitrous oxides probably caused the decline in NO_3^-concentration during the experiment [32].

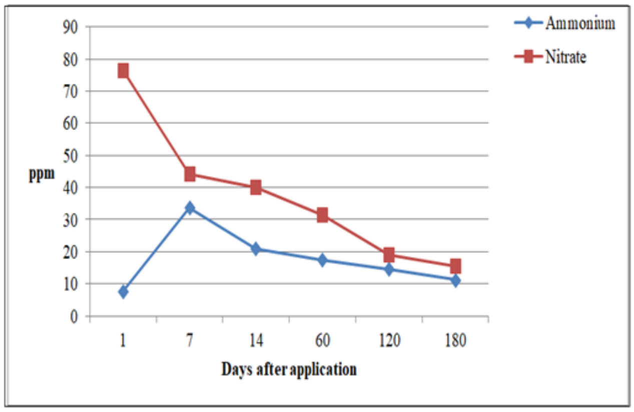

Figure 3: Urea, nitrogen release pattern in the River Estate soil.

Conclusion

Given, that there is a shortage of taro supply in Trinidad, it is important to understand the dilemma faced by taro farmers in Trinidad. The questionnaires were setup to determine demographic information, farm size, workers, taro cultivars, markets available and management practices such as fertilization, irrigation and pesticides applications used in taro farms in Trinidad. According to farmers, taro production is limited by access to land, workers and the increase in imported taro from other Caribbean countries. Support from the Government is critical for sustainable taro production in Trinidad which is important in reducing the country food import bill and providing employment for people in Trinidad. Management practices such as fertilization, irrigation and pesticides application were frequently practised by farmers to improve their productivity and maintaining sustainable taro production. Access to lands, labour and markets were identified as area that needed improving in order to improve taro production. Specific farmer management practices such as farm maintenance and amendments applications were also identified from the survey. Essentially, transferring knowledge from scientists and extension officers to farmers is critical for sustainable and efficient agricultural productions. The survey also revealed that taro is important for the livelihood of people in Trinidad because it provides food security, economic benefits and cultural significance since taro is the main ingredient for the popular Caribbean dish known as callaloo. Taro is also important for the Blue food festival which focussed on a wide range of food that uses taro as the main ingredient. The festival attracts a lot of tourists from around the world who wanted to taste different foods produced from taro.

The second phase of the research is comprised of a greenhouse experiment; which was conducted using taro cultivars, planting materials, yields, irrigations and fertilization rates identified from the survey and the literature review. The results from the greenhouse experiment concluded that taro yields (leaf blades, petioles and corms) were enhanced as a result of nitrogen fertilization which further emphasised the importance of nitrogen in taro plants production. The production of high biomass in taro leaf blades, petioles, corms and suckers require sufficient nitrogen supply. Overall, it was noted that applying 100 kg/ha of nitrogen produced the highest taro yields. It is important to note that the majority of taro farmers in Trinidad apply fertilizers in their farms (from the survey). The results from the greenhouse experiment closely resembled results from greenhouse experiments in the Pacific. These similarities in the yields of taro plants in Trinidad and the Pacific are probably due to their shared origins and similar genomic DNA's.

Finally the nitrogen release pattern experiment shows that the ammonium concentrations of two ammonium based nitrogen sources (polymer coated urea and urea) were higher than the nitrate based fertilizer (calcium nitrate). In terms of NO_3^- concentration; calcium nitrate had more NO_3^- than the two ammonium based fertilizers. The polymer coated urea produced the highest NH_4^+ concentration which confirmed the fact that CR (controlled release) nitrogen fertilizers slowly release nitrogen. The application of calcium nitrate and polymer coated urea leads to the highest NO_3^- concentrations. Regarding the sampling time, it was noted that NH_4^+ concentration increased from 1 to 7 DAA before gradually decreasing from 7 to 180 DAA. The NO_3^- concentration seems to decrease overtime from 1 to 180 DAA. All in all, FR (fast release) nitrogen fertilizers released more nitrogen in the early stages while CR fertilizers slowly released nitrogen overtime.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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