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The Effect of Residual Potassium (K) and Poultry Manure (PM) on the Root Distribution of Two Cultivars of Taro Grown on Tokotoko Soil Series in Fiji

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Abstract: The root growth and development pattern of the two cultivars of taro used in this experiment varied in terms of root distribution, root weight, root number and root length. Vula Ono gave significantly heavier roots (0.21 g per plant) compared with Tausala-ni-Samoa (0.15 g per plant). The addition of poultry manure (10 t ha^{-1}) significantly increased root weight, 0.22 g per plant compared with 0.14 g per plant for treatments receiving no poultry manure. Potassium (K) and PM significantly affected root numbers. Plots with K at 150 kg ha^{-1} produced 29 roots per plant and those with K at 300 kg ha^{-1} gave significantly more roots at 36 roots per plant. Similarly, plots with no PM produced 29 roots per plant and those with 10 t ha^{-1} gave 37 roots. There was a highly significantly cultivar x poultry manure interaction caused by an increase in root numbers with addition of poultry manure in the cv. Vula Ono but no change in the cv Tausala-ni-Samoa. Potassium (K) and Poultry Manure (PM) significantly affected root length when separately applied. Plots with higher rates of K (300 kg ha^{-1}) had significantly longer roots than those with low rates (150 kg ha^{-1}). Similarly, plots with PM had taro with longer roots than those without PM. There was a highly significant cultivar x poultry manure interaction on root length caused by an increase in cv. Vula Ono root length with addition of poultry manure but no effect on the root length of Tausala-ni-Samoa. There was a significant decrease in root weight, number and length with depth for Tausala-ni-Samoa but these were nearly the same for Vula Ono for depths of 0.1, 0.2 and smaller for the depth of 0.3 m. This showed that roots of cv. Vula Ono were more evenly distributed in the soil profile and maybe more efficient in using below ground resources including those applied to the soil. Poultry manure improved root penetration since there was a highly significant difference in root weight, root numbers and root length with depth.

Key words: Residual, potassium, poultry manure, root distribution, taro, interaction, root penetration

INTRODUCTION

Taro (*Colocasia esculenta* (L.). Schott) belongs to the Araceae family and includes several species of aroids cultivated as food crops in the tropics producing corms of varying colours and sizes. The major common edible aroids are the dasheen and eddoe types, known as taro. The dasheen type has a large central corm with few small cormels generally having no economic value, while the eddoe type produces a central corm surrounded by large, well developed cormels that are edible. This study is mainly focussed on two varieties of dasheen taro namely Tausala-ni-Samoa and Vula Ono.

Tausala-ni-Samoa has dark purple stems and has medium height of about a meter. The colour of the corm flesh is pink, the basal ring is also pink and the stems are dark green. This is an unimproved variety but preferred in the export market for its cooking, eating and keeping, qualities. The average yield is about 12 t ha^{-1} (Prasad, 2000).

Vula Ono is an improved variety of taro, a hybrid. This variety, initially known as 160/31 was originally developed during the middle of the 1980s by crossing between the cultivar R16 and Tausala-ni-mumu (R16 is a cross between Samoa and Hawaii cultivars of taro). The resultant is the hybrid Vula Ono, that has undergone further research and evaluation and has become a promising variety among farmers for its vigorous growth, high yield of about 27 t ha^{-1} and excellent eating and cooking qualities. The colour of the basal ring is light pink, stems are light green with scattered stripes of dark purple. The flesh of the corm is light yellow. It grows up to a height of close to two meters. This hybrid was released in 1995 (Kumar, 1995) in Fiji. The main thrust of the research in Fiji has been on accessions and germplasm collection, varietal selections, growth studies, fertilizer responses, plant population studies, planting material responses and engineering research (Sivan *et al.*, 1972). There was no known study on the root distribution patterns or root

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studies on taro in Fiji even though these have been known to influence the uptake of nutrients (Prasad, 1999).

The distribution of roots in the soil has been found to be closely correlated to greater absorption or uptake of nutrients and water and hence growth and productivity (Tofinga and Snaydon, 1992; Fisher and Dunham, 1984). However, according to Kramer (1983) the capacity of roots to absorb water and minerals does not increase in direct proportion to the increase in length or area of root, because while new roots are being added, other roots are maturing and becoming less permeable. It was however, generally found, that more roots are found in the top soil layers and decreasing with depth for most crops. According to Barber and Silverbush (1984), root length and radius can influence nutrient uptake which depends on root surface area and the rate of increase and uptake per unit of root surface.

In general, the length of roots decreases with depth in soil but considerable variation exists in the distribution of roots at different stages of growth. The depth of rooting is of considerable importance especially if water and nutrients are likely to be in short supply. The depth of rooting is therefore of considerable importance especially where there is water shortage. Studies have found that the rooting depth of potato and sugar beet is 0.8 and 0.9 m, respectively which is almost similar to that of taro.

Such mostly theoretical arguments and conflicting conclusions from root distribution and related studies can only be settled by actual research studies on root distribution and root studies on taro. This paper reports the findings of such a study on two varieties of taro, Tausala-ni-Samoa and Vula Ono carried out in Fiji. Specifically the research is focussed on the response of roots of two cultivars of taro [*Colocasia esculenta* (L.). Schott] to residual potassium and poultry manure on Tokotoko soil series in Fiji.

MATERIALS AND METHODS

The experiment was planted in plots of a previous ginger experiment planted on Tokotoko soil that received different rates of N, K and Poultry Manure (PM). The ginger experiment had the following treatments; PM at O and 10 t ha^{-1}, K at 150 and 300 kg ha^{-1} and N at 100, 200, 300 and 400 kg ha^{-1}. In the taro experiment that followed, there were eight treatments replicated six times in a Randomised Complete Block Design (RCBD).

This trial was planted with minimum disturbance to the raised beds on which ginger was planted. In this trial residual effect of K and PM on root distribution and related measurements were studied and therefore all plots having K or PM treatments were planted with the two taro cultivars.

Since there were four rates of N but no yield response in the ginger crop and the residual effect of N is not expected due to its dynamic nature, sufficient N fertiliser was applied to all plots (in taro crop) to provide adequate N (urea at 100 kg ha^{-1}) since N was limiting in Tokotoko soils. Nitrogen is easily lost due to leaching, erosion and volatilisation. The taro experiment which follow consisted of two rates of K (150 and 300 kg ha^{-1}) and two rates of PM (0 and 10 t ha^{-1}) that were applied to the previous ginger crop and two taro cultivars an improved (Vula Ono) and an unimproved cultivar (Tausala-ni-Samoa) combined factorially. The eight treatment combinations were as follow:

- Vuyla Ono, K 150 kg ha^{-1} and Poultry Manure (PM), 0 t ha^{-1}
- Vula Ono, K 150 kg ha^{-1} and Poultry Manure (PM), 10 t ha^{-1}
- Vula Ono, K 300 kg ha^{-1} and Poultry Manure (PM), 0 t ha^{-1}
- Vula Ono, K 300 kg ha^{-1} and Poultry Manure (PM), 10 t ha^{-1}
- Tausala-ni-Samoa (TNS), K 150 kg ha^{-1} and Poultry Manure (PM), 0 t ha^{-1}
- Tausala-ni-Samoa, K 150 kg ha^{-1} and Poultry Manure (PM), 10 t ha^{-1}
- Tausala-ni-Samoa, K 300 kg ha^{-1} and Poultry Manure (PM), 0 t ha^{-1}
- Tausala-ni-Samoa, K 300 kg ha^{-1} and Poultry Manure, 10 t ha^{-1}

In the previous trial (ginger crop), P was incorporated in the soil at the rate of 50 kg ha^{-1} as tripple superphosphate before planting. Lime was applied at the rate of 3 t ha^{-1} two weeks before planting, to improve the soil pH. The initial soil pH was 5.3.

All nutrients were applied during the ginger crop trial planted during 1998 to 1999.

The gross plot was 5.0 m long and 3.6 m wide (two beds of 1.8 m width) and the nett size was 4.0 m long and 1.8 m wide (having two rows of plants). The rows that contained the nett plot or the recording plants had one plant each at either end as guard plants. Each net plot had two rows of eight plants but since a plant at both ends of the row had to be kept as the guard plant, there were twelve plants for recording in total per plot. The trial area was 893 m^2. There were 32 plants per plot of which there were twelve for recording.

Site for experiment: The experiment was planted in a field at Koronivia Research Station in Fiji. This was the field used for the previous ginger trial and in order to study the residual effects of an inorganic fertilizer (K) as KNO_3 and an organic fertilizer (PM) as Poultry Manure, applied to ginger, on root distribution and characteristics of a subsequent taro crop. This taro trial was planted in the same field. The field was used for grazing prior to 1969 after which it was used for flooded rice cultivation for 30 years. In 1999, the field was drained and developed for a ginger trial on raised beds before the current trial. The existing structure such as the bunds around the field, flood irrigation and drainage outlet used for rice cultivation was maintained.

Soil characteristics: The soil type in this field was characterised as Tokotoko Soil Series. Based on soil taxonomy, Tokotoko soil is classified as Aeric Tropaquept, very fine Kaolinitic, isohyperthemic; but based on FAO (1989) classification, it is Eutric Gleysol while based on Twyford and Wright classification, it is Gley soil related to latosols with no dry season. The parent material from which it is derived is Alluvium from intermediate and basic rocks. These soils are found in low lying surfaces on the major flood plains and is very poorly drained (Leslie, 1997). The major limitations are; poor drainage, high water table in wet season, floods, clayey, soil acidity and nutrient deficiencies. Some of the land use options for unimproved lands are; a) shifting cultivation; for dalo (taro), tavioka (cassava) and bananas; b) permanent use: rice, inferior pasture.

The soil, being an inceptisol is characterised as alluvial soil periodically flooded, having high water table throughout the year, clayey loam in texture and blocky structure with high CEC, moderately acid in surface horizon and slightly acidic subsoils, high exchangeable Ca and Mg and low exchangeable K in surface soil, low total and extractable P, low in Na and high in extractable Al, high C: N ratio and base saturation.

Land preparation: After harvest of ginger in August 1999, soil samples were taken from individual plots. The site was sprayed with Glyphosate to control weeds. The land was prepared by ploughing the beds with a reversible plough, rotovating twice, then ridging, with minimum disturbance to the beds that were used for growing ginger. The beds were re-shaped before planting taro in furrows on the beds. Planting was carried out on raised beds to facilitate drainage. The drains between the beds were rectified using a ridger attached to a rotary tiller after land preparation and after planting. The drains were rectified later to remove water and soil that slipped into the drain by rainwater and weathering. The previous crop was grown on raised beds and the present taro crop was grown on raised beds without much disturbance to the beds.

Preparation of raised beds: The raised beds were prepared to facilitate drainage since Tokotoko soils have a high water table and poor drainage. The beds were prepared using a tractor drawn ridger. Each of the beds was 0.45 m high and 1.5 m wide having a 0.3 m wide drain in between the beds. As a result, the width of the bed from centre of the drain on one side to the centre of the drain on one side to the centre of drain on the other side was 1.8 m and therefore the bed width is stated as 1.8 m wide. Since this was a paddy field, deep drainage was formed along the inside of the bunds having an outlet to remove excess water and prevent any water logging.

Planting material and planting details: Before planting, the planting material for the two cultivars were lifted out, the top and the basal portions were trimmed. The material was graded into four categories based on the size and basal diameter. The fourth category were the rejects that were not used for planting and it included the damaged or partially rotten material, small size with basal diameter of below 2.5 cm. The first grade was planted in replication one and two, the second in replications three and four and the third grade in replications five and six. Taro was planted in furrows, on raised beds at a spacing of 0.9×0.6 m. Planting of the whole trial was carried out manually within a day in August 21, 1999 and harvested six months later.

Pest control: Insects were controlled with malathion 50% E.C. The chemical was sprayed three times at the rate of 28 mls in a 14 litre knapsack to control plant hoppers, cutworms, whitefly and cluster caterpillars. Spraying was carried out using a mist blower to ensure thorough coverage of the plants.

Root sampling for root distribution and related studies: Total length of taro root was estimated using non-destructive sampling method described. One plant per plot was selected randomly and a steel soil auger 38 mm (core sampler) in diameter was used to sample the roots at three spots per plant, in a 0.9×0.6 m area around the plant. Sampling was performed first for 0.1 m depth and the soil, together with the roots were taken out. The roots were separated and kept in a labelled polyethylene bag. Similarly, sampling was continued for the 0.2 and 0.3 m depths, the roots were separated and kept in labelled polyethylene bags. After sampling five plants, the samples were taken for estimation of root lengths.

Root lengths were estimated in the laboratory using the method described by Bussell and Bonin (1992). The root pieces were washed carefully of soil and stored temporarily in petri dishes half filled with water. For length estimation, root pieces were poured over a clear transparency sheet which had 5×5 mm grid squares photocopied onto it and which had been placed in the bottom of a clear rectangular glass dish. The root pieces were separated as necessary and then held in place over the grid by a sheet of glass. Counts were made, with the aid of a magnifying glass, of the intercepts of the roots with vertical and horizontal grid lines and accumulated with a hand tally counter. Root length in cm was calculated from the counts using the formula given by Tennant (1975) as follow.

Root length (R) = 11/4 × the number of intercepts (N) × grid unit (in cm).

Other data collected were root weight and root number.

RESULTS AND DISCUSSION

Effects of treatments on root weights, root number and root length of taro.

There was a significant ($p<0.05$) difference in root weight, between the two cultivars. The cv. Vula Ono had fresh root weight of 0.21 g per plant while that of Tausala-ni-Samoa was 0.15 g per plant (SE±0.03) (Table 1). This was based on the root samples that were taken using a core sampler. There was also a significant effect of Poultry Manure (PM) on root weights between the two cultivars. Treatments receiving PM at 10 t ha^{-1} had root weights of 0.22 g per plant while the treatments receiving no PM had 0.14 g per plant (SE±0.03). This could be attributed to the improvement in soil structure caused by application of PM. This effect was greater because Tokotoko soils were heavy due to high clay content.

There were significant ($p<0.05$) effects of K and PM on root numbers. Plots receiving K at 150 kg ha^{-1} had 29 roots per plant while that for plots receiving K at 300 kg ha^{-1} had 36 roots per plant (SE±2.48). Similarly, plots not receiving PM had 29 roots while that for plots receiving PM at 10 t ha^{-1} had 37 roots per plant. An interaction effect of cv and PM on root numbers is given in Table 2.

There was a highly significant interaction between cultivars and application of PM on root numbers. The cv. Tausala-ni-Samoa did no show significant difference in root number with addition of PM, having an average root number of 32 per plant (decrease) but the cultivar Vula Ono had 23 roots per plant for treatments not receiving PM and 41 roots per plant for treatments receiving PM at 10 t ha^{-1}. This could be attributed to the genetic make up of cultivars, the hybrid Vula Ono, growing more vigorously after finding a suitable environment (presence of PM) for root growth, had more roots than the traditional cultivar Tausala-ni-Samoa.

There was a significant ($p<0.05$) effect of K and PM on root length when applied separately. Plots receiving K at the rate of 300 kg ha^{-1} had a root length of 0.013 m longer on an average than the plots receiving K at 150 kg ha^{-1}, which had a root length of 0.051 m per plant. This can be explained by the findings of De La Pena and Plucknett (1969) that application of K enhanced translocation and transformation of sugars and N compounds in all parts of the taro plant. Furthermore, the plots receiving PM at 10 t ha^{-1} had roots that were 0.014 m longer on an average compared to plots receiving no PM and this maybe due to improvement of soil structure. There was no interaction between K and PM on root length of taro. However, there was a highly significant $p<0.01$) interaction between cultivars and PM. The cv. Tausala-ni-Samoa was not influenced by application of PM but the cultivar Vula Ono showed an increase in root length of 0.032 m per plant with addition of PM at the rate of 10 t ha^{-1}.

Table 1: Comparison of root lengths and root weights for the two cultivars for four random plants, each at depths 0.1m, 0.2m and 0.3m at 24 weeks after planting

	Tausala-ni-Samoa Length of roots (m) at depth			Total length (m)	Vula Ono Length of roots (m) at depth			Total (m)
	0.1	0.2	0.3		0.1	0.2	0.3	
	927.58	196.35	40.90	1164.83	1135.65	36.23	69.10	1510.98
	79.63	16.86	3.51	100.00	75.16	20.27	4.57	100.00
	Mass of roots at depth			Total	Mass of roots at depths			Total
Length (%) to total	0.1	0.2	0.3	weight (g)	0.1	0.2	0.3	(g)
Fresh mass (g)	200.32	36.59	8.44	245.35	367.16	84.57	20.00	471.73
(%) to total	81.65	14.91	3.44	100.00	77.83	17.93	4.24	100.00
DM mass (g)	16.03	2.93	0.68	19.64	34.88	8.03	1.9	44.81

Table 2: Interaction effect of cultivars and PM on root numbers

	Tausala-ni-Samoa		Vula Ono	
Cultivars nutrients applied	PM 0 t ha^{-1}	PM 10 t ha^{-1}	PM 0 t ha^{-1}	PM 10 t ha^{-1}
Root numbers	33	32	23	41

SE±3.5

Difference in rooting depth with cultivars: There was a significant ($p<0.05$) difference in the mean weight of roots with depth for the two cultivars (Table 3). The top 0.1 m layer of the soil had a root weight of 0.29 kg plant, the next 0.1 m layer had 0.14 kg plant while the third 0.1 m layer had only 0.02 kg plant for Tausala-ni-Samoa. This was due to the fact that the roots in the top layers were less branched and thicker while those down the profile were thinner and branched. There was a highly significant difference in root length, root numbers and root weight for every 0.1 m, depth of sampling up to the 0.3 m sampling depth. The differences in root weight, numbers and length with depth for the two cultivars of taro are given in Table 3.

The root weight, number and length decreased significantly with depth for Tausala-ni-Samoa while it was almost the same for the cv. Vula Ono for depths of 0.1, 0.2 and relatively small for the depth of 0.3 m but still much larger than those (values) for Tausala-ni-Samoa for the same depths (Table 3). This showed that the roots of cv. Vula Ono were well distributed throughout the soil profile. This made this cultivar a more efficient user of soil nutrients and soil moisture and it had vigorous growth and higher yield.

Rooting depth as influenced by application of PM: There was a highly significant ($p<0.01$) difference in root weight, root numbers and root length with depth (Table 4). This correlates with the fact that application of PM or organic manures improve the soil structure and helps in root penetration especially in heavy soils (Tofinga, 1992; Prakash, 1998). Application of PM also helped in improving soil pH from 5.3 before planting to 5.6 after harvesting. This would have further improved root growth since Al toxicity occurred at soil pH below 5.5 that affected root growth (Tuivavalagi, 2001). An improvement in soil pH further improves nutrient availability and crop growth.

Interaction of cultivars, K and PM on rooting of taro: The weight of root was significantly ($p<0.05$) influenced by the interaction of taro cultivars and PM with depth of rooting (Table 4). The hybrid Vula Ono had better rooting depth compared to the cv. Tausala-ni-Samoa. There was a significant interaction effect of PM with cultivars and rooting depth on root weight, root numbers and root lengths. The difference in root weight shows that the roots were heavier (thicker) for the cv. Vula Ono than that for Tausala-ni-Samoa. This was obvious from the morphology of the plants. The details of root weight, numbers and length with depth as influenced by application of PM, for the two cultivars of taro are given in Table 4. A summary of the root distribution of the two cultivars of taro shows that the roots of Vula Ono are better distributed than those for the cv. Tausala-ni-Samoa. This indicates that Vula Ono may be more efficient in using soil resources or below ground resources and may be more competitive than Tausala-ni-Samoa (Tofinga and Snaydon, 1992).

Root fresh and dry weights: There was a significant ($p< 0.05$) difference in root fresh weights between the two cultivars of taro, the details of which are provided in Table 5. The cv. Vula Ono had a mean root weight of 1468 kg ha^{-1} that was 452 kg ha^{-1} more than that of Tausala-ni-Samoa which was 1016 kg ha^{-1}, while the difference for the control plot was 1588 kg ha^{-1} with root weights of 2585 and 997 kg ha^{-1}. The heavier root weight of Vula Ono indicate that it may have larger root surface area and thus absorb more water and nutrients than Tausala-ni-Samoa, that is, it is more competitive for the soil's limited resources (Tofigna, 1990).

Table 3: Differences in root weight, root numbers and root length with depth for the two cultivars of taro

	Tausala-ni-Samoa			Vula Ono		
Depth (m)	Root weight (kg)	Root nos.	Root length (m)	Root weight (kg)	Root nos.	Root length (m)
0.1	0.29	61	1.08	0.30	41	0.74
0.2	0.14	33	0.60	0.27	42	0.75
0.3	0.02	5	0.10	0.07	13	0.24

SE±0.03 for root weight. SE±2.48 for root number. SE±0.04 for root length

Table 4: Differences in root weight, numbers and length with depth as influenced by application of poultry manure, for the two cultivars of taro

Depth (m)	Root weight		Root number		Root length		Root weight		Root number		Root length	
Poultry manure	-PM	+PM	-PM	+PM	-PM	+PM	-PM	+PM	-PM	+PM	-PM	+PM
0.1	0.23	0.36	61	60	0.11	0.11	0.32	0.29	36	47	0.06	0.08
0.2	0.12	0.17	35	32	0.06	0.05	0.14	0.41	23	61	0.04	0.11
0.3	0.01	0.02	6	5	0.01	0.01	0.04	0.10	11	16	0.02	0.03

SE±0.03 for root weight. SE±2.48 for root number. SE±0.04 for root length

Table 5: Root fresh and dry weights of taro with various treatments at harvest

Poultry manure	0 t ha^{-1}	PM 10 t ha^{-1}		0 t ha^{-1}		PM 10 t ha^{-1}	
K 150 kg ha^{-1}	K300	K150	K300	K150	K300	K150	K300
1613 kg ha^{-1} wet weight	1046	676	731	1364	1758	1697	1052
201.6 kg ha^{-1} dry weight	138.1	111.4	90.4	148.0	232.2	318.1	220.7

SE±333.13 for fresh weight. SE±49.55 for dry weight

CONCLUSION

In this experiment, the root distribution pattern of the two cultivars along with related studies, viz root weight and root number were also studied to relate their implications on nutrient uptake and yield. The cultivars used were Tausala-ni-Samoa which is a traditional cultivar (unimproved) and Vula Ono which is a hybrid (improved). It was expected that nutrient uptake and requirement would be different for the two cultivars and yields would also differ. Indeed, the cultivar Vula Ono is superior than Tausala-ni-Samoa with regards to nutrient uptake and yield.

The root distribution studies showed that the cv Vula Ono had longer and denser root system than the cv. Tausala-ni-Samoa at depths of 0.1, 0.2 and 0.3 m. This explains the fact or observation that the cv. Vula Ono is more robust, higher yielding, drought tolerant and taking up more nutrient than the cv. Tausala-ni-Samoa (Kumar, 2000). Vula Ono also responds well to PM.

Plots receiving K and PM together improved root weight, root numbers and root length. This shows that both K and PM are important for growing root crops on Tokotoko soils. Root distribution for the cv. Tausala-ni-Samoa was less than that for the cv. Vula Ono (Table 3). The roots of the cv. Vula Ono are better distributed throughout the soil profile while the roots of the cv. Tausala-ni-Samoa are mostly found in the top 0.2 m of the soil profile and as a result, it is not tolerant to drought or efficient user of nutrients.

The roots of the cv. Vula Ono are better distributed to take advantage and tap soil nutrients and moisture from a greater soil volume when compared to the cv. Tausala-ni-Samoa. Application of PM improve soil pH, soil structure and drainage that helped in improving root penetration (Kumar, 2000). This is essential for Tokotoko soils that are low to moderate in soil fertility, clayey and have soil pH below 5.5 and the problem of Al toxicity (Leslie, 1997).

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