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Full Length Article

Comparative Growth and Yield of Taro (*Colocasia esculenta*) Accessions Cultivated in the Western Cape, South Africa

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Abstract

The growth and yield characteristics of six accessions (*Amadumbe 2914*, *Amadumbe 3053*, *Amadumbe 43*, *Amadumbe 56*, *Amadumbe Amzam 3553/5118* and *Amadumbe 2919*) of *Colocasia esculenta* (taro) were compared in the Western Cape Province of South Africa. A randomized complete block design with five replications was used. Differences in growth and yield observed among the accessions may be attributed to non-uniformity in the size of the propagules used for establishment of the trial, genotypic and/or climatic factors. *Amadumbe 2914*, *Amadumbe 3053*, *Amadumbe 43* and *Amadumbe 56*, established with bigger cormels (20.37 – 28.33 g) consistently showed superiority in terms of plant height, leaf area and yield over *Amadumbe Amzam 3553/5118* and *Amadumbe 2919,* established with smaller cormels (15.00 and 16.67 g). However, there was no appreciable difference in the size and weight of individual cormels produced by all six accessions. Due to small cormel sizes, a higher proportion (about 92%) of the cormel yield could be classified as unmarketable. Good nutrition can be provided by the leaves and tubers, even though maximum yield may not be attained in the Western Cape due to temperature, radiation and day length limitations, especially in winter. Continued research to determine whether yield can be improved with better nutrition and agronomic practices, is warranted.

Keywords: Amadumbe; *Colocasia esculenta*; Corm; Cormel; Propagule size; Taro

Introduction

Taro [*Colocasia esculenta* (L.) Schott], is an ancient crop cultivated in the tropical and subtropical regions of the world, particularly in the Pacific and Caribbean islands and in West Africa (Hancock, 2004). In South Africa, *C. esculenta* is known as *Amadumbe*. The species is grown mainly for its edible fleshy tubers called corms or cormels, while the leaves are consumed as green vegetables (Aregheore and Perera, 2003). The tubers are good sources of energy (Lewu *et al*., 2010) with easily digestible starch grain (Oke, 1990; Lee, 1999) while, the leaves are excellent sources of protein, dietary fibre, vitamin and minerals (FAO, 1993; Lewu *et al*., 2009a, b). The high protein content of the leaves favourably complements the high carbohydrate content of the tubers. Taro is one of the few major staple foods where both the leaf and underground parts are important in the human diet (Lee, 1999).

Although *C. esculenta* is consumed in most tropical areas, its importance in daily nourishment is steadily decreasing, with more productive root crops like cassava and sweet potato gradually replacing taro (Caillon *et al*., 2006). In South Africa, the potential of *Amadumbe* is yet to be fully exploited when compared with *Zea mays* (maize) and *Solanum tuberosum* (potato), which are the main staples. The cultivation and consumption of *C. esculenta* still remain at subsistence level, though its tubers are cooked and eaten in similar manner to potatoes (Van Wyk, 2005). Despite the crop being grown commercially in many of the Pacific Island countries and some other regions across the world, *C. esculenta* is of minor importance in South Africa (Mabhaudhi *et al*., 2014) with only a small proportion finding its way to the market (Shange, 2004). However, the species currently plays an important role in food and nutritional security in the rural areas, signifying that the crop warrants further research locally (Mare, 2009).

Rapid increase in global population growth demands an increase in the production and diversification of crops. Root and tuber (R&T) crops can play a major role in addressing this issue (Paul and Bari, 2011). However, research on R&T crops such as taro has been rather slow, due to its lower profile among researchers compared to the other staple R&T crops (Mabhaudhi *et al*., 2014). Increasing the competitiveness of R&T crops can play an important role in alleviating poverty and ensuring long-term food security in South Africa. This can be achieved by extending

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the cultivation of *C. esculenta* to all South African provinces suitable for taro production, where the crop is currently not grown. The crop is known to be traditionally cultivated in the coastal and subtropical areas of South Africa, especially in KwaZulu-Natal Province (Shange, 2004; Mare and Modi, 2009). Therefore, increasing taro productivity in the country will not only popularize the crop as an additional tuber crop, but also increase food options for South Africans, hence contributing to sustained food and income security. This study therefore aims to: (1) Assess the suitability of cultivating *C. esculenta* under the Western Cape agro-climatic conditions, and (2) Identify the best yielding accessions amongst the six used in the study.

Materials and Methods

Germplasms, Experimental Design and Agronomic Practices

Tubers (cormels) of six breeding lines (*Amadumbe 2914*, *Amadumbe 3053*, *Amadumbe 43*, *Amadumbe 56*, *Amadumbe Amzam 3553/5118* and *Amadumbe* 2919) of the eddoe type of taro (*Colocasia esculenta* var. *antiquorum* (L.) Schott) were obtained from the germplasm collection of the ARC-VOPI. Genetic variation exists among accessions. The propagules were of varying sizes both within and between accessions, with average size of 24.62 g (*Amadumbe 2914*), 20.37 g (*Amadumbe 3053*), 23.01 g (*Amadumbe 43*), 28.33 g (*Amadumbe 56*), 16.67 g (*Amadumbe Amzam 3553/5118*) and 15.00 g (*Amadumbe* 2919), respectively, and are therefore classified as small-sized propagules (Modi, 2007; Mare, 2009).

The experiment was conducted from spring (October) 2014 to winter (July) 2015. The trial was established at Nietvoorbij (33°55'S, 18°52'E), one of the ARC Infruitec-Nietvoorbij research farms in Stellenbosch, Western Cape, South Africa. Stellenbosch has a Mediterranean climate. Temperature, rainfall and radiation data for the duration of the experiment were obtained from the ARC-Institute for Soil, Climate and Water (ARC-ISCW). These were measured at the closest weather station approximately 2 km from the experimental site.

Prior to the establishment of the trial, composite soil samples were collected with an auger from the 0-300 mm soil layer of the experimental site and analysed to determine the physical and chemical properties of the soil. The soil of the experimental site is sandy clay loam, acidic [$pH_{(KCl)}$ 5.3] and very low in organic carbon (0.28%). After soil preparation (ploughing, harrowing and ridging), *C. esculenta* cormels (whole tubers) were randomly selected for each treatment and planted on ridges spaced 1 m apart and with 1 m within row spacing between plants. Planting depth was 15-20 cm, while blocks were separated by a spacing of 3m. This is equivalent to a plant density of 10000 stands/ha. Each plot measured 10 m^2, consisting of five data plants per plot and covering a total land area of 300 m^2.

The experiment was replicated five times in a randomized complete block design (RCBD), with the different accessions used as treatment levels. Fertilizer [NPK 2-3-2 (22)] was applied in a ring of about 100mm around each plant two months and five months after planting (MAP) at a rate of 350 kg/ha. Weeds were cleared by hand-weeding when necessary. The field was drip irrigated for four hours, three times a week throughout the dry summer and autumn months (December to May) and rain-fed during the winter season (June and July).

Morphological Characterization

Percentage emergence was assessed at three MAP. From then on, data were collected once a month from 25 plants per accession. The number of leaves, plant height and leaf area were recorded from the second to the sixth plants in every plot. These were selected as data plants, thus giving five plants per row for every accession per block. Plant height was measured as the distance from ground level to the attachment point between the leaf petiole and the lamina of the tallest leaf while leaf area was measured using both leaf length (the length from the sinus base to the apex of the largest leaf) and leaf width (maximum leaf width) according to Chan *et al*. (1993).

Yield

The plants were harvested nine MAP. Yield was determined by the number and weight of corms and cormels per plant.

Statistical Analysis

Data generated were subjected to statistical analysis of variance (ANOVA) using the SAS analytical package. Differences between means were tested using the Duncan Multiple Range Test. Significant difference was determined at $P \leq 0.05$. Correlation analysis was conducted on yield data set using SAS software (SAS, 2008), significant differences were determined at 1 and 5% probability levels.

Results

Climate

Table 1 presents the average monthly temperature, rainfall and radiation data measured near the experimental site. There was a progressive drop in temperature and radiation from March 2015 till the crops were harvested in July 2015, while the amount of rainfall continued to increase during the same months, which is typical of a Mediterranean climate.

Emergence

Comparatively, the percentage emergence of the six accessions were generally good, with *Amadumbe 56*

Table 1: Average monthly temperature, rainfall and radiation data for the experimental site

Month	Temperature/month (°C)			Rainfall/ month (mm)	Radiation/ monthMJ/m^2
	Max.	Min.	Mean		
October 2014	28.38	10.75	19.57	6.50	23.00
November 2014	28.88	12.44	20.66	47.10	25.03
December 2014	29.89	13.72	21.81	0.00	29.32
January 2015	32.40	14.28	23.34	0.00	28.31
February 2015	31.26	12.93	22.10	8.90	26.67
March 2015	31.83	13.35	22.59	0.00	21.11
April 2015	27.94	9.89	18.92	4.70	15.78
May 2015	24.42	8.80	16.61	32.60	9.44
June 2015	20.11	6.19	13.15	90.90	8.28
July 2015	18.46	5.35	11.91	120.30	9.10

Table 2: Percentage emergence of six accessions of *C. esculenta* three months after planting

Accession	Emergence (%)
Amadumbe 2914	93.85^{a}
Amadumbe 3053	84.00^{ab}
Amadumbe 43	95.00^{a}
Amadumbe 56	100.00^{a}
Amadumbe Amzam 3553/5118	75.00^{b}
Amadumbe 2919	86.67^{ab}
LSD ($P \leq 0.05$)	14.68

n = 5. Means with different letters differ significantly at the 5% level

showing overall superiority of 100% emergence (Table 2). The result also indicates that there was no significant difference in percentage emergence among the rest of the accessions, except *Amadumbe Amzam 3553/5118* which recorded a significant drop in emergence percentage at 75%.

Emergence of taro plants started 14 DAP. *Amadumbe 2914, Amadumbe 43* and *Amadumbe 56* had a very fast rate of emergence, while *Amadumbe 2919, Amadumbe 3053* and *Amadumbe Amzam 3553/5118* started slowly (Fig. 1). Thirty-nine DAP, *Amadumbe Amzam 3553/5118* had the least number of germinated plants in total.

Growth Parameters

Plant height of *Amadumbe 2914*, *3053*, *43* and *56* were consistently higher from 3 to 7 MAP compared to *Amadumbe Amzam 3553/5118* and *2919* (Fig. 2). Plant height increased progressively in all treatments from 3 MAP until it peaked at 6 MAP. From 6 MAP plant height declined in all the accessions as the plants reached physiological maturity and shoots began to die back.

The number of leaves per plant reached the maximum at 6 MAP and declined thereafter. Overall, there was no significant difference in the mean number of leaves per plant in all the six accessions from 3 MAP to 7 MAP. However, there were exceptions with *Amadumbe Amzam 3553/5118* and *Amadumbe 2919* at 6 and 7 MAP recording significantly fewer number of leaves per plant (Table 3). Similar to the observed trend in plant height, mean number of leaves per plant increased from a minimum of 2.64 - 3.32 leaves at 3 MAP to a maximum of 7.40 - 8.04 at 6 MAP and

Table 3: Number of leaves per plant for six accessions of *C. esculenta* determined from three to seven months after planting

Accession	Number of leaves				
	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
Amadumbe 2914	3.32^{a}	5.24^{a}	7.28^{a}	8.04^{a}	4.04^{a}
Amadumbe 3053	3.32^{a}	5.28^{a}	7.28^{a}	8.00^{a}	3.92^{a}
Amadumbe 43	2.96^{a}	4.96^{a}	6.96^{a}	7.76^{ab}	3.64^{ab}
Amadumbe 56	3.00^{a}	5.00^{a}	7.00^{a}	7.72^{ab}	3.72^{ab}
Amadumbe Amzam 3553/5118	2.68^{a}	4.68^{a}	6.68^{a}	7.44^{b}	3.36^{b}
Amadumbe 2919	2.64^{a}	4.64^{a}	6.64^{a}	7.40^{b}	3.48^{b}
LSD ($P<0.05$)	0.61	0.61	0.60	0.50	0.40

n = 25. Means with different letters within the same column differ significantly at the 5% level

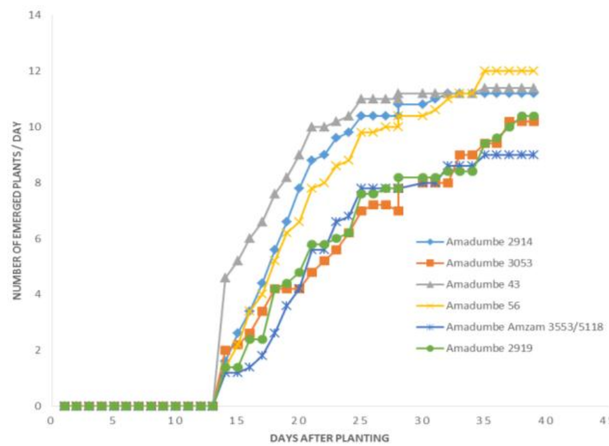

Fig. 1: Rate of emergence of six *C. esculenta* accessions

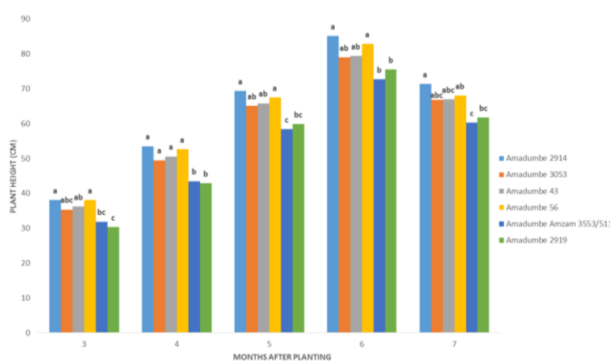

Fig. 2: Mean plant height (cm) for six *C. esculenta* accessions taken from three to seven months after planting

declined thereafter to 3.36 - 4.04 leaves at 7 MAP (Table 3). This is as a result of rapid turnover of leaves experienced in the life cycle of the species; new leaves were constantly emerging, while the older leaves died off, followed by a progressive die back of the shoots from 6 MAP.

Mean leaf area per plant followed a similar pattern as the other growth parameters measured (Fig. 3). *Amadumbe 2914*, *3053*, *43* and *56* had higher tendencies of leaf area values in almost all the months under consideration compared to *Amadumbe Amzam 3553/5118* and *2919*. Leaf area increased with month until it reached its climax at

Table 4: Fresh tuber yield (corm and cormel) of six *C. esculenta* accessions

Accession	Corm		Cormel			Total yield (Corm and cormel)
	No of corm	Weight of corm (kg)	No of cormels	Weight of cormels (kg)	Cormel yield (t/ha)	Total tuber yield (t/ha)
Amadumbe 2914	1.24[a]	0.35[a]	30.68[ab]	1.02[ab]	10.18[ab]	13.72[a]
Amadumbe 3053	1.08[ab]	0.34[ab]	29.08[ab]	0.94[abc]	9.38[abc]	12.74[ab]
Amadumbe 43	1.00[b]	0.37[a]	30.88[ab]	0.92[bc]	9.24[bc]	12.89[ab]
Amadumbe 56	1.08[ab]	0.39[a]	33.48[a]	1.07[a]	10.72[a]	14.65[a]
Amadumbe Amzam 3553/5118	1.04[ab]	0.27[b]	25.88[b]	0.82[c]	8.20[c]	10.86[b]
Amadumbe 2919	1.16[ab]	0.26[b]	27.88[b]	0.86[c]	8.56[c]	11.20[b]
LSD(P<0.05)	0.20	0.08	4.50	0.13	1.34	1.91

n = 25. Means with different letters within the same column differ significantly at the 5% level

6MAP. However, at 7 MAP, mean leaf area per plant started to decline as observed in all the accessions studied in this experiment which is due to a progressive die back and rapid rejuvenation of new leaves from 3 to 6 MAP.

Yield

Average number of corms per plant varied between 1.00 and 1.24. Number of corms produced per plant was not significantly different in all six accessions, with the exception of *Amadumbe 43*, which recorded a significantly lower number of corms (1.00) when compared to *Amadumbe 2914*. However, *Amadumbe 2914* was superior to the other accessions in terms of corm production (Table 4).

Fresh corm weight, number of cormels, fresh cormel weight and total yield of corm and cormel (tuber) were significantly higher (P≤0.05) for *Amadumbe 2914, Amadumbe 3053, Amadumbe 43 and Amadumbe 56* than for *Amadumbe Amzam 3553/5118* and *Amadumbe 2919* (Table 4). *Amadumbe 56* had the highest mean number of cormels per plant (33.48), mean cormel weight per plant (1.07 kg) and total yield (14.65 t/ha), while *Amadumbe Amzam 3553/5118* had the lowest. Most of the cormels produced were small and therefore, not marketable because they fall under the >20 – 40 g size class (Mare, 2009).

Correlation analysis (Table 5), focusing only on the strong positive relationships, indicated that propagule size had a significant, weak, positive correlation with emergence (r = 0.51). However, propagule size did not have a significant positive correlation with cormel yield (Table 5). Likewise, emergence was positively correlated with corm weight (r = 0.51) and total yield (r = 0.52). As expected, the number of cormels was positively correlated with corm weight, cormel weight, cormel yield and total yield, recording between 74-88% positive relationships.

Table 5: Correlation coefficients comparing growth and yield parameters of *C. esculenta*

Characters	A2	A3	A4	A5	A6	A7	A8
A1	0.51**	0.02	0.33	0.42*	0.34	0.34	0.38*
A2		0.05	0.44*	0.51**	0.49*	0.49*	0.52**
A3			-0.08	0.09	-0.13	-0.13	-0.06
A4				0.74**	0.88**	0.88**	0.88**
A5					0.76**	0.76**	0.88**
A6						1.00**	0.98**
A7							0.98**

*Significant at 5% level, **Significant at 1 % level
A1=Propagule size; A2=Emergence; A3=Number of corms / plant; A4=Number of cormels/plant; A5=Corm weight / plant; A6= Cormel weight / plant; A7=Cormel yield (t/ha); A8=total yield (t/ha)

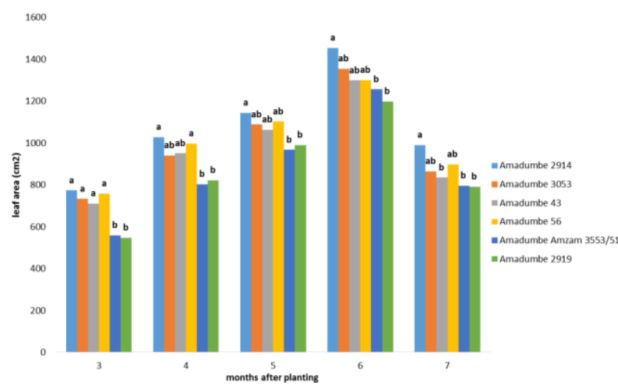

Fig. 3: Mean leaf area per plant (cm^2) for six *C. esculenta* accessions measured from three to seven months after planting

Discussion

The size and weight of cormels used for planting and the genetic potential of the crop could be the main factors responsible for the significant differences in percentage emergence, plant height, number of leaves, leaf area, yield and yield components found in this study. Although the plants produced satisfactory number of cormels, the size on the other hand was disappointing (small) and the yield still low. It was reported that the ability of taro to emerge from the soil is affected by propagule size (Mabhaudhi *et al.*, 2013). Percentage emergence in this study was very good, with the worst performing accession still achieving 75% emergence. Propagule size was apparently not so small to affect emergence negatively.

Plants grown from cormels with average mass above

20 g (20.37 – 28.33 g) namely *Amadumbe 2914, Amadumbe 3053, Amadumbe 43 and Amadumbe 56* showed better growth and yield than plants established with smaller cormels (15.00 g and 16.67 g), namely *Amadumbe 2919* and *Amadumbe Amzam 3553/5118*. It appears that propagule size played a role in this study, which is in agreement with the findings of Stahlschmidt *et al*. (1997) who reported that early planting and large seed cloves produced larger leaf area in garlic. Though it appeared all accessions investigated in this study had relatively uniform number of leaves during growth, *Amadumbe 2914, 3053, 43 and 56*, in contrast, consistently displayed superiority in leaf area per plant throughout the growth period. This indicates that *Amadumbe Amzam 3553/5118* and *2919* had smaller sized leaves per plant in comparison to the other accessions. The resultant effect of leaves having higher leaf area is early rate of establishment, higher plant height, better canopy development, efficient capture of solar radiation and hence more vigour. This is further supported by the significant positive correlation that was observed amongst plant height, leaf area and yield. The findings of this study are consistent with the report of Tsedalu *et al*. (2014). The amount of food reserves contained in planting material is one of the factors which determines quality of the material (Sitompul and Guritno, 1995). It could also be added that increased leaf area observed in the four best performing taro accessions resulted in increased production of photosynthates which is enhanced by the superior leaf surface area and this corroborates early findings (Pratiwi *et al*., 2014).

Propagule size seems like a key factor in terms of growth and yield of taro accessions used for this research. Wide variation in the number of *C. esculenta* tubers (cormels) produced per plant may be due to the non-uniformity in the size of the cormels used to raise the plants in this study. These findings conform to those reported by Khalafalla (2001), who found that seed size of potato tuber had a significant effect on number of tubers per plant and number of stems per plant. In a different field crop variety, Khalafalla (2001) supported the findings of the current study where it was reported that seed tuber size of potato (whole, half and farmer's seed piece) influenced the weight of the marketable tubers. Modi (2007) also reported that crop stand establishment was significantly lowered by the planting of smaller propagules of taro compared with the medium and large propagules and this in turn determines the yield. Hence, the yield of plants grown from large propagules was significantly greater than that harvested from plants grown from smaller propagules. Although the individual cormel weights were thought to be low in this study, they were still higher than the reported mean value of 23.17 g obtained when eighty-two landraces of upland taro *C. esculenta* var. antiquorum were evaluated (Mitra and Tarafdar, 2015). In like manner, the cormel yield in the current study is consistent with the findings of the study carried out in KwaZulu-Natal, South Africa, where 70-85% of the cormel yields were of unmarketable sizes due to the small propagules (5-60 g) used to raise the plants (Modi, 2007). The values obtained for cormel yield in this investigation were slightly lower than the mean value of 12.47 t/ha reported by Mitra and Tarafdar (2015) for different Indian landraces of *C. esculenta* var. antiquorum. Another study conducted in India on nine genotypes of taro (Mitra *et al*., 2007) also reported higher cormel yields than those observed in the current investigation. Compared with the taro yields obtained by other workers (Wang, 1983; Miyasaka *et al*., 2003), the yield obtained in this study are considered low. This could be due to differences in geographical locations, the agronomic factors during cultivation, genetic variations of the germplasms used and climatic factors (Debre and Brindza, 1996).

Taro is a tropical and subtropical crop which requires at least 8-9 months effective summer sunshine for optimum production. In this case, the trial was located in a region with a Mediterranean climate and may have significantly lower temperature compared with previous studies conducted in tropical and subtropical regions of the world, which must have affected the yield. For a tropical and subtropical crop like taro to be grown under a Mediterranean climate of the Western Cape, effect of climate is bound to come to play which may remain a significant limitation. According to several authors, temperature is the most important factor affecting taro growth and yield. Highest yields for taro are obtained under full intensity sunlight (Miyasaka *et al*., 2003; Mare, 2006). The species requires an average daily temperature above 21°C for normal production (Onwueme, 1999) and cannot tolerate frosty conditions. However, in this study, the period of active tuber production which is from 6 MAP till harvest coincided with the period of low temperate and less radiation, and hence, resulting in low yield with small sized cormels. Nevertheless, cultivating taro in this region can still provide good nutrition because of the tuber and leaves that complement each other in supplying balanced nutritive diets, even though the tuber yield may be somewhat low.

The observed growth patterns in all the six accessions under investigation were similar to those reported by other workers (Onwueme, 1999; Tsedalu *et al*., 2014). Such a trend is characterised by rapid shoot growth immediately after sprouting which progressively increases until six months after planting and then followed by a rapid decline. At this stage of growth, a reduction in number of active leaves, plant height and leaf area is generally observed in taro. This affirms that the first six months of growth in taro represents the rapid vegetative growth stage, after which the energy of the species is concentrated towards rapid production of the tubers (Sivan, 1982). Propagule size exhibited a significant positive correlation (51%) with emergence. Emergence in turn displayed positive correlation with corm weight and total yield. Thus, further reiterating the significant role of propagule size in plant emergence, establishment, growth, development and eventually, the yield.

Conclusion

The taro accessions *Amadumbe 2914*, *Amadumbe 3053*, *Amadumbe 43 and Amadumbe 56* performed better than *Amadumbe Amzam 3553/5118* and *Amadumbe 2919* due to differences in their size and mass of propagules used for their establishment. Low cormel yield obtained in this study may be attributed to low temperature from autumn to winter, which coincided with the period of active tuber formation, because taro is temperature sensitive and cannot tolerate frost. Therefore, to grow this crop in the Western Cape, attention should be given to breeding, supplying and planting larger cormels to get their full potential. In addition, optimum nutrient supply during growth is also necessary to enhance productivity. However, future studies are required to generate concrete results and recommendations for best yield by utilizing the uniform sized planting material.

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References

Aregheore, E. and D. Perera, 2003. Dry matter, nutrient composition and palatability/acridity of eight exotic cultivars of cocoyams-taro (*Colocasia esculenta*) in Samoa. *Plant Foods Hum. Nutr*., 58: 1–8

Caillon, S., J. Quero-Garcîa, J.P. Lescure and V. Lebot, 2006. Nature of taro (*Colocasia esculenta* (L.) Schott) genetic diversity prevalent in a Pacific Ocean Island, Vanua Lava, Vanuatu. *Genet. Resour. Crop Evol*., 53: 1273–1289

Chan, L.F., C.T. Lu, H.Y. Lu and C.H. Lai, 1993. A simple method for estimating leaf area in wetland taro [*Colocasia esculenta* (L.) Schott]. *J. Agric. Res. Chin*., 42: 162–172

Debre, F. and J. Brindza, 1996. Potatoes genotypes from the view of production and utility value. *Rost. Výr*., 42: 509–515

FAO, 1993. Tropical Feeds by B. Göhl. Computerized version 4.0 edited by A. Speedy, Rome, Italy

Hancock, J.F., 2004. *Plant Evolution and the Origin of Crop Species*, p: 222. CABI Publishing. Wellingford. UK

Khalafalla, A.M., 2001. Effect of plant density and seed size on growth and yield of *solanum* potato in Khartoum State, Sudan. *Afr. Crop Sci. J*., 9: 77–82

Lee, W., 1999. *Taro (Colocasia esculenta) [Electronic Version]. Ethnobotanical Leaflets*. Available at: http://www.siu.edu/~ebl/leaflets/taro.htm (Accessed: 20 September 2015)

Lewu, M.N., P.O. Adebola and A.J. Afolayan, 2009a. Effect of cooking on the mineral and antinutrient contents of the leaves of seven accessions of *Colocasia esculenta* (L.) Schott growing in South Africa. *J. Food Agric. Environ*., 7: 359–363

Lewu, M.N., P.O. Adebola and A.J. Afolayan, 2009b. Effect of cooking on the proximate composition of the leaves of some accessions of *Colocasia esculenta* (L.) Schott in KwaZulu-Natal province of South Africa. *Afr. J. Biotechnol*., 8: 1619–1622

Lewu, M.N., P.O. Adebola and A.J. Afolayan, 2010. Comparative assessment of the nutritional value of commercially available cocoyam and potato tubers in South Africa. *J. Food Qual*., 33: 461–476

Mabhaudhi, T., A.T. Modi and Y.G. Beletse, 2013. Growth Response of Selected Taro [*Colocasia esculenta* (L.) Schott] Landraces to Water Stress. *Acta Hort. (ISHS)*, 979: 327-334

Mabhaudhi, T., A.T. Modi and Y.G. Beletse, 2014. Parameterisation and evaluation of the FAO-aquacrop model for a South African taro (*Colocasia esculenta* L. Schott) landrace. *Agric. For. Meteorol*., 192: 132–139

Mare, R.M., 2006. Phytotron and field performance of taro (*Colocasia esculenta* L. Schott) landraces from Umbumbulu. *M.Sc. Thesis*. University of KwaZulu-Natal, South Africa

Mare, R.M., 2009. Taro (*Colocasia esculenta* L. Schott) yield and quality response to planting date and organic fertilisation. *PhD. Thesis*, University of KwaZulu-Natal, South Africa

Mare, R. and A.T. Modi, 2009. Influence of planting date and organic fertilisation on growth and yield of taro landraces *9th African Soil Science Conference Proceedings*, pp: 179–189. Cape Town, South Africa

Mitra, S., B. Sinha, H. Pal and J. Tarafdar, 2007. Comparative studies on morphological characters, yield, nutritional status and isozymes activity of some elite genotypes of taro [*Colocasia esculenta* (L.) Schott var. antiquorum] grown in West Bengal. *Acta Hortic*., 752: 219–224

Mitra, S. and J. Tarafdar, 2015. Diversity in morpho-biometrical characters, nutritional facts and isozymes activity of Indian landraces of upland taro (*Colocasia esculenta* var. antiquorum L. Scott). *Int. J. Trop. Agric*., 33: 1163–1166

Miyasaka, S.C., R.M. Ogoshi, G.Y. Tsuji and L.S. Kodani, 2003. Site and planting date effects on taro growth: comparison with aroid model predictions. *Agron. J*., 95: 545–557

Modi, A.T., 2007. Effect of indigenous storage method on performance of taro [*Colocasia esculenta* (L.) Schott] under field conditions in a warm subtropical Area. *S. Afr. J. Plant Soil*, 24: 214–219

Oke, O.L., 1990. *Roots, Tubers, Plantains and Bananas in Human Nutrition*. Rome: FAO Corporate Documentary Repository, Food and Agriculture Organization of the United Nations

Onwueme, I.C., 1999. *Taro Cultivation in Asia and The Pacific*. Food and Agriculture Organization of the United Nations. Regional Office for Asia and The Pacific, Bangkok, Thailand

Paul, K.K. and M.A. Bari, 2011. Studies on Direct and Indirect Effects of Different Plant Characters on Yield of Taro (*Colocasia esculenta* L. Schott) Var. Antiquorum. *Agriculturists*, 9: 89–98

Pratiwi, S.H., R. Soelistyono and M.D. Maghfoer, 2014. The growth and yield of taro (*Colocasia esculenta* (L.) Schott) var. Antiquorum in diverse sizes of tuber and numbers of leaf. *Int. J. Sci. Res*., 3: 2289–2292

SAS, 2008. *Statistical Analysis Software, Version 9.2*. SAS Institute Inc., Cary, North Carolina, USA

Shange, L.P., 2004. Taro (*Colocasia esculenta* (L.) Schott) production by small-scale farmers in KwaZulu-Natal: Farmer practices and performance of propagule types under wetland and dryland conditions. *M.Sc. Thesis*. University of KwaZulu-Natal, South Africa

Sitompul, S.M. and B. Guritno, 1995. *Analysis of the Plant Growth*. Faculty of Agriculture. University of Brawijaya. Gajah Mada University Press, Yogyakarta, Indonesia

Sivan, P., 1982. Growth and development of taro under dryland conditions in Fiji. *In: Proc. Int. Symp. Trop. Root and Tuber Crops*, 5th edition, pp: 637–646. Los Banos, Philippines, 17–21 Sept. 1979. Philippine Counc. for Agric. and Resour. Res., Los Banos, Philippines

Stahlschmidt, O., J.B. Cavagnaro and R. Borgo, 1997. Influence of planting date and seed cloves size on leaf area and yield of two garlic cultivars (*Allium sativum* L.). *Acta Hortic*., 433: 519–522

Tsedalu, M., B. Tesfaye and Y. Goa, 2014. Effect of type of planting material and population density on corm yield and yield components of taro (*Colocasia esculenta* L.). *J. Biol. Agric. Healthcare*, 4: 124–137

Van Wyk, B.E., 2005. *Food Plants of the World*, p: 480. Briza Publications, Pretoria, South Africa

Wang, J.K., 1983. *Taro: a Review of Colocasia esculenta and its Potentials*. University of Hawaii Press, Honolulu, Hawaii, USA

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