TARO [*COLOCASIA ESCULENTA* (L.) SCHOTT] PRODUCTION BY SMALL-SCALE FARMERS IN KWAZULU-NATAL: FARMER PRACTICES AND PERFOMANCE OF PROPAGULE TYPES UNDER WETLAND AND DRYLAND CONDITIONS

LINDIWE PRINCESS SHANGE

BSc. Agric. Hons. (University of Zululand)

Submitted in partial fulfillment of the requirements for the degree of

MASTERS OF SCIENCE IN AGRICULTURE
In the School of Agricultural Sciences and Agribusiness
Crop Science Discipline
University of KwaZulu-Natal
Pietermaritzburg

February 2004

ABSTRACT

Ethno-archaeological evidence shows that taro [*Colocasia esculenta* (L.) Schott] originated in Asia. It may have been brought into South Africa a few hundred years after 300 BC from Madagascar, where Malaysian settlers introduced it about 300 BC. The crop is grown in the tropical and subtropical regions of the world, largely for subsistence on farms. In South Africa, taro is mainly produced in the subtropical coastal belt, stretching from Bizana in the Eastern Cape to the KwaZulu-Natal north coast. Although it is a staple crop for the subsistence farmers who grow it, there are no data on taro agronomy in South Africa. The hypothesis of this study was that traditional knowledge about taro production practices is not adequate to form a basis for agronomic and extension interventions to promote the status of the crop to that of a commercial commodity. A survey was conducted at two districts in KwaZulu-Natal, Umbumbulu and Ndwedwe, where taro is a staple crop. The objective of the survey was to determine the cultural practices associated with taro production, including knowledge about varieties, agronomy, plant protection, storage and marketing. Qualitative data obtained from the survey was used to plan an investigation into the agronomy of taro. The survey showed that subsistence farmers at Ndwedwe and Umbumbulu used traditional methods for taro production that had very small influence from the extension services from the Department of Agriculture.

The farmers identified three varieties of taro, which they designated as the "red", "white" and "Zulu" types. The "red" and "white" designations were based on consistent crop morphological characteristics. This finding confirmed the reliability of indigenous knowledge for crop classification.The survey also revealed that wetland and dryland conditions are used to produce taro. At Umbumbulu, production occurred predominantly under dryland conditions, whereas at Ndwedwe there was an almost even utilisation of both wetlands and drylands. At both locations, the farmers estimated plant spacing using their feet, which showed that the plant populations would be about 18400 plants ha^{-1}. Full corms were a predominant type of propagation material. In the light of the survey findings about site types (wetland or dryland), propagation material and plant spacing for taro production, field experiments were designed to 1) determine the effect of site type on taro production, 2) compare three propagule types (full corm, full corm with a shoot and half corm) in taro production and 3) examine the effect of planting density (18400, 24600 and 37000 plants ha^{-1}) on the performance of propagules with respect to production under wetland and dryland conditions. Field experiments showed that wetland cultivation improved taro yield by 40% compared with dryland production. However, in each of the two site categories, there were significant differences between sites. Using full corms with shoots also enhanced taro yield (42% > full corms without shoots and 66% > half corms), when means were determined across all sites and planting densities. Increasing planting density also caused an increase in taro production (4.9 t ha^{-1}, 6.8 t ha^{-1} and 11.5 t ha^{-1}, for 18400, 24600 and 37000 plants ha^{-1}, respectively; LSD (0.05) = 1.4 t ha^{-1}).

The enhanced performance of taro under wetland conditions, where corms with a shoot were used and at high planting densities may have been associated with photosynthetic efficiency.Wetland conditions and corms with shoots improved plant emergence and plant growth, which are essential agronomic conditions for efficient capture of the sun's energy for photosynthesis. It is proposed that using propagules with shoots and high plant populations under dryland conditions could enhance taro production. Although wetland cultivation enhanced yield, the survey showed that the total area of land that could be used for wetland cultivation at Ndwedwe and Umbumbulu was too small to warrant sustainable wetland production.

DECLARATION

I, Lindiwe Princess Shange, certify that research work reported in this dissertation, unless specifically acknowledged to the contrary, is my own original investigation, and has not been submitted in part, or in whole, to any other university. The research work was carried out at University of KwaZulu-Natal.

Shange

Approved by supervisor ______ Date 03 May 2004

Albert T. Modi

ACKNOWLEDGEMENTS

I am grateful to Dr Albert Thembinkosi Modi, for securing financial support, his encouragement and supervision throughout the course of this study.

The financial support of SANPAD and Mangosuthu Technikon.

My sincere thanks goes to the Department of Agriculture and Ndwedwe District office for securing land for experiments from their farmers i.e., Mr Phewa and Mrs Gcabashe.

Many thanks to all Department of Agriculture's staff members from Umbumbulu and Ndwedwe District who helped during the survey and field experiments.

Many thanks also to :

Dr D.Kotze, my co-supervisor;

Mr B.E Mthembu, Mr S.M Buyeye and Mr K.S Mhlongo for help with field experiments and survey study respectively;

Dr N.G Sibiya and Mr S.Ndlela for their interest and encouragement;

My family members especially Lungile, Nikiwe and Lawrence Shange for their patience and motivation.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Taro (*Colocosia esculenta* L. Schott) is an edible aroid and a member of the Araceae family. The family contains about 110 genera and about 200 species, which are mainly distributed in the tropical and subtropical regions of the world (Chandra, 1984). Edible aroids are produced and consumed as staple foods by some 200 million people in small, isolated communities throughout the tropics (Chandra, 1984). Ethno-archaeological evidence shows that *Colocasia* originated or was domesticated in the Indo-Malayan region (Cable, 1984). As early as 300 years BC, Malagasy (Madagascar) was settled by Malaysians (Alexander and Coursey, 1969). It is likely that taro got to South Africa via Malagasy. Coursey (1976) reported that the introduction of yams was from Indonesia to Africa via Malagasy. According to Gerstner (1938), cited by Fox and Norwood Young (1982), taro was introduced to South Africa before the arrival of Europeans.

The Zulu name for taro is *amadumbe* (*idumbe* = singular), which probably refers to the swollen underground stem (*dumba* = swell in Zulu). Taro is an important staple crop in the subtropical coastal area of South Africa, starting at Bizana district in the Eastern Cape and including the rest of coastal KwaZulu-Natal. There is less cultivation of the crop in the Midlands and generally none in the northern parts of the province, where the climate is drier and cooler.

The crop is also cultivated in the subtropical and tropical parts of Mpumalanga and Limpopo provinces. Most taro production in South Africa is consumed as subsistence food on the farms. Consequently, research and development in taro have been meagre compared with other root crops such as sweet potatoes. There are no commercial cultivars or cultural practices recommended for the crop. The lack of research may have had a negative impact on crop yield and quality.

The objectives of this study were: (a) to conduct a survey of the current cultural practices associated with taro production at Ndwedwe and Umbumbulu districts of KwaZulu-Natal (b) compare dryland and wetland sites with respect to taro yield and (c) determine taro yield in response to propagule types and planting densities. Two wetland and two dryland sites were selected for field experiments at the Ndwedwe district, based on the survey findings. Local farmers at Ndwedwe donated propagules used in the study, and some propagules were modified to create novel planting materials that were compared with traditional propagules.

CHAPTER 2

LITERATURE REVIEW

2.1 General characteristics of taro

2.1.1 Botany and morphological characteristics

Taro (*Colocasia esculenta* (L.) Schott) belongs to the monocotyledenous family, Araceae (Bowers, Takahashi & Whitney, 1997). Numerous agricultural cultivars of taro exist, but they fall generally into two main species: *C. esculenta var. esculenta*, the dasheen type, in which the corm is small and the cormels are large, and *C. antiquorum var. esculenta*, the eddoe type in which the corm is large and the cormels are small (Onwueme, 1978). Taro is generally aquatic, but some varieties are epiphytic (Bowers,Takahashi & Whitney,1997). It is a herbaceous perennial that can grow to a maturity height of 0.5 to 2m, depending on the environmental conditions (Kay, 1987).

The root system of taro is adventitious and fibrous, and it is generally restricted to the upper soil levels, although it arises from the lower portions of the underground stem, which is properly designated as a corm (Onwueme, 1978; Purseglove, 1972).The corms are cylindrical or spherical (15 to 18 cm in diameter), and starchy (Brouk, 1975; Onwueme, 1978; Plucknett, de la Pena & Orbero,1970; Strauss, 1983).

Cells containing raphides (bundles of calcium oxalate crystals) occur in the tissues of the corm, and, to a lesser extent, in all other parts of the plant. They account for the itchiness of the uncooked corm or leaves. As the corm ages, it becomes progressively denser and woody (Onwueme, 1978). One or two layers of cork cambium cells are found below the periderm and interior to these layers are rings of isolated mucilage ducts, of various sizes. The ducts produce a mucilage that is characteristic of the cut surfaces of the corm (Paliwal & Kavathekar, 1972). The cormels represent the lateral branches of the plant stem, while the corm represents the main stem. Cormels, like the corm, are edible and are usually less dense than the corm. Cormels may also arise from the axillary buds of the main corm. Such cormels usually give rise to suckers or daughter plants around the main plant (Onwueme, 1978).

Taro has pale green or purple heart-shaped leaves (20 to 50 cm long) with long leaf stalks from 30 to 90 cm in length, and the surface is covered with a fine wax (Joubert, 1997). The shoot consists mainly of leaves, which arise in a whorl from the apex of the corm. The leaf consists of a long erect petiole, which attaches near the middle of the large lamina.

This peltate leaf form is a diagnostic feature that distinguishes taro from the other edible aroids (Onwueme, 1978). Leaves and petioles display a wide variability in odour (chemistry), shape and size (Strauss, Michaud & Arditti, 1979). No reports were found on taro response to daylength. Flowers and fruits are rarely produced (Joubert, 1997).

The flowers, which can be up to 20 cm long, can be cooked and eaten (Hollyer, Josephson & Sullivan, 1997). Fruiting and seed set in taro are even more rare than flowering (Joubert, 1995). Many inflorescences wither without setting seed. The seed contains an endosperm and germinates with extreme difficulty (Joubert, 1995).

Taro varieties can be differentiated according to stem characteristics red-stemmed and fragrant-stemmed varieties (Liu & Liu, 1995). Growing season, however, is an important agronomic characteristic. It influences plant and corm morphology. Three groups of varieties have been distinguished and described (Ghani, 1984):

(a) Varieties with four to six months of growing season. Generally these are short, herbaceous plants 30 to 60 cm in height and grow clumps of 8 to 10 cormels. If not harvested, the cormels grow into new plants in 4-5 weeks. The cormels are generally all of the same size (3 to 4 cm diameter) and are generally globose and slightly elongated. The central parent corm shrivels and becomes dormant as the cormels increase in number and size.

(b) Varieties with 9-12 months of growing season. They grow to a height of 70 to 90 cm and have thick, succulent petioles which bear large leaves that vary in shape from sagittate, broad to ovate. Leaf colour is green to glaucous green. This group can be further subdivided using corm shape:

(i) Varieties with a single elongated corm that is smooth, starchy and fine in texture. Flesh colour can be pink, cream or white.

(ii) Varities with a central corm with surrounding cormels. The cormels are smaller than the central corm, which is the main part harvested.

(c) Non-corm producing plants. These have short underground rhizomes which are non-edible and acrid. The tender young leaves and skinned petioles can be eaten after boiling to remove the acridity.

In South Africa, upland taro grown under dryland conditions is harvested after seven to eight months during April and May (Westhuyzen, 1967; Young, 1992). A summary of taro growing seasons is presented in Table 2.1.

Table 2.1. Growing seasons of different taro varieties (Joubert, 1995) at different altitudes

Taro Form	**Crop cycle (months)**	
	Upland	Lowland
Eddoe	4-6	-
(C. esculenta var.antiquorum)	7-9	-
	9-12	-
Dasheen	8-10	10-15
(C. esculenta var.esculenta)	9-12	-

2.1.2 Environmental requirements

Taro grows well under tropical, sub-tropical (Purseglove, 1972) and temperate areas with long frost free periods (Westhuyzen, 1967). The optimum temperature range for growth is 21°C to 27°C. Temperatures above 29°C are deleterious to root growth. At 36 to 38°C roots cannot grow beyond 2 cm (Pardales, Melchor & de la Pena, 1982).

A high humidity and well distributed summer rainfall of 1500 mm or more per annum are desirable (Tindall, 1983). A combination of rich forest (organic) soils and an annual rainfall exceeding 2500 mm per annum was found to be favourable for taro production (de la Pena, 1983; Tindall, 1983). The eddoe species is more tolerant of lower soil moisture conditions, lower temperatures and lower humidity levels than dasheens (de la Pena, 1983; Tindall, 1983). It requires well-drained sandy loam to loam soils with a high organic content. The optimum soil pH for plant growth is 5.5 to 6.5 (Tindall, 1983; O'Hair & Asokan, 1986). Most taro varieties can withstand occasional flooding without damage. Onwueme (1978) reported that the dasheen species does best under flooded conditions, but can be also grown under non-flooded conditions. Taro has the ability to transport oxygen from the leaves and petioles down to the corms and roots under flooded conditions, in order to maintain the underground portion of the plant. Some varieties are salt-tolerant and can grow in low-lying saline soils, if occasional flooding occurs (Joubert, 1995).

The altitude for taro productions has been reported to range from sea level to 1200 m, provided that moist conditions and stable temperatures generally prevail (de la Pena, 1983).

2.2 Cultural practices

2.2.1 Nutrient requirements

Nutrients requirements for taro are related to growth stage (Kabeerathumma, Mohankumar & Nair 1985). Generally, the greatest demand for nutrients occurs between the 3rd and 5th month after planting. The peak demand for most macronutrients as well as well as iron (Fe) and manganese (Mn) is the early 2nd or 3rd months after planting, while the highest demand for zinc (Zn) and copper (Cu) occurs close to maturity.

The optimum rate of 280 kg N ha^{-1} is required for corm production (Ramnanan, Ahmad & Griffith, 1995). Taro responds readily to fertiliser application and has a high demand for potassium and calcium (Joubert & Allemann, 1998). According to Zhong *et al.* (1997), potassium increases market yields and improves the quality of the produce by increasing vitamin C and lowering nitrate content. Potassium enables taro to restrict water loss and maintain a higher leaf water potential through the regulation of stoma (Sivan *et al.*, 1996).

The occurrence of “metsubere” corms (deformed corms due to calcium deficiency) was lowest following heavy calcium application and was significantly increased following heavy compost application (Ikeda & Nonoyama, 1993). Taro has a high calcium requirement and addition of lime to soils low in this element is beneficial (Kay, 1973; Onwueme, 1978).

2.2.2 Water management

According to Joubert (1995) taro requires ample moisture throughout its growing season. The large leaves are extensive transpiring surfaces through which large quantities of water are lost. Intermittent water stress results in production of corms that have a dumbbell shape and are poor in quality (Onwueme, 1978). Aside from enhancing the favourable growth of wetland taro, ample cool and fresh water also aids in reducing the incidence of corm and root disease (de la Pena, 1983). Irrigation methods include planting in raised beds within swamps or in flooded pond fields and furrow irrigation (Spriggs, 1980). Table 2.2 indicates differences in yield associated with taro production under rainfed and irrigated conditions.

Table 2.2 Effect of irrigation or dryland production on taro yield (Joubert and Allemann, 1998)

Variety		**Yield (t ha^{-1})**		
	Cultivation	Low	Average	Good
	Dryland	5-8	8-15	>15
Eddoe	Irrigated	10-20	20-30	30-45
	Dryland	3-5	5-10	>10
Dasheen	Irrigated	10-15	15-20	20-30

Although taro can be grown under flooded and non-flooded conditions, flooded conditions have been shown to give a higher yield (de la Pena *et al.*, 1982). However, flooding to a depth of 16 to 20 cm can cause a severe drop in total yield. According to de la Pena & Melchor (1984) the optimum depth of flooding is 4 to 8 cm as this is sufficient to keep weeds under control without causing severe yield losses.

Occasionally, the field may be drained for fertilizer application, but it should be re-flooded a few days after the application. It is necessary that the water on the flooded field be replenished with fresh water. If this is not done severe root rot may develop due to warm stagnant water. The greater yields associated with flooding have been attributed to the plant's greater ability to produce suckers, and to the greater leaf area that results (Ezumah, 1973; Ezumah & Plucknett, 1973). The rate of leaf senescence is also lower and flooding provides an effective method for controlling weeds.

Even in the dryland culture of taro it is still important to ensure a constant availability of water. Where rainfall is irregular, irrigation facilities must be provided, either in the form of furrow or sprinkler irrigation. Onwueme (1978) recommended the following weekly irrigation regimes for upland taro: early stage of development 9 to 23 mm; during active growing period 45 to 60mm.

2.2.3 Weed control

An integrated weed control programme, utilizing thorough land preparation and a combination of pre-emergence and post-emergence herbicides is highly recommended for all the major tropical root and tuber crops. Weeds can be controlled by mulching and high plant densities (Fatuesi *et al.*, 1991). Taro plots are prone to be weedy during the first 3 to 4 months when the leaf canopy is sparse, and clean cultivation is essential in these initial stages of growth. Weeds can also occur late in the season, when the canopy has become open because of older leaf senescence (Onwueme, 1978).

Weed control is therefore critical at two distinct stages: during early vegetative growth and during the period of starch accumulation and maturation (Onwueme, 1978). Purple nutsedge (*C. rotundus*) infestations significantly decreased relative growth rate, net assimilation rate and leaf area of taro at harvest (Nedunzhiyan, 1995).

For dryland taro, mechanical weeding must be shallow to avoid damage to the superficial taro roots. In wetlands, weed control is mainly done by maintaining the water level above soil level (de la Pena, 1983). Various herbicides have been recommended for upland and lowland cultivation e.g., trifluralin and prometryne (Onwueme, 1978). Nitrofen chemical has been approved in Hawaii for taro weed control (de la Pena, 1975). Taro is sensitive to spray drift from certain herbicides. The use of thickening agents and spray application during windless morning hours are precautions well taken (de la Pena, 1983).

2.2.4 Planting material

In other countries, outside South Africa, planting material called huli or setts (corms and cormels, sectioned into 4 to 8 pieces depending on corm size) are prepared from the suckers or main plants (de la Pena, 1983). For upland production sprouted corms or cormels and setts are used. Stem cuttings consisting of 1to 2 cm of the apical portion of the corm and the lower 15 to 25 cm of the petioles can be used for both dry and wetland plantings. Large setts (56 g) produce high yields, while small setts or cormels (28 g) are the most economical (Joubert, 1995). Setts, however, do not multiply rapidly, which limits the quantity of propagules compared with the use of corms.

Stem cuttings give higher yields than even setts from corms. The high yield of taro from stem cuttings may be due to the fact that cuttings produce a greater number of roots and total leaf weight than the other two kinds of planting material. The optimum size of stem cuttings used is about 150 g.

The use of stem cuttings eliminates the need to use part of the edible harvest as subsequent planting material (de la Pena, 1983). Approximately 20 000 to 40 000 (1.5 to 2.0 t) cormels or medium sized corms will plant one hectare (Tindall, 1983). The propagules can also be prepared using tissue culture techniques. Tissue-cultured plantlets are initially tiny and need to be grown out in a nursery for a number of weeks before transplanting them to the field.

It is important to keep in mind that because taro mutates easily, tissue-cultured taro may not be "true" to type for some typical varietal characteristics. Nevertheless, if grown properly and planted in a healthy planting area, tissue cultured plantlets are initially free of nematodes, aphids, bacterial infections, *Pythium* root rot, *Phytophthora* leaf blight, and most other fungi and viruses (Hollyer, Josephson & Sullivan, 1997). The possibility of producing taro using tissue culture techniques revealed that *Colocasia esculenta var. esculenta* was more difficult to culture than *C. esculenta var. antiquorum* (Arditti,1982). However the successful clonal propagation of taro seedlings is important to avoid the need to ship propagating material across quarantine lines.

2.2.5 Planting time

The time of planting is to some extent determined by the time when the farmer's previous crop matures because it provides material for the new crop (Onwuene, 1978). In the tropics, the major determinant of the time of planting is moisture availability. Where there are distinct rainy and dry seasons, planting is done shortly after the rains have become regular. In South Africa, planting is done in spring, so that the crop can grow during the warm summer months, this is because, early spring planting has a longer crop cycle but produces higher yields under favourable growing conditions than later plantings. Joubert & Allemann (1998) presented common planting times for taro (Table 2.3).

Table 2.3. Common times for planting taro in different environmental conditions (Joubert & Allemann, 1998).

Climate	Ideal times	Possible Times
Warm	September-October	July-October
Hot	July-October	March-October

In KwaZulu-Natal, the planting time extends from August to October (Westhuyzen, 1967). The growing period of taro is 150 to 210 days from planting for the eddoe type and 200 to 270 days for the dasheen type (Joubert, 1997).

2.2.6 Planting method

Methods of planting taro differ according to the terrain type. In wetland taro culture, planting is done into 2 to 5 cm of standing water. The stem-cutting is inserted by hand into the loose puddle soil. Most wetland taro is planted in flat fields. The traditional method of planting taro is an extremely unpleasant task, involving hours of stooping, and standing in mud.

The use of a tomato transplanter to plant the crop into fairly dry soil has proved to be reasonably successful (Plucknett, Ezumah & de la Pena, 1973). For dryland taro cultivation, furrows of about 60 to 90 cm apart and 30 cm deep may be made in the field. Setts or cormels that have begun sprouting or stem cuttings are then dropped in at intervals (depending on spacing used) and are covered with a 5 to 8 cm depth of soil (Tindall, 1983). It is important that the sett-piece (or stem cutting) should not be planted too shallowly. Shallow planting causes the new corm to develop above the soil surface, or to be partially exposed. Such exposed corms are prone to damage by pests before they are harvested. Shallow planting also results in extremely shallow rooting so that the plant is prone to moisture stress (de la Pena, 1983).

If the soil water table is high (near stream banks, pans or vleis), the crop may be planted on ridges, which could be helpful during harvesting. Plants are often earthed up after they become established or after a topdressing to encourage corm formation (Tindall, 1983; Taylor, 1988).

Application of mulch, consisting of dead leaves and grasses, soon after planting is sometimes beneficial in upland taro culture. The mulch serves to retain moisture and reduce the temperature around the setts. Taro can also be grown hydroponically.

2.2.7 Intercropping, crop rotation and mulching

Intercropping of taro with other crops is practised in different parts of the world. According to Sen, Adhikar & Das (1993), taro can be intercropped with amaranthus, maize and groundnuts. Intercropping taro with amaranthus led to an increase in taro yield. It was observed that the yield was higher when two rows of maize were intercropped with two rows of taro than when two rows of maize were intercropped with one row of taro (Jiang, 1986). Taro corm yields ranged from 37.04 t ha^{-1} when grown alone to 50.58 t ha^{-1} when intercropped with groundnuts. It is interesting that the yield was increased when taro was intercropped with a legume compared to the yield given in Table 2.2.This shows that taro responds positively to intercropping with a legume.

Intercropping with a legume gave corm yields >45 t ha^{-1} compared with 39-40 t ha^{-1} with sweet corn and sweet potatoes (de la Pena & Melchor, 1988). In the West Indies taros are often inter-planted with other crops, such as okra, pigeon pea, maize or on the banks in sugar cane fields.

It is often planted between young stands of perennial plantation crops (rubber, banana, cocoa, coconut, citrus) and then harvested before the perennial crop closes canopy. The development of upland taro is slow during the first two months, which can allow the growing of a short-cycle intercrop such as mungbean (Villanueva & Abenoja, 1984). In Egypt taro is intercropped with vegetables such as radish, turnip and cucumber. In Nigeria, taro is intercropped with yam (Joubert, 1995).

Taro has been intercropped with hairy squash, cucumber, yard-long bean, small Chinese cabbage, flowering Chinese cabbage, watermelon, chives and ginger in Canton, China. Yields from intercropped taro increased by an average of 2.2 to 3.7 tons ha^{-1} (Plucknett & Beemer, 1981).

According to Joubert & Allemann (1998) taro should preferably not be planted on lands where any root or tuber crop, including taro itself, such as potatoes, sweet potatoes, beetroot, carrots, groundnuts, or cassava were grown during the previous three years. Taro was used in an 8-year rotation programme and grown after the sweet potatoes and it was discovered that after taro soil inorganic N content in the 30 to 60 cm layer increased to 4-6 mg per 100g dry soil. Soil exchangeable K content tended to increase during wheat-groundnuts-taro rotation (Shinohara *et al.*, 1989).

According to Pardales (1985) the main corm yield was increased by deeper planting, but not affected by mulching. Agroforestry may also be practised with taro being intercropped in the plantations (Odumlami, 1991). The Dasheen variety is tolerant to semi-shade conditions and can therefore be included in certain agroforestry systems (Joubert & Allemann, 1998).

2.2.8 Spacing and planting density

Plant spacing used in taro production affects taro growth, corm shape and taro yield due to intraspecific competition for soil moisture, nutrients and light. The following aspects should be considered when determining the correct spacing and plant density for taro: selected density depends on expected vigour of growth, higher yields and lower weed incidence with higher densities, wider spacing tends to produce larger and more uniform corms and lower densities are recommended for areas with a high incidence of overcast days. The optimum plant density depends on plant age at harvest and method of land preparation.

For example, planting on ridges increased yield as plant populations were increased up to 36 000 plants ha^{-1} (Ezumah & Plucknett, 1981). According to Joubert (1997), the plant density can range from 25 000 to 37 000 plants ha^{-1} and 25 000 to 45 000 plants ha^{-1} for dryland and wetland production, respectively. These studies reveal that total yield increases with an increase in planting density, while average yield per plant decreases.

In areas, where growing conditions are not optimal, slightly wider spacing reduces the spread of disease. Wider spacing also produces uniform corms (Pardales & Villanueva, 1984), and more suckers (Sivan, 1984). When planting taro close together, early canopy closure can be gained for more efficient capture of solar energy (Shih & Snyder, 1984).

High yields per hectare continue to be realized even if inter-row spacing is decreased to 30 cm, but at such high density the amount of planting material is enormous and the net return per unit of planting material is low (de la Pena, 1983). Different spacings are practised throughout all the regions where taro is grown commercially or on a subsistence level (Table 2.4). It would be interesting to compare the yield data associated with planting densities in each country. However, these data were not available. The importance of yield data is that they would explain the effect of environmental conditions at each site since it cannot be assumed that high planting density results in high yield. Weed incidence in the field should also decrease when closer spacings are employed. In many traditional settings, taro is grown as an inter-crop. Spacing under such conditions is determined by the density of the other crops that share the field (Joubert, 1995).

Table 2.4 Planting densities used in different parts of the world for taro production

Region	Spacing (cmxcm)	Population (plants ha^{-1})	Remarks	References
West-Africa	100 x 100	10 000	weed problem and low yields	Joubert,1995
Trinidad	90 x 60	18500	recommended normal spacing for the dasheen	Tindall,1983
Phillippines	75 x 60 75x 45	22 200 29 600	recommended for areas with a high incidence of overcast days-eddoe pure stand	Joubert, 1995
	90 x 45	24700	dasheen (pure stand)	Villanueva & Abenoja, 1984
	75 x 50 50 x 50	26 667 to 40 000	upland taro lowland taro	Pardales & Villanueva, 1984
Fiji	60 x 60	27 800	upland taro	Sivan, 1973
Hawaii	60 x 45	37 000	normal spacing for both upland and lowland	De la Pena,1983
Florida		22000 to100 000	lowland taro	Joubert, 1995
South Africa	90 x 45 90 x 30	25 000 37 000	recommended for eddoes in the Northern part of KwaZulu- Natal	Young, 1992
	80 x 40 80 x 30	31 250 41 600	Recommended for eddoesin the Southern part (Port Shepstone area]of KwaZulu–Natal)	Westhuyzen, 1967

2.2.9 Harvesting

The leaves turn yellow and petioles are shortened as the plant reaches maturity (de la Pena, 1983). Often, the main corms are also clearly visible as they push out above soil (de la Pena, 1983). Physiological maturity corresponds to the time when sugars in the corm are at a minimum (Onwuene, 1978). The eddoe would be harvested from 6 to 8 months and dasheen from 8 to10 months (Joubert, 1995).

The crop cycle is also affected by temperature, time of planting, fertilisation levels used and amount of plant available water during the crop growth period. Autumn plantings tend to extend the crop cycle by 2 to 3 months. Harvesting period is from 1 to 4 months, depending on quality needed. Early harvesting yields corms of a tender not so dry texture but with a relatively short shelf-life, whereas harvesting very late, yields drier, more fibrous textured corms with a shelf life of up to a few months (Joubert & Allemann, 1998). Harvesting is done by hand. A fork or shovel is used to lift the plants. The corms are then pulled out carefully to minimize injury. If stem cuttings are not required, the shoots or leaves are broken off. If stem cuttings are to be prepared for the next planting, they are cut carefully with a knife (de la Pena, 1983). For the eddoe variety, all the corms are harvested together, due to its growth habit. Main corms of the Dasheen type are often harvested first, leaving the smaller corms to develop later (Tindall, 1983).

2.2.10 Storage

Taro corms should be stored in a place with suitable temperature that will not result in their deterioration. According to Hashad (1956); Onwueme (1978) & Tindall (1983) taro corms must be stored in cool, dry, well ventilated surroundings. It has been shown that corms can be stored at a temperature of about 10°C to 12°C and a relative humidity of 85 to 90% for a period of 3 to 6 months without deteriorating. Corms decay at high or low storage temperatures. The storage behaviour of taro in storage is variable (Joubert, 1995).

For the fresh market, roots, fibres and outer leaves are removed before the corms are washed. Corms are graded before being packed (Young, 1992). For storage, the corms are cleaned but not washed and then air-dried. Recent studies have focused on extending the shelf-life of the corms by applying fungicides (Adams, Pattanjalidia & Clark, 1988), sprout inhibitors (Passam, 1982) and by modifying the storage environment (Agbor–Egbe & Richard, 1991). McCartan (1994) found that the best results in terms of sprouting rate and success were obtained with Benomyl (4g l^{-1}) applied to corms stored in paper bags at 24°C. Sprouting was also delayed by approximately 5 weeks .

The corms and cormels may, in favourable conditions, be left in the soil throughout winter (Westhuyzen, 1967; de la Pena, 1983). The ability to field store is another advantage of taro, especially where storage facilities are unavailable. This accounts for the popularity of taro as a subsistence crop in many countries (Joubert, 1995).

CHAPTER 3

A SURVEY OF TARO PRODUCTION PRACTICES BY SUBSISTENCE FARMERS AT NDWEDWE AND UMBUMBULU DISTRICTS

3.1 Scope and limitations of the study

Although taro is a staple crop for subsistence farmers in the coastal and hinterland areas of KwaZulu-Natal, there is no clear documentation of the cultural practices associated with its production. The reason for the lack of documented knowledge about taro production may be associated with its status as an underutilised crop in South Africa. That taro originates in South East Asia and the Pacific Islands, where it is produced under wetland conditions, prompted an investigation into how the subsistence farmers of KwaZulu-Natal managed the crop.

The current study was aimed at investigating the cultural practices of subsistence farmers at Ndwedwe and Umbumbulu, two of the major taro producing districts in KwaZulu-Natal. Cultural practices were of major interest, as they were assumed to have a significant impact on productivity (yield), included the types of propagules used, planting density and soil environmental conditions [including soil types, fertilisation and preferred water regimes (wetland or dryland)]. It was also of interest to investigate the knowledge of subsistence farmers about the variety of taro species, they use albeit not in a strict botanical classification.

In this study, the term variety was used because it is broader (relies on morphological characterisation by the farmers) than the term species, which requires taxonomic interpretation that is different from local knowledge. Information about knowledge of taro varieties would allow determination of the predominantly cultivated species or variety and validation of its selection for further agronomic investigations. To obtain supporting data for general discussion of the findings related to the aspects of major interest, issues of minor importance such as crop utilisation, marketing and general plant protection were also included in the investigation (Appendix 3.1).

Reliance on the Department of Agriculture extension officers from the two study locations, regarding the choice of farmers and farms for the study was necessary. However, this approach was also considered to be a major limitation in respect of sampling of informants, because it may have included informants that were less inclined to produce relevant data and excluded some informants that would provide significant data. That is, the personal relationships between the extension officers and the farmers may have played a significant role in determining the participating informants. The survey was conducted at two different districts to minimise the limitation introduced by reliance on extension officers.

Although the study generally used qualitative and quantitative approaches, there were still limitations to data collection and interpretation. The qualitative approach is holistic in nature, and the main aim is to understand social life and the meaning that people attach to their experiences (de Vos 1998).

The limitation of this approach is that it is difficult to test every case quantitatively. Bearing in mind the advantages of combining qualitative and quantitative approaches (Mays & Pope, 1995; Silverman, 1985) an attempt was made to also perform quantitative determination during the survey. However, quantitative determination was performed on only a few farms to test a few aspects such as plant spacing, yield determination and taro varieties. It was not possible to ascertain the types of fertiliser (chemical or organic) used in the past or present crops.

3.2 Survey methods

Permission to conduct the study in the South East Region of the Department of Agriculture in KwaZulu-Natal was granted by the regional director. A questionnaire (Appendix 3.1) was designed, based on current literature on taro and two workshops with extension officers at Ndwedwe and Umbumbulu, respectively, regarding the crop. Ten extension officers participated in each workshop. The outcome of the workshops was that the extension officers determined the farmers and farms that would participate in the survey, based on their knowledge of the local communities. The questionnaire, which was translated from English to Zulu for subsistence farmers, focused on the cultural practices associated with taro production and utilisation.

The survey was conducted using individual farmer interviews (see 3.2.1 for details) followed by focus group interviews to verify individual responses (Morgan 1996). Quantitative analysis was performed by direct observation of soils, taro varieties and implements used.

3.2.1 Sampling framework

Based on the information gathered at the workshops with the extension officers, the key informants, a sampling framework was determined. For the workshops the key informants were selected using purposive sampling. This was done to ensure that only extension officers working with farmers who produced taro participated. This was done to provide reliable information about taro production. From the workshops it was determined that the population of farmers at Ndwedwe and Umbumbulu consisted of subsistence farmers producing taro under dryland and wetland conditions. Random sampling of 56 farmers from Umbumbulu and 44 farmers from Ndwedwe was performed from a population of farmers producing taro under wetland or dryland conditions (Table 3.1). It is interesting to note that most of the interviewees were females (Table 3.1). This may have been due to the fact that in the rural areas the males generally worked in the cities whilst females remained at home to take care of domestic duties.

Table 3.1. Sample grouping of farmers interviewed at Umbumbulu and Ndwedwe

Area	Interview type	Sex		Total
		Male	Female	
Umbumbulu	Individual	23	33	56
	Focus group	7	13	20
Ndwedwe	Individual	21	23	44
	Focus group	5	12	17
Total	Individual interviews			100
	Focus group interviews			37

Data capturing was done using Statistics Programme for Social Sciences (SPSS). Descriptive statistics were used to present data in the form of graphs. The information was categorised into the following key aspects:

(i) general information about the farmer,

(ii) general information on taro and taro types,

(iii) utilization and marketing of taro,

(iv) environmental conditions for taro production,

(v) production practices, and

(vi) pests and diseases of taro.

Cross tabulation counts were also used for comparison of related data (e.g., types of taro known and the age of respondents). A chi-square test was used to test the significance level of differences between means, where this was relevant (Appendix 3.2).

3.3 Some environmental characteristics of the study locations.

Selection of two locations where the study was conducted, Ndwedwe and Umbumbulu districts, was based on the (i) research focus (farmers growing taro in wetland and dryland areas were targeted) and (ii) logistics – ease of access to the sites in relation to Durban and Pitermaritzburg, from where the researcher commuted.

At the time of the study, the two districts were under the jurisdiction of the South East Region of the KwaZulu-Natal Department of Agriculture. The South East Region provides agricultural services in the Durban Metro and Ugu Regional Council. Table 3.2 and Figure 3.1 show the relevant natural resources important for taro production.

Table 3.2. Some environmental characteristics of Umbumbulu and Ndwedwe districts. From The Natural Resources Section, Cedara Research Station (2001).

	Location	
Natural factor	Umbumbulu	Ndwedwe
Mean annual rainfall	956 mm	1138 mm
Terrain type	Broken/rolling	Rolling
Altitude range	394 - 779 m	409 - 661 m
Slope	Either steep > 12% or moderate 5-10 %	Steep >12 %
Extent of cultivation	Widespread > 50%	> 50%
Indicator species	*Aristida junciformis*, *Lantana camara* , *Solanum mauritianum* *Strelitzia* spp. , *Syzigium cordatum.*	*Aristida junciformis*

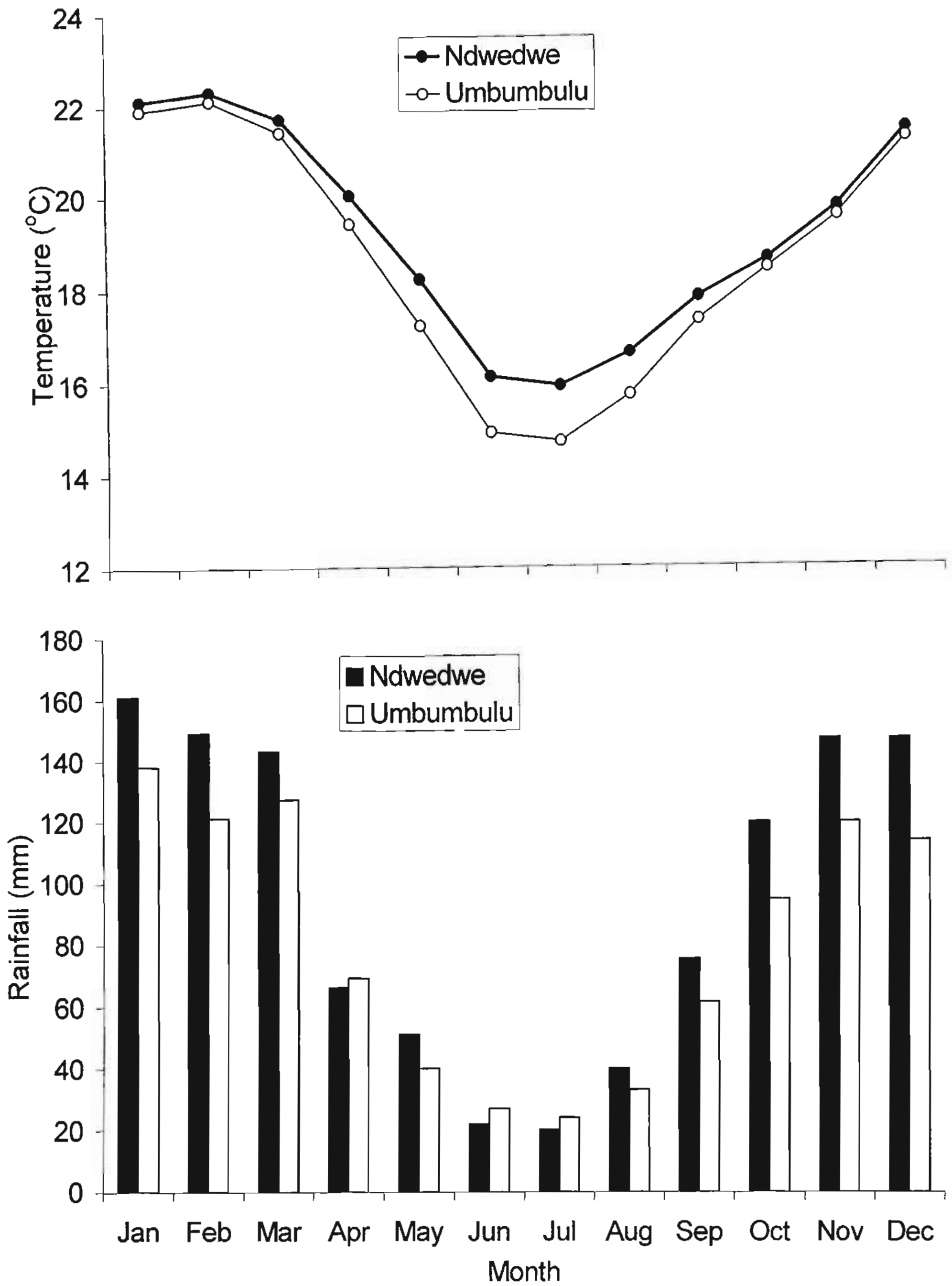


Figure 3.1. Temperature and rainfall distribution at Umbumbulu and Ndwedwe District Data are means over a period of 10 years to 2000. From The Natural Resources Section, Cedara Research Station (2001).

Taro requires hot and humid conditions with daily average temperatures of 21-27°C, and when grown in temperate areas or at high altitudes there must be six to seven months of a frost-free period (Kay, 1987). According to Joubert (1997) taro requires a well distributed summer rainfall of at least 800 mm during the growing season. From the climatic data in Figure 3.1 it is appears that if the planting season were to start in September or October and end in March or April, the mean annual rainfall at both Umbumbulu and Ndwedwe would be adequate for taro production. However, the temperature seems to be sub-optimal.

3.4 Results and discussion

3.4.1 Characteristics of farmers, crop knowledge and utilisation

The ages of the respondents varied from 20 to 80 years, and two thirds of them were older than 40 years (Table 3.3). Among the farmers above 40 years of age 67% were females. By modern standards, family sizes were generally large, because 90% of the families comprised of ≥ 7 members. A family of four or five members is generally accepted as a modern norm. A combination of large family sizes and small land owned by the farmers (87% of the farmers had access to 1 ha or less land) had serious implications for food security at Ndwedwe and Umbumbulu. The importance of land in food security was also shown by poor education of the farmers. Eighty percent of the farmers had grade seven or less formal education (Table 3.3). The influence of the demographic characteristics on the survey was significant.

The senior citizens (≥ 50 years of age) among the farmers held more knowledge of traditional convention (e.g. taro varietal differences, ability to differentiate between a wetland and a dryland site and explanation of the reasons for choice of taro variety and soil) than the younger farmers. The youth were more knowledgeable about technical information such as estimation of land size and plant spacing for taro production. It was also interesting to note that women showed better knowledge about practices associated with taro agronomic management (e.g., weeding, plant protection and mounding) than men. Apparently women are generally more involved in crop production than men. Some evidence of the differences between males and females is illustrated in Table 3.4. For example, in the 31 to 40 age class, 89% of the women had been cultivating taro for more than 10 years, while for males in the same age category only 25 % had been cultivating taro for more than 10 years (Table 3.4).

Table 3.3. Demographic characteristics of the subsistence farmers who participated in the study at Umbumbulu and Ndwedwe districts.

Characteristic		Umbumbulu	Ndwedwe	Total
Gender	Female	33	23	56
	Male	23	21	44
Age (years)	20-30	4	8	12
	31- 40	9	12	21
	41-80	41	26	67
Family (members)	1-10	46	36	82
	11-20	2	6	8
Land ownership	Owned	52	44	96
	Rented	4	0	4
Land size (ha)	0.1-0.5	43	20	63
	0.6-1.0	13	11	24
	1.1-5.0	7	6	13
Formal education	None	18	24	42
	Grade 1- 4	15	21	36
	Grade 5 -7	0	2	2
	Grade 8-12	9	5	14
	Tertiary	6	0	6

Table 3.4. Experience of farmers in taro production at Ndwedwe and Umbumbulu expressed as a percentage of females (F) and males (M), in relation to age

			Years in taro production							
	Total (n)		1-10		11-20		21-30		>31	
Age (years)	F	M	F	M	F	M	F	M	F	M
20-30	2	10	100	100	0	0	0	0	0	0
31-40	9	12	11	75	67	25	22	0	0	0
> 40	45	22	7	36	10	55	80	9	3	0
Total	56	44								

The study revealed that 42% of the farmers had never been to school. This was evident when farmers were asked questions about the size of their plots, taro spacing and yield. It was difficult for farmers to give accurate information on aspects like spacing and the yield since they did not keep records and some of them could neither read nor write. It was, however, interesting to note that all farmers agreed on a standard spacing measurement using one's feet.

There were various reasons for taro production (Figure 3.2). Sixty one percent of the farmers cited home consumption (food) and marketing (market) as the main reasons for their production of taro (Figure 3.2). Thirty five percent produced mainly for home consumption (food) and they would occasionally sell or exchange taro to their neighbours if there was a need or surplus. For the remaining 4%, producing taro was associated with a cultural sentiment (culture) (Figure 3.2).

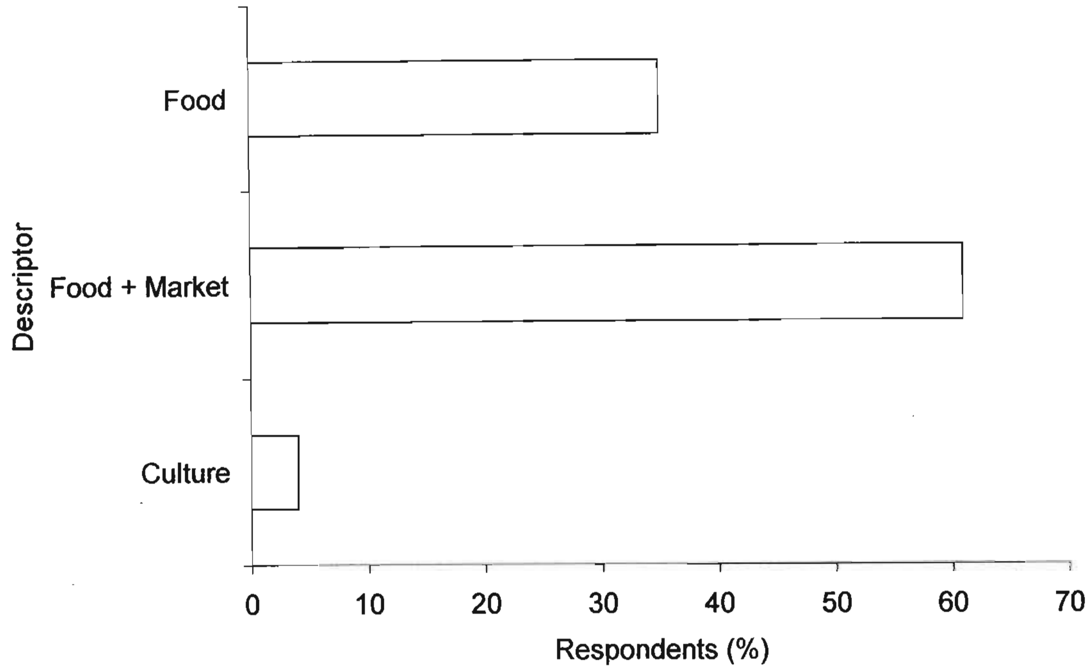


Figure 3.2 Utilisation of taro by subsistence farmers at Umbumbulu and Ndwedwe.

Modi (2003) found that subsistence farmers at Umbumbulu and Umsinga districts of KwaZulu-Natal regarded taro as an indigenous crop, but only Umbumbulu farmers marketed it. The findings of the present study concur with those of Modi (2003) with respect to the attitude of Umbumbulu farmers towards taro. The finding that the majority of farmers produce taro as a staple food (Figure 3.2) and there are those who solely attach a cultural value to their involvement in its production suggests that the crop has been adopted as an indigenous crop by the subsistence farmers at Umbumbulu and Ndwedwe. Modi (2003) concluded that subsistence farmers accept a crop as being indigenous mainly because of the role it plays in their culture and the length of time the crop has been associated with the farmers as a staple.

Hence, the term indigenous, in the context of South African black farmers, may not mean "African only" as the meaning is generally construed (Modi, 2003). It was also encouraging to note in the present study and that of Modi (2003) that subsistence farmers have identified taro as a marketable crop.

However, the study revealed that the farmers knew little about taro's origin. Some suggested that taro was of Indian origin. They also expressed their belief that the number of years spent on taro production might have led to a genetic evolution, which led to the rise of a South African type. According to Purgeslove (1972) taro varieties are distinguished by the colour of the flesh of corms and cormels (which may be white, pink or yellowish-cream), pigmentation of the lamina, veins, petiole, and acridity of corms and leaves. Some of Purgeslove's (1972) classification was confirmed by the farmers at Ndwedwe and Umbumbulu. The study revealed that the farmers knew three types of taro which they referred to as "red type", "white type" and the "Zulu type" (Table 3.5). The use of the word Zulu to designate the latter suggested that the variety was believed to be indigenous (Modi, 2003). It was also evident that the young generation was less familiar with the Zulu type compared with the older people (Table 3.5).

Table 3.5 Relationship between farmer age and knowledge of local taro varieties at Ndwedwe and Umbumbulu

Age range (years)	**Percentage of respondents with knowledge of taro varieties**	
	Red, White, Zulu	Red, White
20 - 30	8	92
31 - 40	43	57
> 40	93	7

Farmers distinguished the "red" variety by the red colour of the petiole, which was also visible on the adaxial leaf surface. The "white" variety had a white petiole. The "Zulu" variety had a similar petiole colour to the "red" variety. However, it was a smaller plant with smaller root-like corms that were characterised by a distinct irritant taste. The "red" and the "Zulu" varieties were also described as having drier mature corms, which also had a drier texture when consumed, compared with the more succulent "white" variety. These characteristics were personally confirmed to be true. The morphological characteristics of the "red" and the "white" varieties are presented in Figure 3.3. Joubert and Allemann (1998) described these varieties as the eddoe and dasheen varieties (Figure 3.3).

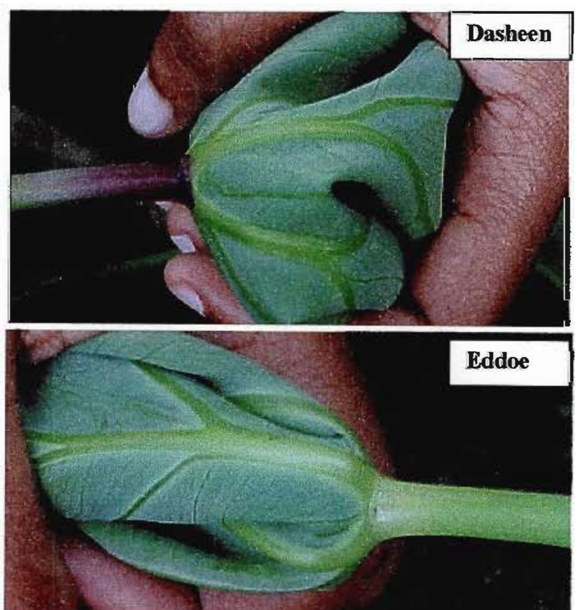


Figure 3.3 Morphological characteristics used by subsistence farmers at Umbumbulu and Ndwedwe to distinguish local taro varieties. The dasheen and eddoe varieties(Joubert and Allemann, 1998) were locally referred to as the "red" and white" varieties. The variety that was locally referred to as the "Zulu" variety shared a similar morphology with the "red" variety.

In terms of varietal preference, 100% of the farmers mentioned that they mainly grew the "red" variety. Regarding the "white" variety, the farmers mentioned that it had a better yield compared to the "red" variety, and under moist conditions it can outgrow the "red" variety if they are planted in the same field. This difference between the varieties suggested that the "white" variety may be more suitable to wetland conditions than the "red" variety. Nevertheless, the latter was generally grown under all environmental conditions.

There were certain reasons why the "white" variety was not popular among the farmers. The first reason was that there is a superstition that if you grow the "white" variety the head of the family might die earlier. It was also mentioned that the taste was poorer than that of the "red" variety. The "Zulu" variety was characterised by a small size, irritant taste quality and it took longer to cook. Hence, it was also less commonly grown. The irritating or acrid agent of the corms can be destroyed by boiling (Joubert, 1997). The irritant quality of taro is associated with the presence of calcium oxalate crystals (Wang, 1983). This might suggest that the "Zulu" variety has a higher percentage of calcium oxalate compared to the red and white taro type. Although there are various uses of taro including human consumption, animal feed, medicinal use (e.g. treating snakebites) and industrial uses (Kay, 1987). All the respondents in the present study only mentioned human consumption.

The corms are generally used as the main starch in meals (Joubert ,1997). Most respondents (86%) with 54% from Ndwedwe and 46% from Umbumbulu acknowledged that both taro leaves and corms could be used for food. Cooking of leaves was not considered a standard practice and it was mainly associated with impoverished families.

The main method for cooking taro was the boiling of corms (72%), whilst 28% of the farmers reported that they boiled corms and made fried leaves. The leaf of taro is a rich source of calcium, phosphorus, iron, vitamin A, thiamine, riboflavin, and niacin (Onwueme, 1978; Maga, 1992). This suggested that the majority of the farmers were underutilizing the crop and were perhaps unaware of the nutritive value of the crop. Sixty seven perecent of the farmers were familiar with the practice of using grass called (*imbeje)* (*Cymbogon spp.*) when boiling taro. This grass was boiled together with taro so as to give a certain aroma to taro after cooking. However, the farmers mentioned that this practice was no longer common. In terms of preference after cooking, the survey revealed that 84% of the farmers preferred the dry taste of taro, 10% preferred the sticky taste and 6% would go with any texture. The only reason highlighted regarding preference was that the dry type ("red" variety) was easy to peel.

Among the respondents, 92% agreed that they fed taro to children. The reason being that they were told at the health clinic that it helped with digestive problems and it supplemented iron. This was in line with the report from Joubert and Allemann (1998), which stated that the excellent digestibility of taro made it an ideal starch source, especially for infants and people with digestive problems. Eight percent of the respondents reported that they had never tried feeding taro to children and they did not state any reason.

3.4.2 Agronomic practices

3.4.2.1 Environmental conditions and water requirements for taro production

Farmers were asked to describe the soil types used for taro production. The responses were evaluated using physical samples to determine whether the soil type was loam, sand or clay. The study revealed that 87% (46% Umbumbulu and 54% Ndwedwe) of the farmers planted on loam soil. Three percent of the farmers from Umbumbulu and none from Ndwedwe planted on sandy soil, and 10% (20% from Umbumbulu and 80% from Ndwedwe) reported that they planted on a sandy loam soil. The farmers producing in dry land conditions on sandy soils reported that their taro was small in size and the annual yield was normally less than 4t ha^{-1}.

In spite of the benefits associated with fertilizer application, 68% of the farmers interviewed neither used inorganic fertilizers nor organic fertilizers. This suggested that taro has a potential to be produced as an organic crop. At least 24% of the farmers used organic material, mainly kraal manure and compost. They believed that kraal manure improved the yield. The respondents reported that the use of inorganic fertilisers caused a watery taste to taro corms. Only 4% of the farmers (from Ndwedwe) used inorganic fertilizers, white 4% used both inorganic and organic fertilizers (75% of these were from Umbumbulu and 25% was from Ndwedwe).

Modi (2003) reported that more than 80% of subsistence farmers at Umbumbulu practised organic farming. The reasons mentioned in that study included, lack of resources, food safety and better crop performance. It is interesting that in the present study inorganic fertilizers are also associated with poor crop quality.

At Umbumbulu, the majority of farmers produced taro under dryland conditions, with much smaller proportions producing under wetland only or wetland and dryland conditions. At Ndwedwe the proportion of farmers producing under wetland conditions was much higher than at Umbumbulu (Figure 3.4). Although the wetland conditions were common at Ndwedwe it was interesting that some of the farmers who had wetland conditions preferred dryland conditions because they feared that their produce would be washed away near the streams.

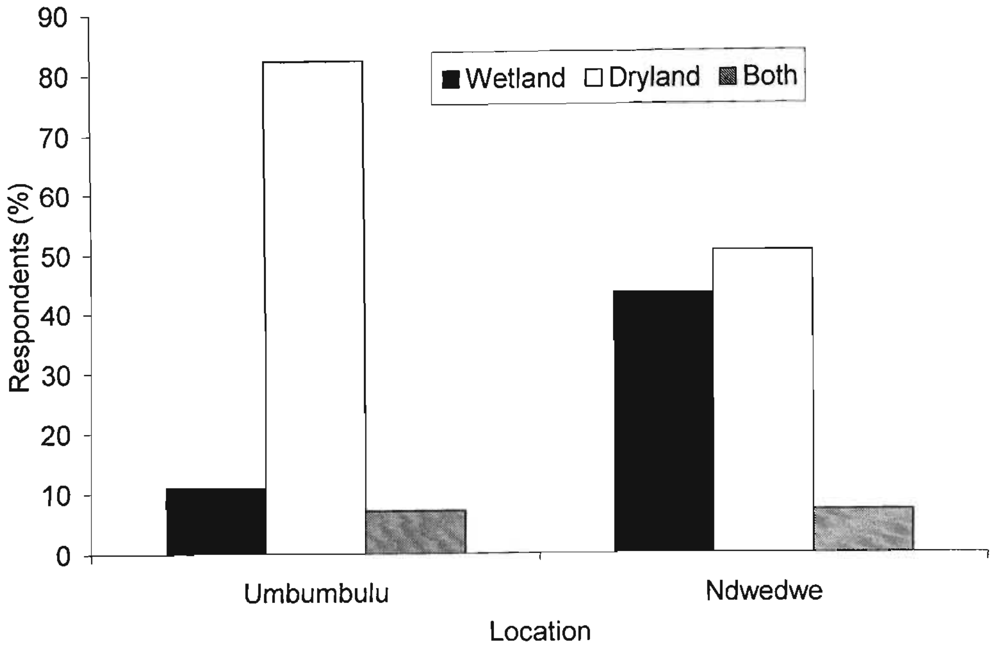


Figure 3.4. Environmental conditions used for taro production at Umbumbulu and Ndwedwe

Although taro requires high soil moisture regimes throughout its growing season (Onwueme, 1978), none of the farmers mentioned that they irrigated the crop. They stated different reasons for not irrigating: 2% mentioned that they could not afford the irrigation equipment, 65% said that they did not consider irrigation necessary for taro production, 4% mentioned that there was no water for irrigating, 24% mentioned that they had no irrigation facilities, and 5% said it was not necessary because they planted in wetland conditions.

3.4.2.2 Land preparation and planting

Farmers who produced under dryland conditions could hire tractors or use hand hoes for land preparation. At Ndwedwe, 18% of the farmers hired tractors but this was not a standard practice at Umbumbulu. Farmers who produced in wetland areas relied on hand hoes as tractors could not efficiently work on wet sites.

Regarding the period of planting, 57% of the farmers planted during spring rains, 16% in September and 27% between October and November. An early spring planting has a longer crop cycle, but it produces higher yields under favourable growing conditions than later plantings (Joubert & Allemann, 1998). The farmers who produced taro under wetland conditions reported that they did not wait for the rains, and they considered early spring to be the best time for planting. One of the farmers producing in a wetland at Ndwedwe mentioned that he produced taro throughout the year. All farmers planted by hand, but 36% considered planting to be a time consuming operation. Taro can, however, be planted using mechanical means (Joubert, 1997). It is important to note that mechanical planting would be expensive to a small-scale farmer and could also have adverse environmental impacts on wetland areas.

3.4.2.3 Planting material of taro

Only 6% of the farmers mentioned that they mainly used the main corms (*izideku*) and 94% used both main corms and daughter corms for their taro production. The most common planting material are corms of 25-80 g in weight (Joubert & Allemann, 1998). These would be allowed to produce eyes (new sprouts that had not developed into shoots) before planting. Only 14% of the farmers had tried to cut taro as they had seen it done on potatoes. However they mentioned that it was not a common practice and they only did it when there was a shortage of propagules.

It appeared that 86% farmers were not familiar with other types of propagules that could be used in taro production i.e. stem cuttings and cut pieces of the corms. This presented an opportunity to investigate the effect of alternative propagules on taro yield. Lack of a reliable source of propagules was cited as one of the major constraints by 53% of the farmers. An opportunity to use certified taro seed, as in potatoes, was desired by farmers, and they understood they would be expected to pay for certified propagules.

3.4.2.4 Spacing and planting density

All the farmers interviewed mentioned that they relied on the size of their feet for spacing taro plants. The intrarow spacing was determined by putting two feet from one taro plant to the other. The interrow spacing was determined by taking one step in between the rows. Considering that the size of the foot and strides were not the same, it was clear that the plant spacing and density would vary from farmer to farmer.

For both districts farmers mentioned that since they used one foot (approximately 30 cm) for maize which they considered a crop with low water requirement, compared to taro they thought two feet (approximately 60 cm) would be adequate for taro since taro required mounding. This applied to both dryland and wetland producers.

3.4.2.5 Plant protection

The farmers at Umbumbulu and Ndwedwe reported amaranthus, blackjack, purple nutsedge and couchgrass to be the weeds associated with taro production, mainly in wetland areas. A study to observe the effect of different types of weeds on growth and yield of taro indicated that *C.rotundus* (purple nutsedge) infestations significantly decreased relative growth rate, net assimilation rate and leaf area of taro at harvest (Nedunzhiyan, 1995). The farmers at Umbumbulu and Ndwedwe did not single out one weed that would have a significant impact on taro yield. However, they acknowledged that it was important to keep taro plants weed free until tuber initiation.

All farmers reported that they did not use chemicals for weed control. Farmers mainly relied on hand hoeing for weed control. The respondents mentioned that they were not aware of any chemical that could be used in taro production and they would be keen to try one. When farmers were asked about the most time-consuming and difficult operation for taro production, 56% considered weeding to be the most time consuming.

3.4.2.6 Intercropping and crop rotation

Only 31% of the respondents intercropped taro with other crops. Among these farmers only 3% produced under wetland conditions at Ndwedwe compared with 97% under dryland conditions. Among farmers who practised intercropping, 93% intercropped with maize and 6% intercropped with dry beans. The farmers who intercropped in a wetland condition only intercropped with maize. The maize and taro intercropping in the wetland conditions was only done in the drained part of the site. The farmers cited that it was difficult to intercrop in wetland conditions since other crops did not have the same water-logging tolerance as taro.

De la Pena & Melchor (1988) reported that taro corm yields ranged from 37.04t ha^{-1} when grown alone to 50.58 t ha^{-1} when intercropped with groundnuts. Intercropping with a legume gave corm yields greater than 45 t ha^{-1} compared with 39-40 t ha^{-1} with sweet corn and sweet potatoes (de la Pena & Melchor, 1988). According to Sen *et al.*, (1993) besides maize, a short season crop such as cabbage can be planted during the first two months after planting.

The 69 farmers who did not intercrop taro mentioned that they did not think it was beneficial. They considered intercropping to be a practice for farmers who did not have enough land to plant other crops. The main reason that the farmers highlighted about intercropping taro with either maize or dry beans was that these crops had low water requirements than taro. This made farmers believe that there was minimal moisture competition among these crops.

Farmers who reported practising crop rotation constituted 91% of the respondents. This revealed that crop rotation of taro was a standard practice among small-scale farmers. The survey revealed that 9% of the farmers used maize in crop rotation, 16% used dry beans and 66% used maize and dry beans. However farmers who planted in wetland conditions stated that it was difficult to plant any other crop, which might be tolerant of wet conditions. As a result they would leave the land fallow for at least one year instead of planting a crop that would not survive in wet conditions.

Diseases appeared not to be a major problem in taro production at Umbumbulu and Ndwedwe. Among the respondents, only 26% reported to have noted diseases in their taro plants. No diseases were cited as being responsible for major reduction in yield. They all mentioned that they did nothing to control the diseases, because of lack of information on taro diseases and their control measures. The diseases mentioned were downy mildew and corm rot. Downy mildew was reported by 12% of Umbumbulu farmers and one of the Ndwedwe farmers repoted it. Taro yield was not significantly affected by pests. Hence there were no stringent measures for pest control.

The pests and diseases and their levels were fairly similar at the two sites with millipedes being most frequently cited (Table 3.5). The farmers considered the earthworm to be a problematic pest as it bore holes in the corms. This was interesting in the light of the earthworm's role in soil structure improvement.

Table 3.6 Percentage of respondents who reported important pests at Umbumbulu and Ndwedwe.

Pest	Umbumbulu	Ndwedwe
Porcupine	2	5
Mite	4	2
Cutworm	14	14
Mole	14	2
Millipede	45	51
Earthworm	21	22

3.4.2.7 Production in relation to wetland and dryland conditions

The production in the study areas was measured in 20 litre tins. The 20 litre tin containers full of taro weighed an average of 12.5 kg. Although farmers could not quantify their yield per size of their plots, the average yield was ~5 t ha^{-1}. In South Africa 13.5 t ha^{-1} is regarded as a fair crop, and a yield of 18 t ha^{-1} has been reported in the Port Shepstone area (Joubert, 1995).

It was evident that most of the respondents (71%) considered 4.1-5.5 t ha^{-1} (Table 3.6) to be a common yield at Umbumbulu and Ndwedwe. The data presented in Table 3.6 does not allow a clear comparison of the difference between wetland sites and dryland sites with respect to productivity. The reason for this may be associated with differences in plot sizes used for each site type.

Most wetland sites were small (~ 0.1 ha on average) compared with dryland sites (~ 2 ha on average). Consequently, a personal assessment of yield on two sites (one wetland and one dryland) showed that wetland sites could produce 10 to 30% more than dryland sites by virtue of corm size difference.

Table 3.6. Taro yield as reported by farmers who produced at different site types.

	Yield range per household (t ha^{-1})		
Site type	**2.84-4.00**	**4.1-5.5**	**5.6-6.5**
Dryland	3	55	10
Wetland	8	12	5
Both (wetland and dryland)	1	4	2
Total	**12**	**71**	**17**

3.4.2.8 Harvesting and storage

The farmers stated that withering of the petiole was an indication that the taro plant had reached maturity. All farmers harvested taro by the hand hoe. In Cuba a modified potato harvester for mechanized lifting of a taro crop (Plucknett & White, 1979). It would be important to note that farmers in Cuba might not be small-scale farmers like the respondents interviewed. The farmers would only harvest taro that they needed for cooking or selling and the rest would be left in the field as seed material for the next season. The farmers kept taro in the fields for different periods, 77% (of which 10% planted in wetland conditions and 90% in dryland conditions) only kept it for 1-3 months and they mentioned that it could be rotten if kept for a long time in the field.

The other 23% of the farmers only kept taro on the field for 4-6 months until the next season. The majority (64%) kept taro in the field until the next season. The farmers who specified the period for which they keep taro in the field highlighted that keeping taro for a long period led to the corms rotting, especially in wetland sites.

3.4.2.9 Marketing

The farmers believed that with the exodus of rural people to the urban areas they stood a chance of selling taro at big markets. Taro produced at Ndwedwe and Umbumbulu was sold to hawkers or consumers in the districts or directly to market outlets or consumers in local townships: Umlazi, Kwa-Makhutha and Inanda. The price was determined using a container size.

A 20 L tin would cost R35.00 and a small dish which might be equivalent to a kilogram would cost R3.00-R5.00 depending on the size of the corms and the demand. Farmers mentioned that the consumers considered taro to be of cultural value. It was reported that special orders were made for Zulu customs (e.g. umbondo: traditional Zulu custom whereby a bride has to take food to the bridegroom's place). The farmers mentioned that they had no transport for their produce to be taken to market places.

3.4.2.10 Production Constraints

The major constraints reported were shortage of seed material (53%), inadequate land (29%) and transportation (18%). Land was the main problem at Umbumbulu compared to Ndwedwe (Table 3.7). Umbumbulu farmers mainly produced under dryland conditions which suggests that there was a competition for land between taro and other crops. It was evident that the main production constraint was seed material in both districts. However, there were significant differences in production constraints reported in both districts ($P < 0.01$) as indicated in the Table 3.7.

Table 3.7. Problems associated with taro production reported by farmers at Umbumbulu and Ndwedwe. Data are percentages of respondents.

	Constraints		
Area of production	Land	Transportation	Seed material
Umbumbulu	41	16	43
Ndwedwe	14	20	66

3.5. Conclusions and future directions

Subsistence farmers at Ndwedwe and Umbumbulu produce taro under wetland and dryland (rainfed) conditions. However, at Umbumbulu, taro production occurs predominantly under dryland conditions, whereas at Ndwedwe there is approximately an equal number of farmers producing under wetland and dryland conditions.

Taro yields could be estimated to be approximately 5 $t.ha^{-1}$, based on the reports by farmers producing under wetland and dryland conditions. However, there was no sufficient data to compare the productivity of wetland sites compared with dryland sites. The farmers acknowledged that wetland sites produced better than dryland sites, and this was associated with soil moisture availability at the wetland sites. However, dryland sites were preferred because they are easy to cultivate compared with wetland sites. It would be interesting to investigate the validity of the farmers' identification of sites as being wetland or dryland. Temporary waterlogging or poor drainage have caused some sites to be described as wetlands.

Taro is generally produced with no chemical inputs to improve soil fertility or combat diseases and pests at Umbumbulu and Ndwedwe. This study did not produce clear explanations for the organic approach, except for the reported negative effect of fertilizers on crop consumption quality, which could not be tested. The largely organic approach to taro production suggested that this crop has a potential as an organic crop. However, it is also likely that the crop is not adequately fertilized, and negative effects on soil nutrient status could be deteriorating. This assumption could be investigated by long term studies of soil chemistry and physics under taro monoculture and rotation with other crops.

Although a few farmers have used cut corms as planting material, it was clear in this study that full corms were the traditional type of propagule for taro production.The quality of these propagules would be improved by sprouting (without shoot production), which occurred during storage. It was clear that the farmers did not use different propagules depending upon the type of site (wetland or dryland) used. Taro production is likely to be influenced by the type of propagule used to establish the crop, as well as planting density. Information obtained during this study about planting density is not reliable for the purposes of advising farmers about taro production.

Rainfall and temperature at both locations are generally suitable for taro production, although temperatures may be slightly lower than the desired average for the growing season. It is, however, difficult to conclude that the soil conditions are optimal or not, from the findings of the present study.

It is proposed that field experiments be conducted to investigate:

(a) the differences between wetland and dryland taro production,

(b) the effect of propagule type on taro crop establishment and yield,

(c) the effect planting density on taro crop establishment and yield,

(d) the effect of taro organic production on soil nutrient and physical quality and

(e) taro storage in response to wetland or dryland production.

The major significance of field experiments would be to allow validation of site description as wetland or dryland, by subsistence farmers. This validation was not performed in the present study, and the use of present data to select wetland and dryland sites would be important for confirming the correlation of subsistence farmers' local knowledge with the scientific description of wetlands and drylands. Although Umbumbulu and Ndwedwe were included in the present study, data presented in Figure 3.5 suggest that at Ndwedwe there is an even distribution of current wetland and dryland production. Hence, conducting field experiments at Ndwedwe would be appropriate. The predominant cultivation of the dasheen taro variety ("red variety") at both locations suggested that it would be valid to focus on this variety for the first investigation of taro production in KwaZulu-Natal. Field experiments to investigate (a) the differences between wetland and dryland taro production, (b) the effect of propagule type on taro crop establishment and yield, and (c) the effect planting density on taro crop establishment and yield are discussed in chapter 4.

CHAPTER 4

TARO PRODUCTION IN WETLAND AND DRYLAND CONDITIONS AS INFLUENCED BY PROPAGULE TYPE AND PLANTING DENSITY

4.1. Introduction

A survey of production practices at Ndwedwe and Umbumbulu showed that subsistence farmers produce taro under wetland and dryland conditions. However, the majority used dryland conditions. It was not clear from the study why farmers described a site as a wetland, as this description was largely based on local, non-documented knowledge. Full corms with young buds (sprouts) were a predominant type of propagule, and the farmers did not show evidence of using alternative types of propagules or manipulation of traditional propagules to enhance taro production. The use of feet to measure plant spacing is common in subsistence farming of taro and other crops. However, it does not provide a consistent measure of plant populations. Therefore it cannot be reliably used to determine planting density as a factor influencing taro production.

It was of interest to examine the sites described by the farmers as being wetlands and compare their productivity at various planting densities. Traditional propagules were also compared with propagules manipulated before planting, to enhance growth, and those that could be used in situations of scarce planting material, with respect to taro production.

4.2 Materials and methods

4.2.1 Description of sites

Four sites were offered by the farmers (Phewa and Gcabashe), the Msunduzi Training Centre and the Department of Agriculture at Ndwedwe (29°27′S; 30°58′E), KwaZulu-Natal, in 2001. Ndwedwe is in the bioresource group 3 (Moist Coast Hinterland, Ngongoni veld) on bioresource unit zb3 (Camp, 1995). In this study, the four sites were designated according to the land owners as follows: P = Phewa site, G = Gcabashe site, NDA = Ndwedwe Department of Agriculture and MTC = Msunduzi Training Centre.

During the survey of production practices at Ndwdwe (Chapter 3), these sites were described by the owners as wetland (P and G) and dryland (NDA and MTC), based on local experience. Pedological soil descriptions (Appendix 4.1) and fertility analyses (Appendix 4.2) were performed at each site. Further, the wetland sites (P and G) were examined to describe their characteristics based on published literature (Appendix 4.3).

4.2.2 Planting material

The situation analysis (chapter 3) showed that the "red" or dasheen variety (Figure 3.4) of taro were predominantly cultivated at both Ndwedwe and Umbumbulu. Consequently, the dasheen variety was selected for the present study. Traditionally used taro planting material was donated by the farmers from Ndwedwe in the form of corms (80 – 200 g $corm^{-1}$).

To minimize variation in planting material size, corms of 100 to 120 g were selected for field experiments. Some of the corms were stored under a moist (20%) pine bark in plastic bins at 20/27°C (day/night) for one month to induce sprouting. Subsequently, the sprouts were hardened and allowed to develop into shoots (10 ± 2 cm) at the same temperatures on air-dry surfaces for two weeks. The planting material was characterized by three types of propagules: full corms without shoots (C), corms with shoots (CS) and half corms developed by cutting full corms without shoots (Figure 4.1). Half corms were submerged in a 1:1 (3.5% NaOCl: tap H_2O, v/v) for approximately 15 minutes) (Joubert and Allemann, 1998) to decontaminate them before planting.

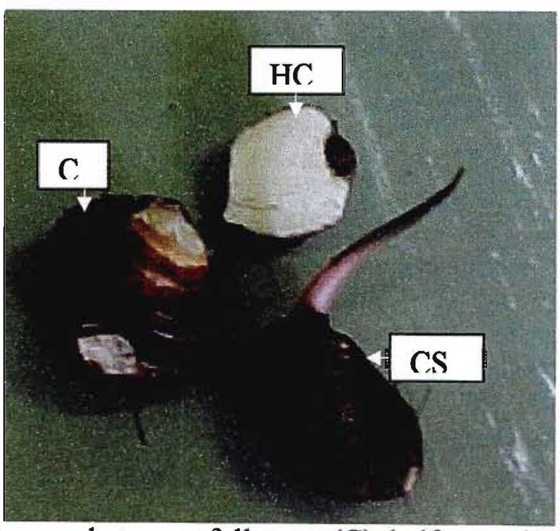


Figure 4.1. Propagule types: full corm (C), half corm (HC) and , corm with shoot (CS).

4.2.3 Land preparation and planting

In dryland sites, conventional mouldboard ploughing was performed followed by hand-planting. In wetland sites, only hand hoes were used to prepare seedbeds. During planting, propagules were placed at a depth of about 15 cm, in planting stations created by hand-hoes. Propagules were planted at 90 cm interrow spacing and 30 cm, 45 cm and 60 cm intrarow spacings to create plant populations of 37000, 24600 and 18400 plants ha^{-1}, respectively. Details of the experimental layout, including plot sizes, are presented in Appendix 4.4. In accordance with traditional practice in the study area (Chapter 3), no fertilizer was applied at planting or during crop growth. At all sites, planting took place in the first week of October 2001. At each site, the crop was weeded and ridged three times during the growing season until harvesting occurred in May 2002.

4.2.4 Determination of plant growth and yield

Plots were monitored weekly to determine emergence. Emergence was observed from the eighth to eleventh weeks after sowing, after which no further emergence was observed. Plant height was determined biweekly on the main stalk from week 12 after sowing to the harvest time (week 24 after sowing). Corms were harvested by digging with a hand-hoe. Taro yield was determined by the total corm mass per plot, which was presented in tons per hectare.

4.2.5 Statistical analysis

A split block design was used. The propagules (HC, C nad CS) and planting densities (37000, 24600 and 18400 plants ha^{-1}) constituted the main and sub-plots, respectively (Appendix 4.4). The experiments were replicated three times (Appendix 4.4, Blocks) at each site. Site type (wetland or dryland) was used as a third factor during the analysis of variance (GenStat®, version 6.1, Rothamted, UK). Analysis of variance tables for plant growth and yield are presented in Appendices 4.5 and 4.6). Means and standard deviations for emergence were calculated manually (using a scientific calculator), hence no analysis of variance table is presented.

4.3 Results and discussion

4.3.1 Site descriptions

In terms of vegetation (data not shown) and soil characteristics (Appendices 4.1 and 4.3) site P was subject to noticeably more prolonged saturation than site G. For the soils, this is indicated by the fact that site P had higher soil organic carbon levels than site G (16 % compared with 2.1%) and lower chromas of the soil matrix (0 compared with 1 and 2 in G).

The Phewa (P) site was dominated by plant species such as *Cyperus latifolius* and *Phragmites australis*, which characteristically occur under prolonged saturation, while wetland site G was dominated by a mixture of hydrophilic species such as *Fimbristylis dichotoma* and *Cyperus sphaerospermus* which are common in wetland margins, and by species such as *Digitaria eriantha* which occur both in wetlands and extensively outside of wetlands. The other two sites, NDA and MTC, did not show significant wetland characteristics.

Generally, wetland and dryland sites differed in their soil fertility status. Phewa (P) wetland site had a high amount of plant available bases (Ca, Mg and K) and high soil organic carbon and P content compared with the other three sites. Gcabashe (G) wetland site, which was dominated by plinthic soils had low amount of bases especially Ca and K, which were lower than the Ndwedwe District Office (NDA) dryland site. The soil organic carbon content was also low in this wetland site, which suggested that the site had low organic material and low fertility. The lowest soil organic carbon content was at the MTC dryland site (Appendix 4.1).

4.3.2 Effect of propagule type, planting density and site on taro emergence

Allowing corms to develop shoots before planting caused a significant improvement in emergence compared with the use of full corms without shoots and half corms (Figure 4.2). Cutting corms reduced the final crop stand (week 11) by 18% compared with planting with full corms without shoot. There was a 27% reduction in final stand when half corms were compared with corms with shoots (Figure 4.2). Full corms caused a 7% reduction in final stand compared with full corms with shoots (Figure 4.2).

The reduction in emergence and final plant stand, where half corms where planted, might be associated with pathogen infection of the cut areas of the corm. It would have been interesting to determine the effectiveness of the NaOH treatment, compared to no decontamination of the half corms. The difference in the performance of traditionally used full corms without shoots, compared with corms with shoots explained the need for pre-planting treatment of corms to enhance crop stand. The effect of corms with shoots on plant emergence and stand establishment may be important when rainfall is low during the crop establishment stage or when the crop is planted late in the normal growing season. Water shortage is characteristic of the areas where subsistence farming is practised, because of there is generally no irrigation. Hence, manipulation of corms to cause shoot development prior to planting might be important in improving crop establishment in the subsistence farming areas where taro is produced.

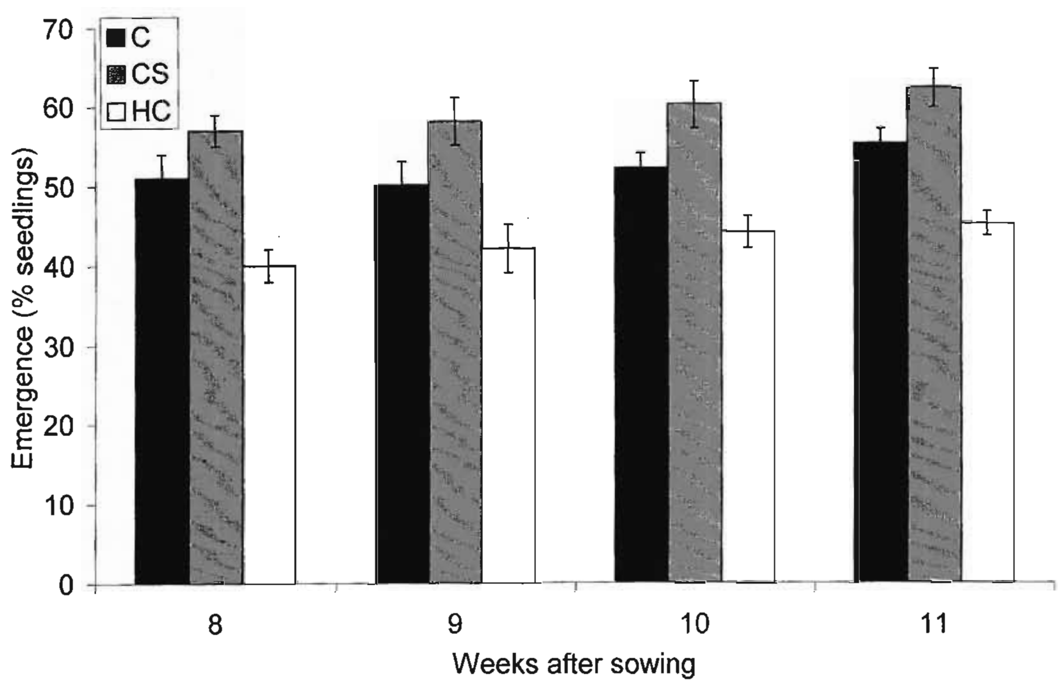


Figure 4.2.Emergence of taro seedlings in response to planting of full corms (C), corms with shoots (CS) and half corms (HC) determined from the eighth week after sowing, when emergence was first observed, to the eleventh week after sowing, when the final crop stand was established.

Increasing the planting density did not improve emergence and final crop stand (Figure 4.3). This finding was important in that it confirmed that plant population (plants per unit area) was influenced only by the number of propagules planted. Hence, crop performance determined during growth and at harvest could not be confounded by the effect of planting density.

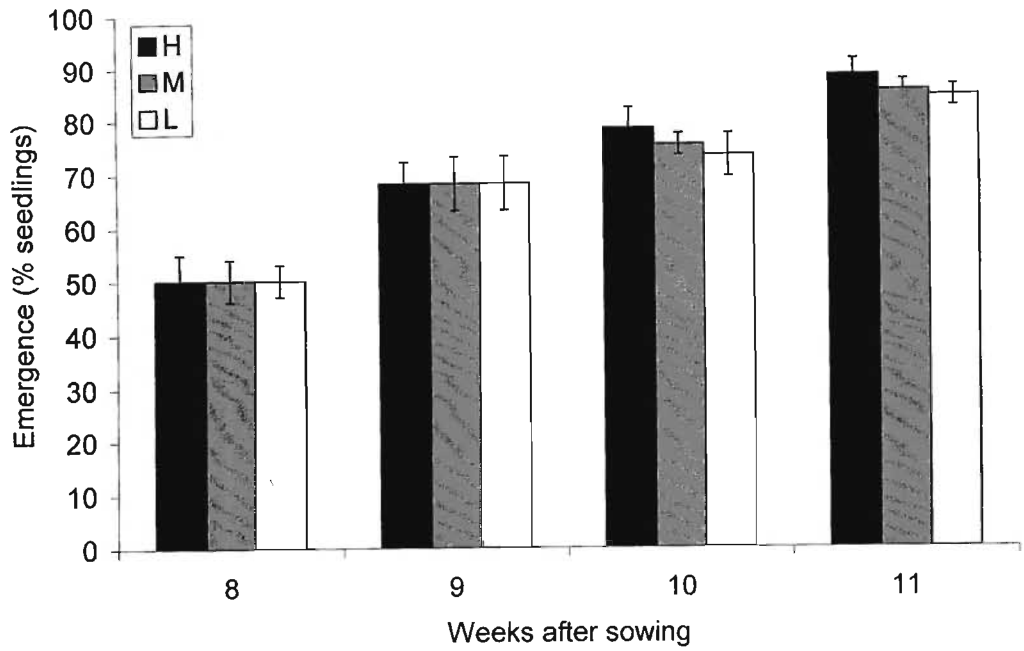


Figure 4.3. Emergence of taro planted at 37000 (H), 24600 (M) and 18400 (L) plants ha^{-1} determined from the eighth week after sowing, when emergence was first observed, to the eleventh week after sowing, when the final crop stand was established.

Among the sites, it was only the Phewa (P) wetland site that showed a significantly higher seedling emergence and final crop stand (Figure 4.4). The Gcabashe (G) site was not significantly different from the two dryland sites (NDA and MTC). The better performance of propagules at the P site suggested that water availability enhanced seedling emergence at the wetland sites compared with the dryland sites (Onwueme, 1978). Note that, although it was not significantly different from the dryland sites, the G site also showed a generally greater (except for week 10) emergence than the dryland sites (Figure 4.4).

shoots produced more vigorous seedlings than the corms without shoots. Similarly, full corms produced more vigorous seedlings than half corms.

The significance of these findings is that planting corms with shoots may enhance the ability of taro plants to withstand environmental stresses associated with poor plant competitiveness during growth.

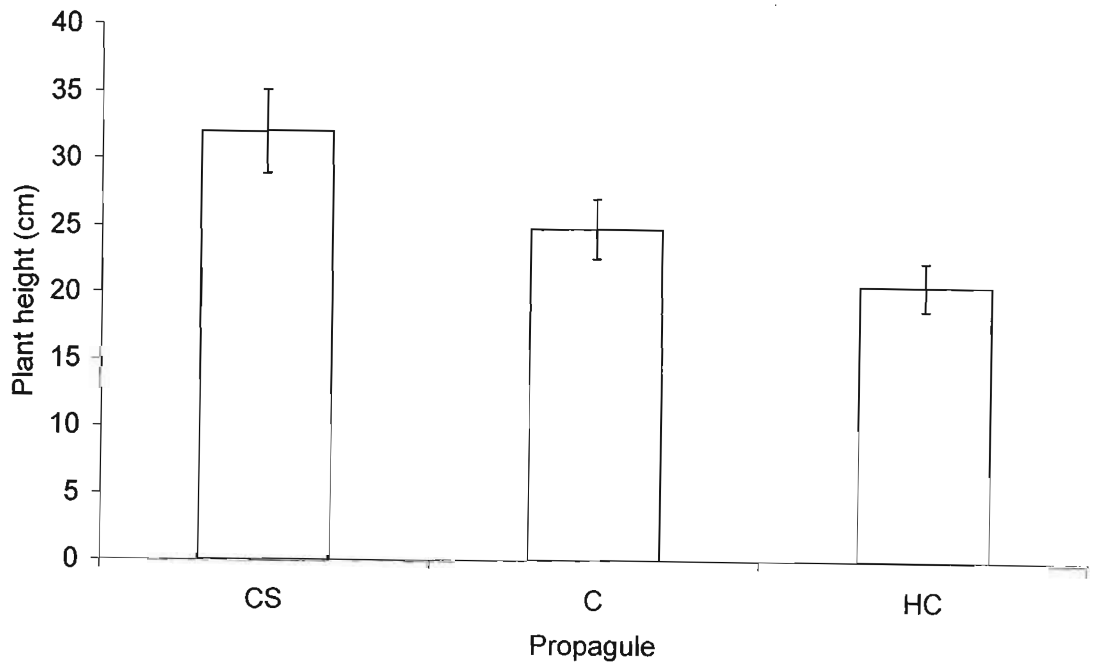


Figure 4.5. Taro plant height in response to propagule type across all sites and planting densities.

Every two weeks, from week 12 to week 18, there was a significant ($P < 0.001$) taro growth (Figure 4.6). The last six weeks of the season, however, were characterised by no increase in plant growth. It is likely that during these last two weeks, taro growth was occurring in the corms, because senescence also ensued at this time.

According to Chandra (1984) and Shih & Synder (1984) corm development in taro commences early and the leaf and the corm develop synchronously up to a maximum canopy attainment at about 20 weeks. After planting and after maximum canopy formation, leaf growth slows down and leaf area declines rapidly but rapid corm growth continues until very little leaf area remains.

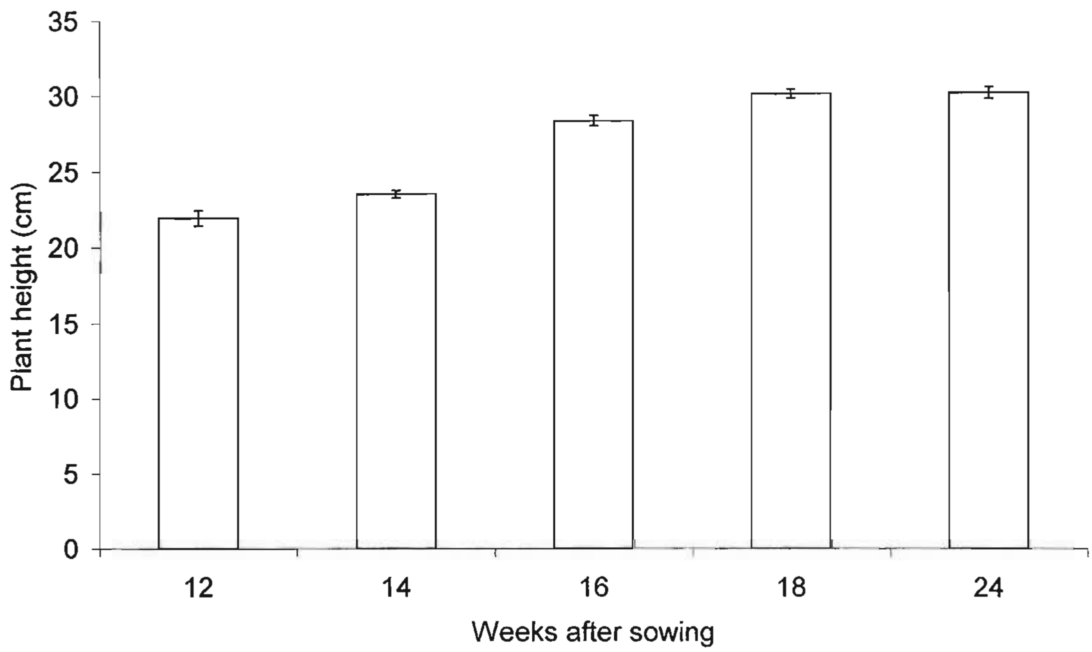


Figure 4.6. Taro growth during weeks 12 to 24 after sowing. Data are means determined across all sites, propagule types and planting densities.

Taro performance with respect to plant height did not categorically separate wetland sites and dryland sites. However, there was a significant difference between sites (Figure 4.7), which indicated that P > G > NDA > MTC. This trend showed that water availability in wetland sites enhanced plant growth, but there was a significant difference between the two wetland sites and no difference between the dryland sites (Figure 4.7).

The positive relationship between stand establishment (Figure 4.4) and plant growth, as shown by site P confirms that taro production is enhanced by wet environments. Taro plant height was greater by ~33% at P site compared with the dryland sites (NDA and MTC), and ~12% compared with site G, which was also a wetland site.

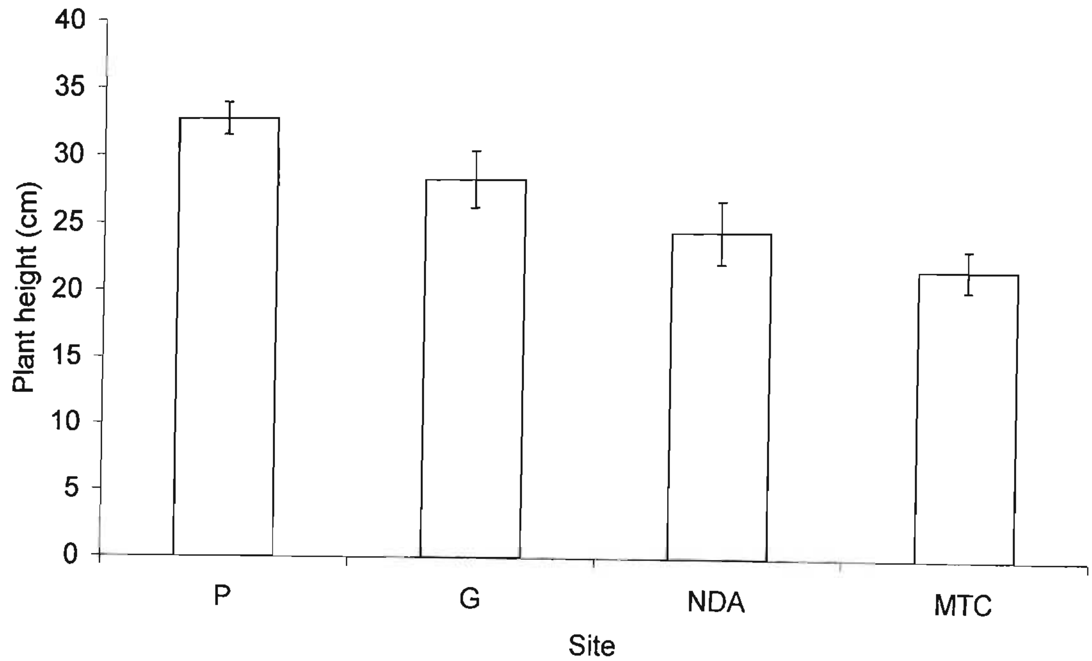


Figure 4.7. Taro plant height at the wetland (P and G) and dryland (NDA and MTC) sites determined at all planting densities and propagule types.

4.3.4 Effect of propagule type, planting density and site on taro yield

The positive effect of corms with shoots on taro performance was observed at harvest, when the yield of plots planted with this propagule was 42% and 66% greater that that produced from full corms without shoots and half corms, respectively (Figure 4.8). It is likely that availability of nutrient reserves in full corms enhanced plant growth and development in the subsequent seedlings until plant maturity. Moreover, an early start in photosynthesis may have improved the performance of corms with shoots, such that accumulation of photoassimilates from the leaves to the corms occurred earlier and in larger quantities compared with corms without shoots.

It was expected that the use of traditional corms (C) in this study would produce a yield similar to that reported by the majority of farmers (5 t ha^{-1}) during the survey of taro production practices at Ndwedwe and Umbumbulu (Chapter 3). However, corms without shoots produced 40% greater yield than that reported by 70% of the farmers producing under wetland and dryland conditions. Half corms, however, produced a significantly lower yield than the farmers' average yield (Figure 4.8), which suggested that this type of propagule may not be acceptable to improve taro production.

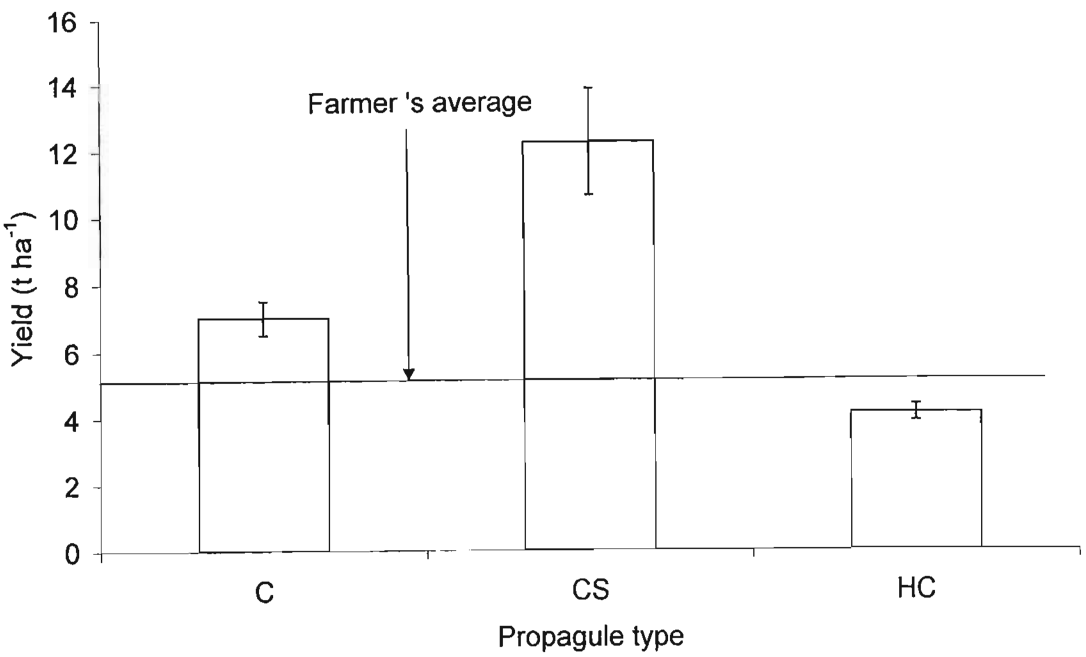


Figure 4.8. Taro yield in response to planting full corms (C), full corms with shoots (CS) and half corms (HC).

Taro yield increased significantly ($P < 0.001$) as plant populations were increased (Figure 4.9) at all sites. These results were not consistent with previous findings about crop emergence and plant growth, where the effect of planting density was not significant (Figure 4.3). A greater number of plants per unit area under high plant populations, hence the number and mass of propagules, may have influenced the increase in yield. It was interesting to note that the average yield reported by the majority of farmers during the survey of production practices was achieved with the lowest planting density (Figure 4.9). This finding suggests that low plant populations may be the reason for low taro yields in the subsistence farming areas of KwaZulu-Natal.

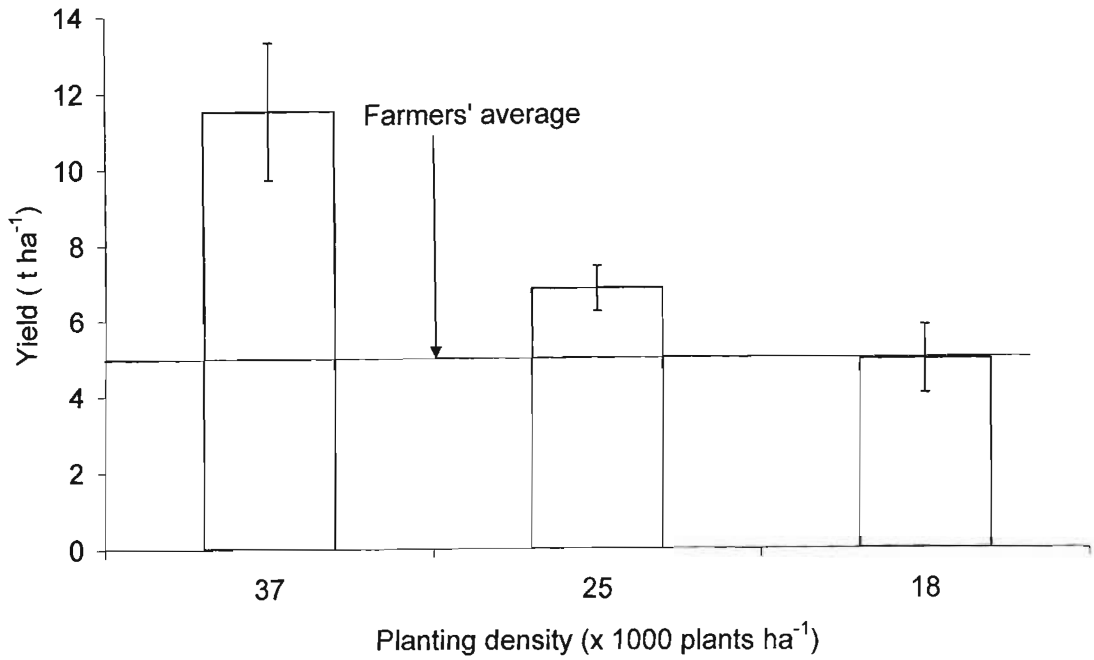


Figure 4.9. Taro yield in response to three planting densities.

These findings agreed with a study reported by Pardales & Villanueva (1984) on the effects of plant population on taro production. Kagbo *et al.* (1973) suggested that the increase in yield is due to the higher number of plants per unit area of land, which intercept solar radiation and thereby enhancing photosynthesis on a unit area basis. Plucknett, De la Pena & Orbero (1970) suggested that apart from giving greater yield, a higher plant population offered an added advantage since it provided much earlier full ground cover which suppressed the weeds effectively.

In agreement with the findings on crop stand establishment and plant growth, the P site showed a significantly ($P < 0.001$) greater yield than all the other three sites (Figure 4.10). The G site, although also a wetland site, was not significantly different from the NDA (dryland site), with respect to yield (Figure 4.10).

The average yield reported by the majority of farmers at Ndwedwe and Umbumbulu was below the yield obtained at the wetland sites, but similar to the dryland site yield, in the present study. Better water availability to a crop that was domesticated in wetland conditions are proposed to be the reasons for a better yield at the wetland sites compared with dryland sites.

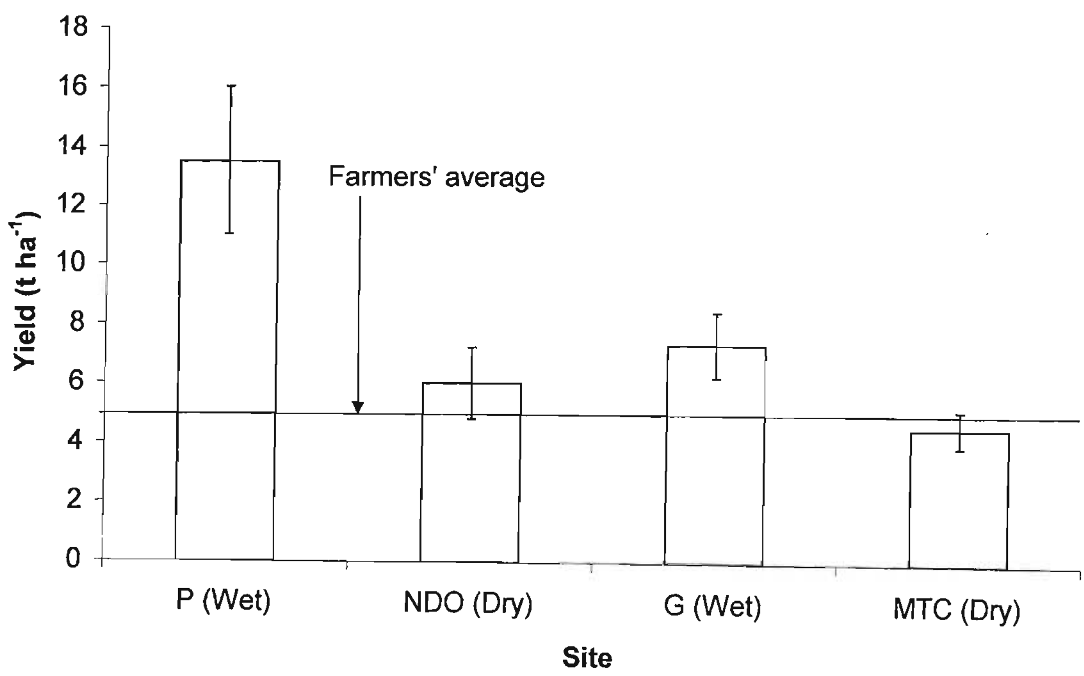


Figure 4.10. Taro yield at wetland (P and G) and dryland (NDA and MTC) sites at Ndwedwe.

4.4 Conclusions

Improvement of taro production by corms with shoots is likely due to the early start of the crop with respect to photosythesis. Low nutrient reserves in half corms likely retard seedling development and subsequently cause a poor plant vigour, and low yields. High planting density does not significantly affect taro performance with respect to emergence and plant growth. However, it causes greater yields by virtue of plant, and possibly corm, numbers. In this study, a clear categorisation of wetland and dryland sites was not achieved, despite the crop performance trend, which favoured wetlands. This trend was largely influenced by crop performance at the P wetland site. The P site was consistently better than the G site, although the latter was also a wetland site. A close examination of the pedological and fertility characteristics of these two sites, however, showed that the G site was more similar to the dryland sites (NDA and MTC) than it was to the P site. This observation suggests that the G site may not be a typical wetland site.

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

The survey conducted during this study revealed that taro is produced on a small scale by subsistence farmers at Ndwedwe and Umbumbulu. Despite that, the crop is an important staple. Attempts to determine traditional practices used in taro production produce little information to show that the present practices are adequate for use in extension services aimed at introducing the crop in new areas. Sustainable production, including consistent successful marketing, of the crop require that there be a sound knowledge base about the cultural crop production practices.

Whereas there was no indication of crop failure due to lack of sound cultural practices, it was clear that exploration of opportunities to enhance productivity existed. These opportunities seemed numerous, judging by the findings discussed in chapter 3, and by personal observation by the author. Among them were those that related to the choice of site, planting material and plant population for taro production. These aspects are directly relevant to the agronomy of taro, and their explanation would have a significant impact on taro research and extension of knowledge about its production. Hence, the present study focussed on determining the effect of producing taro under wetland or dryland conditions, practices that already existed at Ndwedwe and Umbumbulu without supporting data as to show which production site type was more appropriate in terms of productivity.

To compare wetland and dryland sites, with respect to taro productivity, propagule types and planting density were selected as key factors influencing plant performance. Lack of diversity of planting materials and lack of a clear description of planting density, as shown in chapter 3, prompted the selection of propagule types and planting density in this study.

Findings from field experiments showed that growing taro under wetland conditions significantly increased yield. Greater emergence and enhanced shoot growth may have been the two key factors influencing better crop yield under wetland conditions compared with dryland conditions. However, the survey of production practices at Ndwedwe and Umbumbulu showed that there is generally much less land (an order of magnitude) used for wetland cultivation than that which is used for dryland production of taro. Therefore, the positive effect of wetlands on taro yield might be offset by the small areas of cultivated lands. The finding that wetland production was better than dryland production, therefore, suggested that the taro variety that was used in this study prefers high water regimes during its establishment and growth.

Allowing propagules to develop shoots prior to planting enhanced taro yield at both wetland and dryland sites. This finding suggested that, there could be alternative means to improving taro yield to the use of wetland sites. Comparing the average yield attained by the farmers when traditional propagules are used (5 t ha^{-1}) with the yield attained when half corms without shoots were used in this study, it was clear that half corms without shoots were inferior propagules. However, this type of propagule has a potential as a seed production material.

Taro was also shown to respond positively to increasing plant population from 18400 to 37000 plants ha^{-1}. The positive response occurred, regardless of the type of propagule (corms with shoots, corms without shoots or half corms) used. The findings of this study about the response of taro to planting density may be important when farmers make decisions regarding intercropping and control of soil erosion. It was also shown in this study that the farmers were using low planting densities and, hence practised less than optimum land use. The survey showed that the farmers' spacing was approximately 0.9m x 0.6m (interrrow x intrarow). That spacing would produce approximately 18400 plants ha^{-1}, which is equivalent to the lowest plant population used in this study.

Further knowledge about the agronomy of taro could be expanded by investigation of the following aspects, that were raised by the present study:

1. The role of half corms as seed material for taro production,
2. Relative yield efficiency of taro in a multiple crop culture,
3. Contribution of the shoot to taro economic yield,
4. Effect of taro monoculture on soil quality and
5. Taro water use efficiency.

Data produced in the present study will play an important role in improving taro production. Farmers could enhance production by using corms with shoots to reduce time taken to establish a crop stand. That way photosynthesis would be allowed to occur early in the season. A combination of propagules with shoots and high planting density could further enhance production, by improving the ability of a crop stand to photosynthesise and smother weeds.

REFERENCES

ADAMS, H., PATTANJALIDIA L. & CLARK, A., 1988. The effects of metalaxyl and benomyl on post-harvest decay of corms of Dasheen (*Colocasia esculenta* (L) Schott). In: Viith symposium of the International Society for Tropical Root Crops Proceedings–Paris 1985 (ed.) INRA.

ADAMUS, P. R., CLARAIN E .J., SMITH R. D., & YOUNG R. E., 1987. Wetland evaluation technique (WET). US Army Corps of Engineers, Vicksburg, MS. Tech. Rep. T-87.

AGBOR-EGBE, T. & RICHARD, J.E., 1991. Study on the factors affecting storage of edible aroids. *Ann. of App. Biol.* 119: 131-138.

ALEXANDER, J & COURSEY, D.G. 1969.The origins of yam cultivation. In: Ucko, P.J. & Dimbleby, G.W. (eds). The domestication and exploitation of plants and animals, pp. 405-425. G. Duckworth and Co., London.

ARDITTI, J., 1982. Tissue culture of taro: Tissue culture of economically important plants. *Proceedings of the international symposium*, 28-30.

BOWERS, F.A.I., TAKAHASHI, M.& WHITNEY, L.D., 1997. Taro Varieties in Hawaii, pp. 5-20. University of Hawaii, Manoa.

BROUK,D.S., 1975. Plants Consumed by Man. Academic Press, New York.

BRINSON M. M., 1988. Strategies for assessing the cumulative effects of wetland alteration on water quality. Environmental Management 12: 655-662.

CABLE, W.J., 1984. The spread of taro (Colocasia sp.). In: S. Chandra (ed.). Edible aroids, pp.28-36. Clarendon Press, Oxford.

CAMP, K.G.T., 1995. The Bioresourse Units of KwaZulu-Natal. Cedara, Pietermaritzburg.

CHANDRA, S., 1984. Edible Aroids. Claredon Press, Oxford.

COURSEY, D.G., 1976. Yams, *Dioscorea* spp. (Dioscoreaceae). In: Simmonds, N.W. and COURSEY, D.G. (eds). Evolution of crop plants, pp.70-74, Longamn, London.

DE LA PENA R.S., 1975. Nitrofen for Taro weed control. Circular, Cooperative Extension Service, University of Hawaii No.488.

DE LA PENA, R.S., ZAAG, P.V., FOX, R.L.& BELEN, E.H.,1982. The comparative phosphoms requirements of flooded and non- flooded taro. *In : 5th International Symposium on Trop. root and tuber crops*. Hawaii Univ., Honolulu.

DE LA PENA, R.S., 1983. Agronomy. In : Wang, J.K. (ed.) A review of *Colocasia esculenta* and its potentials, pp. 165-167.Univ. of Hawaii Press, Honolulu.

DE LA PENA, R.S., MELCHOR, F. M., 1984. Water use and effeciency in lowland taro production. *Proceedings; 6th Symposium of the International Society for Trop. Root Crops* 1984: 97-101.

DE LA PENA, R.S., MELCHOR, F.M., 1988. Effects of intercropping on growth and yield of upland taro, variety Bun-long. *Trop. Root Tuber Crops Newsletter*. 18, 22-25

DE VOS A.S., 1998. Research at grassroots. pp. 95-106. Van Schaik publishers.

EZUMAH, H.C., 1973. The growth and development of taro. *Colocasia esculanta* (L.) Schott in relation to selected cultural management practices. Abstracts international 34 : 24.

EZUMAH, H.C. & PLUCKNETT, D.L., 1973. Response of taro, *Colocasia esculenta* (L.)Schott to water management, plot preparationa nd population. In: *3rd Int. Symp. Trop.* Root Crops, Ibadan, Nigeria. Food and Agriculture Organisation of the United Nations (FAO) (1992) Rome, Italy.

EZUMAH, H.C & PLUCKNETT, D.L., 1981. Cultural studies on taro, *Colocasia esculenta* (L.) Schott. *J. of root Crops* 7, 41-52.

FATUESI, S., TAUILI, I., TAOTUA, F.& VARGO, A., 1991. Cultural Method of Pest Control on Taro (*Colocasia esculenta Schott*) in American Samoa. No.3 Supplement, 123-127.

FOX, F.W. & NORWOOD YOUNG M.E., 1982. Food from the veld: edible wild plants of Southern Africa. Delta Books, Johannesburg.

GERSTNER, J., 1938. Preliminary checklist of Zulu names of Plants. Bantu Studies, Johannesburg.

GHANI F.D., 1984. Preliminary studies on flowering in taro cultivars in Malaysia . In: S. Chandra (ed.) *Edible aroids*. Clarendon Press, Oxford.

GOODE, D. A., MARSAN A. A. & MICHAUD J. R., 1977. Water resources. In: Radforth and Brawner, (eds.) Muskeg and the northern environment in Canada. University of Toronto Press, Toronto.

HASHAD, M.N., 1956. Transformation of carbohydrates in taro plants during storage.In Onwueme, I.C. (ed.) The tropical Tuber Crops: Yams, Cassava, Sweet potato and cocoyams.pp. 261-267 Ain Shams Univ., Cairo.

HOLLYER, J.R., JOSEPHSON, M.E. & SULLIVAN, J.L., 1997. Taro Mauka to Makai. pp. 18-72.University of Hawaii, Manoa.

IKEDA, K. & NONOYAMA, Y., 1993. Method of liming material application to minimize metsubere corm formation in taro: *Jap. J.of Soil-Sci. and Plant Nutrition* 64(6), 634-641.

INGRAM J., 1991. Wetlands in drylands: The agroecology of savanna systems in Africa. part 2: Soil and water processes. International institute for environment and Development, Drylands Programme.

JIANG,G.Z.,1986.Grain and tuber crop intercropping to increase yield and income. *Nangtong Agric. Exp. Sta*. 9, 9.

JOUBERT F.J., 1995. Review of Taro (*Colocasia esculenta* (L.) Schott). pp.1-42. University of Pretoria.

JOURBERT F.J, 1997. Taro (*Colocasia esculenta*) an under exploited crop in South Africa. *J. of the Southern Afric .Soc. for Hort.* Sci. (7)2, 39-43.

JOUBERT F.J .& ALLEMANN, L., 1998. Madumbe Production Guidelines. Cedara Report

KABEERATHUMMA, S., MOHANKUMAR, B. & NAIR ,P.G., 1985. Nutrient uptake by taro (*Colocasia esculenta*) 2. Uptake pattern of secondary and micronutrients at different stages of growth. *J. of Root Crops* 11(1-2), 51-56.

KAGBO, R.B., DE LA PENA, R.S., PLUCKNETT, D.L.& FOX, R.L., 1973. Mineral nutrition of taro *Colocasia esculenta* with special reference to petiolar phosphorus level and phosphate fertilizer. *Proc.3rd Symp. Inter. Soc.Trop. Root Crops*, pp. 138-44.

KAY, D.E., 1973. Root crops. *Trop. Prod. Inst. Crop. Prod. Dig.* 2 : 71-75, 168-179.

KAY,D.E.1987. Root Crops.pp. 15-33. Tropical Development and Research Institute, London.

LAVESQUE, M.P., MARTHUR S. P. & RICHARD, P. J. H, 1982. A study of physical and chemical changes in a cultivated organic soil based on palynological synchronization of subsurface layers. Naturaliste Canada 109: 181-187.

LIU, Y. & LIU, Y.L.,1995. China Vegetables:Main taro cultivars in and techniques for cultivatingthem. pp. 23-25 .Jiangyan City, Jiangsu Province.

MAGA, J.A., 1992. Taro: Composition and Food uses. Food Reviews International. 8755, 8(3), 443-473.

MAYS, N., & POPE, C., 1995. Rigour and qualitative research. *British Med. J.ournal*, 311, 109-112.

MCCARTAN, S.A., 1994. Vegetative Propagation of *Colocasia esculenta* (L.) Schott. M.Sc. Thesis, Univ. of Natal, Pietermaritzburg, South Africa.

MILES, N. & MANSON, A. D., 1991. Considerations on the sustainability and environmental impacts of intensive pastures. *Journal of the Grassland Society of Southern Africa* 9: 135-140.

MODI, A.T. 2003.What do subsistence farmers know about indigenous crops and organic farming ?Preliminary case in KwaZulu-Natal. Development Southern Africa 20, 673-682.

MORGAN, L.,(1996). Focus groups as Qualitative Research. Qualitative research methods series Vol 16, 2nd (ed.) Sage Publications.

NATURAL RESOURCES SECTION, 2001. Temperature and rainfall Distribution at Umbumbulu and Ndwedwe, Cedara.

NEDUNZIHIYAN, M., 1995. Influence of purple nutsedge on growth and yield of taro.*J. of Root Crops* (21) 2, 113-115.

ODUMLAMI, F.K., 1991. Socio-economic Aspects of Agrogorestry in Ondo State Afforestration Project of Nigeria. Nigerian Journal of Forestry 21(1-2) ,18-21.

O'Hair, S.K. & Asokan, M.P., 1986. Edible aroids. Botany and Horticulture, Horticultural Review 8, 43-99.

OKIGBO, B.M. 1989. Roots and Tubers in Tropical Africa. In : Wickens G.E. Hagen and Day P.(eds) *New crops for food and industry.* Chapman and Hall, London.

ONWUEME, I.C., 1978. The Tropical Tuber Crops : Yams, Cassava, Sweet Potato, and Cocoyams. John Wiley, Chichester, New York, Brisbane, Toronto.

PALIWAL, G.S. & KAVATHEKAR. A.K., 1972. Anatomy of vegetative food storage organs. *Acta Agron. Acad. Sci. Hung.* 21,313-318.

PARDALES, J.R. & VILLANUEVA, M.R., 1984. Cultural management for lowland taro under monoculture systems in the Philippines. In: Chandra, S (ed.) Edible Aroids. pp. 45-51. Claredon Press, Oxford.

PARDALES, J.R., MELCHOR, F.M. & DE LA PENA, R.S., 1982. Effects of water temperature on
the early growth and development of taro. *Ann. Of Tropical. Research* 4 (4), 231-238.

PARDALES, J.R., 1985. Effect of mulch application and planting depth on growth, development and productivity of upland taro. *Ann. of Tropical Research*,727-738.

PASSAM H.C., 1982. Experiments on the storage of eddoes and tannias (*Colocasia and Xanthosoma spp.*) under tropical ambient conditions. *Tropical Science* 24, 39-46.

PLUCKNETT, D.L., DE LA PENA R.S. & OBRERO, F., 1970. Taro (*Colocasia cesulenta*), a Review. *Field Crop Abst.* 23 : 413-426.

PLUCKNETT, D.L., EZUMAH H.C. & DE LA PENA. R.S., 1973. Taro (*Colocasia esculenta*) mechanization experiements in Hawaii.In: *3rd Int. Symp. Trop. Root* Crops, Ibadan, Nigeria.

PLUCKNETT, D.L. & BEEMER H.L., 1981. *Vegetable farming in China.* Westview Press Colorado.

PLUCKNETT, D.L. & WHITE, M.S., 1979. Storage and processing of taro in the peoples Republic of China, 1979. Small-scale processing and storage of tropical root crops. pp.119-123

PURSEGLOVE, J.W.,1972. Tropical Crops. Monocotyledons 1, 58-75. Wiley, New York.

RAMNANAN, N., AHMAD, N., GRIFFITH, S.M.& AHMAD, N.,1995. Fate of CO (NH2) 2-15 N applied to taro (*Colocasia esculenta var. esculenta*) in an acid Vertisol of Trinidad nitrogen economy in acid Vertisol of Trinidad nitrogen economy in tropical soils. Fertilizer Research 42 (1-3), 109-115.

REPPERT, R.T., SIGLEO, W., SRACKHIV, E., MESSMAN, L., & MEYERS, C., 1979. Wetland values: Concepts and methods for wetlands evaluation. IWR Res. Rep. 79-R-1,U.S. Army Corps Engrs., Fort Belvoir, VA.

SEN, H, ADHIKARY, D.D. & DAS, P.K., 1993. Possibility of growing summer vegetables intercropped with taro. J. *of Root Crops.* 19 (1) 52-54.

SHINOHARA, S., INO, M.J., KIMURA, N.& KATSUKITAH, H., 1989. Influence of rotation with taro, wheat and peanut on sweet potatoes and plant nutrients in soil. Bulletin of the Chiba prefectual Agricultural Experiment Station 30, 51-60.

SHIH, S.F.& SNYDER, G.H., 1984. Evopatranspiration and water use efficiency of taro. *Trans. ASAE* 27 , 1745-1748.

SILVERMAN, D., 1985. Qualitative methodology and sociology. Aldershot (Hants.)

SIVAN, P.,1984. Review of taro reseash and production in Fiji. In: *Edible aroids.* ed. S. Chandra S. (ed.) Claredon Press, Oxford.

SIVAN, P, ASHER, C.J., BLAMEY, F.P.C, CRASWELL, E.T. & O'SULLIVAN, J.N., 1996. Effects of potassium on drought tolerance of taro and tannia. In: Asher, C.J. (ed.). pp. 100-104. Mineral nutrient disorders of root crops in the Pacific: *Proceedings of a workshop*, Nukualofa.

SPRIGGS, M., 1980. Taro irrigation in the Pacific: a call for more research. South Pacific bulletin 30 (1), 15-18.

STRAUSS, M.S., MICHAUD J.D., & ARDITTI, J., 1979. Seed storage and germination and seedling proliferation in taro, *Colocasia esculenta* (L.) Schott *Ann. Bot.* 45: 429-437.

STRAUSS M.S., 1983. Anatomy and Morphology of Taro *Colocasia esculenta* (L.) Schott. In: J.K. Wang (ed.) Taro a review of *Colocasia esculenta* and its potentials.pp. 20-33. University of Hawaii Press, Honolulu.

TINDALL, H.D., 1983. Vegetables in the Tropics. pp 52-65. Macmillan Press, Longon.

TAYLOR, D., 1988. Agricultural Practices in Eastern Maputaland. Development Southern Africa 5(4) : 465-481.

VILLANEUVA, M.R. & ABENOJA, E.,1984. Adaptability of taro in the upland under monoculture, crop rotation, and intercropping systems in the Phillipines.. In: S. Chandra (ed.) Edible aroids.pp. 37-44. CLARENDON Press, Oxford.

WANG, J.K., 1983. Introduction. In: Wang J.K. (ed.). Taro a Review of *Colocasia esculenta* and its potentials.pp. 1-13.University of Hawaii Press,Honolulu.

WESTHUYZEN, J.J.N., 1967. Madumbies, Extension Office, Port Shepstone. Reprint from "Farming in South Africa" August 1967.

YOUNG, B.W. 1992. Vegetable production : Madumbies, Horticultural Advisory notes. Cedara Agricultural Development Institute, Pietermaritzburg, South Africa.

ZHONG, N., ZHANG, Y., ZHANG, Y.S. & LIN, X. Y., 1997. The effect of different K sources on yield and quality of some vegetable crops. *Acta AgriculturaeZhejiangensis* 9(3): 143-148.

APPENDICES

APPENDIX 3.1

QUESTIONNAIRE USED FOR THE SURVEY OF TARO PRODUCTION PRACTICES BY SUBSISTENCE FARMERS AT NDWEDWE AND UMBUMBULU DISTRICTS, KWAZULU-NATAL

- The purpose of this questionnaire is to find out about the traditional management practices that KwaZulu- Natal farmers apply when growing taro. This information will be used to help farmers improve their income through taro production.

- THIS INFORMATION IS CONFIDENTIAL AND THE RESPONSES TO THE QUESTIONS WILL ONLY BE USED FOR THE STUDY. FARMERS WILL REMAIN ANONYMOUS AND ONLY GEOGRAPHIC WARDS WILL BE NOTED.

- The participants are requested to respond to questions asked and they are not compelled to answer anyquestions.

- It will take approximately 30 minutes to go through all the questions.

A. Respondent's Information:

Age Group: A.20-30
B.31-40
C.41-80
D.81-100

Gender: 1. Male
2. Female

How big is your family: 1.3-10
2. 11-20

Are you the landowner: 1.Yes______
2. No______

Farm size in which you plant taro (ha):

1. 0.1-0.5
2. 0.6 - 1.0
3. 1.0 –5.0
4. >5

Education level:

A. Never to school
B. Primary school
C. Higher Primary School
D. High School
E. Matric
F. Tertiary Education

B: GENERAL QUESTIONS ON TARO

1. For how many years have you been producing taro?

2. Do you think taro production can alleviate poverty-related problems in South Africa?

3. If Yes, Why?

4. Give an estimation of a good yield you get if you plant 1= 20L container of taro? Answer should be provided in terms of the size of 20L tins used for carrying taro after harvesting.

C. TARO TYPES

a) Do you know where taro originated?

1. Yes

2. No

b) Name and describe the type of taro you know?

Name	Description

c). Which type of taro do you plant the most?

----

d). Why is this type of taro mostly grown?

----

e).Are there reason/s you do not plant the other types of taro?

1. Yes
2. No

f). If E Yes: State the reasons:

----

g) What characteristic of the plant would you use to differentiate the different types of taro?

D. USES AND MARKETING OF TARO

a) Which part of taro do you use for meal preparations?

1. Corms
2. Leaves
3. Corms and leaves

b) Describe how you cook taro:

----

c) Do you know anything about the type of grass used when cooking taro

1. Yes
2. No

d) If C is Yes state the name of the grass:

____

____

e) What is the significance of using the grass

----

f) What types of meals do you prepare from taro?

Name of the meal	Brief description

g) Do you feed taro to children less than 5 years old?

1.Yes
2.No

h) If G is Yes:

----

i). If G is No:

----

j) What do you do with the material not consumed if any?

k) Besides food preparation are there other uses of taro that you know?

1.Yes
2.No
8. Do not know
9. No answer

l) If K is Yes state them

m) If the farmer sells how is the price determined?

n). If the farmer sells taro how much does she charge for 20L tin?

o) Approximately how many 20-L tins do you sell per year especially after a good yield?

p). What is the main problem that is associated with selling of taro:

E: ENVIRONMENTAL ASPECTS

Describe the conditions in which you grow taro in terms of the following aspects:

a) Is the area in which you grow taro?

1. Wetland (swampy area)

2. Non-wetland (dry area)

3. Both

8. I do not know

b) If the answer in A is wetland area is it?:

1.Permanent

2. Seasonal

c) Do you irrigate taro?

1.Yes

2.No

d). If c) is Yes how do you irrigate

----

e). If c)is No why is taro not irrigated?

----

f) Describe the soils you use for taro production?

1. Loam soil
2. Clay soil
3. Sandy soil
4. Other

8. I dot know

g). Is there a problem with this soil type?

1. Yes
2. No

h) If G is Yes, what is the problem with your soil? :

i) Temperature requirements:

----

j) Are you able to produce taro during the winter and summer season (throughout the year)

1.Yes
2.No

k) If j) is Yes does the yield remain good throughout the year? Explain

F. PRODUCTION PRACTICES

a) Within the past three years have you taken soil samples for laboratory analysis before planting taro?

1. Yes
2. No

b). If A is Yes, did you follow the recommendations of the analysis and the extension worker's advise?

1. Yes
2. No
9. No answer

c). If A is No why?

----

d). When planting taro do you use fertilizer? :

----

e) If D is organic fertilizer why do you prefer manure:

----

f) If D is organic fertilizer what type of manure do you use?

----

g) If D is inorganic fertilizer why do you use commercial fertilizers?

----

h) Do you know the difference between taro that had fertilizer application (either organic or inorganic) and that had no fertilizer application at all.

1.Yes

2. No

i) If H is Yes explain how did you note the difference.

j) Do you use crop rotation in a taro field?

1. Yes
2. No

k) If J is Yes after how many years do you crop rotate?

----

l) If J is Yes , which crops do you consider for crop rotation with taro?

1.Maize
2.Dry beans
3. Potatoes
4. Sweet potatoes
5. Maize and dry beans
6. Other

m) Why do you include this particular crop(s) in your crop rotation programme ?

----

n) Do you practise intercropping when growing taro?

1.Yes

2.No

o) If N is Yes which crop do you include in the intercropping programme?

1.Maize
2.Dry beans
3.Sweetpotatoes
4.Other

p) Why the above-mentioned crop ?:

----

q) If N is No is it because?

----

r) When planting taro do you allow the land to rest at a certain stage?

1.Yes

2.No

s) If r) is Yes for how many years ?

----

t) What are the possible benefits that have been derived from resting the land when planting taro?

----

u) What is the interrow spacing of taro?

----

v) What is the intrarow spacing for taro

----

w) Why do you choose this particular spacing?

----

x) During which time of the year do you prepare to plant taro?

1. Spring
2. Summer
3. Autumn
4. Winter

y) Where do you obtain the propagules?

----

z) Which part of taro do you use as seed material?

1. Leaves
2. Corms
3. Both

aa) Do you ever cut taro into pieces to prepare the seed material?

1. Yes
2. No

bb) If Z Yes under which conditions :

----

cc) If you use corms do you use the major corms or daughter corms:

----

dd) If you use major corms how do you identify those that give a good yield:

----

ee) If you use daughter corms how do you identify those that will give you a good yield.

----

ff) Do you harvest taro all at once:

----

gg) How do you harvest taro?

----

hh) Give a description of a good taro crop in terms of size

----

ii) Give a description of a good taro crop in terms of shape

----

jj) Give a description of a good taro crop in terms of firmness

----

----

kk) What type of a container do you use to store taro after harvest?

----

ll) How long can you keep taro in a field after reaching maturity ?

----

mm) Considering soil preparation, planting, weeding and harvesting which management practice would you say consumes the most time when producing taro?

----

nn) Do you do all the production practices yourself?

1. Yes
2. No

oo) If No, who helps you?

1. Family members, give number:

----

2. Hired laborers, give number:

----

pp) How do you pay for your production expenses?

G: DISEASES AND PESTS

a) Do you have disease problems in taro production?

1. Yes
2. No

b) If A is Yes, how did you diagnose the disease?

----

c) If A is Yes in which part of the plant were diseases observed?

----

d) If A is Yes how did you treat the diseases?

----

e) Where did you get the information on how to treat the disease ?

----

f) If A is Yes which diseases caused a huge decrease in the yield?

----

g) Are there pests that are problematic in taro production?

1.Yes

2.No

h) If G is Yes describe the pests that have been observed?

----

i) If G is Yes which pest is a major problem in taro production?

----

j) If G is Yes how did you treat the pests?

----

k) Where did you get the information on how to treat the pests

----

----

* : A Zulu version was used during the survey.

APPENDIX 3.2 CHI-SQUARE TEST RESULTS OF TARO PRODUCTION CONSTRAINTS AT UMBUMBULU AND NDWEDWE DISTRICTS

	Value	Df	Asymp.Sig.(2 sided)
Pearson chi-square	9.129	2	.010
Likelihood Ratio	9.662	2	.008
Linear by linear association	8.156	1	.004
No of valid cases	100		

APPENDIX 4.1

Pedological description of experimental site soils. Sites: P (Phewa), NDO – Ndwedwe District Office, G (Gcabashe) and MTC (Msunduzi Training Centre).

Map: 2930 (Topocadastral)(1:250 000)
Latitude and longitude 29^{0}C27'S/30^{0}58'E
Bioresource group (BRG) 3, Moist hinterland, Ngongoni veld
Bioresource:zb 3

Site	General soil description		Horizon		Soil Depth (mm)		Soil Texture	Perme-ability Class	Diagnostic Horizon		Slope	Land Class	Soil Name	Soil Family	Ecotope
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil			Topsoil	Subsoil					
P	Black (2.5YR2.5/0 moist); Granular; Waterlogged	Black (2.5YR2.5/0 moist); Granular; Waterlogged	O	O	0-500	>500	>35%	3	Organic	Organic	<3%	III	Champagne	2100 (GRASKOP)	K.1.2
NDO	Dusky-red (10R 3/2 dry); Weak	Dusky-red (2.5 YR3/4 dry) Weak	A	B	0-400	400-900	>35%	4	Humic	Red apedal	<3%	II	Inanda	1200 (HIGHLANDS)	A.1.1
G	Reddish-grey (5YR5/1 moist); Mottles	Grey (5YR 6/2 moist)	A	B	0-350	>350	15-35%	6	Orthic	G horizon	4 to 8%	V	Katspruit	1000 (LAMMERMOOR)	I.2.3
MTC	Greyish-brown 10YR 4/2 dry)	Dusky red (2.5 YR 3/2)	A	B	0-600	>600	>35%	5	Humic	Red apedal	<3%	II	Inanda	2200 (GLENARIFF)	A.1.1

APPENDIX 4.2. SOIL ANALYTICAL RESULTS FOR PHEWA (P): UPPER AND LOWER SITE, NDWEDWE DEPARTMENT OF AGRICULTURE (NDA), GCABASHE (G), AND MSUNDUZI TRAINING CENTRE (MTC) SITES.

Soil analytical results

		mg/L						%		
Site	pH (KCL)	P	K	Ca	Mg	Zn	Mn	Acid sat.	NIRS Organic Carbon	NIRS clay
P (Phewa wetland (upper site)	4.46	7	75	1046	310	2.7	5	4	16	50
P-lower lite	4.55	8	86	1642	411	5.5	6	2	16	46
NDO (dryland)	4.64	2	89	500	76	2.8	1	11	>6.0	48
G (wetland)	4.14	5	74	180	150	4.4	3	33	2.1	31
MTC (dryland)	3.95	5	76	176	104	3.8	19	33	<0.5	26

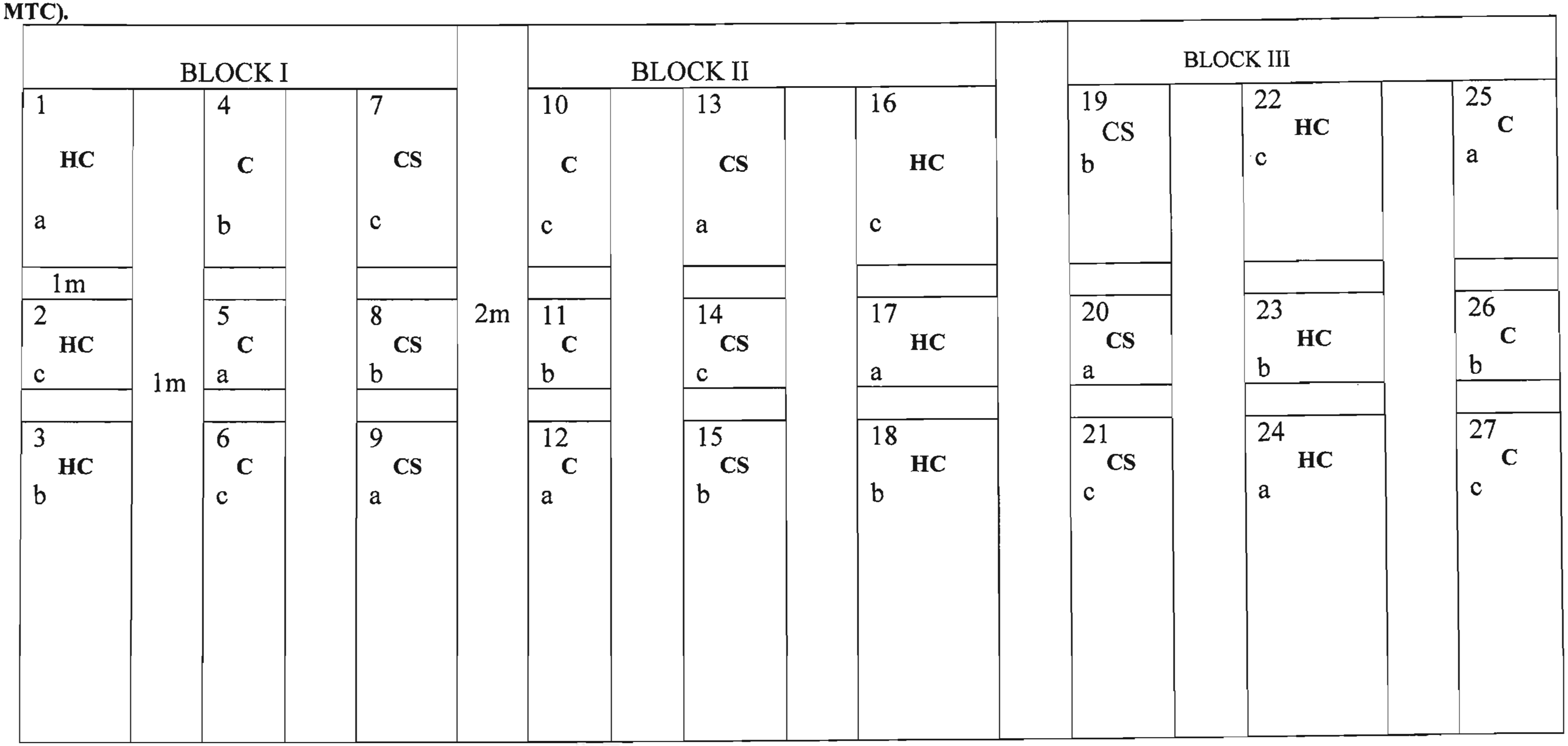
*Phewa site was divided into two sections i.e. upper and lower site due to the nature of the site

APPENDIX 4.3. WETLAND CHARACTERISTICS OF WETLAND SITES P AND G IN RELATION TO THE POSSIBLE LEVEL OF IMPACT (HIGH, MEDIUM OR LOW) OF THE AGRICULTURAL PRACTICES.

Wetland Characteristic	P	G
Flow pattern alteration thereby reducing the degree of wetness (Goode *et al.*, 1977; Lavesque *et al.*,1982; Brinson, 1988; Ingram, 1991)	Medium	Low
Soil disturbance and its frequency (Miles and Manson, 1991)	High	High
Degree to which soil organic matter is likely to decrease as a result of lowered water table / or greater soil disturbance (Ingram, 1991; Miles and Manson, 1991)	High	Medium
The extent to which roughness coefficient of the wetland is decreased (Reppert *et al.*, 1979; Adamus *et al.*, 1987)	Medium	Low

APPENDIX 4.4

PLAN OF FIELD PLOT EXPERIMENT SHOWING PLOT NUMBERS (1, 2, ... 27), PROPAGULE TYPES (C, HC AND CS) AND PLANTING DENSITIES (A = HIGH DENSITY AT 37000 PLANTS HA^{-1}, B = MEDIUM DENSITY AT 24600 PLANTS HA^{-1} AND C = LOW DENSITY AT 18400 PLANTS HA^{-1}) AND PLOT SIZE AND SOME MANAGEMENT SPECIFICATIONS. PLOT SPECIFICATIONS. RANDOMIZATION WAS VARIED FOR EACH SITE (P, G, NDA AND MTC).



Plot size and some management specifications
(a) Subplot size = 4.9 m X 2.9 m
(b) Inter-row spacing = 0.9 m
(c) Intra-row spacing for high, medium and low density, respectively = 0.3, 0.45and 0.6 m
(d) Planted 4 rows plot^{-1} and harvested 2 inner rows
(e) Fertilizer application: none (see Appendix 4.2 for soil analysis)
(f) Weed control: mechanical (hand-hoeing)

APPENDIX 4.5 ANALYSIS OF VARIANCE OF TARO PLANT HEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.	Level of significance
Site	3	9592.73	3197.58	52.80	<.001	**
Week	4	6147.07	1536.77	25.38	<.001	**
Density	2	38.18	19.09	0.32	0.730	NS
Propagule	2	7460.23	3730.12	61.59	<.001	**
Site.Week	12	5182.39	431.87	7.13	<.001	**
Site.Density	6	79.94	13.32	0.22	0.970	NS
Week.Density	8	408.32	51.04	0.84	0.565	NS
Site.Propagule	6	1139.66	189.94	3.14	0.005	**
Week.Propagule	8	1093.88	136.73	2.26	0.023	NS
Density.Propagule	4	292.29	73.07	1.21	0.308	NS
Site.Week.Density	24	471.56	19.65	0.32	0.999	NS
Site.Week.Propagule	24	1136.00	47.33	0.78	0.760	NS
Site.Density.Propagule	12	295.50	24.63	0.41	0.961	NS
Week.Density.Propagule	16	872.93	54.56	0.90	0.568	NS
Site.Week.Density.Propagule	48	983.05	20.48	0.34	1.000	NS

APPENDIX 4.6 ANALYSIS OF VARIANCE OF TARO YIELD

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.	Level of significance
Site	3	1272.92	424.31	4.59	0.05	*
Density	2	847.27	423.64	4.59	0.013	*
Propagule	2	1215.25	607.62	6.58	0.002	**
Site.Density	6	669.82	111.64	1.21	0.312	NS
Site.Propagule	6	810.31	135.05	1.46	0.204	NS
Density.Propagule	4	434.59	108.65	1.18	0.329	NS
Site.Density.Propagule	12	1099.34	91.61	0.99	0.466	NS