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Full Length Research Paper

Diversity of landraces, agricultural practises and traditional uses of watermelon (*Citrullus lanatus*) in Mozambique

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A survey was carried out in three provinces of Mozambique with different agroecological conditions to document traditional knowledge related to cultivation and use of indigenous watermelons, and to describe the diversity of landraces within the country. Semi-structured interviews were used to collect information at the household level or in farmers' watermelon fields. Watermelons were intercropped with the main cereals, mainly sorghum in the driest areas and maize in the more humid areas. Three main types were found: A dessert type with sweet, white to red, spongy flesh, a seed type with white either firm or spongy flesh, and a cooking type with yellow, firm flesh. Watermelon was an important food item consumed before harvest of cereals in the surveyed areas. Sweet dessert types were marketed in both local and urban areas. Only local landraces were cultivated, mostly from farmer-saved seed. Primary *in-situ* description of fruit and seed characters revealed a considerable variation. Significant differences were found among provinces for rind thickness, flesh colour, and seed size. This study highlighted that traditional knowledge related to the cultivation and use of watermelons, and that indigenous landraces persist in Mozambique.

Key words: *Citrullus lanatus*, cropping systems, ethnobotany, germplasm, landrace, traditional plant use, Mozambique, watermelon.

INTRODUCTION

Watermelon (*Citrullus lanatus* (Thunb.) Matsum. and Nakai) is an important horticultural crop, mostly known for its sweet and juicy fruit, grown in warm climates all over the world (Robinson and Decker-Walters, 1997; Jeffrey, 2001). In Africa, watermelon accounted for 5.4% of the harvested area devoted to vegetable production in 2008, and this contributed to the world watermelon production with 4.6% of 99,194,223 tonnes (FAOSTAT, 2008). Watermelon originates from Africa, but the exact geographical origin and domestication process of the crop watermelon is not clear. One probable gene centre is in the Kalahari Desert region where the species can still be found in the wild in various forms (van der Vossen et al., 2004), but it has also been suggested that the origin is in the Sahel Region in Northern Africa (Wasylikowa and van der Veen, 2004).

Watermelon spread from Africa to Asia about 800 AD and to Europe in 961 AD and was subsequently brought to America by Europeans in the 17th Century (Wehner, 2008). Modern watermelon breeding has mainly taken place in the USA, from where many of the well known varieties originate, but also China and other parts of the Far East have played an important role in breeding of cultivated types of the species (Wehner, 2008). C. lanatus is an annual species containing cultivated, semi-domesticates and wild forms, widely distributed in tropical and subtropical areas (Jeffrey, 2001). Different

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infraspecific classification systems have been proposed for this species. One system recognises three subspecies, namely: ssp. *lanatus,* ssp. *vulgaris* (Schrad.) Fursa and ssp. *mucosospermus* Fursa (Fursa, 1981; Jeffrey, 2001). According to Jeffrey (2001), the primitive cultivars and wild forms from the Kalahari Desert known as 'tsama' and the citroides group consisting of cultivars whose rind is used for preserves, jellies and conserves, belong to ssp. *lanatus*. The cultivated watermelon, mainly used as a dessert fruit, is assigned to ssp. *vulgaris*. Lastly, the forms with seeds surrounded by a pericarp, in some countries of West Africa also known as 'egusi melons', are placed under ssp. *mucusospermus*. However, the current trend seems to be towards a classification of the species into only two botanical varieties namely: *C. lanatus* var. *lanatus* (Thunb.) Matsum. and Nakai, including the sweet watermelon and 'egusi' type, and *C. lanatus* var. *citroides* (L. H. Bailey) Mansf., comprising the "tsama" type and citroides group (Dane and Liu, 2007; GRIN, 2010).

Watermelon is mostly cultivated as an under sown intercrop together with cereals or root crops (Matanyaire, 1998; Ikeorgu, 1991) in the same way as other cucurbits (Ndoro et al. 2007). In contrast with legumes where intercropping studies are relatively common (Silwana and Lucas, 2002; Tsubo et al., 2005; Vesterager et al., 2008), there are few intercropping studies regarding watermelon in Africa (Ikeorgu, 1991). Under dry conditions, watermelon is intercropped with pearl millet, the dominating cereal in Namibia (Matanyaire, 1998).

Relatively little is known about the importance of watermelon in Africa. Indications are that watermelon has versatile uses. For instance, farmers grow three different types: dessert types, seed types and cooking types at the northern border of the Kalahari Desert (Maggs-Kölling et al., 2000). In West African countries, the habit of using watermelon seed as a food source is reported (Loukou et al., 2007). A survey carried out in Benin indicates that watermelon seed may be more important as a food source than previously anticipated (Achigan-Dako et al., 2008). The so called 'egusi' seed crops, also including other cucurbit species, were ranked among the 10 most important crops, and watermelon accounted for 70% of the cultivated area of 'egusi' seed crops (Achigan-Dako et al., 2008). From a nutritional point of view, the red and sweet watermelon flesh is an important source of carotenoids, including lycopene and β-carotene, a precursor of vitamin A (Setiawan et al., 2001; Edwards et al., 2003). Further, watermelon flesh is a rich source of citrulline, which can be metabolised to arginine. This amino acid is a substrate for the synthesis of nitric oxide and it plays a role in cardiovascular and immune functions (Collins et al., 2007).

Species in the genus *Citrullus*, in particular wild types, are adapted to water deficit stress (Kawasaki et al., 2000; Akashi et al., 2001; Yokota et al., 2002). This is of interest in the view of climate change and the need for plants that are adaptable to drought prone areas. Previous studies of indigenous genetic resources of watermelon seem mainly to relate to West Africa. It is of interest also to study landraces, agricultural practises and traditional uses of watermelon in other regions of Africa to broaden the understanding of the diversity within the plant, for instance to make local and even region specific conservation strategies, and to identify the potential of local genetic resources to enhance food security, nutrition and income generation. With this in mind, the present survey was carried out in three agroecologically different areas of Mozambique to assess landrace diversity, crop management practises and seed systems of watermelons from semi-arid zones to more humid conditions. The study also included a germplasm collection and a primary *in-situ* characterization of fruits and seeds of landraces.

MATERIALS AND METHODS

Site selection

A survey mission was carried out in three main watermelon growing areas, namely the Province of Cabo Delgado (Northern Mozambique), the Province of Manica (Central Mozambique) and the Province of Gaza (Southern Mozambique), identified on the basis of informal interviews with extension officers at the National Directorate of Agriculture Extension (Figure 1). The actual survey areas in each province were identified in consultation with local extension officers after preliminary interviews with key informant farmers. The survey took place during March to April 2008 at the end of the rainy season. The survey areas represented a gradient of annual rainfall: relatively high rainfall (1000 to 1400mm, Cabo Delgado), medium precipitation (500mm to 1000mm, Manica) and semi-arid areas (400 to 600mm, Gaza). The three provinces were dominated by different ethnic groups: Macua and Maconde in Cabo Delgado, Ndau, Xibarue/Ximanica and Nhungue in Manica, and Changane in Gaza.

Data collection

The survey included 51 watermelon farmers: 23 from Cabo Delgado, 9 from Manica, and 19 from Gaza Province (Figure 1). Semi-structured interviews were used to collect information on cropping systems, seed supply and storage and plant uses. Interviews were held at the household level or in farmers' watermelon fields and the response was given by the farmer on behalf of the household. In cases where other family members were available, they were given the opportunity to discuss and agree on the response on behalf of the household. Local extension officers assisted with interviews and translation from local languages.

Primary *in-situ* characterisation

The germplasm collection was carried out in late March in Cabo Delgado and early April in Manica and Gaza Provinces to match the harvesting time of the crop in each area, based on information gathered from the local extension officers. The seed samples were collected either from farmers' traditional seed storage facilities/ containers or from single fruits, selected by farmers in the field.

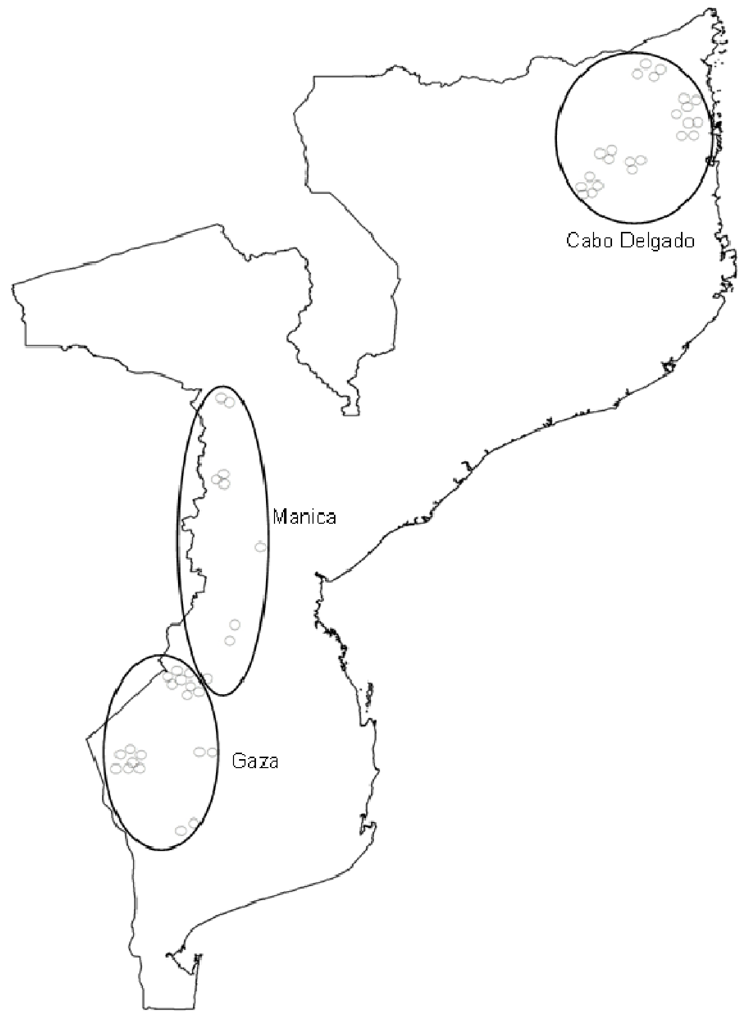

Figure 1. Map of Mozambique with provinces and sites where the watermelon survey in the present study was carried out.

The collection strategy was to collect the maximum of diversity recognised by the farmers in fields and seed stores, plus additional types identified during the survey period.

The *in-situ* primary characterisation was carried out on the basis of descriptors developed by Eastern Africa Plant Genetic Resources Network (ARC, 2007). Only fruit and seed traits were recorded due to the advanced development stage of the crop during the collection. The traits recorded included fruit rind thickness, fruit flesh colour and seed size. In addition, other seed traits were studied after the collection. A sample of each accession is kept at the National Plant Genetic Resource Center, Agriculture Research Institute of Mozambique.

Data analysis

Data analysis was carried out on the total number of responses per province for each question. Fisher's exact tests were made by using the statistical programme R (R Development Core Team, 2010) to assess differences among the three provinces.

RESULTS

Cropping systems and management practises

Watermelon was grown as a rain fed crop, intercropped with the dominating cereal food crops by 94.1% of respondents, and more than half of respondents (58.8%) sowed the crop at the beginning of the rains (Table 1). The practise of sowing at the beginning of the rains was mainly pronounced in the semi-arid Gaza (84.2%) and the medium humid Manica (88.9%), whereas in the more humid Cabo Delgado only 28.6% of respondents sowed watermelon at the start of the rain.

Direct sowing was practised, either in holes or by scattering the seeds on the soil in the field. Scattered sowing was mainly used in connection with dry sowing, sometimes in mixture with pumpkin seed to obtain a more

Table 1. Cropping systems related to watermelon cultivation in three provinces of Mozambique.

	Cabo Delgado (N[1] = 23)		Manica (N = 9)		Gaza (N = 19)		Total (N = 51)		P^3
	%	R^2	%	R	%	R	%	R	
Sowing condition									
Dry sowing	57.1	(12) [4]	55.6	(5)	21.1	(4)	41.2	(21)	ns
Start of rains	28.6	(6) [4]	88.9	(8)	84.2	(16)	58.8	(30)	<0.001
Late sowing	14.3	(3) [4]	0.0	(0)	0.0	(0)	5.9	(3)	ns
Water supply									ns
Rainfed	87.0	(20)	100.0	(9)	100.0	(19)	94.1	(48)	
Water can	13.0	(3)	0.0	(0)	0.0	(0)	5.9	(3)	
Intercropping system									<0.001
Maize	56.5	(13)	66.7	(6)	26.3	(5)	47.1	(24)	
Maize and sorghum	4.3	(1)	11.1	(1)	0.0	(0)	3.9	(2)	
Maize and rice	17.4	(4)	0.0	(0)	0.0	(0)	7.8	(4)	
Maize and cassava	8.7	(2)	0.0	(0)	0.0	(0)	3.9	(2)	
Sorghum	0.0	(0)	22.2	(2)	52.6	(10)	23.5	(12)	
Pearl millet	0.0	(0)	0.0	(0)	21.1	(4)	7.8	(4)	
Vegetables	13.0	(3)	0.0	(0)	0.0	(0)	5.9	(3)	

[1] N: Number of interviews carried out. [2] R: Number of respondents. [3] *P*: Fisher's exact test, ns: Not significant at 5% level. [4] In Cabo Delgado only 21 respondents answered the question related to sowing conditions. Percentages are accordingly calculated on the basis of these 21 respondents.

or less covered canopy under the cereal crop. Watermelon was grown in several intercropping systems of which the most common was the combination with maize (47.1%) or sorghum (23.5%), with significant regional differences (Table 1). Maize was the common intercrop in the systems in Cabo Delgado (56.5%) and Manica (66.7%), whereas sorghum was the common intercrop (52.6%) in the drier Gaza. Inter-cropping with maize and upland rice was found only in Cabo Delgado, while intercropping with pearl millet was found only in the Gaza.

No fertiliser or agrochemicals were used in the surveyed areas, and this practice was general for all crops, except for an intensive cropping system involving vegetables in one village in Cabo Delgado. This cropping system was quite different from the traditional systems described above.

Here watermelon plants were established at the end of the rainy season in April and intercropped with cash crops of vegetables, mainly tomatoes, with irrigation using watering cans. Plants were raised in seed beds and later transplanted into the field. The farmers used organic matter as fertiliser and agro-chemicals for plant protection, and acquired seed from informal markets. Thus all together this system represented a more intensive way of production.

However, all varieties collected during the mission from this area seemed to be local landraces, and no moderncommercial varieties were identified.

Seed supply, selection and storage

Most farmers relied on their own self-saved seeds (94.1% of respondents) stored without any special treatment (Table 2). Overall, the majority of farmers (60.8%) reported that they did not make seed selection for the next growing season. However, some farmers stored seeds with different colour apart but bulked them in preparation for sowing.

Some farmers also maintained that they were able to distinguish the pink flesh colour from the remaining colours, based on the whole fruit appearance before cutting. Testing this in practice revealed some uncertainties. Most farmers in Gaza (73.7%) selected seeds at harvest for the next cropping season based on fruit characteristics. The most important criterion for selection was tasty and sweet fruit flesh.

A wide range of seed containers, namely glass and plastic bottles (51% of respondents); calabashes (33.3% of respondents), tins or pots (25.5% respondents) and sisal bags (15.7% of respondents) were used for watermelon seed storage. The use of calabashes for watermelon seed storage was more common in Cabo Delgado (52.2% of respondents) and Manica (33.3% of' respondents) than in Gaza (10.5% of respondents). In addition, a traditional plant based seed storage container was also used, called 'Xifunge' (Gaza) or 'Colombo (Cabo Delgado). This consists of a cylindrical envelope of a braided mat of grass tied around the seed and hung in

Table 2. Seed supply, selection and storage of watermelon seed in three provinces of Mozambique

	Cabo Delgado (N[1]=23)		Manica (N=9)		Gaza (N=19)		Total (N=51)		*P*[3]
	%	R[2]	%	R	%	R	%	R	
Seed supply									ns
Farmer-saved seed	87.0	(20)	100.0	(9)	100.0	(19)	94.1	(48)	
Purchased, informal market	13.0	(3)	0.0	(0)	0.0	(0)	5.9	(3)	
Seed selection for next season									<0.001
No seed selection	82.6	(19)	77.8	(7)	26.3	(5)	60.8	(31)	
Seed selected at harvest	17.4	(4)	22.2	(2)	73.7	(14)	39.2	(20)	
Seed storage									
Bottle	56.5	(13)	33.3	(3)	52.6	(10)	51.0	(26)	ns
Calabash	52.2	(12)	33.3	(3)	10.5	(2)	33.3	(17)	0.013
Sisal bag	13.0	(3)	22.2	(2)	15.8	(3)	15.7	(8)	ns
Tin or pot	17.4	(4)	44.4	(4)	26.3	(5)	25.5	(13)	ns
Xifunge/Colombo[4]	4.3	(1)	0.0	(0)	15.8	(3)	7.8	(4)	ns

[1]N: Number of interviews carried out. [2]R: Number of respondents.[3]*P*: Fisher's exact test, ns: Not significant at 5% level. [4]A traditional seed storage method consisting of a cylindrical envelope of a braided mat of grass tied around the seed and hung in a tree.

a tree. This system was also used for storage of seed of the major crops.

Crop uses and purpose of production

Watermelon was a multi-purpose crop and it was used for food by all respondents, non-alcoholic beverage (39.2% of respondents), alcoholic beverage (27.5% of respondents), medicine (2% of respondents) and fodder (5.9% of respondents) (Table 3). However, the use of stems and fruits of watermelon to feed livestock was only reported in Gaza. The use of watermelon as a medicinal plant was only mentioned by one respondent. Further interview with this respondent revealed that it was believed that leaf macerates cured ear aching and that the fruit flesh cleaned the stomach and had an aphrodisiac effect.

Almost all parts of the plant: fruits, seeds and leaves/ stems were used for various purposes with the tendency that seeds were used by all households in Cabo Delgado (100%) and less in Manica and Gaza (Table 3). The fruits were used for fresh consumption by 94.1% of respondents, and 27.5% fermented the juicy flesh to produce traditional wine, called 'xicalavatla'. This practise was more common in Gaza (68.4% of respondents), to a lesser extent in Manica (11.1% of respondents), while in Cabo Delgado no alcoholic beverage processing was reported. Some respondents (45.1%) used cooked young leaves and fruits as vegetables for human consumption. Flour, prepared by pounding either raw or roasted seeds, which could be coming from any of the types, was widely used in all provinces as a food condiment to give taste and thicken vegetable based dishes (74.5%). This dish was considered a speciality to be made for special occasions, such as the visit of in-laws. According to traditions, this dish is served to show the appreciation of in-laws.

Most of the production of watermelons was destined for household-consumption (70.6%), while the excess was mostly sold in local markets (29.4%). In Cabo Delgado, some road side sales were observed during the survey. In Gaza, an informal link between watermelon producers and big markets in Maputo was established by women traders living in Maputo. The women travelled to informal village markets to buy watermelons from farmers, sometimes coming from very remote villages. They jointly hired a lorry and transported the watermelons to be sold in Maputo about 400 km away, half of the distance travelling on gravel roads.

Primary *in-situ* characterisation

The primary *in-situ* characterisation was carried out on single fruits of 78 accessions from farmers' fields and revealed significant differences among accessions from the three provinces with regard to fruit rind thickness, flesh colour, and seed size (Table 4). In the three provinces the genotypes were called by different names, according to local languages, but apparently also according to types. The names usually reflected the colour of the flesh, or some other characteristics, such as taste. The province of Cabo Delgado had a relatively high number of watermelon types with thick rind (40% of the accessions) compared to Gaza and Manica, where only 8.3% and 4.5% of the characterised accessions had a thick rind, respectively. Overall, the fruit flesh colour of watermelon

Table 3. Plant uses and purpose of production of watermelon in 3 provinces of Mozambique.

	Cabo Delgado (N[1]= 23)		Manica (N=9)		Gaza (N=19)		Total (N=51)		*P*[3]
	%	R[2]	%	R	%	R	%	R	
Plant uses									
Food	100.0	(23)	100.0	(9)	100.0	(19)	100.0	(51)	ns
Non-alcoholic beverage	52.2	(12)	44.4	(4)	21.1	(4)	39.2	(20)	ns
Medicine	0.0	(0)	11.1	(1)	0.0	(0)	2.0	(1)	ns
Alcoholic beverage	0.0	(0)	11.1	(1)	68.4	(13)	27.5	(14)	<0.001
Fodder	0.0	(0)	0.0	(0)	15.8	(3)	5.9	(3)	ns
Part used									
Fruits	95.7	(22)	100.0	(9)	94.7	(18)	96.1	(49)	ns
Seeds	100.0	(23)	66.7	(6)	73.7	(14)	84.3	(43)	0.008
Leaves and stems	17.4	(4)	22.2	(2)	26.3	(5)	21.6	(11)	ns
Preparation									
Fresh	91.3	(21)	100.0	(9)	94.7	(18)	94.1	(48)	ns
Cooked	43.5	(10)	44.4	(4)	47.4	(9)	45.1	(23)	ns
Seed pounded for flour	78.3	(18)	66.7	(6)	73.7	(14)	74.5	(38)	ns
Juice or flesh fermented	0.0	(0)	11.1	(1)	68.4	(13)	27.5	(14)	<0.001
Purpose of the production									ns
Mainly household consumption	78.3	(18)	66.7	(6)	63.2	(12)	70.6	(36)	
Mainly sold to local market	21.7	(5)	33.3	(3)	36.8	(7)	29.4	(15)	

[1]: Number of interviews carried out. [2] R: Number of respondents.[3]*P*: Fisher's exact test, ns: Not significant at 5% level.

types varied from white/cream to light red/pink or red colour, with white/cream flesh types being the most frequent (42.3% of the accessions). Such white fleshed types were most often found in Cabo Delgado (60%) compared to Manica (45.5%) and Gaza (30.6%).

Fruit and seed appearance generally exhibited variation in farmers' fields, but could be grouped into three main types (Table 5 and Figure 2). The three main types included: a dessert type with spongy flesh of either white, light red or red colour, a seed type with either firm or spongy white flesh, and a cooking type with firm, yellow flesh. The sweetness of these types varied from low to high. The dessert type was common in all three provinces. The seed type could be further differentiated into two forms with different flesh characteristics. One had firm, white flesh and produced small non-sweet fruits (10 to 15 cm diameter), and was found in Cabo Delgado and Gaza. Seeds from this type were extracted after fermentation of the fruit flesh, and the remaining flesh was fed to livestock. This type of *C. lanatus,* known as 'kutasse' (Macua language) in Cabo Delgado, was by some of the respondents considered a species different from watermelon. Farmers claimed that this type of watermelon grew in the wild and spread through animal dung.

Another seed type had spongy, white and non-sweet flesh and produced larger fruits (18 to 20cm diameter). It was only found and used for extraction of seed in Gaza. After the survey, a visit was again undertaken to Gaza. Here, a cooking type of watermelon was now encountered: a type with yellow, firm flesh. For preparation, the flesh can be boiled separately or with other vegetables and is then mashed and served as porridge. This type was found in two villages. When interviewing the extensionist participating in the survey mission in the North of Gaza, it was confirmed that this type was common in the Northen part of Gaza, and the Southern part of Manica. On the contrary, extensionists from the Northern part of Manica and Cabo Delgado were not aware of this type.

The seeds were highly variable in colour: white, cream, yellow, tan, red, grey, brown or black, with or without cream, yellow or black rim or eye. However, red seeds were only found in the pink/light red flesh dessert type in Cabo Delgado (Figure 2). The seed type with firm flesh, a relatively small fruit size, and white or cream seeds, was only reported in Cabo Delgado and Gaza. The seed type with spongy flesh and white seed was found only in Gaza. Two accessions of the yellow fleshed type had cream coloured seeds.

Table 4. *In situ*-characterisation of selected fruit and seed traits of watermelon in three provinces of Mozambique.

	Cabo Delgado (N[1]=20)		Manica (N=22)		Gaza (N=36)		Total (N=78)		P^3
	%	R^2	%	R	%	R	%	R	
Rind thickness									0.004
Small (≤ 1cm)	20.0	(4)	36.4	(8)	13.9	(5)	21.8	(17)	
Medium (> 1cm ≤ 2cm)	40.0	(8)	59.1	(13)	77.8	(28)	62.8	(49)	
Large (> 2cm)	40.0	(8)	4.5	(1)	8.3	(3)	15.4	(12)	
Flesh colour									0.025
White/cream	60.0	(12)	45.5	(10)	30.6	(11)	42.3	(33)	
Pink/light red	10.0	(2)	45.5	(10)	38.9	(14)	33.3	(26)	
Red	30.0	(6)	9.1	(2)	30.6	(11)	24.4	(19)	
Seed size									<0.001
Small (≤ 0.7cm)	5.0	(1)	9.1	(2)	0.0	(0)	3.8	(3)	
Medium (> 0.7cm ≤1cm)	85.0	(17)	90.9	(20)	16.7	(6)	55.1	(43)	
Large (>1 cm)	10.0	(2)	0.0	(0)	83.3	(30)	41.0	(32)	

[1] N: Number of accessions characterised. [2] R: Number of accessions which scored the trait.[3] *P*: Fisher's exact test, ns: Not significant at 5% level.

DISCUSSION

It is clear from the present study that watermelon was grown as a companion crop in combination with the most widely cultivated cereal crop in each of the regions surveyed. This cropping system may be advantageous as intercropping has been reported to be an effective strategy adopted by farmers as insurance against complete crop failure to ensure food supply and income needs (Tsubo et al., 2005; Vesterager et al., 2008). Equally important, an increase of total return from unit of land was reported when cassava and maize were intercropped with vegetables including watermelon in southern Nigeria (Ikeorgu, 1991). In the present study, maize was the major cereal crop intercropped with watermelon in all surveyed areas, except the semi-arid Gaza, where sorghum was the dominating cereal intercrop. Matanyaire (1998) described a rather similar intercropping system in Namibia under similar semi-arid conditions, where watermelon also was intercropped with pearl millet.

In the northern part of Mozambique, where the rainy season is longer, and annual precipitation is higher, watermelon was predominantly grown under a well developed canopy of maize. This is rather similar to the intercropping system previously described for southern Nigeria, where watermelon was intercropped with maize and cassava (Ikeorgu, 1991). In Benin, watermelon is also grown in areas with a rather high precipitation, but intercropped with more crop species than found in Mozambique, for example in association with cotton (*Gossypium hirsutum*) and yam (*Dioscora* sp.), and these cropping systems are mainly found in home gardens (Achigan-Dako et al., 2008). Another important benefit of intercropping with watermelon is that fruits can be harvested before the main cereal intercrop, and fruits can be stored for some time to provide food security during periods with food scarcity.

Watermelon uses seem to vary considerably between regions within Africa and some uses reported from other countries were not recorded in this study in Mozambique. For instance, watermelon seed used for oil extraction is found in Namibia (Maggs-Kölling and Christiansen, 2003) and its important use for thickening in traditional 'egusi' soups of West Africa (Loukou et al., 2007) were not mentioned. However, seed was used as a highly valued condiment, particularly for special festive dishes. In contrast, the fruits were commonly used for alcoholic beverages in some provinces, depending on ethnicity and religious belief. The use of watermelon as an important source to enhance food security and nutrition in rural communities seemed clear as 70.6% of the crop in the present study was used for household consumption. Dovie et al. (2003) attributed monetary value to smallholder harvested crops grown in a semi-arid village in the Limpopo Province (South Africa), neighbouring the province of Gaza. Watermelon consumed on farm contributed with 20.3% of the total crop value in the households, highlighting the importance of the crop for livelihood and food security.

Vitamin A deficiency is a serious health problem in many Sub-Saharan African countries affecting 43.2 million children below the age of 5 years (Aguayo and Baker, 2005; Nojilana et al., 2007). This also includes Mozambique, where 2.3 million children below the age of 5 are vitamin A deficient (Aguayo et al., 2005). A food-based approach introducing orange-fleshed sweet potatoes in Mozambique has proven efficient in

Table 5 Names, flesh and seeds characteristics of seed, cooking and dessert types of watermelon in Mozambique based on a survey carried out in the Provinces of Cabo Delgado, Manica and Gaza.

Province/Type	Seed types		Cooking type[1]	Dessert types (more or less sweet)		
	Firm, white flesh (Figure 2a)	**Spongy, white flesh (Figure 2b)**	**Firm, yellow flesh (Figure 2c)**	**Spongy, white flesh (Figure 2d)**	**Spongy, pink/light red flesh (Figure 2e)**	**Spongy, red flesh (Figure 2f)**
Cabo Delgado						
Language: Local name:	*Macua*: Kutasse			*Macua:* Maraca Yotheela *Makonde:* Rangui Yanaswe	*Macua:* Maraca Yoquilae	*Macua:* Maraca Yocherya *Makonde:* Rangui Yanauvi
	(2) [2] Cream seed	(0)	(0)	(10) Black seed with cream eye	(2) Red seed	(6) Brown or black seed with or without black rim or eye
Manica						
Language: Local name:			*Changana:* Mariwa (Southern part)	*Nhungue*: Yoyera *XiManica and Ndau:* Macthena	*Nhungue:* Yotuwa *XiManica:* Mavinho	*Nhungue:* Yofira *Ximanica:* Bvembe Tchuco
	(0)	(0)	(0)	(10) Cream, tan or black seed with black or cream rim or eye	(10) Cream, brown or black seed with or without black or yellow rim or eye	(2) White seed
Gaza						
Language: Local name:	*Changana:* Kheva Yakwati('wild')	*Changana*: Kheva Yobasa	*Changana:* Mariwa	*Changana:* Kheva Yobasa	*Changana:* Kheva Yaribungo	*Changana:* Kheva Yopfsuka
	(1) White seed	(1) White seed	(2) Grey, tan	(11) White, cream, yellow, grey or black seed with or without black rim or eye	(13) White, cream or brown seed with or without black or yellow rim or eye	(11) Cream, tan or brown seed with or without black rim

[1] The cooking type was not revealed during the actual survey mission, but during a later visit in Gaza, followed up by contact to extensionists in Gaza, Manica and Cabo Delgado. [2] The number of accessions collected.

increasing the vitamin A status (Low et al., 2007). However, the role of other locally grown crop which are also important sources of vitamin A, such as watermelons (Setiawan et al., 2001; Edwards et al., 2003) may be assessed to strengthen this approach. Watermelons are already cultivated in Mozambique, and they could become a central component to enhance the vitamin A status, particularly in drought prone areas where it may be difficult to grow other crop providers of vitamin A. Bioavailability of β-carotene, a precursor of vitamin A, may also be higher when consumed in diets containing oil (van het Hof et al., 2000). The oil rich seeds of watermelon may in this way be prepared in combination with fruit flesh to enhance bioavailability of β-carotene from watermelons, and even from other locally grown β-carotene rich vegetables (Das et al., 2002).

A potential for expansion of production and marketing of the sweet types may exist, particularly in Gaza, where small farmers were linked to market outlets in Maputo by women traders living in Maputo. The intensive vegetable

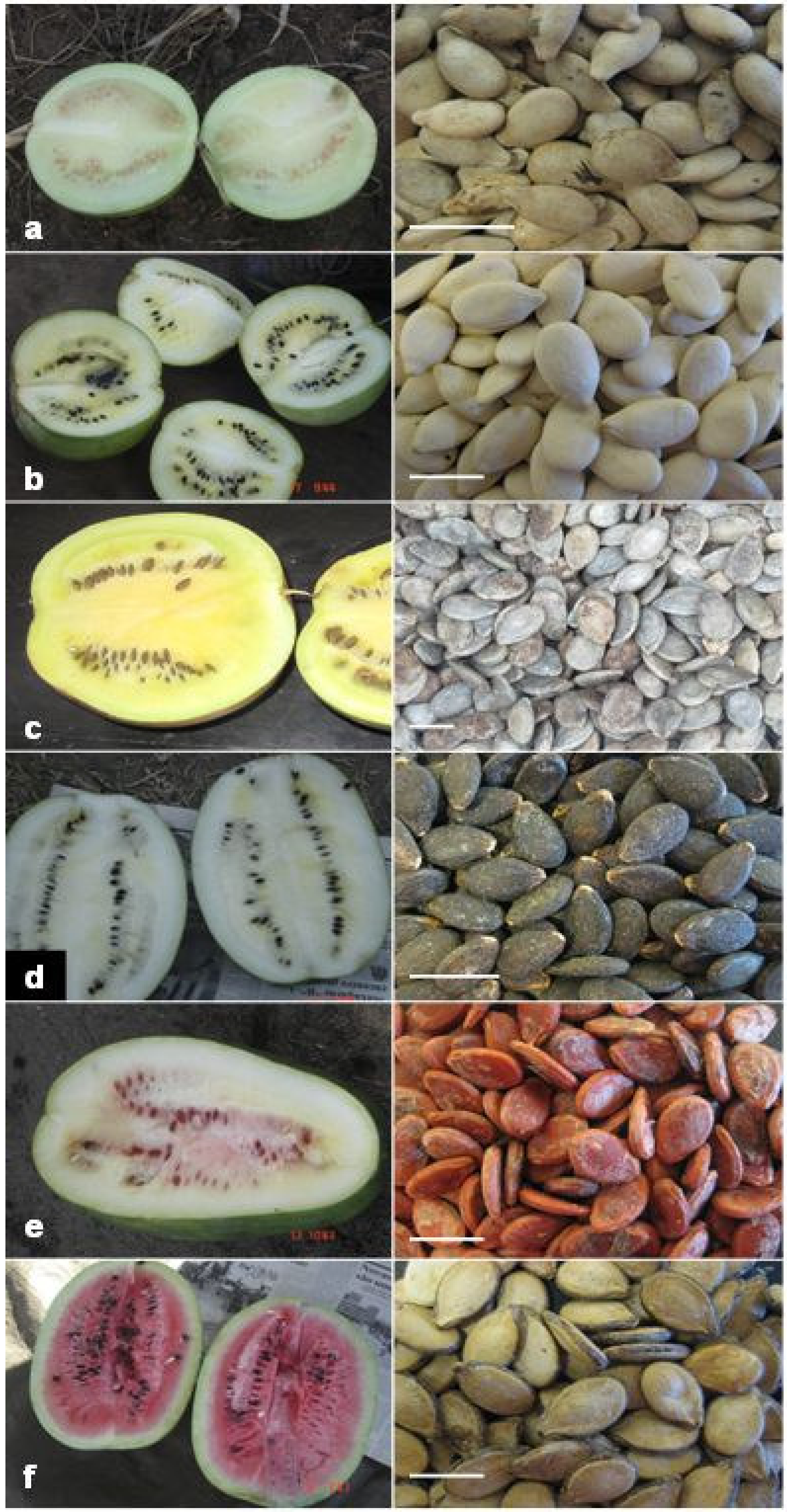

Figure 2. Examples of cut fruits and seeds of three major types of watermelons in Mozambique. The seeds are representatives of the three types, but not necessarily from the same fruits as those cut. Seed types (a to b): a: firm, white flesh: b: spongy, white flesh. Cooking type (c): firm, yellow flesh. Dessert type, sweet (d to f): d: white flesh; e: light-red flesh; f: red flesh. Scale bars for seeds represent 1 cm.

system identified in one village of Cabo Delgado may also pave the way for a more organised cash crop watermelon production. A study in Northern Mozambique of the promoted cash crops, including tobacco, cotton, sesame and sunflower, showed that smallholders in Mozambique need to be convinced that they can make a good profit, before they decide to cultivate a cash crop (Lukanu et al., 2009). The reliability of price, access to inputs, extension service and reliable buyers are central to make them decide to cultivate a 'new' cash crop. In addition, it has been shown that farmers are more likely to adopt a new crop (sunflower) when some farmers in their network also adopt, but only when not too many adopt (Bandiera and Rasul, 2006), probably to avoid the effect of competition. In the context of watermelons, it would in this way perhaps also be possible to market the local types more widely in Mozambique, but the study by Bandiera and Rasul (2006) suggests this will require input, extension service and backup from market outlets.

This study highlights 1) the cultivation and use of different local watermelon types in Mozambique, 2) that distinct types can be found in the three regions studied, and 3) that some of these types uniquely are grown and used in some of these three regions. This suggests that seed is mainly sourced from within provinces where the same languages are spoken, and that the exchange among provinces is less pronounced. This may be due to differences in culture and traditions in the provinces, inhabited by different ethnic groups. The role of social factors, such as ethnicity, on the prevalence of types and uses of local maize genotypes, has for instance similarly been shown in Mexico, even in areas where two ethnic groups live side by side (Brush and Perales, 2007). The reliance mainly on farmer-saved seed also support that types mainly are maintained and used within provinces, and that exchange of seed is not so common between provinces. This may assist in maintaining and conserving the distinct types, but at the same time there is little driving force to create new types and maintain a high level of diversity. Again for maize, it has been shown that the most common source of seed is self saved, but that experimentation and curiosity, and not seed loss, is the driver for acquiring new seed, and that seed then mainly is acquired from trusted sources, such as family and friends (Badstue et al., 2006). The exchange among family members and friends in the village communities was not studied here, and it would be interesting to further characterise the seed supply system and driving forces creating and maintaining the local genetic diversity. Continued maintenance and conservation of the present watermelon types and landraces will depend on their cultivation and use. At the moment the system seems resilient, although we do not know the types and landraces which may already have been lost by replacement with other landraces or other crop species. Future changes, such as the introduction of improved varieties may alter this scenario. The variation in fruit characteristics observed within fields indicates a potential for improvement through selection within the local germplasm. Farmers' participation and collective action in such a process could perhaps be a part of a future strategy to preserve the locally adapted material *in situ* on farm in the different provinces. This may prevent that local genetic resources are replaced by introduced cultivars, which have been bred under other climatic conditions. This survey has demonstrated that watermelon was cultivated in different agroecological zones of Mozambique, including semi-arid areas. Climate change as a driver of increased drought frequency and severity is a major challenge predicted to affect agriculture in many African countries, particularly in semi-arid areas (Mertz et al., 2009; Stringer et al*.,* 2009). Based on a yield simulation study of six major African crops (cassava, maize, wheat, sorghum, rice and millet), taking climate and population data into account up to 2030, it was concluded that regions, in for instance Mozambique, might face more serious under- nutrition in the future (Liu et al., 2008). Therefore, adaptive climate change measures need to be taken, such as improving crop varieties and optimizing crop types (Liu et al., 2008). In addition, short, dry spells are often the major course of low yields in Sub-Saharan Africa, and many improved varieties are not drought tolerant, and produce the expected high yields only when free of water stress (Love et al., 2006). Promotion of locally adapted, drought tolerant crops is one effective strategy to mitigate the effect of predicted drought events in Africa (Hassan, 2010). This warrants for more detailed research into the potential of locally adapted crops, such as the watermelon types identified in the present study, both with the view to develop a conservation strategy locally, and to study their potential to enhance food security, nutritional status and income generation.

Conclusion

Traditional knowledge related to the cultivation and use of watermelons, and indigenous landraces are still persisting in Mozambique. It will be of interest to study the diversity of the landraces further to enable local conservation strategies, and to identify potential local genetic resources to enhance food security, nutrition and income generation. In addition, it may be of interest to carry out local participatory selection and breeding within the material to further enhance the yield and attributes of some the genotypes encountered.

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