HortScience 41(2):352–356. 2006.

Fruit Variability and Relationships between Color at Harvest and Quality during Storage of *Uapaca kirkiana* (Muell. Arg.) Fruit from Natural Woodlands

Irene Kadzere,[1] Chris B. Watkins,[2] and Ian A. Merwin
Department of Horticulture, Cornell University, Ithaca, NY 14853

Festus K. Akinnifesi
International Centre for Research in Agroforestry, Box 134, Zomba, Malawi

John D. K. Saka
Chemistry Department, Chancellor College, Malawi University, Box 280, Zomba, Malawi

Jarret Mhango
International Centre for Research in Agroforestry, Box 134, Zomba, Malawi

Additional index words. wild loquat, indigenous fruit, color, soluble solids concentrations, Malawi

***Abstract*. The full commercial potential of wild loquat [*Uapaca kirkiana* (Muell. Arg.)], a fruit that is widely used for food and income in parts of Africa, is restricted by its short shelf life and variability in postharvest quality. We have evaluated within and among tree variability in fruit size and color at harvest, and changes of color, soluble solids concentrations (SSC) and pulp deterioration during storage, of fruit harvested during the maturation period. The relationships between fruit shape, size, seed number and SSC of fruit harvested at the ripe stage of maturity was also assessed. Size and color of fruit within and among trees at harvest varied greatly within the same location on the same harvest date. The a* values (redness) were more variable than for other color attributes, reflecting a range of fruit colors from greenish to brown. During a 6 day storage period, fruit color lightness and yellowness decreased, while redness increased, and variation in color attributes decreased. Although fruit color intensified during storage, the SSC of fruit after ripening was linked more with fruit color at harvest, with mean concentrations ranging from 6.7% to 13.8% among trees. When fruit were harvested four weeks later and categorized by color at harvest, SSC varied from 11.8% in greenish-yellow fruit to 14.5% in browner fruit. Pulp deterioration of stored fruit harvested unripe was observed by 6 days. The SSC of fruit harvested when ripe was not significantly correlated with shape, size or seed number. These observations have important implications for germplasm selection and collection of *U. kirkiana* for domestication purposes. Timing of harvest and/or postharvest sorting of fruit is likely to reduce variability in SSC during the postharvest period.**

Uapaca kirkiana (Muell. Arg.), a member of the Euphorbiaceae, is a tree species that is indigenous to the miombo woodlands of several countries in eastern, central and southern Africa (Ngulube et al., 1995). The trees are currently grown in the wild without horticultural management, but *U. kirkiana* is part of a domestication program in southern Africa to increase its cultivation and utilization (Akinnifesi et al., 2004). The tree can grow to 11-13 m at maturity, and depending on location, the fruit mature between August and November (Mateke at al., 1995; Mwamba, 1995). *Uapaca kirkiana* fruit are spherical or oval in shape and about the size of a plum (Fig. 1A), with a hard tough skin when unripe surrounding green to light yellow flesh (Fig. 1B). As fruit ripen the skin and flesh soften and the flesh becomes sweet and edible. The fruit is highly valued as a source of nutrients and income to local communities (Saka and Msonthi, 1994; Ramadhani, 2002). One study reported that average consumption was 180 fruit/day for children, 80 fruit/day for women and 50 fruit/day for men, and that in some regions 50% to 99% of all houses consumed the fruit mainly as snacks (Mithöfer, 2004). During famine periods, 50% of the population in these areas consumed the fruit as a meal compared with 1% during normal seasons.

The fruit of *U. kirkiana* were traditionally harvested by gathering naturally abscised ones from the ground in undomesticated stands (Ngulube, 1996; Ramadhani, 2002; Saka et al., 2004). However, increased demand for fruit used in household consumption and marketing (Akinnifesi et al., 2004; Kadzere et al., 2001, 2006; Mithöfer and Waibel, 2003) has resulted in earlier harvesting by villagers using various objects to dislodge unripe fruit, including climbing up the trees to shake off fruit from the branches. Harvest timing criteria used by fruit gatherers include visual changes in fruit morphological characteristics, e.g., fruit color, ease of fruit abscission and development of a sweet taste and loss of astringency, and fruit softening (Kadzere et al., 2001; Kadzere et al., 2006). Fruit harvested early in the season (e.g., the first half of October) require incubation treatments such as enclosing fruit in clay pots or soil burial, before they are ready to eat; but the fruit are highly variable in taste (sweetness) and color at the time of use (Kadzere et al., 2006). A short shelf life, averaging 3 d, limits utilization of the fruit, but the extent to which high variability in quality of the fruit at harvest influences the subsequent shelf life of the fruit is not known.

Mwamba (1995) and Chishimba and Mwanabute (2003) have studied *U. kirkiana* fruit variability in Zambia, and quantified the soluble solids concentrations (SSC) of fruit from trees growing in the wild. Chishimba and Mwanabute (2003) also related SSC to other fruit attributes such as size and seed number. Genetic variation among some *U. kirkiana* provenances has also been studied by Agufa (2002). Mwamba (1995) categorized fruit color into cream, brown and rufous, but there are no reports of objective quantification of color variability of the fruit. Survey results from Malawi have suggested that SSC of the *U. kirkiana* fruit is to some extent related to fruit color (both pulp and skin color), an attribute that sometimes was reported to change with fruit maturity (Kadzere et al., 2006). In that study, some correlations between SSC and pulp color were found, but the correlation of the color at harvest was unknown since fruit had been sampled from markets after ripening through incubation.

This study has been carried out as part of an investigation into the evaluation of preharvest, harvest and postharvest causes of variation in quality of harvested *U. kirkiana* fruit. To investigate the relationships among *U. kirkiana* fruit characteristics at harvest and during storage, we have addressed two objectives: 1) to determine the variation in fruit quality attributes among trees harvested at the same time and location and 2) to evaluate relationships among fruit color, size, shape and seed number at harvest with SSC of fruit during storage.

Materials and Methods

Plant material. Mature wild *U. kirkiana* trees growing in natural woodlands at Dedza

Received for publication 25 Oct. 2005. Accepted for publication 17 Dec. 2005. This research was supported by the Rockefeller Foundation through the African Food Security and Natural Resources Management (AFSNRM) Program housed in Cornell International Institute for Food and Agriculture Development (CIIFAD) at Cornell University. The staff at the International Center for Research in Agroforestry (SADC ICRAF Agroforestry Programme), and in the Chemistry Department at Chancellor College, University of Malawi and Forestry College in Dedza, Forestry Research Institute (FRIM) of Malawi and also Singatia Chithenga and Dinnah Solomon are thanked for their assistance during the study. We thank Francoise Vermeylen, Statistical Consulting Office at Cornell University, for assistance.

[1]Present Address: Dept of Agricultural Research and Extension, Ministry of Agriculture and Rural Resettlement, Box CY 594, Causeway, Harare, Zimbabwe.
[2]Corresponding author; e-mail cbw3@cornell.edu.

Fig. 1. (**top**) Whole and (**bottom**) cut *Uapaca kirkiana* fruit.

Forest Research Institute, Malawi (latitude 14°19" south and longitude 34°15" East, at an elevation of around 1600 m above sea level), were used as the source of fruit for our first two studies. The third study was to evaluate some relationships among characteristics of fruit harvested ripe from the Luwawa Forest (elevation around 1550 m above sea level, latitude = 12°15" south and longitude = 33°38" east) in the Mzimba district, Malawi.

Measurement of fruit characteristics. Fruit color was measured using a data processor chromameter (DP-100; Minolta Camera Co. Ltd., Japan). Color attributes of the fruits were measured as L* (lightness or brightness), a* (–a* = greenness, +a* = redness) and b* (–b* = blueness, +b* = yellowness). Fruit size (length and diameter) was measured using a caliper. SSC, uncorrected for acid content, were determined on extracted pulp using a handheld digital refractometer (Atago Palette-Style; Cole-Parmer Instrument Co.) for fruit after storage because unripe fruit were hard, and the absence of juice means that pulp could not be sampled. Pulp color deterioration was visually assessed using a scale of 0 to represent pulp that had deteriorated (showing a brown color and disintegration), or 1 = pale orange, 2 = medium orange 3 = deep orange for those fruit that were not deteriorated. Fruit weight was recorded using a balance (Oertling model KB23, London, U.K.).

Throughout the experiment, the fruit were harvested unripe but during the harvest season as practiced by the local communities. The peak maturation period of the fruits in Malawi is November to December (Ngulube et al., 1997).

Fruit characteristics at harvest and during storage. Fruit were harvested on 9 Nov. 2003, from seven trees that were selected for fruit color that ranged from greenish-yellow to brown. Tree rating was based on decreasing fruit skin greenness (determined by visual assessment), where tree 1 had the greenest fruit and tree 7 had the brownest fruit. Thirty fruit were randomly picked from each tree and their skin color was individually measured within 3 h of harvest and again 3 and 6 d after harvest. The SSC of these fruit were measured only on day 6. During the experiment, fruit were kept in polythene plates in a laboratory at 25 to 30 °C and 45% to 50% relative humidity (RH).

Fruit color at harvest and SSC and pulp color deterioration during storage. To investigate the association between color at harvest and subsequent SSC and deterioration of fruit during storage, unripe fruit were harvested from ten trees on 4 Dec. 2003 and bulked, taken to the laboratory within 5 h of harvest and immediately grouped into three categories according to their visual skin color as, greenish-yellow, intermediate (yellow-brown/green-brown) and brown fruit. For each color category, 150 fruit were randomly selected and 50 fruit were sub-sampled 2, 4, and 6 d after harvest and assessed for pulp color and SSC.

Size, shape, and number of seeds and SSC of ripe fruit. To determine the association of fruit attributes and SSC, naturally abscised ripe fruit were gathered from underneath the canopies of 30 trees from Luwawa Forest on 28 Dec. 2003. The fruit were brought into a laboratory and, within 24 h, 220 ripe fruit were randomly picked and the diameter and length of each was measured. Fruit were considered to be ripe if they felt soft during gentle squeezing between the thumb and the index finger. Overly soft fruit were discarded. The selected fruit were grouped into three shape categories, based on the length to diameter ratio, as flat = 1 (ratio <0.90), round = 2 (ratio of 0.91 to 1.00) and oval = 3 (ratio >1.00). Forty fruit were used for all categories because among the 220 fruit used, only 40 were categorized as oval. Immediately after assessing shape and measuring the size, each fruit was split into two parts and seeds were extracted and counted while a sample of the pulp was obtained to measure SSC.

Data analysis. Descriptive statistics (means, minimum and maximum values, and coefficients of variation (CV)) were generated to describe the variation in fruit size, color and SSC within and among trees. The Proc GLM procedure in SAS Version 9.1 (SAS Institute, Inc. Cary, N.C.) was used to analyze the data. Treatment mean differences were ascertained using the Tukey LSD method in the Proc GLM procedure.

In the second experiment, the color categories were treated as fixed effects. Since there were no random factors in this experiment, to ascertain differences among treatment means, an Analysis of Variance followed by mean separation and comparison using the Tukey's LSD, was performed in Proc GLM in SAS.

The Proc GLM procedure was also used for the third experiment, where fruit shape was a fixed effect. An Analysis of Variance

Table 1. Mean diameter, length and color (L*, a* and b*) of *Uapaca kirkiana* fruit measured at harvest. Values are based on 30 fruit per tree for each of seven trees.

Tree	Visual color description	Fruit size and color at harvest									
		Diameter (mm)	CV (%)	Length (mm)	CV (%)	L*	CV (%)	a*	CV (%)	b*	CV (%)
1	Greenish-yellow	31.9	9.7	32.1	8.3	64.7	3.0	–4.3	54.5	39.8	6.8
2	Greenish-yellow	30.4	9.9	32.1	8.2	65.4	4.5	–2.2	111.0	44.5	9.9
3	Intermediate	28.3	8.3	30.0	7.7	61.9	4.9	2.4	103.7	39.8	7.4
4	Intermediate	29.2	9.2	35.3	10.1	62.0	5.7	5.2	58.5	38.9	8.1
5	Intermediate	37.3	9.9	36.6	9.7	60.4	5.2	6.3	47.6	39.4	10.4
6	Brown	33.1	9.3	35.1	7.6	54.6	6.3	8.7	31.1	30.8	17.7
7	Brown	30.2	7.1	30.2	8.2	58.1	4.7	8.9	35.3	35.8	10.1
Mean	---	32.0		33.6		61.0		3.6		38.4	
P	---	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
LSD		1.479		1.474		1.530		1.406		1.968	
CV (%)	---	10.0		7.8		6.2		145.2		11.0	

Table 2. Fruit color (L*, a* and b*) of *Uapaca kirkiana* fruit measured 3 and 6 d after harvest, and SSC 6 d after harvest. Values are based on 30 fruit per tree for each of seven trees.

Tree	Fruit color on day 3 after harvest						Fruit color and SSC on day 6 after harvest							
	L*	CV %	a*	CV %	b*	CV %	L*	CV %	a*	CV %	b*	CV %	SSC (%)	CV (%)
1	63.6	3.1[z]	–2.9	91.3	38.3	8.8	46.5	4.3	6.4	16.7	22.5	11.3	6.7	20.8
2	61.3	5.8	0.5	685.6	39.7	14.9	48.3	7.1	8.1	20.2	23.2	15.4	9.4	23.6
3	58.8	6.0	4.7	35.3	36.2	11.2	47.5	2.9	7.6	16.4	24.3	7.2	9.0	21.9
4	59.5	5.3	6.6	35.3	36.3	9.1	48.5	6.1	10.6	19.3	27.2	16.3	12.2	7.8
5	56.4	7.0	8.2	26.2	35.2	12.0	44.7	3.5	9.4	13.8	20.7	12.1	10.8	12.2
6	51.8	7.0	9.7	15.7	26.6	18.1	43.9	3.4	10.0	11.3	18.5	17.2	13.8	14.3
7	55.9	6.1	9.6	24.1	33.5	13.2	44.7	5.1	9.7	15.9	20.8	16.9	12.1	13.4
Mean[y]	58.2		5.3		35.1		46.3		8.8		22.5		10.6	
P	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
LSD	1.721		1.635		2.236		1.161		0.743		1.617		0.860	
CV (%)	8.4		95.1		16.7		4.1		17.1		12.6		22.5	

[z]Within trees.
[y]Among trees.

followed by mean separation and comparison using the Tukey's LSD, was performed. Where appropriate, regressions were performed using Proc Reg in SAS to determine the strength of the relationships among some variables.

Results and Discussion

Fruit characteristics at harvest and during storage. Fruit size varied greatly at harvest among trees at the same location (Table 1). The diameter and length of the fruit ranged from 28.3 to 37.3 mm and 30.0 to 36.6 mm, respectively. Within tree variation for fruit size was smaller however, with CVs of generally less than 10% for both fruit diameter and length.

Increasingly positive a* values from –3.2 for greenish-yellow to 8.8 units for brown fruit were associated with decreasing L* values from 65.1 units to 56.4 units (average of both trees per color category), respectively. The b* values were more variable among trees than within trees. The CV for the a* value was much greater (145%) among the trees than for the other color attributes. Within trees, the color characteristics of fruit at harvest were also variable, although the extent of variation depended on the attribute being considered. While fruit yellowness (b* values) and lightness (L* values) at the time of harvest had low CVs, the CVs for redness (a*) values ranged from 31.1% to 111% within the trees (Table 1).

The fruit became progressively darker as they ripened during storage as reflected by decreasing L* values. They became less green but more redder/browner, as indicated by increasing a* values, and decreasing b* values, respectively (Table 2). During ripening the variability of color attributes remained similar for L* and b* values, but decreased markedly for a* values (Table 2).

The absence of juice in unripe *U. kirkiana* fruit at harvest does not allow measurement of the SSC, and therefore they were measured only on day 6. At this time SSC were generally lowest in fruit that were greenish-yellow at harvest and highest in fruit that were brown at harvest (Table 2). SSC were more variable within trees with fruit that were greener at harvest, compared with those trees that were harvested with more brown fruit (Table 2). The results showed that although the redness increased during storage in fruit harvested green, their

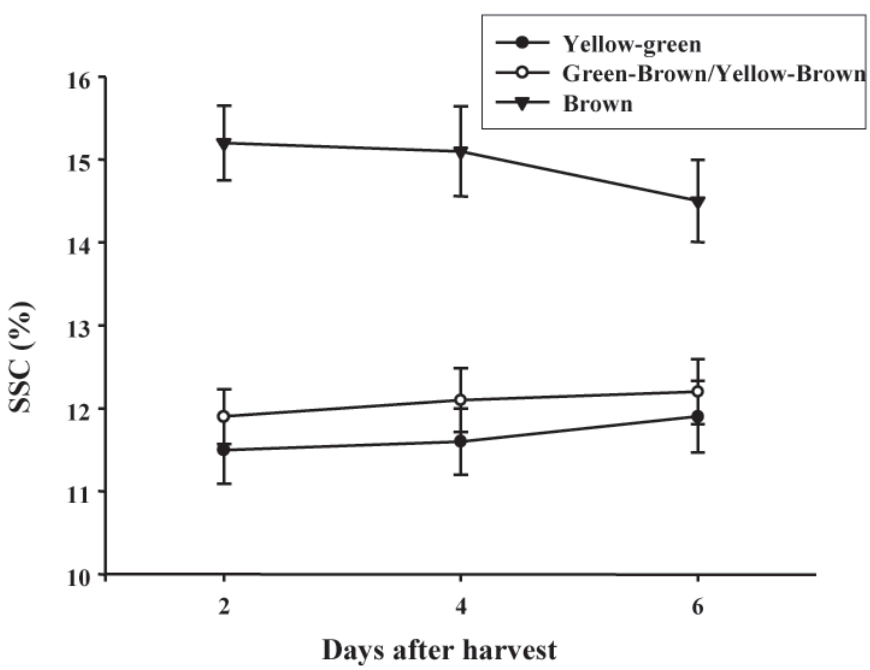

Fig. 2. Total soluble solids concentrations (SSC) of *Uapaca kirkiana* fruit harvested unripe at greenish-yellow, intermediate and brown color stages from Dedza Forest, Malawi, 9 Nov. 2003, and stored for 2, 4, and 6 d after harvest. Values are based on data from 50 fruit for each color category at each assessment time. Vertical bars on the graphs represent standard errors of the means.

Table 3. Relationships among diameter, length, seed number and SSC with fruit shape of naturally abscised *Uapaca kirkiana* fruit gathered from the Luwawa Forest, Malawi, on 28 Dec. 2003. Values are based on 40 fruit per shape category.

	Fruit shape				
Variable	Flat	Round	Oval	LSD	*P*
Diameter (mm)	34.7	33.9	32.7	1.742	0.071
Length (mm)	29.5	30.6	34.9	1.714	<0.001
Number of seeds	4.2	4.0	3.6	0.187	<0.001
SSC (%)	17.6	17.5	17.7	1.211	0.949

mean SSC was significantly lower than those harvested with more brown color.

Both fruit maturity and genetic differences among trees could be responsible for the variability in fruit color and SSC observed in our study. Large differences in variation of fruit size, color and SSC within trees may be associated with a prolonged flowering period (peak flowering being between January and March) of the trees as reported by Ngulube (1996). In the Dedza region, knocking down unripe fruit from trees was the most common method of harvesting *U. kirkiana* fruit, particularly early in the season (Kadzere et al., 2006). This harvesting method is necessitated by the large size of the trees (up to 13 m height (Palgrave, 1989)) which makes handpicking from the ground impossible for many trees and also the fact that when not fully mature, fruit are strongly attached to twigs. Due to the indiscriminate nature of this harvesting method, fruit of varying maturities are dislodged (Kadzere et al., 2006). Given the high variation among fruit from the same trees in our study, and the nondiscriminate harvesting methods used by fruit gatherers, it is not surprising that postharvest variability in fruit color, and lack of sweetness in fruit are commonly reported quality problems particularly early in the season when most or all fruit are being harvested unripe (Kadzere et al., 2006). With such great variation among fruit within trees, it may be beneficial to sort fruit by color at harvest or if possible spot pick browner fruit from trees to reduce the variability in subsequent fruit quality.

Our findings on fruit variability among trees is consistent with the genetic variability reported for *U. kirkiana* populations by Agufa (2002), who observed greater genetic variability within versus among populations. Since our fruit were harvested from trees at the same location on the same day, the effects of environment are likely to be similar for the trees, leaving genetic differences as a plausible cause of variation among the trees. Our findings also support comments by interview respondents in Malawi about color and sweetness variability among trees growing within the same location (Kadzere et al., 2006). *Uapaca kirkiana* is a dioecious tree species (Ngulube, 1996). Considering that most of the *U. kirkiana* trees in the wild are a result of natural regeneration, the observed phenotypic non-uniformity in fruit characteristics in our study could be due to the effects of sexual reproduction on genetic make-up of seedling tree populations. It is well known that unpredictable performance of seedling trees (from sexual propagation) has led to reliance on vegetative propagation to clone for uniformity and capture desirable attributes in many horticultural tree fruits.

Mwamba (1995) also reported wide variation in *U. kirkiana* fruit size and SSC (6% to 23% within, and 8% to 21% among trees) from trees at the same location in natural woodlands in Zambia and believed that the differences were genetic. In contrast to our findings, however, in that study SSC were less variable than fruit size, and they were not closely linked with fruit color. The underlying differences between observations in Zambia and our findings could be genetic but could also be due to differences in phenological characteristics of the trees and levels of fruit maturity at the time of harvest in these two studies. Mwamba (1995) did not indicate the date when the fruit were harvested. A possible difference in maturity of fruit between the two studies is supported by the observation that flowering in *U. kirkiana* occurred over a 5- to 6-month period among some populations (Ngulube, 1996). Also, a progressive increase in fruit sweetness perception by gatherers and objectively measured increased SSC as the harvest season progressed from October to January in Malawi has been reported (Kadzere et al., 2006).

Although tree to tree genetic variation may be undesirable with regard to fruit harvesting efficiency and quality, it presents an opportunity to select and clone for desirable phenotypic characteristics. Examples might include differences in fruit maturity/ripening dates to create controlled diversity in future orchards, and deliberately extend the harvesting and availability periods of the fruit. Successful domestication of *U. kirkiana* will require further work to evaluate genetic characteristics, using targeted phenotypic fruit attributes, and fruit growth and development (including time to maturity) characteristics within and among the different populations of the species in the wild.

Fruit color at harvest and subsequent SSC and pulp color deterioration during storage The SSC of the fruit during the 6-d assessment was linked with fruit color at harvest (Fig. 2). Brown fruit at harvest had higher SSC compared with those that initially had either an intermediate or a greenish-yellow color. However, the latter two fruit categories had similar SSC, with little change over time, in contrast to a slight decrease in the SSC in brown fruit from 4 to 6 d. The interaction between color category and time was not significant and a regression analysis of the SSC against storage time showed no relationship between the two variables ($P = 0.956$). However, regression analysis of SSC and pulp color rating (excluding the deteriorated fruit) showed that the SSC generally increased with increasing pulp color rating (increasing intensity of the orange color) ($P < 0.001$), although the R^2 was only 0.42.

Pulp did not deteriorate on days 2 and 4, but by day 6, 29%, 35%, and 18% of fruit in each of yellowish green, yellowish-brown/greenish brown and brown categories, respectively, had deteriorated.

The results again demonstrate the need for sorting fruit by color at harvest rather than after harvest to obtain fruit with a more uniform sweetness. The SSC of the fruit did not increase during storage, suggesting that fruit have to be harvested after they have accumulated adequate amounts of sugars to attain high sweetness characteristics. Unpublished evidence suggests that *U. kirkiana* may be nonclimacteric, but further studies are required.

Size, shape, and number of seeds and SSC of ripe fruit. There was no significant relationship between size, shape, and number of seeds in fruit and SSC of ripe fruit (Table 3). The poor relationship between either fruit size or shape and SSC suggests that fruit size is likely to be a less important variable in predicting SSC in ripe fruit although in some species larger fruit are less sweet due to the dilution effects of size on sugars. Chishimba and Mwanabute (2003) also did not find any consistent relationship between SSC and *U. kirkiana* fruit size and seed number in Zambia.

Conclusions

Large variations existed in fruit size, color at harvest and during storage, and SSC after ripening, within and among trees for fruit harvested on the same day at the same location. Unripe fruit harvested with more green attributes of skin color and a pale orange pulp color generally had lower SSC, providing a potential mechanism of developing visual maturity indices for the species. It is uncertain whether the color and SSC of the green fruits change over the harvest season. When ripe, SSC values increased with increasing orange color intensity of the fruit. Variability in color and SSC of fruit, especially for greener fruit within and among trees suggests that sorting fruit by color at harvest early in the season might be beneficial. It could be useful to determine the effect of harvesting fruit at intervals during the harvest season to control the variability of fruit color and SSC at harvest and during storage.

Literature Cited

Agufa, C.A.C. 2002. Genetic variation in *Sclerocarya birrea* and *Uapaca kirkiana*—Indigenous fruit trees of the miombo woodlands. MSc thesis. Jomo Kenyatta Univ. Agr. Technol., Kenya

Akinnifesi, F.K., F. Kwesiga, J. Mhango, A. Mkonda, T. Chilanga, and R. Swai. 2004. Domesticating priority miombo indigenous fruit trees as a promising livelihood option for smallholder farmers in southern Africa. Acta Hort. 632:15–30.

Chishimba, W.K. and N. Mwanabute. 2003. Natural variation in size and soluble solids concentration of *Uapaca kirkiana* fruits. J. Trop. For. Sci. 15:313–319.

ENDA-Zimbabwe. 1996. The use and value of fruit trees in communal areas of Zimbabwe: Results and report of a survey conducted in selected communal lands. Environ. Dev. Agency Zimbabwe (ENDA), Harare, Zimbabwe.

Kadzere I., L. Hove, T. Gatsi, M.T. Masarirambi, L. Tapfumaneyi, E. Maforimbo, I. Magumise, J. Sadi, and P.R. Makaya. 2001. Current practices on post-harvest handling and traditional processing of indigenous fruits in Zimbabwe. Final Tech. Rpt. Dept. Res. Spec. Serv., Min. Agr. Rural Resettlement, Harare, Zimbabwe.

Kadzere, I., C.B. Watkins, I.A. Merwin, F.K. Akinnifesi, J.D.K. Saka, and J. Mhango. 2006. Harvesting and postharvest handling practices of *Uapaca kirkiana* (Muell. Arg.): A survey of roadside markets in Malawi. Agrofor. Sys. (in press).

Mateke, S.M., C.S. Kamara, and P. Chikasa. 1995. Ripening periods of edible indigenous fruits in Zambia: Implications for utilization and domestication, p. 58–65. In: J.A. Maghembe, Y. Ntupanyama, and P.W. Chirwa. (eds.). Improvement of indigenous fruit trees of the miombo woodlands of southern Africa. Proceedings of a conference held on 23–27 Jan. 1994 at Club Makokola, Mangochi, Malawi. Intl. Centre Res. Agrofor.

Mithöfer, D. 2004. Economics of indigenous fruit tree crops in Zimbabwe. Unpublished PhD thesis. Univ. Hannover, Germany.

Mithöfer, D. and H. Waibel. 2003. Income and labour productivity of collection and use of indigenous fruit tree products in Zimbabwe. Agrofor. Sys. 59:295–305.

Mwamba, C.K. 1995. Variations in fruits of *Uapaca kirkiana* and the effects of *in situ* silvicultural treatments on fruit parameters, p. 27–38. In: J.A. Maghembe, Y. Ntupanyama, and P.W. Chirwa. (eds.). Improvement of indigenous fruit trees of the miombo woodlands of southern Africa. Proceedings of a conference held on 23–27 Jan. 1994 at Club Makokola, Mangochi, Malawi. Intl. Centre Res. Agrofor.

Palgrave, C. 1989. Trees of Southern Africa. Struik Publ., Cape Town.

Ngulube M.R. 1996. Ecology and management of *Uapaca kirkiana* in Southern Africa. PhD thesis. Univ. Wales, Bangor.

Ngulube, M.R., J.B. Hall, and J.A. Maghembe. 1995. Ecology of a miombo fruit tree: *Uapaca kirkiana* (Euphorbiaceae). Forest Ecol. Mgt. 77:107–117.

Ngulube, M.R., J.B. Hall, and J.A. Maghembe. 1997. Fruit, seed and seedling variation in *Uapaca kirkiana* populations from Malawi. Forest Ecol. Mgt. 98:209–219.

Ramadhani, T. 2002. Marketing of indigenous fruits in Zimbabwe. PhD thesis. Univ. Hannover.

Saka, D.J.K. and J.D. Msonthi. 1994. Nutritional value of edible fruits of indigenous wild trees in Malawi. Forest Ecol. Mgt. 64:245–248.

Saka J.D.K., R. Swai, A.A. Mkonda, A. Schomburg, F. Kwesiga, and F.K. Akinnifesi. 2004. Processing and utilization of indigenous fruits in southern Africa, p. 342–352. In: M.R. Rao and F.R. Kwesiga (eds.). Proceeding of the Regional Agroforestry Conference on Agroforestry Impacts on Livelihoods in Southern Africa: Putting research into practice. World Agrofor. Centre (ICRAF), Nairobi, Kenya.