Progress in Developing Technologies to Domesticate the Cultivation of Shea Tree (*Vitellaria paradoxa* L.) in Ghana

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Résumé

Yidana, Adam Joshua. *Progres Realises dans le Developpement des Technologies pour Domestiquel la Cultivation du Karitier (Vitelleria paradoxa L.) au Ghana.* Des études ont étés menées sur la pollination naturelle croisée, la propagation sexuelle et végétative, la regénération natuerlle caracteristiques des fruits et la production des arbres individuels du Karitier (vitelleria paradoxa L). La localisation des études étaient à la sous station de Cocoa Research Institute of Ghana (CRIG) (l'Institut des Recherches sur le cacao du Ghana) Bole de 1989 à 1994 et à University of Development Studies (l'Université d'Etudes en Développement) au campus de Nyankpala de 1995 à 2003. Les objectifs des études étaient la suite : développer des techniques de la pollination croisée (par main), méthodes de propagation sexuelle et végétative et de réviser des études sur la réponse de l'amande de Karité aux pratiques agronomiques au Ghana. Les techniques de pollination croisée, la germination des graines et les pratiques de la pépinière, méthodes pour planter des coupages des branches et le déposage en couches dans l'air ont été développés. La forme et taille des fruits ont ete utilisées pour décrire quatre types principaux du Karité. Il a été observé que les populations du Karité dans les champs ont développé a travers la regénération naturelle et avaient des densités d'arbre de 1,200 arbres par hectare et qu'ils commençaient à porter des fruits sept ans après être établis.

Mots clés : Vitellaria paradoxa, karitier, technologies, pollination.

Abstract

Studies were conducted on natural and hand pollination, sexual and vegetative propagation, natural regeneration, fruit characteristics and individual tree yields of sheatrees (*Vitellaria paradoxa* L.). The locations of the studies were at the Cocoa Research Institute of Ghana (CRIG) sub-station, Bole from 1989 to 1994 and at the University for Development Studies, Nyankpala Campus from 1995 to 2003. The objectives of the studies were to: develop hand pollination techniques, sexual and vegetative propagation methods and to review studies on response of sheanut to agronomic practices in Ghana. Hand-pollination techniques, seed germination and nursery practices, methods for rooting shea tree stem cuttings and air layering were developed. Fruit shape and size were also used to describe four main types of sheatrees. It was also observed that shea tree populations on farms developed from natural regeneration had tree densities of 1,200 trees per hectare and begin to bear fruit within seven years of establishment.

Keywords: *Vitellaria paradoxa,* shea trees, technologies, pollination.

Introduction

Shea trees grow naturally throughout the Sudanian region centre of endemism from Senegal to the foothills of the Ethiopian highlands (White, 1983). It occurs in 19 countries: Benin, Burkina Faso, Chad, Cameroon, Central African Republic, Cote D'Ivoire, Ethiopia, Ghana, Guinea, Guinea Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leon, Sudan, Togo, Uganda and Zaire (FAO, 1988).

The tree is a monotypic genus and belongs to the family Sapotaceae and in the genus *Vitellaria*. The genus has two subspecies: *V. paradoxa* subspecies *paradoxa* Synonyms: *Bassia parkii* G. Don *Butyrospermum parkii* (G. Don) Kotschy, *Butyrospermum paradoxum* (Gaertner) Hepper, *Butyrospermum parkii subspecies parkii* (G. Don) Hepper. The West African populations are of this subspecies.

Vitellaria paradoxa subspecies *nilotica* (Kotschy) Henry, Chithra et Nair, Comb.nov. Synonyms: *Butyrospermum niloticum* (Kotschy); *B. parkii* subspecies niloticum (Kotschy) Hemsley); B. paradoxum subspecies niloticum (Kotschy) Hepper. It is generally identified by the scientific name *Vitellaria paradoxa* L. (Gaertn) (Syn. *Butyrospermum paradoxa)*(Henry *et al.*, 1983). This subspecies occurs in East and Central Africa (Cameroun, Uganda, Ethiopia).

Botany

The distinctive feature of *Vitellaria* as a genus is the possession of the trees of a large number of twigs and clustered leaves with craspedodromous venation with a prominent marginal vein, secondaries parallel; tertiaries parallel to the secondaries or reticulate; quaternaries finely areolate. Inflorescences densely clustered at the shoot apex in the axils of scale leaves. Flowers bisexual, calyx of two whorls of (3-4) free sepals, the outer whole valvate. Stamens (6-8), in a single whorl inserted at the top of the corolla tube; filaments free; anthers extrorse. Staminodes (6-8), well-developed, alternating with the stamens, erect or inflexed and forming an envelop round the gynaecium, lanceolate, margin erose, terminated by a filiform point. Ovary (5-6) locular, hairy, placentation axile; style slightly exserted. Fruit 1-5 seeded but 1-3 more common, indehiscent, fleshy berry; endosperm absent from globose seed. Pollen appear as a dry white powdery mass that mature before the flower opens (Yidana, 1989).

Ecology and geographical distribution

The tree is perennial and deciduous. It occurs mainly on dry open slopes. Coull (1928); Hill (1930) and Dalziel (1955) have described the growth and yield of shea trees. Mature tree heights vary considerably, with some trees attaining heights of over 14 m. and girths of over 1.75 m. Individual tree yields vary considerably, from 1 kg of fresh fruit to

over 60 kg in others. In Ghana, shea trees are found mainly in the interior Savannah (8-11N). Small populations are also found in the Brong-Ahafo, Ashanti, Eastern and the Volta regions in southern Ghana.

In the northern Ghana where the majority of Ghana's sheanut population grow, the natural vegetation is savannah wood- and grassland. Here, bush fires are widespread in the dry season, occurring mostly from November to January and thus coinciding with the peak of flowering of shea trees in the area. The vegetation is described as Sudanian *Isoberlinia* woodland (White,1983). The soils are variable but are mostly savannah ochrosols, groundwater laterites and lithosols. FAO-UNESCO (1977) describes the soil as mainly luvisols with smaller areas of euteric rigosols and lithosols.

Shea trees begin flowering by early November and the picking of the ripe fruits which drop upon ripening lasts from April to August. Tree yields are erratic, varying from year to year and between populations. Trees on protected or cultivated land produce higher yields and bear fruit more consistently than those in bush lands. Pests and diseases that attack the tree include insect pests, epiphytes and fungal diseases. Insect pests attack the leaves, stem, flowers and the fruits. The leaf eating insects include beetles, leaf hoppers, and the larvae of the moth, *Cirina forda*, (Owusu-Manu and Kuma, 1989), also described by Baker (1962) as *Cirina butyrospermii* Vuillot (Family Saturniidae, Lepidoptera). Fungal diseases include leaf spot and various moulds that attack the fruits and the nuts which are the main economic product.

Economic importance

Sheanuts (the dried nuts obtained from the fruits of shea trees) contain a fat commonly called shea butter which has characteristics similar to that of cocoa butter (Adomako, 1974, 1975). The fat is used locally as a cooking oil, for treatment of cuts, sprains and colds. In industry, it is used as a substitute of cocoa butter in the manufacture of confectionery and as a base for medicines and lotions in the pharmaceutical and cosmetic industries. It is an important raw material for the manufacture of soaps and candles.

As a rural industry sheanut contributes considerably to the annual income of the rural communities of West African countries. According to Olivier Krugg, quoted in Spore (1991), "The shea butter tree provides more than half the income of village women" in sheanut growing areas in Mali.

Owing primarily to the fact that sheanuts become available during the period of food scarcity (April to July each year), they play an important role in food security for rural people, income from sale of sheanuts being used for the

purchase of food and other important requirements for most families. The sheanut industry employs mainly women and the youth and thus provide income for the most vulnerable groups in the rural communities. The thick pulp covering the fruit is also eaten as a delicious fresh fruit sometimes as a main meal when other foods are very scarce.

The shea tree is also counted as a medicinal tree species in Ghana. The bark is used in various mixtures for the treatment of common illnesses such as stomach ache. It is also used as an eye lotion and facilitates delivery (Bennett-Lartey and Asare, 2000). It is also used in the treatment of abdominal pains, muscular aches and rheumatism.

Sheanut and shea butter are important export commodities. According to the Ghana Exports Promotion Council, the value of sheanut exported from Ghana was US $4,484,600 in 1996. The quantity of sheanut exported in that year was 32,018.1 metric tons. Small quantities of shea butter are also exported. The quantities of sheanut exported in 1996 and 1997 were 110.38 and 504.473 metric tons respectively. The value of the export in 1997 was 14.1 billion cedis (about 5.6 million US dollars). With the potential output of over 100,000 tons of sheanut per annum, Ghana could earn a significant amount of revenue by improving the production base and the quality of the produce and by processing into shea butter which attracts higher prices.

Production in Ghana

The population of shea trees growing naturally in Ghana has been estimated to be about 9.4 million with a potential yield of 100,000 tons of dried sheanut per year (Ghana Cocoa Marketing Board (GCMB) News, 1980, quoted by Abbiw , 1990). The shea tree population covers the whole of Northern Ghana, an area estimated to be over 77,670 sq. km, about two thirds of the total land area of the country (Coull, 1928; Miles, 1929 cited by Adomako, 1985). Adomako (1985) estimated the export potential to be 135,000 tons. Quantities of sheanut purchased annually since the 1970s have been smaller than these estimates, with the largest quantity since 1973 being 40,000 tons purchased in 1985. Table 1 shows the quantities of sheanut purchased locally and exported from 1975 to 1996. The Ghana Cocoa Marketing Board (G.C.M.B.) had monopoly of sheanut purchases from 1976 to 1992 whilst purchases afterwards was mainly by private sheanut purchasing companies. Annual quantities of nuts from a 24 mile square of natural sheanut plantation at the Cocoa Research Institute sub-station at Bole also shows a similar wide fluctuation.

The major sheanut exporting companies immediately after privatisation period were: Kassarjian Industries which is the leading private sheanut company, Olam

Table 1. Local purchases and export of sheanuts in Ghana from 1976 to 1996 (metric tons).

Year	*Local purchases*	*Exports*	*#CRIG collection*
1976	9074	5334	na
1977	1823	1826	na
1978	506	497	na
1979	na	na	na
1980	765	764	na
1981	2205	2275	na
1982	2300	2392	1860
1983	115	2000	563.40
1984	1385	na	448
1985	4	na	360
1986	40267	na	4200
1987	10093	na	1200
1988	na	na	185
1989	na	na	3400
1990	3959	2856	585
1991	5040	3200	na
1992	1852	2015	na
1993	9479	na	na
1994	7808	na	na
1995	22680	na	na
1996	32018	na	na

Source: Ghana Cocoa Board Handbook 7th edition (1987) and Ghana Cocoa Board Annual Report and Accounts 1991/92
na = Not available; # = unpublished data.

Ghana Limited, A. A. Dimbala Farms Limited and Farmers Services Company Limited.

Problems with picking from wild populations

The sheanut industry relies on nuts collected from natural stands of shea trees. As wild trees, they exhibit a cyclical yielding pattern that spans over 3 to 5 years and thereby making the supply base of sheanut unstable. This has hampered its industrial development. Also, local communities in West Africa that rely on the yield of sheanut for their livelihood are constantly faced with failure of the trees to bear fruit. Attempts to domesticate the trees for cultivation have failed due to a long gestation period (vegetative growth period) of 16 to 20 years before fruiting. The long waiting period is unattractive to farmers. Other problems associated with the reliance on the natural tree populations are: harvesting of immature nuts that produce butter of poor quality. Valuable time is wasted on searching for the nuts from widely dispersed trees. Harvesters of the nuts are confronted with dangers of snake bites and other hazards of the range land. Also, delays in processing lead to poor quality butter. The picking of small quantities of fresh shea fruits from various trees over a long period before boiling them contributes to poor quality of the nuts and butter. The nuts picked earlier germinate by the time they are boiled. Shea butter extracted from such nuts have high free fatty acid content (up to 18%), and is unsuitable for industrial use (Aye and Adomako, 1990, unpublished). The natural tree populations are subjected to annual bush burning, competition from weeds, and several species of epiphytes that drastically reduce yields and destroy

many of the trees.

All these factors make it difficult to see a real increase in the production of sheanuts simply by increasing the picking of the nuts from wild trees. The obvious solution to these problems is to bring shea trees under cultivation and intensive management as a tree crop. Unless a purposeful collection of shea diversity is made and conserved, cultivation and intensive management would not necessarily favour the conservation of shea genetic diversity. The studies reported here are part of on-going efforts to bring the shea tree under cultivation and were conducted to (i) study the effect of hand pollination on fruit production in shea trees (ii) study the development of the seedling during germination of shea seeds and develop appropriate nursery practices (iii) develop methods of rooting shea stem cuttings, air-layering, side- and approach grafting and (iv) study variability in the size, shape and fat content of shea fruits.

Materials and methods

Location of study

Experimental procedures

Natural tree stands near communities at Bole, Nyankpala, and Wulugu in the Northern Region of Ghana were used for these studies.

Pollination

Forty-five mature shea trees that had been observed to flower and bear fruit in the previous year (1989) on the sheanut plantation of the Cocoa Research Institute of Ghana sub-station at Bole were selected in 1990 for these studies. They were tagged as soon as flower buds were observed on them from the first week of November. Fifteen twigs with more than 10 flower buds were tagged per tree. Ten of the twigs were covered with bags made from high-density muslin cloth to prevent insects from having access to the flowers as shown in Plate 1.

The remaining five twigs were left un-bagged for open pollination (Plate 1b). Flowers of 5 of the 10 bagged twigs were pollinated with pollen from the same tree (selfing) whilst the remaining 5 of each tree were pollinated with pollen obtained from different trees (cross-pollination). Only flower buds with exerted styles on each twig were counted and pollinated. Open flowers and flower buds in which the style had not yet exerted were removed before pollination. Number of fruits set per twig were counted and monitored till the fruits ripened. Percentage fruit production by

Plate 1. Shea fruits bagged with muslin cloth.

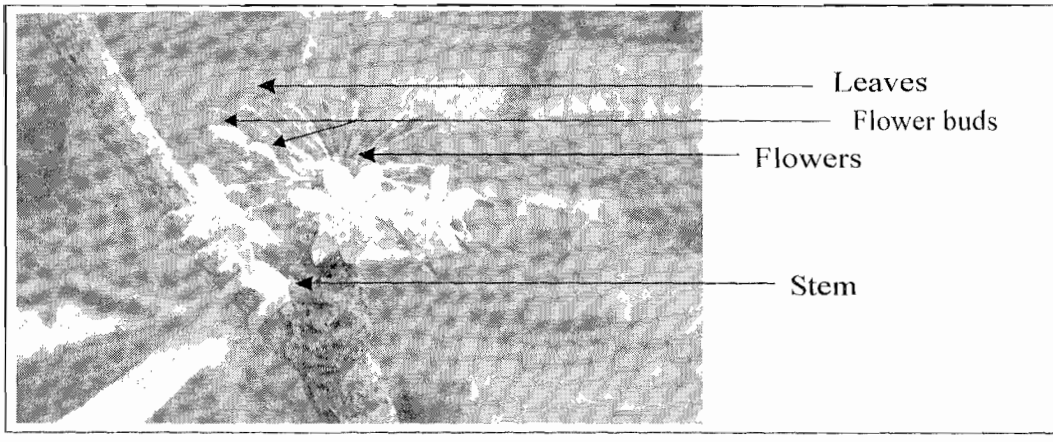

Plate 1b. Stem, open flowers, flower buds and young leaves of shea tree.

each method of pollination was calculated as a percentage of the number of flowers pollinated by each method. The floral structure, and the stage of pollen maturity were also studied.

Seed germination and nursery practices

Five hundred freshly fallen ripe fruits were collected from different trees, depulped and pre-germinated for 10 days. Those that showed an active radicle were potted in 30 each of three sizes of polybags (6 cm x 8 cm, 12 cm x 18 cm and 8 cm x 30 cm). The seedling plants were subjected to different nursery practices as follows:

A. Root pruning
B. Packing on a supportive platform
C. Lifting at 4 weeks intervals
D. Transplanting at three months, six months , one year, two years and three years after potting.

Rooting of stem cuttings

Leafy stem cuttings were made and set Under high humidity (100 %) in propagation bins equipped with a mist spraying device. Two hundred cuttings were set in each of five batches. One hundred cuttings of each batch (50 %) were treated with 'Rootone' (powdered preparation of naphthalene acetic acid, NAA). The remaining 100 cuttings (50 %) were set without any hormone. Rooted cuttings were potted on a sand soil mixture for one month and then transferred into polybags filled with black soil. They were observed for three months before transplanting to the field. The plants were observed in the field for six years.

Air-layering

High yielding individual shea trees were selected as scion source for the study. Fifteen "epicormic shoots" (shea branches growing upwards and resemble seedling plants) and fifteen

normal branches (lateral branches on a mature shea tree) were air-layered as described by Hartman and Kester (1983) on each of fifteen trees using soil, sand and sterilised rice hull as the rooting media and NAA as the rooting hormone.

Side and approach grafting

High yielding individual trees were also selected as the source of scion. Twenty-five young shea trees of about six years old growing in the CRIG sub-station Sheanut plantation at Bole were selected as the rootstock. The sideveneer grafting as described by Hartmann and Kester (1983) was used. Grafting was carried out at the beginning of the rainy season when the weather was cool and moist but not too wet from April to June 1991. Shallow vertical cuts of 4 - 6 cm long were made into one side of the stem of each rootstock and the corresponding scion. The cut piece of bark with some wood was removed by making a short horizontal cut at the base of each vertical cut. The side opposite the cut on the scion was also sliced to expose the cambium. The cut surfaces on scion and rootstock were matched in each case and tied firmly with binding tape. The grafted plants were left *in situ* and observed for union over a four week period.

Natural regeneration

Plots of land were cleared of all vegetation except sheanut seedlings. Seedling counts were conducted on the plots three times during the year. The studies were carried out on five plots, 2 on-station and 3 on farmers' fields. Seedlings were counted using quadrats of 10 m x 10 m.

Variation among shea fruits

During the studies on pollination, it was observed that there is a pattern in shea fruit shape and size. Seventy-five shea trees with different fruit shapes and sizes were tagged and nuts collected from each tree separately and morphological measurements made over a three-year period. Other fruits were collected from trees in fifteen other locations in Northern Ghana as follows: Mankuma, Sankpa-ala, Yendi, Walewale and Samini in the Northern Region, Kpalgu, Sumbrungu, Bawku, Sandema and Uwasi in the Upper East Region and Wa, Gaa, Sankana, Nadowli and Lawra in the Upper West Region. Fat content of the dry kernels obtained from trees at various localities in the Northern and Upper East Regions was also assessed by collecting ripe fruits, processing and analysing them for fat content at the Laboratories of Cocoa Research Institute of Ghana. Fruit and nut yields of individual shea trees were also monitored for a period of three years by collecting all ripe nuts separately from each tree.

Data analysis

Data was analysed using descriptive statistics (percentages, means, standard error) and qualitative description.

Results

Floral development and the effect of hand pollination on fruit production.

Studies conducted on the development of the flower bud observed that pollen become mature and fertile just before anthesis. This stage can be recognised by the partial appearance of white strips of the corolla as the calyx begins to open (Figure 1). Plate 1b shows a typical shea inflorescence.

Hand pollination increased the number of fruits set in crosses between trees whilst selfing produced no fruit set (Table 2) except in one case which could be due to pollen contamination. All cross-pollinated flowers produced fruits, thus confirming that the trees are largely out crossing. Table 3 and Table 4 show flower counts and fruit set per inflorescence in young shea tree populations under open pollination.

Germination and growth of sheanut seedlings

Fresh seed extracted from fully ripened shea fruits germinated easily, often producing up to 100 % germination. This was achieved by removing the pulp covering the seed and washing the de-pulped seed with water before planting. Pre-germination lasted for 10 days. The pseudo-radicle of germinating shea seeds emerged 2-6 days after sowing. The radicle showed a visible swelling after 21 days. This contained the shoot bud which eventually forced open the swollen root and emerged from underground after about 28 days (Figure 2). Germination is cryptogeal (Plate 2).

Seedling growth and transplanting

Sheanut seedlings were successfully raised in polythene bags of various sizes (6 cm x 8 cm, 12 cm x 18 cm and 8 cm x 30 cm). There was little difference in the

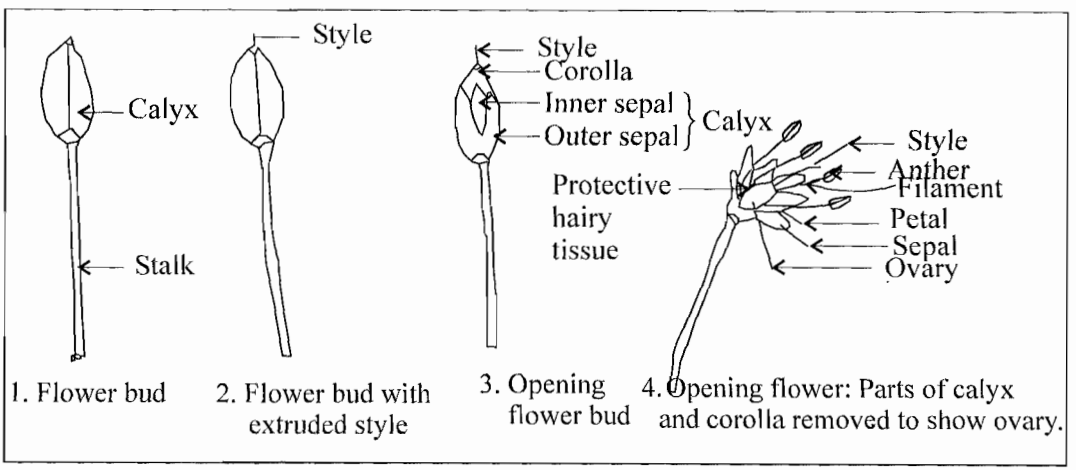

Figure 1. Stages of anthesis of shea flowers.

Table 2. Fruit formation in shea trees under hand and open pollination.

Tree No.	*Type of pollination*	*No. of flowers pollinated*	*No. of ripe fruits produced*	*% Fruit production*
T1	Open-	324	10	3.09
	Selfed-	39	2	5.13
	Crossed-	21	8	38.10
T2	Open-	78	11	14.10
	Selfed-	44	0	0.00
	Crossed-	33	15	45.46
T3	Open	78-	5	6.41
	Selfed	25-	0	0.00
	Crossed-	30	12	40.00
T4	Open-	84	10	11.91
	Selfed-	35	0	0.00
	Crossed-	21	9	42.86
T5	Open-	55	3	5.46
	Selfed	40-	0	0.00
	Crossed-	39	12	30.77

Table 3. Flower count per twig on a young sheanut plantation at Kpachi near Tamale.

Tree label	*Flower count per inflorescence*							
	B1	*B2*	*B3*	*B4*	*B5*	*Total*	*Mean*	*SE*
T1	47	48	44	60	28	227	45.4	5.13
T2	55	41	41	38	21	196	39.2	5.43
T3	67	66	39	66	38	276	55.2	6.82
T4	44	50	57	13	37	201	40.2	7.56
T5	49	43	66	32	18	208	41.6	8.07
T6	24	29	54	10	44	161	32.2	7.70
T7	59	55	154	91	21	380	76.0	22.43
T8	75	66	39	34	66	281	56.2	8.17
Total						**1930**	**48.25**	

CV (%) = 302.25
SE= 8.91

Table 4. Immature fruit count per twig at Kpachi.

Tree label	*Immature fruit count per twig*							
	B1	*B2*	*B3*	*B4*	*B5*	*Total*	*Mean*	*SE*
T1	3	3	2	0	0	8	1.6	0.68
T2	0	3	1	2	1	7	1.4	0.51
T3	4	11	5	4	9	33	6.6	1.44
T4	1	10	6	0	6	24	4.8	1.83
T5	1	5	3	2	11	22	4.4	1.78
T6	0	1	0	2	1	4	0.8	0.37
T7	3	5	2	3	0	13	2.6	0.81
T8	12	6	3	4	1	26	5.2	1.88
Total							**27.4**	

CV (%) = 16.98
SE 9.

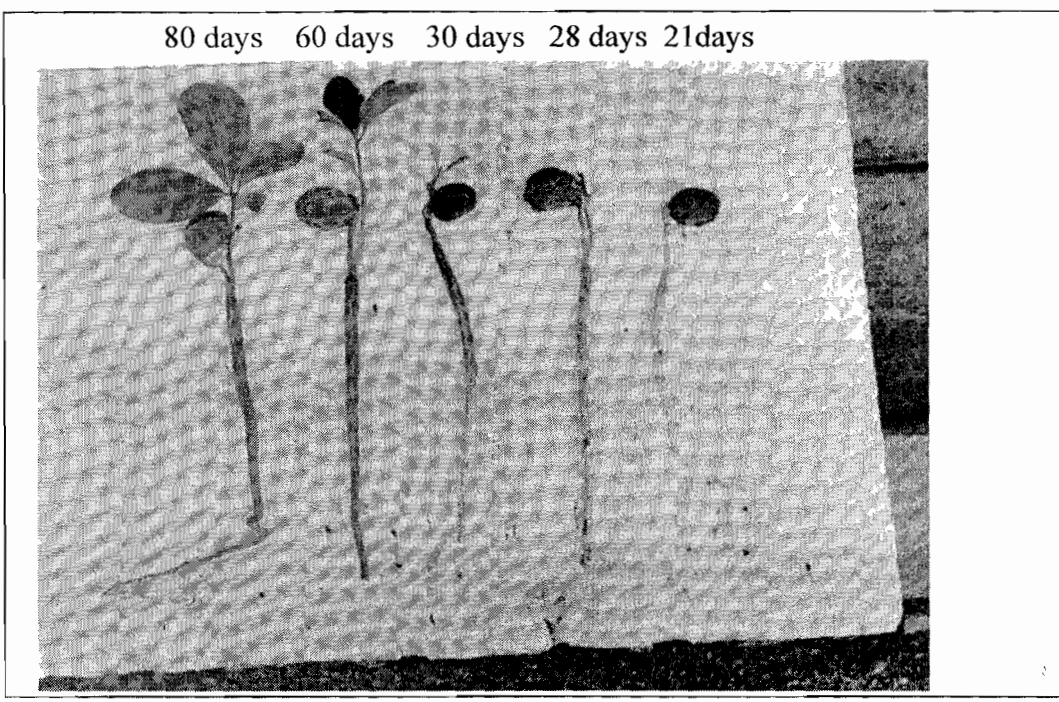

Plate 2. Cryptogeal germinating shea seedlings.

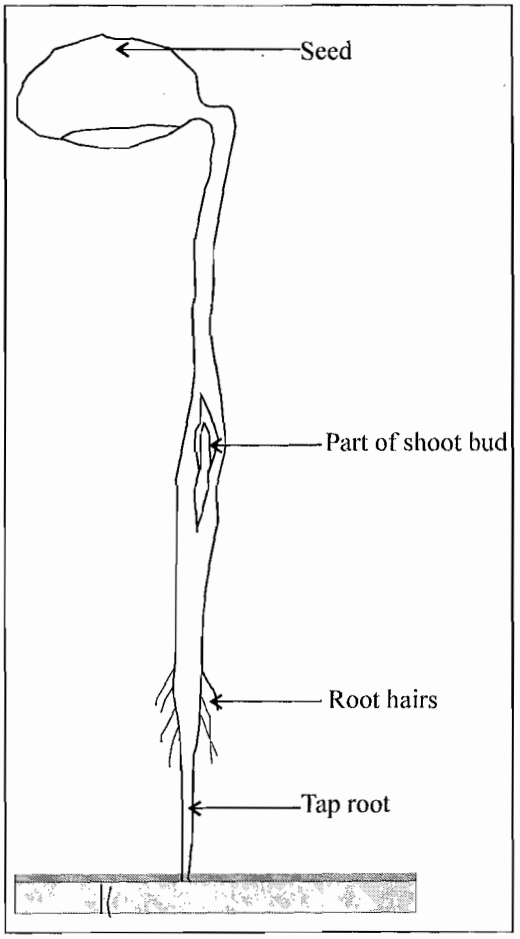

Figure 2. Germinating shea seedling.

performance of the different sizes of polybags. Seedlings raised in medium size polybags (12 cm x 18 cm) were easier to transplant. Transplanting at 3 months after sowing gave the highest seedling survival. The seedlings had a height of 6-8 cm at this stage and possessed 4-6 fully expanded green leaves (Plate 3). Further growth was however slow, the seedlings attaining heights of only 8cm-22 cm 3 years after

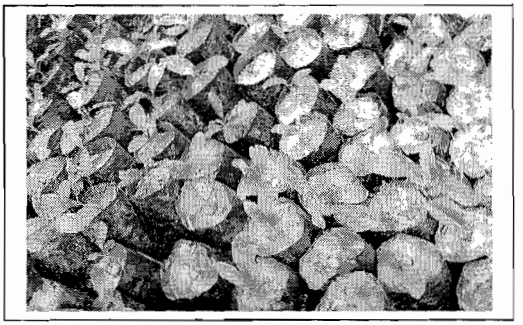

Plate 3. Shea seedlings at 3 months after germination.

transplanting. Three hundred seedlings were kept in the nursery for three years without any adverse effects. The regular nursery practices that were effective in seedling maintenance were root pruning and regular watering, (three times a week). When roots were pruned, new root tips developed and continued to grow normally. When the tap root was cut close to the base however, it became stunted and subsequent growth of the seedling was retarded.

Vegetative propagation methods

Rooting of Stem Cuttings

Stem cuttings of shea trees did not root readily. They however produced sufficient roots when treated with plant growth regulators. Per cent rooting obtained after treatment with indol-3-acetic acid (IAA) and or indol-butyric acid (IBA) varied from 20 % to 80 % in each treatment. The higher percentages were obtained when mist propagation was used. Sufficient root growth was obtained 70 days after setting the cuttings (Plate 4). Hardening the cuttings for one month before

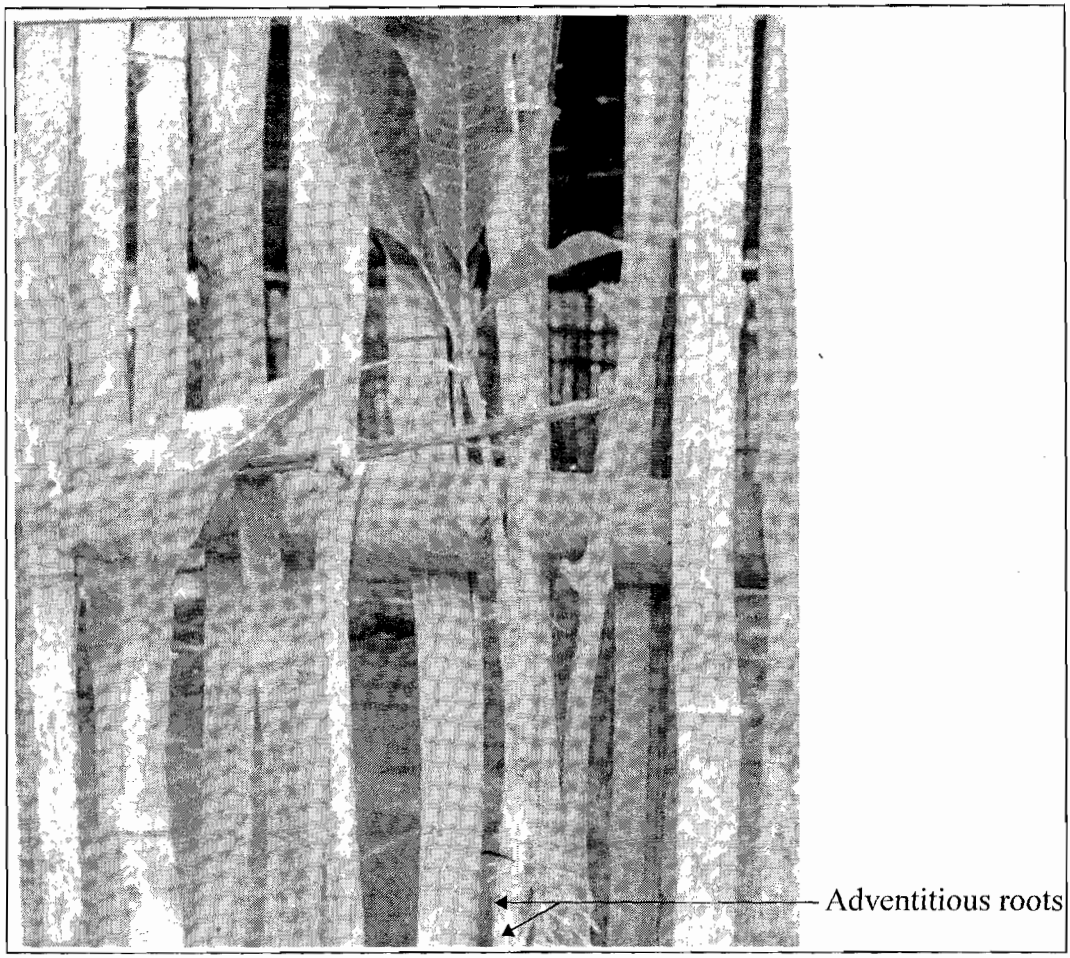

Plate 4. Rooted shea stem cutting.

transplanting produced the highest survival of rooted cuttings after transplanting.

Air-layering

Epicormic shoots produced roots within 51 days whilst normal shoots rooted after 70 days (Plate 5). Plants produced by this method grew faster, reaching plant heights of over 1m two years after transplanting.

Variation among shea trees

Individual tree yields

Table 5 shows the variation that existed in some important characters of shea trees. Total yield of fresh fruits and dry kernels, weight per fruit, per cent kernel yield and fat content of the kernels were all widely variable (Table 5). The largest number of fruits a single tree produced was 4,309 fruits in tree number YA15.

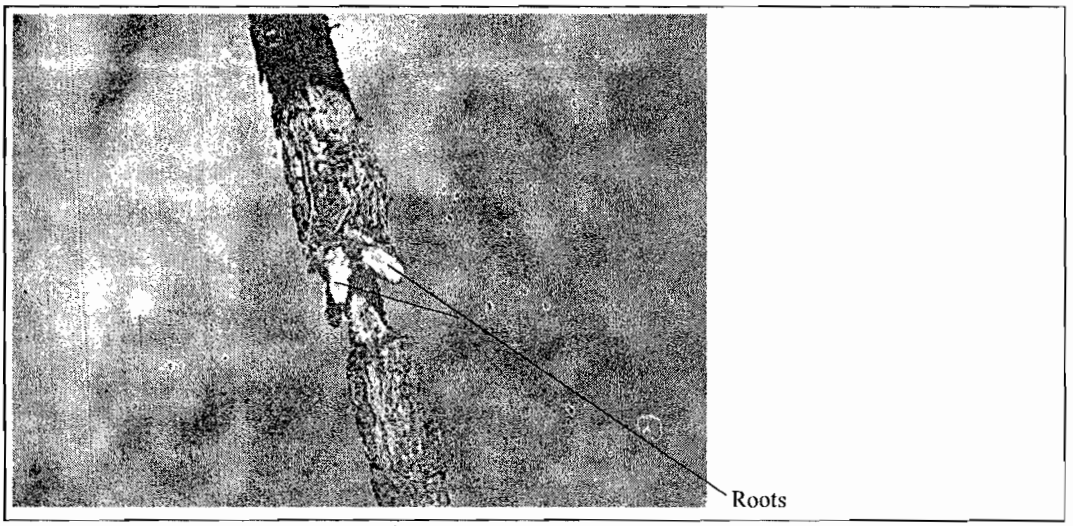

Plate 5. Rooted air-layer of shea tree.

Table 5. Variation in fruit and kernel yield of individual shea trees.

Tree No.	*No. of fruits*	*Mean fruit weight (g)*	*Total weight of fruit (kg)*	*Weight of dry kernel(kg)*	*% Yield of dry kernel*
YA4	515	11.26	5.80	1.75	30.17
YA22	1335	10.82	14.45	4.20	29.07
YA8	192	39.58	7.60	2.15	28.29
YA6	2638	25.04	66.05	18.07	27.36
YA14	562	10.59	5.95	1.45	24.37
YA15	4309	15.15	65.27	15.80	24.21
YA9	133	14.29	1.90	0.45	23.68
YA12	2318	14.88	34.50	8.15	23.62
YA19	294	12.48	3.67	0.85	23.16
YA20	327	10.00	3.30	0.75	22.73
YA25	2198	19.05	41.87	7.40	17.67
YA1	1207	11.35	13.70	1.75	12.77
YA5	192	16.41	3.15	0.30	9.52

The largest fresh fruit weight per tree was 66.05 kg in YA 6.

Table 6 shows variation in fat content (34 - 47 %) of sheanut obtained from different trees on the shea plantation of the CRIG sub-station at Bole in the Northern Region of Ghana. Adu-Ampomah *et al.* (1995) reported a wider variation (33 to 63 % fat content) from nuts collected over a wider geographical coverage (Northern, Upper East and Upper West regions).

Table 6. Variation in fat content of sheanut kernel from eight tree types at CRIG sub-station, Bole in Northern Ghana.

Tree No.	*% Fat content of kernels*	*Tree height (metres)*	*Tree girth (metres)*	*Fruit type*
YA8	47.17	8.39	0.76	Type 2
YA5	47.14	6.57	0.65	Type 1
YA2	44.85	5.22	0.45	Type 1
YA4	43.19	4.35	0.52	Type 1
YA7	40.70	10.60	0.11	Type 2
YA3	38.90	5.16	0.50	Type 1
YA6	35.16	13.25	0.14	Type 2
Ya1	33.93	16.19	0.17	Type2

Variation in shea fruit types

Data collected over a period of three years show that a shea tree usually produces one fruit type predominantly but other fruit types may be present. These differences are consistent enough to use as a basis for developing sheanut varieties (Table 7 and Figure 4). Figure 3 shows the computed length to breadth ratios (L:B ratios) of four types of shea trees. Plate 6 illustrates the variation in fresh ripe shea fruits.

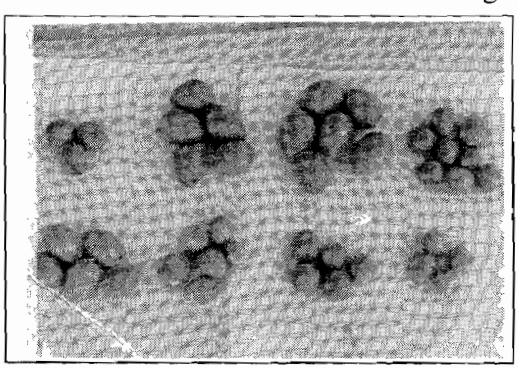

Plate 6. Variation in fresh shea fruit size and shape.

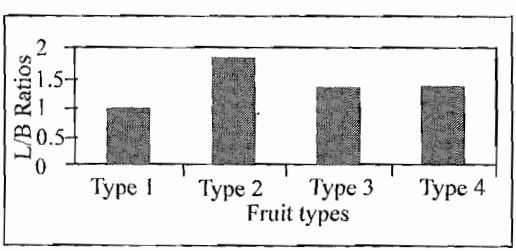

Figure 3. L/B ratios of four sheanut fruit types.

Table 7. Characterisation data of four shea tree types.

Shea tree type	*Characteristics*
Type 1	Large rounded fruits with lengths of fruit approximately equal to the breadth. (L/B ratio approx. = 1). Fruit length and breadth of Type 1A (100 fruit wt > 1 kg) vary from 4cm to 5cm and less in Type 1B (100 fruit wt < 1 kg).
Type 2	Large long fruits with lengths approx. twice that of breadth. L/B ratios vary from 1.7 to 2 or more. Fruit lengths in Type 2A vary from 4cm to 7cm whilst those of Type 2b are usually less.
Type 3	Fruits have rounded proximal ends and pointed distal ends. The degree of distal tapering vary among trees. Mild tapering is indicated by 'a' and 'b' by stronger tapering. L/B ratios vary from 1.1 to 1.5.
Type 4	Fruits with tapering or elongated proximal ends and rounded distal ends. L/B ratios vary from 1.3 to1.5.

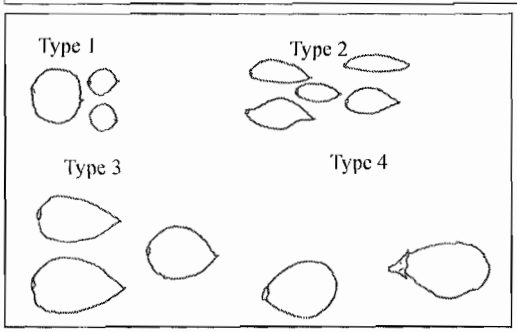

Figure 4. Shea fruit types.

Discussion

Enhancing pollination and fruit yield

Early studies by Coull (1928), Symond (1930) and others established that shea trees are predominantly cross-pollinating. The current study has established that hand pollination and other artificial methods of pollination is effective. The effect of bee keeping as a method of increasing pollination has not been studied but the results of hand pollination has shown it is possible to apply artificial pollination techniques to shea trees.

Prospects for early bearing shea trees

Sheanut seedlings can be raised in containers and kept under nursery conditions for over three years. This permits for selection for vigour and faster growth. This will contribute to healthier and faster growing trees with the added possibility of grafting the rootstock for early bearing. Grolleau (1989) reported achievement of grafting of 4 year old sheanut seedlings and they fruited within two years. The technology can be employed together with the techniques for seedling production to produce grafted sheanut plants for planting by farmers. Farmers have already demonstrated their interest

in the cultivation of sheanut by developing plantations through natural regeneration and preserving natural stands on their farmland. Rooting of cuttings is easier but contributes little to the shortening of the long vegetative growth phase of sheanut. Rooted cuttings and plants produced by air-layering and transplanted since 1991 have still not started bearing fruit. Frimpong and Adomako (1986) demonstrated that about 74% of the dry matter of seedling plants is found in their roots, indicating that shoot development is suppressed in the early stages of shea seedling growth. Developing the grafting techniques offers the best opportunity to reduce the gestation period of the crop and make it more attractive as a tree crop.

Plantations developed by natural regeneration also grow faster due to an already developed root system of those growing from old stumps. The technique can be improved further by grafting the regrowths with scion from selected high yielding shea trees. The variation observed in mature trees can be used as a basis for selecting trees for use as source of scion.

No success was recorded for both side and approach grafting in the present study, the cut surfaces dried up before the graft union could form. Review of the literature however revealed that success was achieved by Grolleau (1989). This gives promise to the possible application of the grafting technique to shea trees in Ghana.

The methods for hand pollination in shea nuts are useful tools for producing crosses that would enhance selection for further improvement of the crop.

Seedlings sprayed with biozyme were also reported to grow more rapidly (Frimpong *et al.*, 1990). Results were best at concentration of 500 ppm. This treatment can be employed to enhance rapid growth and early bearing in shea trees.

Other relevant technologies that have been reported in the literature include solar drying by use of transparent polyethylene sheet on a simple wooden frame. This prevents the kernels from getting mouldy (Aye and Adomako, 1990, unpublished). Nuts that are not properly dried rapidly become mouldy and this increases the free fatty acid content of sheabutter. The world market now demands less than 1 % free fatty acids in shea butter, but improper nut handling can raise this to over 40 %.

Methods for controlling epiphytes on shea trees have been reported by Phillips and Ollennu (1990) and Boussim *et al.*, 1993.

Conclusion

Significant progress has been made in research on sheanut leading to the development of technologies that could be applied to increase the production and quality of sheanuts and shea butter. The estimated potential production of 130,000 tons of sheanuts per annum could easily be surpassed if the available technologies are applied on a commercial scale.

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