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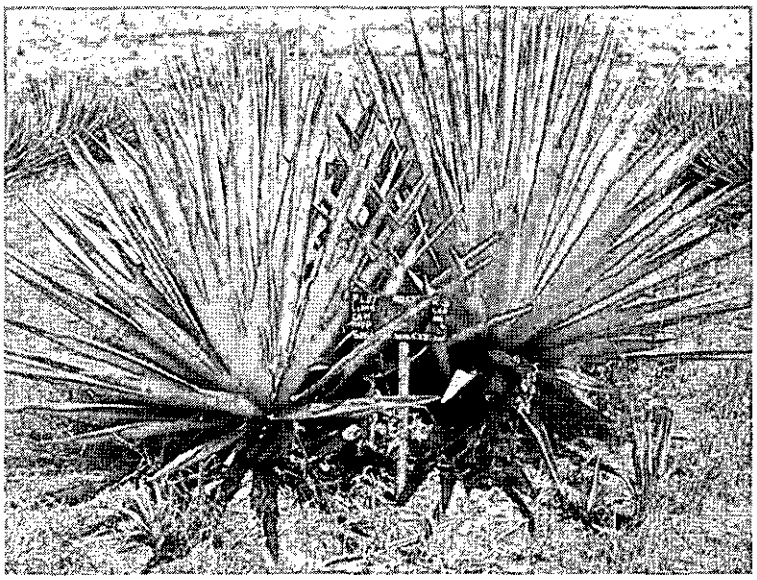
Common Fund for Commodities

PROJECT CFC/FIGHF/07

PRODUCT AND MARKET DEVELOPMENT OF SISAL AND HENEQUEN

Project Completion Report



Addendum A.3 - Part One: Kenya

Variety Trials in Estates

January 1997 – December 2004

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

COMMON FUND FOR COMMODITIES

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Product and Market Development of Sisal and Henequen

Project completion report
Addendum A.3 – Part One: Kenya

Variety Trials in Estates

Kenya
January 1997 – December 2004

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna 2005

Project Completion Report preparation: National and international experts and consultants involved with the project, with contributions and support from the national teams.
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Project Completion Report

Sub-component A.3 – Part One: Kenya
"Variety Trials in Estates"

CONTENTS

Abbreviations and acronyms

A.	Agave
ARI	Agricultural Research Institution
CFC	Common Fund for Commodities
FAO	Food and Agriculture Organization
Ha	Hectare
HLSRS	High Level Sisal Research Station
Hyb.	Hybrid(s)
IFAD	Food and Agricultural Development Organization
IGGHF	Intergovernmental Group on Hard Fibre
KARI	Kenya Agricultural Research Institute
KLS	Korogwe leaf spot
KRRC	KARI Regional Research Center
KSB	Kenya Sisal Board
MASL	Metres above the sea level
MT	Metric tonne
R&D	Research and Development
Spp.	Species
UNIDO	United Nations Industrial Development Organization

Explanatory Notes

Fibre Yield (MT/Ha)	Total fibre (metric tonne) harvested per hectare in a specific time, e.g. one year or production cycle.
Meters/Tonne	Number of cubic meters of leaf required to give one metric tonne of fibre.
Meter of Leaf	One cubic meter of leaf harvested by one cutter. This is the normal daily task for a cutter. This is made up 100 bundles of leaf. One bundle of leaf normally has 25 leaves as the standard, but it could vary up to 33 in different estates and depending on the size, and weight of the leaf. One meter of leaf therefore contains between 2,500 and 3,300 leaves. For variety trials, the standard 2,500 leaves/meter was used.
Fibre recovery	Percentage of long fibre recovered against total weight of leaf.

I. Project sub-component summary

1. **Title:** Variety trials in estates

2. **Location:** Kenya

3. **Starting Date:** January 1997

4. **Completion Date:** December 2004

5. **Sub-component external financing** – excluding counterpart contribution

Total sub-component cost:	US$ 101,118
Of which:	
CFC financing:	US$ 46,098
Belgium Government:	US$ 14,467
UNIDO:	US$ 40,553

II. Background and context in which the sub-component was conceived

Sisal fibre (fibre derived from agave species (Spp) has traditionally been used for the manufacture of harvest and baler twine. This traditional harvest and baler twine market has however been consistently and vigorously eroded by synthetic fibres since the late 1960s, leading to a decline in world annual production from about 782,000 metric tones (MT) in 1970 to about 327,000 MT in 1994.

Critical analysis indicates that the prospects of revival and expansion of sisal production in the long run largely depend on investment in research and development (R&D) to find new end uses, to add value through local manufacture, to better utilize waste products, and to treat wastes from decortication to generate bio-energy and other derivatives.

To achieve this goal, it was recognized that biological research, which ceased in the early 1970s, would play a central role in improving productivity, cost effectiveness, and competitiveness.

One of the strategies included in the line of action to achieve this goal, was to conduct sisal variety trials in sisal estates, to evaluate the performance of the existing sisal varieties in the different agro-ecological zones where sisal is commercially grown. This was considered necessary to develop standard recommendations for improved sisal production and fibre productivity in the short run.

The objective of this sub-component is to build on the existing knowledge in order to improve agronomic and crop management practices and to select varieties for pulp in order to expand the varieties available for traditional uses.

The output expected is the identification of suitable varieties for pulp and traditional uses, and the production of a technical paper summarizing results and advising on the selection of varieties and cultivation practices for different end uses.

The project target beneficiaries are sisal producers.

Extensive observations and discussions with farmers revealed that, over the years, the sisal plant has been changing and yields have been declining. One sisal estate reported a decline of up to 50% in productivity of their sisal crop. Observations on growing sisal crop in the estates grown both from bulbils and suckers showed significant variability in size and morphology of plants. The average productivity of sisal fibre in the estates was reported to be averaging 0.5 MT to 1 MT per hectare (Ha) depending on the level of management. Farmers reported falling production cycles for most of the commercial clones. Hybrid 11648, which was originally reported to have a production cycle of 10 to 14 years, was reported to be poling in 5 to 7 years.

Other observations in the field included Agave Sisalana plants producing suckers with spiny and smooth edged leaves from the same smooth leafed mother plant. In Hybrid 11648 fields, plants were found producing variegated and non-variegated suckers from the same mother plant itself with no variegations. In another field a Hybrid

11648 plant was found producing both albino and green bulbils on the same pole. This was also observed on an Agave Angustifolia plant. (Agave Angustifolia is one of Hybrid 11648's parents).

III. Implementation and results achieved

Sisal variety evaluation started in 1952 when the High Level Sisal Research Station in Thika (HLSRS) planted a trial to compare sisal (Agave Sisalana Perrine) with its mutants such as the non-flowering sisal. Another mutant named Hildana later found at Lomolo estate in Mogotio near Nakuru, was also included in the trials. In the late 1950s and up to the early 1960s, hybrids including H 1155, 1269, 1300, 1475, 1660, 6064, 7131 and 11648, selected from a series of crosses made at ARI-Mlingano, were introduced, and this formed the main focus of sisal variety trials in Kenya.

Unfortunately, these trials were abruptly interrupted in 1972 when the High Level Sisal Research Station at Thika was closed down. The trials and the clones were abandoned wherever they were, before the experiments could be concluded and reports prepared. Consequently, most of the clones, and hybrids in the trials were lost, except for a few including hybrids 11648 and 1300, which had been transferred to field trials in sisal estates.

The closure of the HLSRS led to the loss of all sisal research information generated over the years as well as of the germplasm collection, which had a collection of over 100 agave clones and crosses. Farmers attempted to collect as much of the information as they could but since it was not well documented and preserved, most of it was disjointed and inconclusive. Nevertheless, the farmers did the best they could with it and have kept the sisal industry alive to date.

Farmers adopted Hybrid 11648 and Agave Hildana for commercial production in addition to Agave Sisalana due to their reported high leaf productivity and long production cycle. The only sisal estate, growing Hybrid 1300 commercially (Samar Estate) closed down in the late 1980s. However, isolated plants of the Hybrid 1300 are normally found in Hybrid 11648 fields.

Farmers continued growing Hybrid 11648, Agave Sisalana and Hildana depending on the farmers' preference, using suckers and bulbils as planting material. After about 80 years of growing Agave Sisalana and 30 years of continuous cultivation of hybrid 11648, signs of degeneration started to become evident, with poling coming earlier than expected, plants succumbing to diseases like soft and dry bole rot and, especially, the Korogwe Leaf Spot (KLS), and reduced yields.

The "Product and Market Development of Sisal and Henequen" Project identified research in the improvement of varieties, agronomic practices, harvesting and processing technologies and machinery as a key component in the improvement of productivity and reduction of production costs in order to produce price competitive fibre for the envisaged new markets and uses. As a first step, a comprehensive evaluation of all varieties in commercial production and available promising clones and hybrids was considered necessary.

Detailed agronomic trials including fertilizer and plant density trials were planned to be conducted at ARI Mlingano, which had an operational sisal research unit. Kenya was mandated to carry out a comparative variety trial based on the farmers' current practices, incorporating all commercial varieties, promising clones and hybrids

available from the germplasm collection at ARI Mlingano, in the different agroecological zones where sisal is grown.

III.1. Agro-ecological description of experimental sites

An extensive and detailed survey was conducted in the sisal growing areas to collect practical information from farmers' experiences on sisal growing. Extensive discussions were held with farmers and thorough observations were made in operating sisal estates, abandoned estates and on other Agave species growing in wild and ornamental gardens.

From information gathered in the survey, suitable experimental sites were identified in the low altitude (0-20 MASL), mid altitude (900 MASL), and high altitude (1200-1500 MASL) areas where sisal is commercially grown in Kenya.

Sisal plantations in the respective areas were approached to participate and host the trials. Unfortunately only the Alphega estate in the Mogotio area near Nakuru was willing to host the high altitude trial. The mid altitude trial was established in an abandoned sisal plantation owned by the University of Nairobi at Kibwezi, while the low altitude trial was established at KARI Regional Research sub-center at Msabaha – Malindi. A description of the sites is included below.

III.1.1 Nakuru

The area is classified as upper midland zone 5 or livestock-sorghum zone with medium to long cropping season and intermediate rains. It lies 0° S and 36° E at an altitude of 1,500 MASL.

It receives an annual mean rainfall of 700 mm, in mainly two seasons, April – June, and September – December. The area has an annual mean temperature of 18.9 °C - 19.6 °C.

The area has soils of moderate to high fertility. The soils are well-drained, moderately deep dark reddish brown, friable to firm and slightly smeary, bouldery and stony clay loam to clay. In some areas the soil is calcareous (ando-Chromic CAMBISOLS) with Calcic xerosols. Soil analysis results showed the area to have a slightly low pH, to be very low in Phosphorus, organic matter, Sulphur, and Boron, low in Nitrogen, and high in Potassium and Calcium.

III.1.2 Kibwezi

The area is classified as Lowland Midland zone 5 or Livestock-millet zone with very short cropping seasons. According to the Farm Management Handbook of Kenya, the area has a crop failure risk of 7 out of 10 seasons for maize. It lies 2°25' S and 37°59' E at an altitude of 900 MASL.

It receives an annual mean rainfall of 641 mm, in two seasons in March – May and November – January. The period between June and September is extremely dry with

hardly a drop of rain. The rainfall is normally 50 – 160 mm in the first season and 150 – 220 mm in the second season. The area has an annual mean temperature of 21.6 °C - 24 °C.

The area has soils developed on undifferentiated basement system rocks, an association of well drained, moderately deep to deep dark red to dark reddish brown, friable to firm sandy clay to clay (Chromic LUVISOLS). The soils are classified as low fertility soils. Soil analysis results showed the area to have low pH, to be low in organic matter, Phosphorus and Nitrogen and high in Potassium and Calcium.

III.1.3 Malindi

Malindi/Msabaha site is located in the KARI regional research sub-center at Msabaha, about 8 Km from Malindi. The site was previously cropped with cashew nut trees and other annual crops including cassava, maize, cotton and horticultural crops for research.

The area is classified as coastal lowland 4 zone or cashew nut, cassava zone with medium cropping season and intermediate rains.

It lies between 3°25' S and 40° E at an altitude of 20 MASL. It receives an annual mean rainfall of 1,049 mm, in mainly one season in March – September. The area has an annual mean temperature of 26.6°C – 24.9 °C.

The area has soils developed on raised coral reef limestone with a mixture of lagoonal deposits. The soils are well drained, deep dark red to reddish brown, friable sandy clay loam to sandy clay with a top soil of loamy sand (rhodic FERRALSOLS) with a medium to heavy texture. The soils are classified as low fertility soils.

Soil analysis results showed the area to have low pH, to be low in organic matter, Potassium and Nitrogen, although with adequate Phosphorus and Calcium.

III.2. Bulbil sourcing and collection and nursery establishment

Bulbils were collected in sisal plantations as follows: -

- Hybrids 11648 and 1300 from Dwa sisal estate at Kibwezi;
- Agave Sisalana and Hildana from Alphega estate and Lomolo estate at Mogotio – Nakuru respectively;
- Agave Angustifolia from an ornamental garden at Muthaiga estate in Nairobi;
- Agave Americana, Mlola 487, MLI were sourced from the germplasm collection at ARI Mlingano. Due to plant quarantine requirements a few suckers were planted under quarantine at the Plant Quarantine Station – KEPHIS for screening and certification.
- Agave Amaniensis (blue sisal) was collected from the field in Taita area but only a few suckers were available.

A quarter hectare nursery was established in each of the three sites. Hybrid 11648 and 1300, Agave Sisalana, Agave Angustifolia and Hildana were included in the nurseries. Only bulbils were used as planting material. A few Agave Amaniensis suckers were planted in each site for observation beside the trial.

Kibwezi and Nakuru nurseries were lifted in November 1998, exactly 12 months after planting. The nursery at Kitsoeni (Malindi) was lifted in May 1999 (17 months).

The Kibwezi and Nakuru nurseries did not experience major problems with either diseases or pests. However, due to the heavily humid and warm weather, the Malindi nursery was seriously affected by weevil attack, which caused an appreciable level of bole rot attack. It was also seriously affected by heavy weed growth, which necessitated continuous weeding. This stress caused the plants to grow much slower than in the other two sites. The plants were also much weaker than in the other sites.

An enumerator was stationed at each nursery to maintain the nursery, observe and take all data on growth, disease and pest attack, the rate of establishment and survival of the bulbils, and climatic data. Since planting coincided with the onset of "El niño" rains of 1997, there was no need for irrigation on any of the nurseries.

III.2.1 Nakuru

The nursery was located at Alphega sisal estate at Mogotio, 40 km north of Nakuru town. The plot had been planted with Hybrid 11648 and the old sisal was crushed and ploughed in the soil using heavy machinery. The plot was ripped, ploughed and harrowed before planting and decomposed sisal waste applied as in Kibwezi. The same treatment was given as in Kibwezi (below), before the bulbils were planted. The nursery was planted on 25 November 1997.

III.2.2 Kibwezi

The nursery was located in an abandoned sisal estate, which was previously planted with Agave Sisalana. The estate had been in disuse for over 20 years and was overgrown with bush and sisal suckers. Two hectares of the bush were cleared by hand, trees uprooted and the plot ripped to clear roots. The plot was then ploughed twice, harrowed and fenced with a chain link to keep off troops of baboons, which inhabit the bush.

Decomposed sisal waste was applied by hand at the rate of 50 MT/Ha and ploughed into the soil.

The bulbils were graded into a uniform size of approximately 6 cm and dipped in thiodan solution before planting, to prevent attack by sisal weevil and grubs. The bulbils were planted at a spacing of 25 cm x 50 cm (80,000 plants/Ha), as is the conventional practice in the estates.

The nursery was kept completely weed free by hand weeding and was sprayed with thiodan and termidor as and when signs of sisal weevil attack were noticed.

The nursery was planted on 21 November 1997 and a permanent caretaker engaged to keep baboons off.

III.2.3 Malindi

Due to pressure of time, as negotiations with KARI, initially selected for the trials, had not been finalized, this nursery was established in a small holder farmers plot at Kitsoeni, 60 km South of Malindi, but the same altitude (10 - 20 MASL). One hectare of bush fallow was cleared and prepared as in Kibwezi. The same treatment of bulbils was given as at Kibwezi. This nursery was planted on 29 November 1997.

III.3. The variety trials

At Nakuru and Kibwezi, the trials were planted on the same sites (not same plots) where the nursery was located. For the low altitude trial, the plants from Kitsoeni nursery were transferred to the KARI – Regional Research sub-center at Msabaha – Malindi.

At transplanting, it was decided to leave out Agave Angustifolia due to its very short and spiny leaves, which made it unsuitable for line fibre and for pulping. Consequently, only Agave Sisalana, Hildana, Hybrid 11648 and Hybrid 1300 were included in the trials. A few suckers of Agave Amaniensis, were planted for observation beside the trial in all sites, while after the release of Mlola 487 and MII from quarantine, a few suckers of each were planted in Malindi, Kibwezi and Plant quarantine Station-Muguga for observation.

The seedbed was prepared in the conventional farmers way by ploughing and harrowing. The trial was laid down as in the trial plan in Figure 1, in a randomized complete block design with four blocks and four varieties, Agave Sisalana, Hildana and Hybrids 11648 and 1300 as treatments. The clones were planted in plots measuring 12.5 meters by 20 meters, separated by 4-meter wide paths on all directions. Spacing of 1.25 m X 2.5 m between plants and between rows respectively in single row arrangements was used. This translated into a plant density of 3,200 plants per hectare, which is close to the conventional 3,333 plants per hectare density used by farmers.

Figure 1. Field experimental plan

BLOCK 1		*BLOCK 2*		*BLOCK 3*		*BLOCK 4*
Variety 1		Variety 1		Variety 1		Variety 1
4 meter path		4 meter path		4 meter path		4 meter path
Variety 2	4 meter path	Variety 2	4 meter path	Variety 2	4 meter path	Variety 2
4 meter path		4 meter path		4 meter path		4 meter path
Variety 3		Variety 3		Variety 3		Variety 3
4 meter path		4 meter path		4 meter path		4 meter path
Variety 4		Variety 4		Variety 4		Variety 4

At planting, the plants were again graded into uniform sizes. At Kibwezi, plants weighing 2.0-2.5 kg with 16 leaves were planted. At Nakuru and Malindi plants weighing 1.5 – 2kg with over 20 leaves were planted.

The plants were dipped in a thiodan solution and termidor to prevent attack by sisal weevil, termites, and grubs. No fertilizers were applied, but an application of thiodan and termite killer was occasionally given whenever signs of pest attack were noticed.

All the recommended agronomic/husbandry practices including weeding, disease and pest control, and harvesting routine were strictly applied and kept on schedule.

The trials were kept completely weed free by hand weeding.

In the second and third years, sand leaves (old drying leaves) were harvested in all sites. No irrigation was done, as this is not practiced in sisal plantations.

III.4. Data collection methods

After the seventh month of growth, collection of monthly data on the number of new leaves produced was commenced. After the thirteenth month of growth, the length and width of new leaves was recorded every two months. Disease and pest attack were recorded as soon as the first symptoms were noticed and treatment was given immediately, as explained above, to prevent serious damage.

First production of suckers was recorded 6 months after planting; counting was done before desuckering and subsequent weeding.

Counts of plants showing signs of water stress by drooping of leaves were also taken during dry seasons.

Data was collected from a net plot comprising the center 27 plants in each plot. The outer ring of 28 plants in each was left as guard rows.

Monthly rainfall, temperature and humidity readings were taken from the nearest weather station to the trial whenever it was available.

Each trial had an enumerator stationed permanently to collect data and maintain the trial.

First harvesting at Nakuru was conducted after 35 months, after 46 months at Kibwezi and after 48 months at Malindi. The difference in the first harvest explains the high number of leaves recorded for Kibwezi and for Malindi. All the leaves above 45° to the central spine were harvested each time. This left 50 to 70 leaves on the plants. Subsequent harvests were conducted anytime after between six and eight months depending on how fast the plants grew to have over three rings of mature leaves. Harvesting continued until 60% of the plants had poled.

At harvesting, the fresh weight of leaves, length and width, pests, diseases, and any other occurrences were recorded. At decortication a sample of 100 leaves from each variety was decorticated dry, to separate and measure long fibre, flume tow and bogas recoveries. The rest of the leaves were decorticated, air-dried and brushed per plot. Un-brushed and brushed fibre weight and tow were recorded.

Since it was not possible to carry out pulping and pulping tests in Kenya, samples from every harvest were sent to Moshi and Iringa in Tanzania for pulping and pulping tests respectively.

The data recorded was statistically analyzed and the results are reported in the following section. In particular the most interesting variables were:

- Fibre yields potential of the four varieties in the three agro-ecological zones;
- Rate of maturity, life cycle and harvesting, frequency and interval;
- Production curve for the whole production cycle of the varieties;
- Response to climatic conditions;
- Disease and pest incidence;
- Lessons learnt and recommendations for further research.

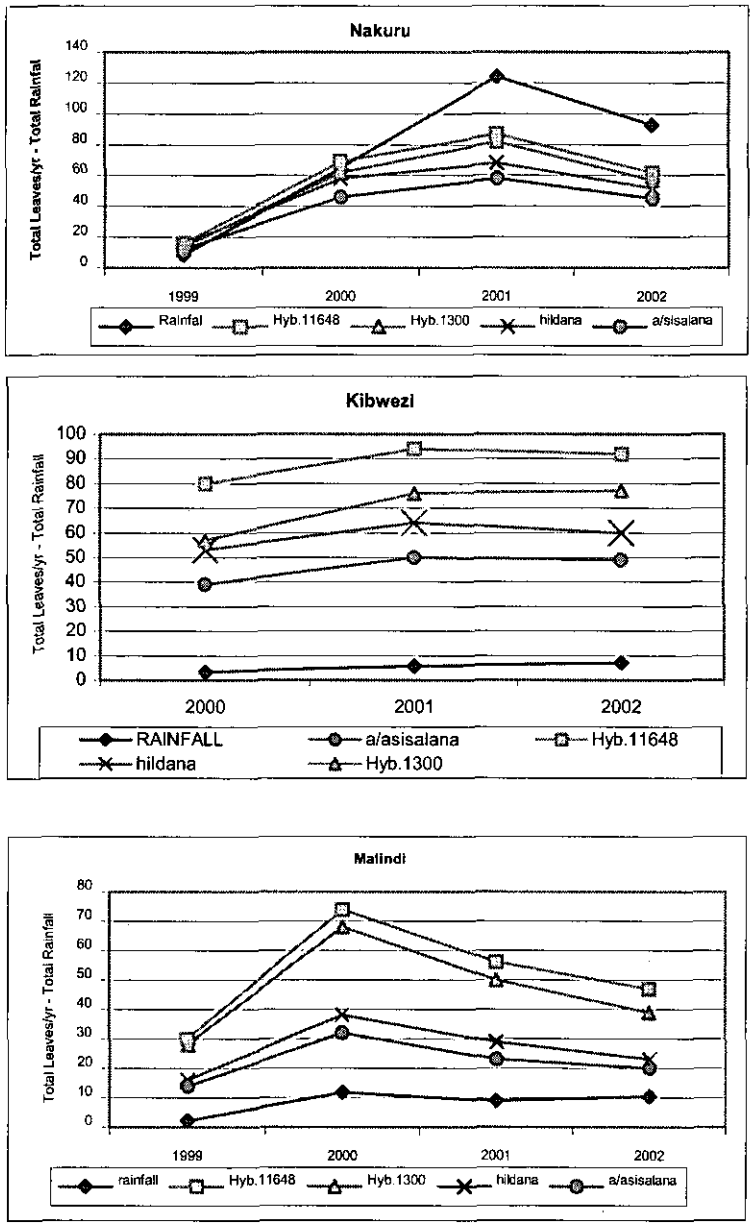
III.5. Trials performance

III.5.1 Effect of rainfall and temperature on total annual leaf production

While there seemed not to be much effect on the number of leaves produced as long as the temperatures remained around 27 to 30°C, the effect of rainfall was evident, at least up to the maturity stage.

Leaf production increased with the increase of total rainfall up to maturity stage after which, when the process of poling started, leaf production consistently declined until the plant poled. This is evident from the graphs reported in Figure 2.

Figure 2. Effect of rainfall (mm) on total annual leaf roduction (No. of leaves)



III.5.2 Fibre yields potential

The data collected at the different sites (leaf length, leaf width, number of leaves harvested per plant, fibre yield) at the different harvesting times and for the different varieties is included in Annex 1. As harvesting at Kibwezi and Malindi started six months later than scheduled, the first and second harvests were combined as can be seen by the high number of leaves/plant harvested in the first harvest. Likewise in both sites the last harvest was conducted six months earlier than scheduled as the project came to an end. This caused the loss of the first and of the sixth harvests.

III.5.2.1 Nakuru

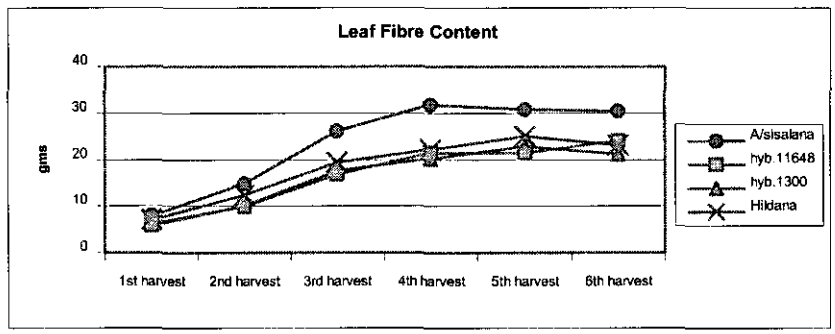
Leaf length increased up to the third harvest and then leveled off. Agave Sisalana recorded the highest length followed by Agave Hildana, Hybrid 11648 and Hybrid 1300.

Leaf width, like length, increased up to the third harvest and then slowly started declining for all varieties.

The number of leaves harvested per harvest generally decreased with every harvest. Hybrids 11648 and 1300 recorded higher leaf production than Agave Sisalana and Hildana.

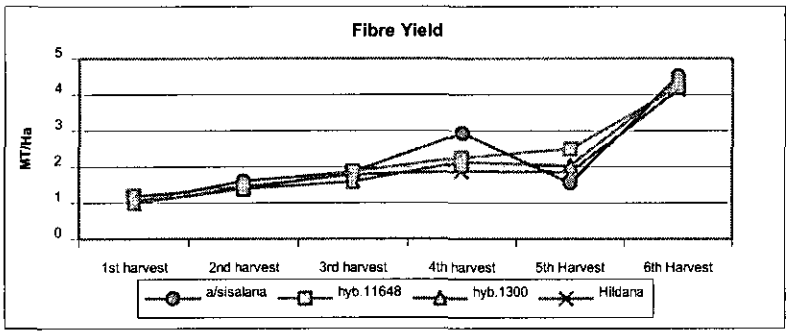
As shown in Figure 3, leaf fibre content increased faster for Agave Sisalana up to the fourth harvest and then slowly declined. For the other varieties the fibre content increased at a slower rate but continued to increase up to the fifth harvest, indicating that the varieties were still growing.

Figure 3. Leaf fibre content (fibre yield/leaf) in grams – Nakuru trials



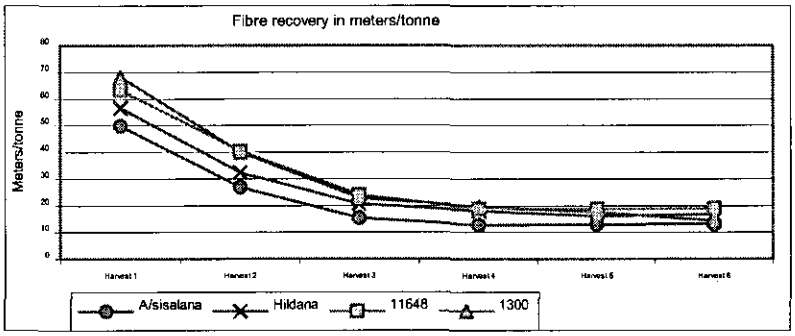
The fibre yield per hectare (Figure 4) steadily increased at more or less the same rate for all varieties up to the third harvest. Agave Sisalana had then a sharp increase as a result of plants poling and being cut out in the fourth harvest after which there was a sharp decline. Hildana increased at a slower rate after the third harvest while the Hybrid 11648 continued to rise showing indications of continued growth after the fifth harvest. The Hybrid 1300 showed a slight decline after the fourth harvest.

Figure 4. Fibre yield in MT/Ha – Nakuru trials



The difference between varieties on fibre content (Figure 5) is not significantly pronounced in Nakuru (as it is in Kibwezi, particularly between Hybrid 1300 and the other varieties in the early stages of growth.) The trend, however, is the same shown in the two other sites with the varieties tending to reach the same fibre content at maturity.

Figure 5. Fibre recovery in meters/tonne – Nakuru trials



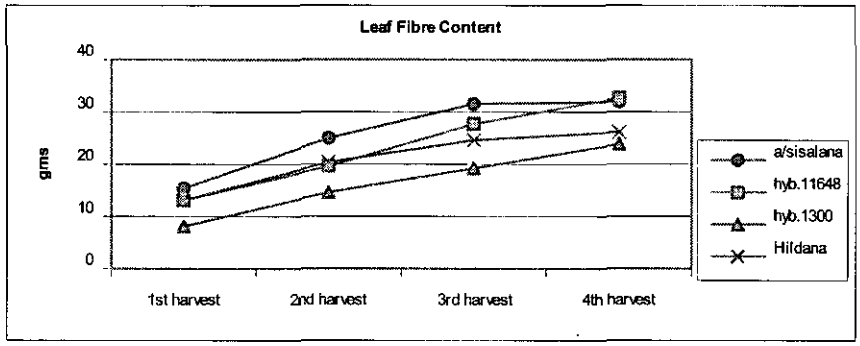
III.5.2.2 Kibwezi

Leaf length increased up to the third harvest and then declined for Agave Sisalana, Hildana and Hybrid 1300. It appears that the Hybrid 11648 was still growing after the third harvest but at a slower rate. Agave Sisalana had the highest leaf length followed by Hildana, Hybrid 11648, and Hybrid 1300 had the shortest leaves.

Leaf width increased up to the second harvest and then slowly started declining for all varieties. Hybrid 11648 recorded a higher width up to the third harvest and then declined. At the fourth harvest all varieties recorded equal leaf width.

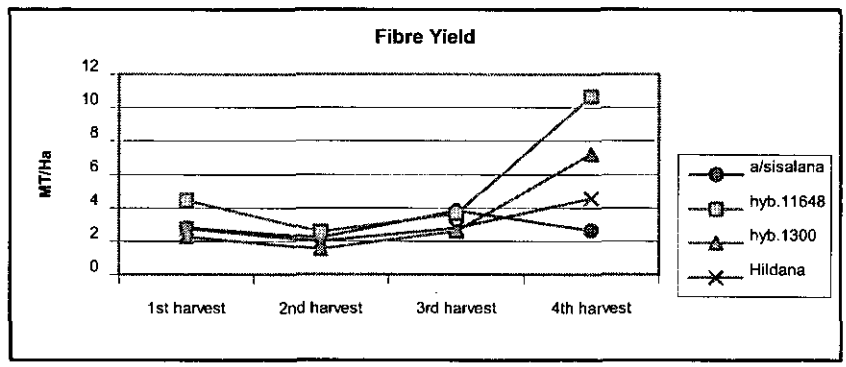
All varieties recorded a steady increase in leaf fibre content (Figure 6) up to the third harvest. Agave Sisalana had the highest fibre content up to the third harvest but leveled off after this point. Agave Hildana increased its fibre content at the same rate with Hybrid 11648 up to the second harvest but reduced the rate after this point. Hybrid 11648 continued to increase its fibre content steadily up to the fourth harvest where it equaled Agave Sisalana and still showed indications of further increase. Hybrid 1300 had the lowest fibre content and increased at a lower rate but showed steady indications of continued growth after the fourth harvest.

Figure 6. Leaf Fibre Content (Fibre yield/leaf) in grams – Kibwezi trials



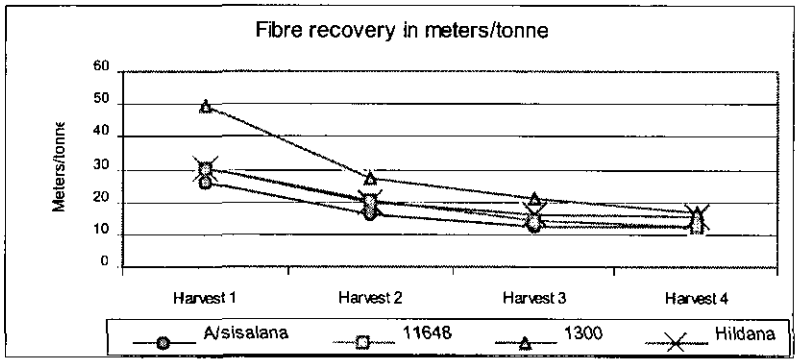
Figures 7 shows the mean fiber yield per hectare. The trials confirmed that for all the varieties the number of leaves harvested per harvest is a critical factor determining the amount of fibre realized per hectare.

Figure 7. Fibre yield in MT/Ha – Kibwezi trials



Comparison of fibre recovery in meters/tonne of fibre, as represented in Figure 8, shows that all varieties had very low fibre content in the first harvest but this quickly increased from the second harvest. Hybrid 1300 had the lowest fibre content at the beginning but caught up with the other varieties at the fourth harvest. This indicates that this variety has a slower rate of growth at the beginning but reaches the other varieties at maturity. Hybrid 11648 and Agave Hildana had the same growth trend but at maturity the Hybrid 11648 recorded higher fibre content. Agave Sisalana had the highest fibre content in the young stage but the other varieties reached it at the second harvest.

Figure 8. Fibre recovery in meters/tonne – Kibwezi trials



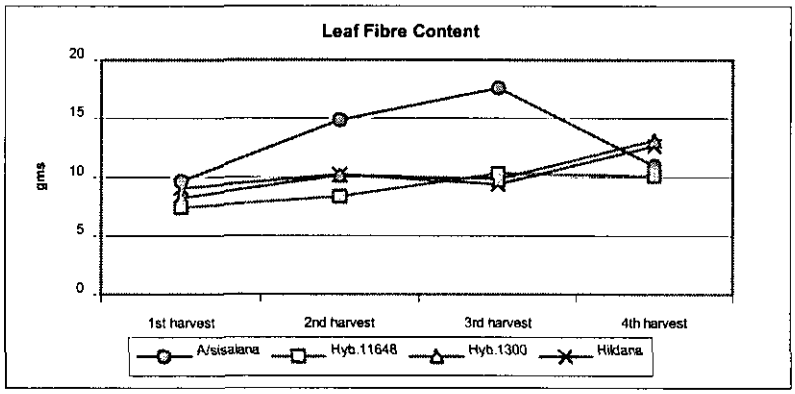
III.5.2.3 Malindi

Leaf length changed only slightly during the trial; Agave Sisalana had the longest leaves followed by Agave Hildana, Hybrid 1300, and Hybrid 11648 which had the shortest leaves.

Leaf width declined after the second harvest in all varieties. It is noted that the curve of Agave Sisalana and Agave Hildana are very similar while those of Hybrid 11648 and Hybrid 1300 are also very similar indicating that the two sets of varieties possibly share a similar genetic background.

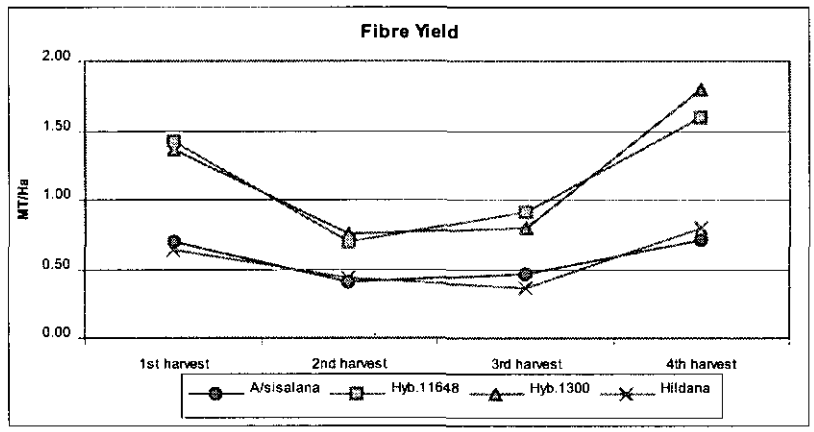
Agave Sisalana recorded the highest leaf fibre content (Figure 9), which increased up to the third harvest and then suddenly declined in the fourth harvest. Hildana and Hybrid 1300 recorded a similar trend of increase in fibre content and at the fourth harvest still indicated continued increase. Hybrid 11648 leveled off after the third harvest.

Figure 9. Leaf fibre content (fibre yield/leaf) in grams – Malindi trials



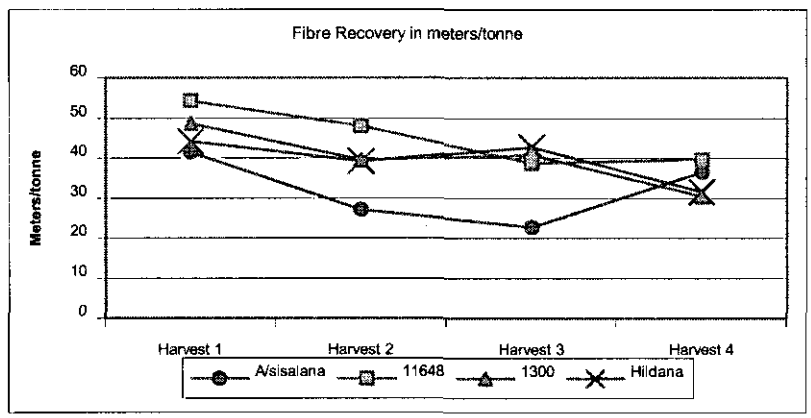
All the varieties showed similar trends in number of leaves harvested per plant and the resultant fibre yield per hectare (Figure 10). As mentioned above regarding leaf width, the curves for Agave Sisalana and Agave Hildana are very similar, and the same can be noted for Hybrid 11648 and Hybrid 1300, giving a strong indication that each of the two sets of varieties could share common origins.

Figure 10. Fibre yield in MT/Ha – Malindi trials



The fibre content (Figure 11) increased up to the third harvest, and then decreased. This is completely in accordance with the trend observed at Kibwezi and Nakuru.

Figure 11. Fibre recovery in meters/tonne – Malindi trials



III.6. Pulping and pulping trials

Pulping and pulping tests on all the four test varieties for the first to fourth harvests at Malindi and Kibwezi, and first to sixth harvests at Nakuru, were conducted at Kibo Pulp and Paper Mill-Moshi and Mufindi paper Mill-Iringa respectively. The tests were conducted at two different times by Katani Ltd. subcontracted by KSB.

The tests were conducted under the following conditions:

a. Pulping

Active Alkali (NaOH)	13.5%
Anthraquinone (second test only, not used first test)	0.1%
Time to maximum temperature	90 Min
Time at maximum temperature	90 Min
Bath ratio	1:4

b. Pulp tests

The pulp was refined in a PFI mill and freeness determined using Canadian Freeness Tester to about 300 CSF. Standard hand sheets were made and air-dried for testing strength properties. The pulp was washed after refining before determination of kappa number by titration.

III.6.1 Observations

Visual appearance of the pulp
On the first to second harvests at Malindi and Kibwezi, and the first to fourth harvests at Nakuru (first test), the pulp had shives while in the third to fourth harvests at Malindi and Kibwezi and fifth to sixth at Nakuru (second test), no shives were observed. These tests were conducted at different times hence the difference could therefore be attributed to different pulping conditions.

Pulp hand sheet color
Brown/pink

Hand sheet appearance
Black spots in the first test and good shade with no black spots in the second test.

III.6.2 Pulp yield

Pulp yield ranged between 56 and 78%. Agave Hildana in Nakuru in the fourth harvest recorded the highest yield while Agave Hildana and H. 11648 in Nakuru recorded the lowest yield in the sixth harvest.
Higher yields were also observed in third and fourth harvest of H. 11648 in Nakuru, second and third harvest of Agave Hildana in Nakuru, fourth harvest of Agave Sisalana and H. 1300 in Nakuru.

Pulp yields in the fifth and sixth harvests in Nakuru in all varieties and third and fourth harvests of all varieties in Malindi and Kibwezi are generally low. This was probably caused by the use of Anthraquinone in the second tests where more lignin was dissolved and removed than in the first tests where Anthraquinone was not used.

No clear trend of pulp yield could be between varieties, location or harvest stage probably due to the different conditions used in the first and second tests.

Table 1. Pulp yield (%) – all harvests
(see Graph in Annex 3)

VARIETY	LOCATION	HARVEST					
		1	2	3	4	5	6
H11648	Nakuru	71	72	75	74	58	59
	Malindi	71	73	60	69		
	Kibwezi	70	72	67	69		
H1300	Nakuru	71		72	74	60	56
	Malindi	73	73	62	60		
	Kibwezi	70	72	64	63		
Sisalana	Nakuru	74		73	75	62	59
	Malindi	70	72	62	62		
	Kibwezi	72	74	67	66		
Hildana	Nakuru	71	75	76	78	61	56
	Malindi	73	75	59	73		
	Kibwezi	70	71	65	65		
Blue sisal	Kibwezi		75				

III.6.2 Kappa number

Kappa number of the pulp samples ranged between 9 and 20. The lowest Kappa number was observed in the third harvest of H. 1300 at Malindi and in the fifth harvest of Agave Sisalana in Nakuru while the highest was observed in the third harvest of Agave Sisalana at Nakuru.

Kappa numbers of the samples tested in the second test were generally lower than the samples tested in the first test. This was most probably attributed to the use of Anthraquinone in the second test which acts as catalyst in reaction during cooking. This is an indication that the pulp will use less chemicals during bleaching as most of the lignin would have been dissolved during cooking and removed during refining and washing.

Table 2. Kappa number – all harvests
(see Graph in Annex 3)

VARIETY	LOCATION	HARVEST					
		1	2	3	4	5	6
H11648	Nakuru	14	14	16	11	14	13
	Malindi	17	16	14	15		
	Kibwezi	15	12	13	14		
H1300	Nakuru	13		14	12	16	10
	Malindi	18	18	9	13		
	Kibwezi	15	15	14	13		
Sisalana	Nakuru	13		22	12	9	11
	Malindi	19	18	13	12		
	Kibwezi	15	12	12	13		
Hildana	Nakuru	20	11	11	13		
	Malindi		19	14	12	13	11
	Kibwezi	12	12	12	15		
Blue sisal	Kibwezi		16				

III.6.3 Tensile strength expressed in breaking length

Agave Hildana in Malindi in the second harvest recorded the highest breaking length followed by H 1300 in Malindi in the first harvest while the lowest was Hildana in Kibwezi in the fourth harvest. Higher recordings were also made on H11648 in Kibwezi in the third and fourth harvest, Agave Sisalana on the third harvest in Nakuru, first harvest in Malindi, third and fourth harvest at Kibwezi and Hildana in the second harvest at Kibwezi.

The results indicate a general decrease in tensile strength of H11648, H1300 and Hildana in Nakuru from the first to the third harvest and an increase after the sixth harvest. In Malindi H1300, Agave Sisalana and Hildana recorded decreased tensile strength from the first to the fourth harvest. In Kibwezi tensile strength of H11648 and Agave Sisalana increased from the first to fourth harvest.

Table 3. Breaking length (Km) – all harvests
(see Graph in Annex 3)

VARIETY	LOCATION	HARVEST					
		1	2	3	4	5	6
H11648	Nakuru	3.9	3.7	2.7	3.7	3.2	3.8
	Malindi	3.6	3.21	3.5	3.9		
	Kibwezi	3.7	3.6	4.3	4.2		
H1300	Nakuru	3.5	-	3.8	3.2	3.7	4.0
	Malindi	4.5	4.1	3.7	3.7		
	Kibwezi	3.7	3.6	3.7	3.6		
Sisalana	Nakuru	3.6	-	4.2	4.1	3.9	4.0
	Malindi	4.2	3.8	3.9	3.5		
	Kibwezi	3.9	4.1	4.2	4.2		
Hildana	Nakuru	4.2	4.0	3.6	3.3	3.4	3.7
	Malindi	-	4.6	3.6	3.0		
	Kibwezi	3.2	4.2	3.5	2.4		
Blue Sisal	Kibwezi	-	3				

III.6.4 Tear strength

Tear index ranged from 11 to 40 Nm^2/g for all varieties. H 11648 recorded the highest Tear Index 40 Nm^2/g in the fourth harvest in Malindi followed by Agave Sisalana in the first harvest at Kibwezi. High Index was also observed in Agave Sisalana at Malindi in the second and third harvests.

Table 4. Tear index (Nm^2/g) – all harvests
(see Graph in Annex 3)

VARIETY	LOCATION	HARVEST					
		1	2	3	4	5	6
H11648	Nakuru	19	21	19	22	16	14
	Malindi	16	15	20	40		
	Kibwezi	27	23	18	23		
H1300	Nakuru	14	-	19	21	13	23
	Malindi	21	21	13	24		
	Kibwezi	18	19	15	15		
Sisalana	Nakuru	23		32	28	16	28
	Malindi	26	35	35	14		
	Kibwezi	37	27	23	31		
Hildana	Nakuru	30	33	27	22	11	31
	Malindi	-	31	27	19		
	Kibwezi	26	30	28	23		
Blue sisal	Kibwezi		13				

III.6.5 Burst strength

Burst Index ranged from 2.2 to 4.5 kPam^2/g. Hildana in the 2nd harvest at Kibwezi and H 1300 at the sixth harvest at Nakuru recorded the highest burst Index. Higher values were also observed in H1300 in the fourth harvest at Kibwezi, Agave Sisalana in the fourth harvest at Kibwezi, and Hildana in the first harvest at Nakuru.

Table 5. Burst index (kPa m^2/g) – all harvests
(see Graph in Annex 3)

VARIETY	LOCATION	HARVEST					
		1	2	3	4	5	6
H11648	Nakuru	3.0	3.1	2.2	3.1	2.8	3.0
	Malindi	2.6	2.3	2.7	3.5		
	Kibwezi	2.7	2.9	2.5	3.3		
H1300	Nakuru	2.8		3.2	2.8	3.0	4.4
	Malindi	2.9	3.6	3.0	2.7		
	Kibwezi	3.3	3.1	2.9	4.3		
Sisalana	Nakuru	3.2		3.6	3.1	3.6	3.8
	Malindi	4.0	4.2	3.3	2.7		
	Kibwezi	3.8	3.7	3.5	4.3		
Hildana	Nakuru	4.3	3.6	3.6	2.9	2.3	3.9
	Malindi		4.2	3.6	2.7		
	Kibwezi	2.8	4.5	2.5	3.4		
Blue sisal	Kibwezi		2.3				

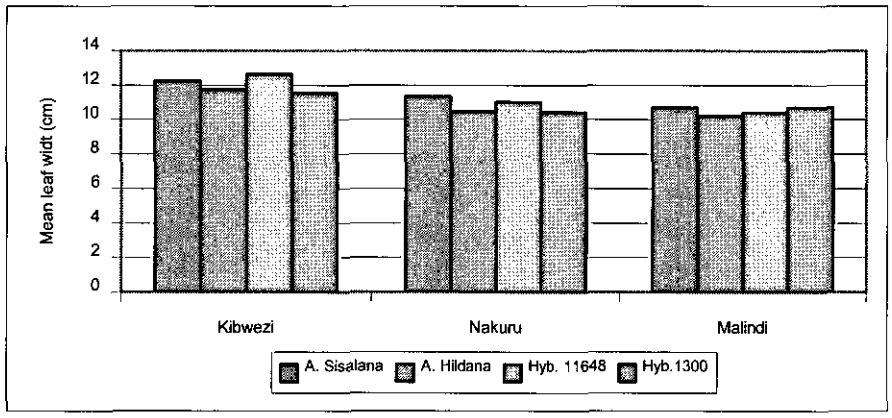
III.7. Results achieved

III.7.1 General variety performance in different sites

It was observed (Figure 12) that leaf width, as a mean of the values measured at each harvest, varies in all sites by variety and therefore no best performer was distinguished.

Figure 12. Mean leaf width (cm) at harvesting, by varieties in different sites

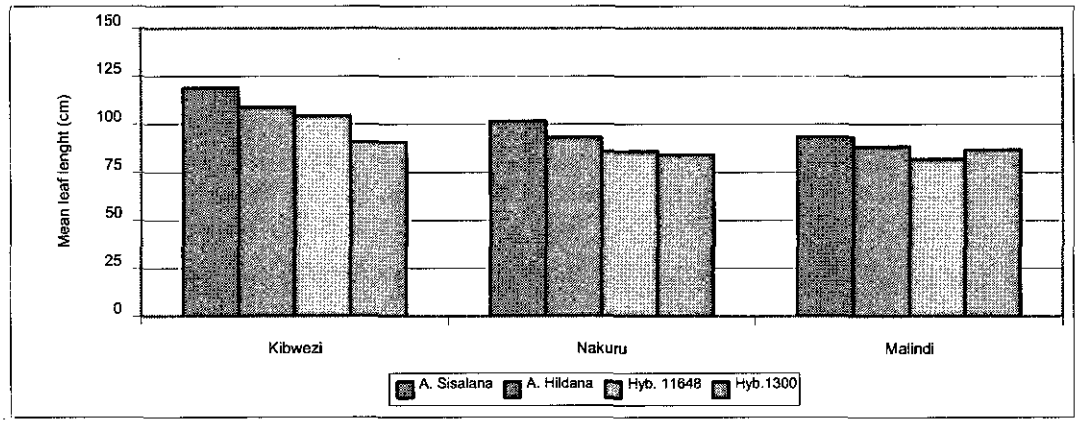
Location	Variety			
	A. Sisalana	A. Hildana	Hyb. 11648	Hyb.1300
Kibwezi	12.24	11.74	12.62	11.53
Nakuru	11.33	10.46	11.01	10.41
Malindi	10.67	10.19	10.4	10.7



In terms of leaf length (Figure 13) Agave Sisalana recorded the highest values in all sites followed by Agave Hildana, Hybrid 11648 and lastly Hybrid 1300.

Figure 13. Mean leaf length (cm) at harvesting, by variety in different sites

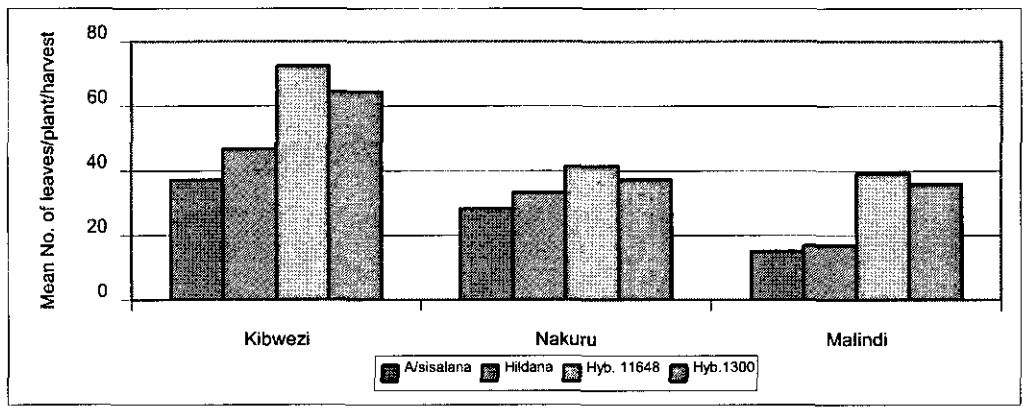
Location	Variety			
	A. Sisalana	A. Hildana	Hyb. 11648	Hyb.1300
Kibwezi	119.07	109.14	104.47	90.69
Nakuru	101.52	93.19	85.88	83.94
Malindi	93.32	88.27	81.75	86.58



The number of leaves harvested per plant per harvest (Figure 14) was highest for the Hybrid 11648 in all sites followed by Hybrid 1300, Agave Hildana and Agave Sisalana.

Figure 14. Mean number of leaves harvested/plant/harvest, by variety in different sites

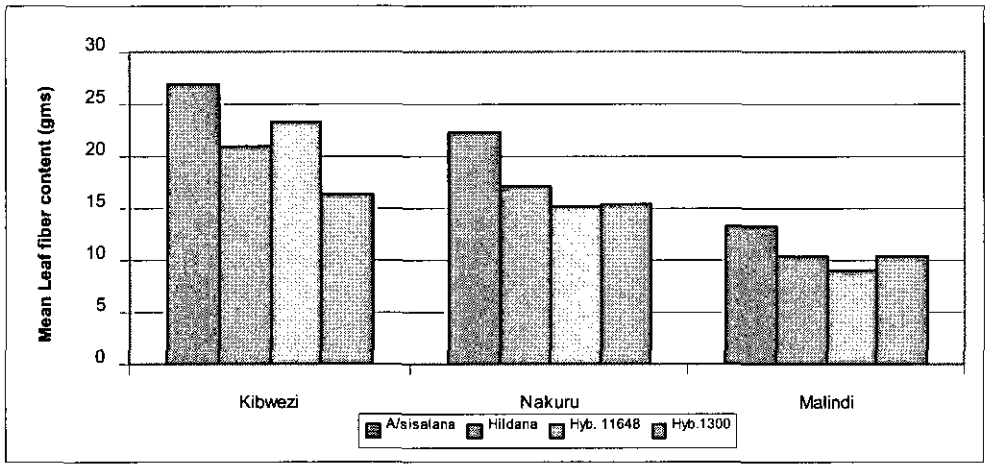
Location	Variety			
	A. Sisalana	A. Hildana	Hyb. 11648	Hyb.1300
Kibwezi	37.11	46.72	72.34	64.42
Nakuru	28.18	33.27	41.36	37.19
Malindi	15.00	16.79	39.16	35.77



The mean of the values recorded for leaf fibre content per leaf (grams) (Figure 15) for the different varieties shows the highest values for Agave Sisalana followed by the Hybrid 11648, Agave Hildana and lastly Hybrid 1300.

Figure 15. Mean leaf fiber content (grams) by variety in different sites

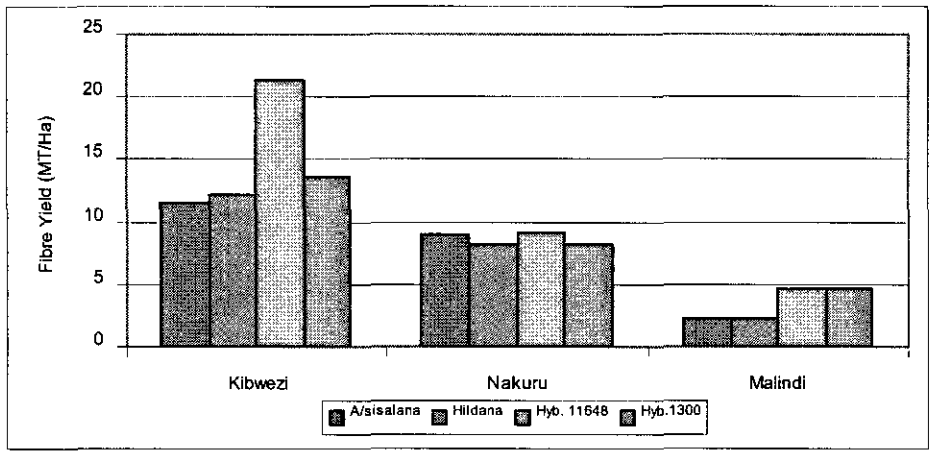
Location	Variety			
	A. Sisalana	A. Hildana	Hyb. 11648	Hyb.1300
Kibwezi	26.99	21.03	23.27	16.38
Nakuru	22.31	17.2	15.15	15.3
Malindi	13.26	10.32	9.02	10.32



In terms of fibre yield (MT/Ha) (Figure 16) the Hybrid 11648 recorded the highest total fibre production (in MT/Ha) in all sites followed by Hybrid 1300, Agave Hildana and Agave Sisalana

Figure 16. Mean fibre yield in MT/Ha by variety in different sites

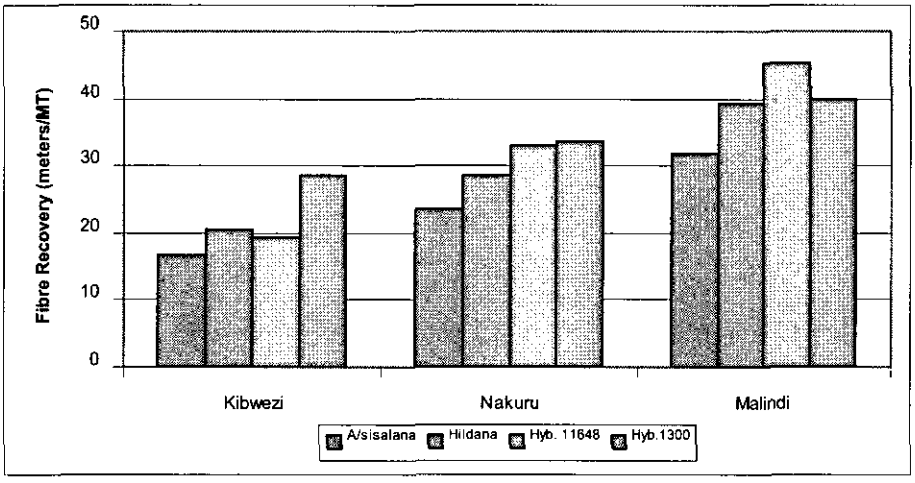
Location	Variety			
	A. Sisalana	A. Hildana	Hyb. 11648	Hyb.1300
Kibwezi	11.52	12.14	21.29	13.59
Nakuru	10.76	9.74	11.04	9.77
Malindi	2.86	2.79	5.77	5.88



The fibre recovery (meters/tonne) (Figure 17) was highest for the two hybrids and lower for Agave Hildana and for Agave Sisalana.

Figure 17. Mean fibre recovery in meters/MT by variety in different sites

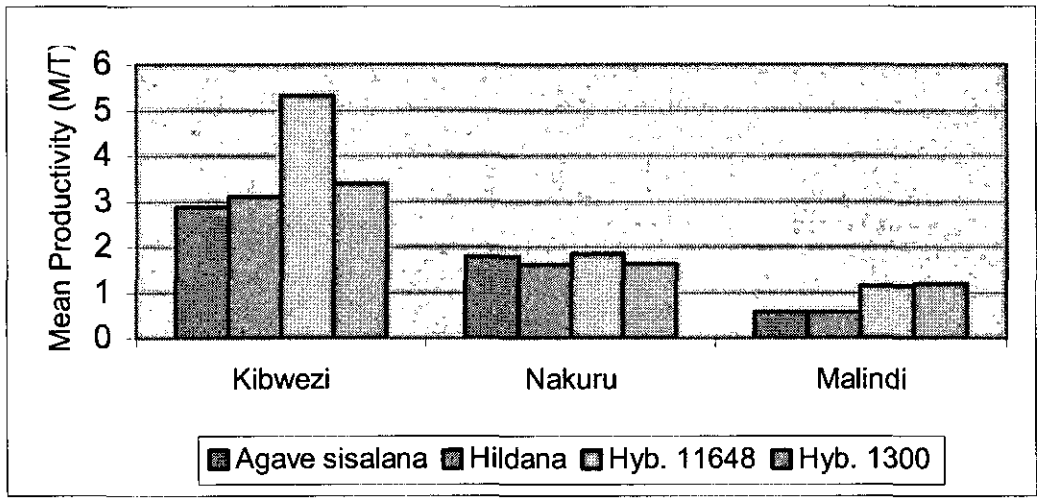
Location	Variety			
	A. Sisalana	A. Hildana	Hyb. 11648	Hyb.1300
Kibwezi	16.78	20.43	19.48	28.71
Nakuru	23.54	28.69	32.97	33.65
Malindi	31.92	39.41	45.19	39.85



The fibre productivity (or fibre recovery) in meters/tonne (Figure 18) was recorded highest in Kibwezi, followed by Nakuru and lastly Malindi. The Hybrid 11648 had the highest production in all sites, followed by Hybrid 1300, Agave Hildana and lastly Agave Sisalana.

Figure 18. Average Mean fibre yield in meters/MT by variety in different sites per year

Location	Variety			
	A. Sisalana	A. Hildana	Hyb. 11648	Hyb.1300
Kibwezi	2.88	3.11	5.32	3.39
Nakuru	1.79	1.62	1.84	1.63
Malindi	0.57	0.56	1.14	1.18



III.7.2 Pulping variety performance in different sites

It was attempted to evaluate the overall characteristics of the pulp obtained from different varieties in different sites. Pulp was considered to have significant quality when:

Yield 65% and above (Y)
Breaking Length 3.5 km and above (L)
Tear Index 3.0 Nm^2/Kg and above (T)
Burst Index 3.5 kPa m^2/g and above (B)

An asterisk (*) indicates when the pulp's quality is higher than the benchmarks (Table 6 below); one point was given to each asterisk and then totalled.

Table 6. Combined Evaluation of Main Pulp Quality Indicators

VARIETY	LOCATION	HARVEST																								Points
		1				2				3				4				5				6				
		Y	L	T	B	Y	L	T	B	Y	L	T	B	Y	L	T	B	Y	L	T	B	Y	L	T	B	
H11648	Nakuru	*				*				*				*												4
	Malindi	*				*								*		*	*									5
	Kibwezi	*				*				*	*			*	*											6
H1300	Nakuru	*								*				*									*		*	5
	Malindi	*	*			*	*		*																	5
	Kibwezi	*				*											*									3
Sisalana	Nakuru	*								*	*	*	*	*	*						*		*		*	10
	Malindi	*	*		*	*		*	*			*														7
	Kibwezi	*		*	*	*			*	*	*		*	*	*	*	*									12
Hildana	Nakuru	*	*	*	*	*	*	*	*	*			*	*										*	*	**13**
	Malindi	*				*	*	*	*				*	*												7
	Kibwezi	*				*	*	*	*	*				*												7
Blue sisal	Kibwezi					*																				1

As seen from Table 6, Agave Hildana and Agave Sisalana recorded higher pulp yield and strength in Nakuru in the first to fourthharvests. Agave Sisalana also performed better at Kibwezi in the first to fourth harvests. At Nakuru, Agave Sisalana recorded higher breaking length and burst strength in the later stages.

For pulping purposes, the current results indicate that Agave Sisalana and Hildana could be considered better varieties when grown at Nakuru while Agave Sisalana is the best at Kibwezi.

Generally Agave Sisalana and Hildana appeared to perform better in terms of combined pulp yield and strength throughout the experiment compared to H11648 and H1300.

However these results are not conclusive, as the test conditions and age of the samples during the two experiments were not the same. The use of Anthraquinone in the second tests might have affected some of the parameters in different harvests of the plant as in the first test Anthraquinone was not used. The difference in harvesting time for the three sites should also be kept in mind.

III.8. Disease and pest incidence

Disease problems and sisal weevil problem was highest at Malindi followed by Kibwezi and was negligible at Nakuru. At Malindi, all Mlola 487, ML1, and Agave Amaniensis plants were completely wiped out by bole rot after the first harvest.

The data collected is included in Annex 2.

There was considerable leaf scotch on all varieties, in all sites in the first two years but after the third year the frequency decreased to be only occasional. This was more pronounced for Agave Hildana, Agave Sisalana and Hybrid 1300. At Kibwezi and Malindi moisture stress on Agave Sisalana and Agave Hildana was serious during dry periods with all opened leaves falling and new leaf production stopping completely.

III.9 Dissemination of results

The results of this subcomponent were disseminated through:

- A review workshop attended by 64 participants, held in Tanga in April 1998;
- The publication of a Technical Paper (2001);
- A Dissemination Workshop held in Tanga in February 2003; at the Workshop presentations were given by the national and the international experts and the Technical Paper was distributed to the participants;
- An International Dissemination Workshop held in Tanga in November 2004; at the Workshop presentations were given by the national and the international experts.

IV. Lessons learned

IV.1 Development lessons

The objective of sub-component A.3 was fully achieved, despite some delays in implementation, and the outputs were produced as originally envisaged in the Appraisal Report. Although the harvests at the three sites should have taken place at the same time, unfortunately this was not possible.

IV.2 Operational lessons

The implementation arrangements and the sub-component management did not generate any major difficulty. Delays in the publication of the Technical Report were caused by the fact that the publication was not included in the Appraisal Report and by disruptions caused by the change of project manager in the PEA.

V. Conclusions and recommendations

The trials were conducted at similar conditions to those at which farmers in respective areas grow commercial Sisal. The only major variation was the spacing, spatial arrangements and that the trials were kept completely weed free by hand weeding throughout the trial duration. The trials were planted using single row method with spacing of 2.5 meters between rows and 1.25 meters between plants. This gave a plant density of 3,200 plants per hectare compared to 3,333 plants/hectare done by farmers in double rows. Disease and pest control was done following the conventional recommendations but the routine was strictly followed.

The costs of the variety trials, compared to the estate costs of production, are included in Annex 6. With the exception of Malindi the costs (USD/ha) are lower in the trials than in the estates, if fencing, enumerator and caretaker are not considered.

The average fibre productivity per hectare in the estates currently lies between 0.5 – 1.5 MT/Ha where the latter is realized in the best-managed estates. Tables included in Annex 2 show that with application of better agronomic practices, it is possible to increase production per hectare considerably. At Kibwezi, all the varieties recorded more than 2.5 MT/Ha, while Hybrid 11648 recorded an average of 5.32 MT/Ha.

With no fertilizers applied, this production confirmed that a high level of management, application and maintenance of sound agronomic practices could considerably enhance sisal production. The main variation from the normal farmers' practice was that the plants were planted in single rows with more space between plants, the trials were kept completely weed free, old and drying leaves were removed routinely. These practices reduced the competition for nutrients and moisture as much as possible. During harvesting a certain optimum number of leaves (not over cut) was left on the plant to ensure adequate photosynthetic surface, and enough leaf surface area for trapping and collection of moisture from even the slightest shower.

It was noticed in all sites that Agave Sisalana which has a sparse leaf formation suffered more from moisture stress and made the situation worse by drooping leaves backwards and hence directing any trapped moisture further away from the plant base. Hybrids 11648 and 1300, which have a dense leaf formation, trapped moisture and directed it to the base of the plant.

It is suspected that the lower yields at Nakuru and Malindi are strictly related to soil fertility status. For example at Malindi where yields were poorest, the soils were very low in Nitrogen, Potassium, organic Carbon, Magnesium and Zinc.

All varieties performed best at Kibwezi followed by Nakuru and lastly Malindi.

Hybrid 11648 performed best of all the varieties in all the sites followed by Hybrid 1300, Agave Hildana and then Agave Sisalana.

Hybrids 11648 and 1300 were more susceptible to diseases and pests particularly bole rots and weevil damage. Malindi was the worst site in this respect followed by Kibwezi. Nakuru recorded negligible disease and pest problems apart from sun scotch in the early stages of growth.

The main determinants of fibre yield were the number of leaves harvested per harvest, leaf fibre content, leaf width. Leaf length had the least effect. This indicates that for selection of high performing clones the parameters to look for include mainly the number of leaves produced per unit of time, leaf width, and the average leaf fibre content.

Rainfall was the most critical factor affecting leaf production particularly distribution.

It was observed that during poling, Agave Sisalana and Agave Hildana simultaneously produced poles from suckers. This phenomenon was also observed in other Agave species in the field. It was also observed that in old hybrid 11648 fields plants with variegated suckers were common, while some large plants were still growing long after the field was cut out. In an abandoned Agave Hildana field, vigorous plants were found still growing in thick bush growing up to three meters high. Observations were also made of Agave Angustifolia and Hybrid 11648 plants producing both albino and normal bulbils from the same pole. Since suckers and bulbils are vegetatively produced these observations indicate that there is variability in the bulbils and suckers produced by Agave plants, which could explain the farmers' fears that the sisal plantations have changed over time.

This phenomenon requires further study to ensure that any superior Agave varieties developed are maintained for longer periods

Conclusions on pulping are reported under section III.7.2.

Annex 1. Harvest data

Nakuru

Variety	Leaf length (cm)	Leaf width (cm)	No. of leaves harvested per plant	Unbrushed fibre (kg)/ 27 Plants	Fibre yield MT/Ha	Fibre yield/leaf (grams)	Meters/ tonne of fibre
Nakuru-1st harvest-9/10/01							
A/sisalana	67.34	8.43	40.50	8.75	1.04	8.02	49.87
Hildana	67.38	7.76	51.56	9.88	1.17	7.09	56.42
Hyb.11648	61.79	8.03	58.71	9.25	1.19	6.33	63.19
Hyb.1300	63.36	6.72	52.89	8.38	0.99	5.87	68.15
Nakuru-2nd harvest-30/7/02							
A/sisalana	94.46	11.37	33.67	13.50	1.60	14.85	26.94
Hildana	90.00	10.78	36.42	12.13	1.44	12.36	32.37
Hyb.11648	74.96	11.02	43.50	11.63	1.38	9.91	40.36
Hyb.1300	77.29	10.94	44.14	11.88	1.40	9.98	40.08
Nakuru-3rd harvest-27/2/03							
A/sisalana	112.00	12.65	22.13	15.63	1.85	26.12	15.31
Hildana	101.26	11.55	28.80	15.13	1.79	19.42	20.60
Hyb.11648	93.41	11.69	35.15	15.88	1.88	16.72	23.92
Hyb.1300	89.81	11.47	28.17	13.38	1.59	17.64	22.68
Nakuru-4th harvest-30/11/03							
A/sisalana	115.68	12.20	28.84	24.75	2.93	31.75	12.60
Hildana	103.86	11.17	26.40	15.75	1.87	22.14	18.07
Hyb.11648	101.48	12.34	32.87	19.00	2.25	21.39	18.71
Hyb.1300	95.45	11.75	32.70	17.88	2.12	20.26	19.74
Nakuru-5th harvest-26/1/04							
A/sisalana	118.13	12.00	15.75	13.10	1.55	30.81	12.98
Hildana	103.46	11.05	23.17	15.63	1.85	24.98	16.01
Hyb.11648	97.77	11.98	36.55	21.13	2.50	21.41	18.68
Hyb.1300	93.78	11.20	28.05	17.23	2.04	22.75	17.58
Nakuru 6th harvest-2 /6/ 04							
A/sisalana	105.55	11.89	46.55	26.78	4.51	30.31	13.20
Hildana	99.98	11.58	54.90	35.64	4.22	24.01	16.66
Hyb. 11648	95.65	11.65	64.98	31.61	4.40	21.15	18.91
Hyb. 1300	94.50	11.70	56.00	34.98	4.15	23.14	14.29

Kibwezi

Variety	Leaf length	Leaf width	No. of leaves harvested per plant	Unbrushed fibre (kg)/27 Plants	Fibre yield MT/Ha	Fibre yield/leaf (grams)	Meters/tonne of fibre
Kibwezi-1st harvest-17/9/02							
A/sisalana	96.05	12.30	56.60	23.60	2.80	15.44	25.91
Hildana	93.27	11.52	65.53	23.30	2.76	13.16	30.39
Hyb.11648	83.50	11.66	106.13	37.45	4.44	13.07	30.60
Hyb.1300	63.52	10.59	87.47	19.00	2.25	8.04	49.76
Kibwezi-2nd harvest-24/4/03							
A/sisalana	120.79	12.70	27.76	18.63	2.21	24.88	16.08
Hildana	110.01	12.38	30.72	16.75	1.99	20.24	19.76
Hyb.11648	102.17	13.54	40.28	21.63	2.56	19.62	20.14
Hyb.1300	94.86	12.39	32.68	12.88	1.53	14.63	27.33
Kibwezi-3rd harvest-28/11/03							
A/sisalana	133.46	12.23	38.08	32.50	3.85	31.61	12.65
Hildana	119.46	11.63	35.55	23.75	2.81	24.74	16.17
Hyb.11648	116.22	13.47	41.16	30.75	3.64	27.58	14.42
Hyb.1300	105.17	11.73	42.30	21.88	2.59	19.16	20.88
Kibwezi-4th harvest-21/4/04							
A/sisalana	125.99	11.72	26.00	22.48	2.66	32.02	12.49
Hildana	113.84	11.45	55.07	38.65	4.58	25.99	15.39
Hyb.11648	115.99	11.81	101.78	89.90	10.65	32.79	12.20
Hyb.1300	99.20	11.40	95.23	60.95	7.22	23.70	16.88

Malindi

Variety	Leaf length (cm)	Leaf width (cm)	No. of leaves harvested per plant	Unbrushed fibre(kg)/27 Plants	Fibre yield MT/Ha	Fibre yield/leaf (grams)	Meters/tonne of fibre
Malindi-1st harvest-11/11/02							
a/sisalana	87.09	10.20	22.56	5.88	0.7	9.65	41.45
Hildana	87.87	9.98	22.30	5.38	0.64	9.06	44.15
Hyb.11648	77.66	10.40	60.23	12.00	1.42	7.38	54.20
Hyb.1300	85.49	10.88	51.79	11.50	1.36	8.22	48.66
Malindi-2nd harvest-15/6/03							
a/sisalana	95.35	11.26	8.74	3.5	0.41	14.83	26.97
Hildana	90.06	10.75	13.63	3.75	0.44	10.19	39.25
Hyb.11648	82.39	10.77	26.00	5.85	0.7	8.33	48.02
Hyb.1300	87.15	11.02	23.13	6.33	0.75	10.13	39.49
Malindi-3rd harvest-29/11/03							
a/sisalana	97.23	10.77	8.41	4.00	0.47	17.61	22.71
Hildana	88.84	10.31	11.86	3.00	0.36	9.37	42.69
Hyb.11648	87.27	10.69	27.76	7.73	0.92	10.31	38.80
Hyb.1300	86.95	10.93	25.52	6.75	0.8	9.8	40.82
Malindi-4th harvest-8/5/04							
a/sisalana	93.61	10.44	20.29	6	0.71	10.95	36.53
Hildana	86.31	9.70	19.37	6.63	0.79	12.67	31.55
Hyb.11648	79.70	9.76	49.22	13.38	1.59	10.07	39.72
Hyb.1300	86.72	9.97	42.63	15.13	1.79	13.14	30.44

Annex 2. Disease and pests incidence

Nakuru

Variety	Korogwe leaf spot	Soft bole rot	Dry bole rot	Sisal weevil	Baboon damage
Agave Sisalana	0 spots noticed	1 plants dead out of 880	No plants affected	No weevils noticed	None
Hyb. 11648	0 spots noticed	No plants affected	No plants affected	No weevils noticed	None
Hyb. 1300	0 spots noticed	No plants affected	No plants affected	No weevils noticed	None
Agave Hildana	0 spots noticed	No plants affected	No plants affected	No weevils noticed	None

Kibwezi

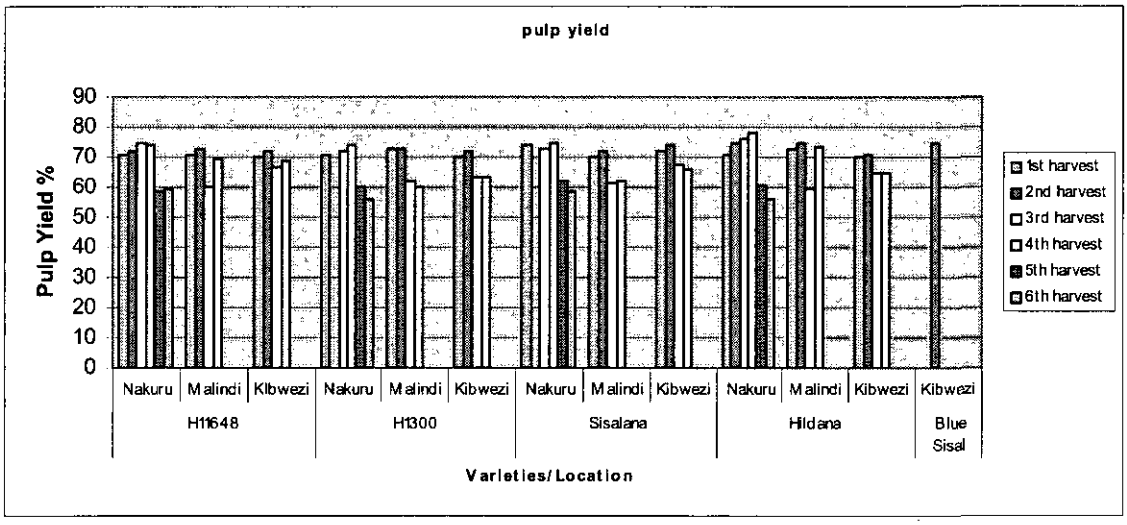
Variety	Korogwe leaf spot	Soft Bole rot	Dry bole rot	Sisal weevil	Baboon damage
Agave Sisalana	0 spots noticed	3 plants dead out of 880	No plants affected	7 weevils/ plant at harvesting	25 plants ou 880
Hyb. 11648	Av. 2 spots per leaf	One plant out c 880	No plants affected	4 weevils/ plant at harvesting	10 plants ou 880
Hyb. 1300	0 spots noticed	No plants affected	No plants affected	4 weevils/ plant at harvesting	10 plants ou 880
Agave Hildana	0 spots noticed	No plants affected	No plants affected	5 weevils/ plant at harvesting	5 plants out 880

Malindi

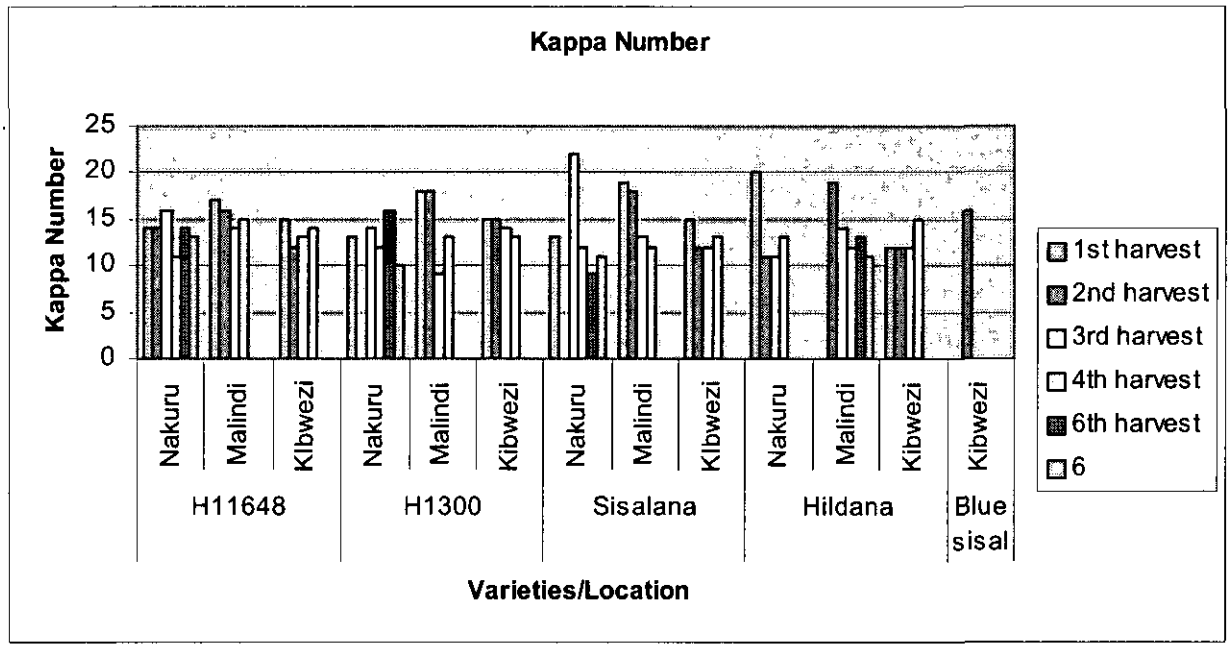
Variety	Korogwe leaf spot	Soft bole rot	Dry bole rot	Sisal weevil	Baboon damage
Agave Sisalana	0 spots noticed	15 plants affected out of 880	10 plants affec out of 880	7 weevils/ plant at harvesting	None
Hyb. 11648	0 spots noticed	5 plants affected out of 880	15 plants affec out of 880	7 weevils/ plant at harvesti	None
Hyb. 1300	0 spots noticed	5 plants affected out of 880	7 plants affected out of 880	7 weevils/ plant at harvesti	None
Agave Hildana	0 spots noticed	5 plants affected	8 plants affected out of 880	7 weevils/ plant at harvesti	None

Annex 3. Pulping tests

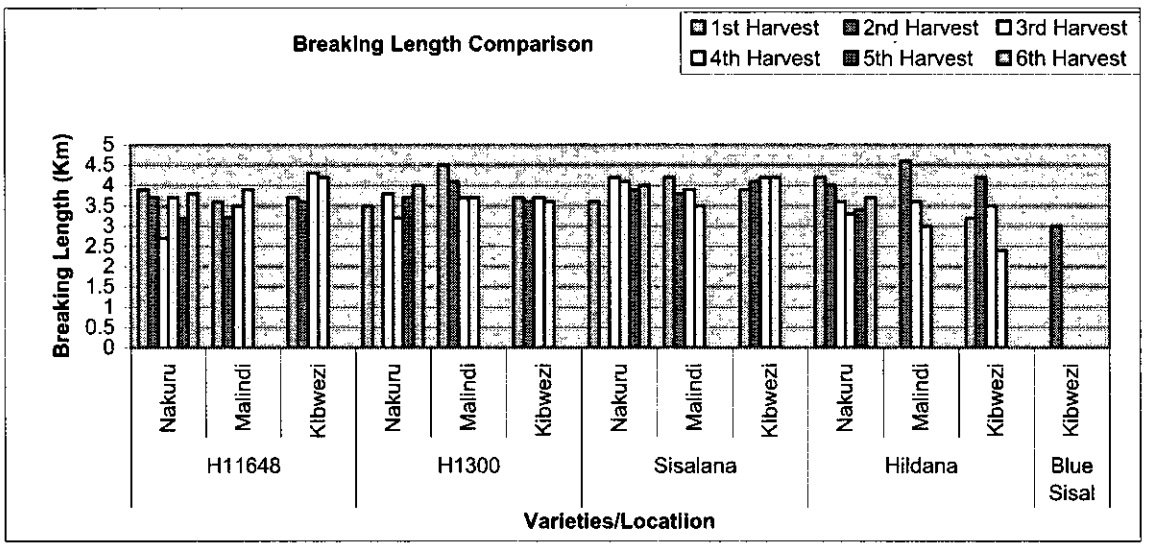
Pulp Yield (%)



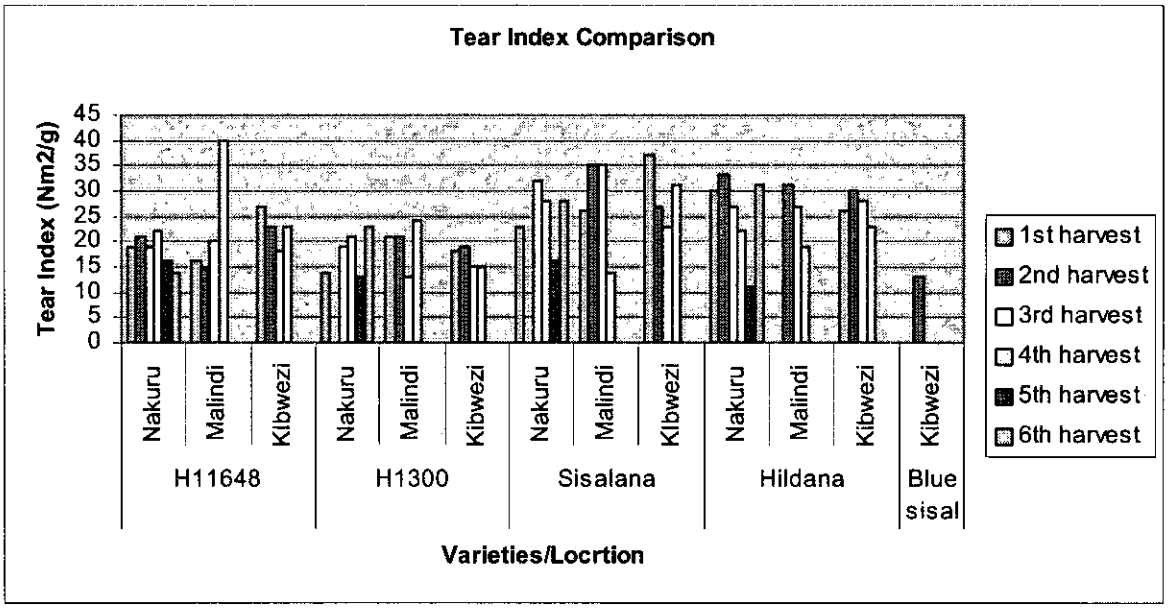
Kappa Number



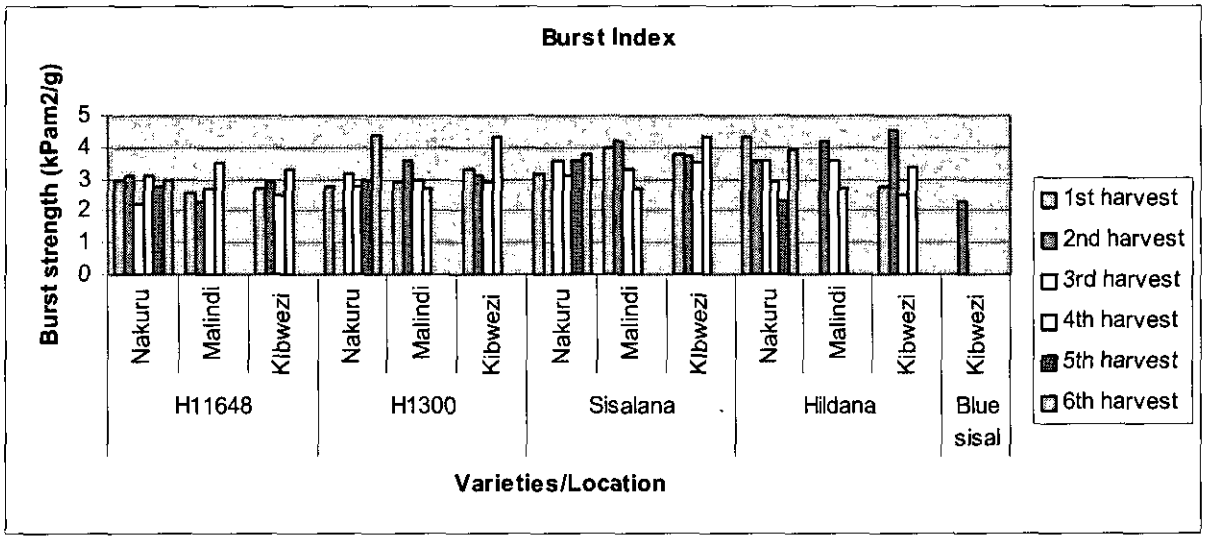
Breaking Length (km)



Tear Index (Nm^2/g)



Burst Index (kPam^2/g)



Annex 4. Cost of variety trial compared to estate cost of production (USD/Ha)

	OPERATION	KIBWEZI	NAKURU	MALINDI	ESTATES
1	**Land preparation**				
	Bush clearing	448			911
	Fencing	748			
	Caretaker house	645			
	Ripping				382
	Ploughing	220	220	220	21
	Harrowing				
	Soil analysis	110	110	110	
	Sub-total	**2171**	**330**	**330**	**1314**
2	**Nursery planting**				
	Bulbil collection	54	54	54	84
	Grading and sorting	48	12	12	
	Treatment/insecticide	48	48	48	128
	Planting	249	249	249	126
	Fertilizing/sisal waste	145	145	145	214
	Weeding	91	91	91	10
	Caretaker	135			
	Enumerator/data taker	300	300	300	
	Sub-total	**1070**	**899**	**899**	**562**
3	**Field planting**				
	Land preparation				
	Bush clearing				86
	Ripping				382
	Ploughing	270	270	270	128
	Harrowing	90	90	90	60
	Sub-total	**360**	**360**	**360**	**656**
4	**Planting**				
	Transport of seedlings	30	30	30	18
	Planting	150	150	150	170
	Sub-total	**180**	**180**	**180**	**188**
5	**Maintenance**				
	Inputs	870	870	870	
	Weeding	330	330	330	291
	Harrow				58
	Gyromowing				60
	Herbicides				96
	Caretaker	4,200			
	Enumerator	7,140	7,140	7,140	
	Sub-total	**12,540**	**8,340**	**8,340**	**505**
	Harvesting and decortication	**1,600**	**1,200**	**2,400**	**1,368**
	Grant total cost	**16,481**	**11,309**	**12,509**	**4,658**
	Less-Fencing, enumerator, caretaker and caretaker house costs	13,168	7,440	7,440	0
	Actual total cost	**3,313**	**3,869**	**5,069**	**4,658**

Annex 5. References

1. Common fund for Commodities *Technical Paper No. 8; 2001; Sisal, Past Research Results and Present Production Practices in East Africa*

2. IGGHF/FAO Reports

3. Kenya Sisal Board, *1972: Annual Report*

4. Lock G. W. 1969: *Sisal.* 2nd Edition, Tanganyika Sisal Growers Association, Longman, London

5. Ministry of Agriculture, *Farm Management Hand Book Vol. II*

Annex 6. Costs of variety trial compared to estate cost of production(USD/Ha)

	OPERATION	KIBWEZI	NAKURU	MALINDI	ESTATES
1	**Land preparation**				
	Bush clearing	448			911
	Fencing	748			
	Caretaker house	645			
	Ripping				382
	Ploughing	220	220	220	21
	Harrowing				
	Soil analysis	110	110	110	
	Sub-total	**2171**	**330**	**330**	**1314**
2	**Nursery planting**				
	Bulbil collection	54	54	54	84
	Grading and sorting	48	12	12	
	Treatment/insecticide	48	48	48	128
	Planting	249	249	249	126
	Fertilizing/sisal waste	145	145	145	214
	Weeding	91	91	91	10
	Caretaker	135			
	Enumerator/data taker	300	300	300	
	Sub-total	**1070**	**899**	**899**	**562**
3	**Field planting**				
	Land preparation				
	Bush clearing				86
	Ripping				382
	Ploughing	270	270	270	128
	Harrowing	90	90	90	60
	Sub-total	**360**	**360**	**360**	**656**
4	**Planting**				
	Transport of seedlings	30	30	30	18
	Planting	150	150	150	170
	Sub-total	**180**	**180**	**180**	**188**
5	**Maintenance**				
	Inputs	870	870	870	
	Weeding	330	330	330	291
	Harrow				58
	Gyromowing				60
	Herbicides				96
	Caretaker	4,200			
	Enumerator	7,140	7,140	7,140	
	Sub-total	**12,540**	**8,340**	**8,340**	**505**
	Harvesting and decortication	**1,600**	**1,200**	**2,400**	**1,368**
	Grant total cost	**16,481**	**11,309**	**12,509**	**4,658**
	Less-Fencing, enumerator, caretaker and caretaker house costs	13,168	7,440	7,440	0
	Actual total cost	**3,313**	**3,869**	**5,069**	**4,658**

Annex 7 - Photographs

PHOTOGRAPHS OF NURSERIES

Plate 1. Bush clearing for nursery at Kibwezi

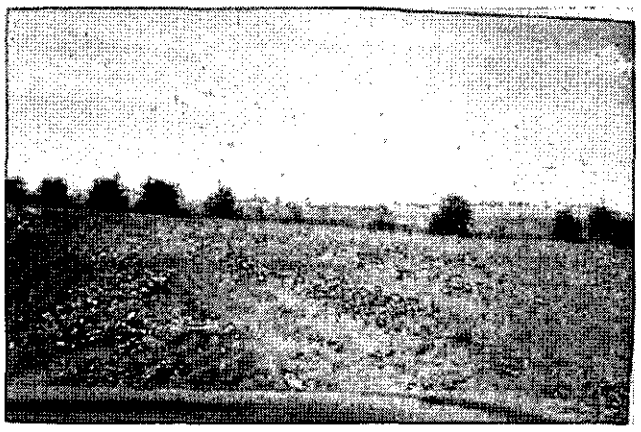


Plate 2. Land preparation for nursery at Nakuru

Plate 3. Land preparation for nursery at Malindi

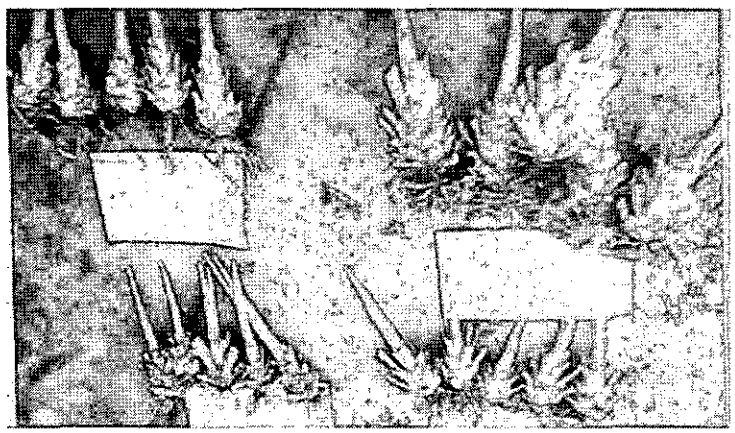


Plate 4. Grading seedlings for transplanting

Plate 5. New nursery at Kibwezi

Plate 6. Grown Nursery ready for transplanting at Nakuru

VIEW OF VARIETY TRIALS IN VARIOUS SITES

Plate 7. Variety Trial at Malindi (0-20 MASL)

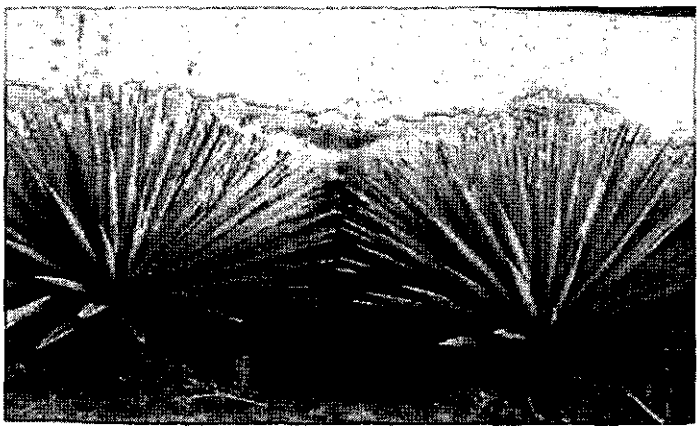


Plate 8. Variety Trial at Kibwezi (900 MASL)

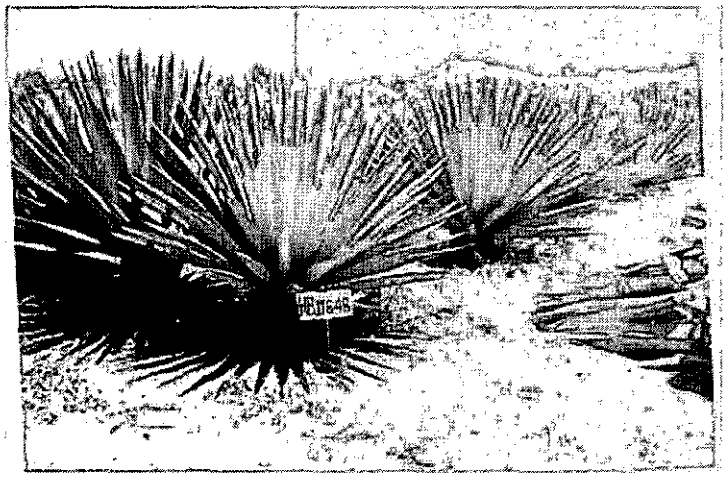


Plate 9. Variety Trial at Nakuru (1,500 MASL)

Plate 10. Collecting harvest data in the field

Plate 11. Collecting fibre data at the drying lines

Plate 12. Taking fibre measurements at brushing

SISAL VARIETIES (CLONES)

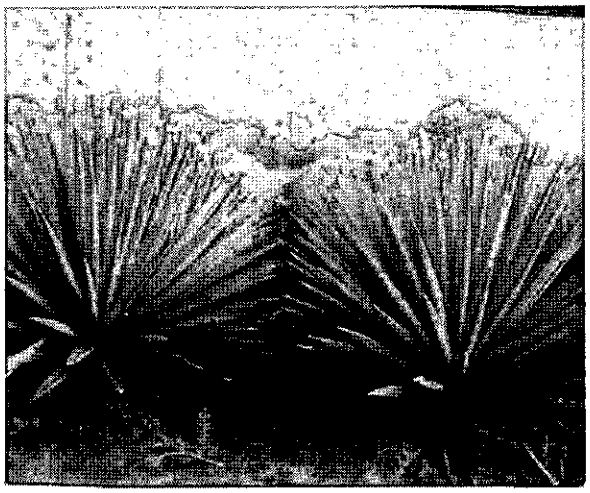


Plate 13. Hybrid 11648 at Kibwezi

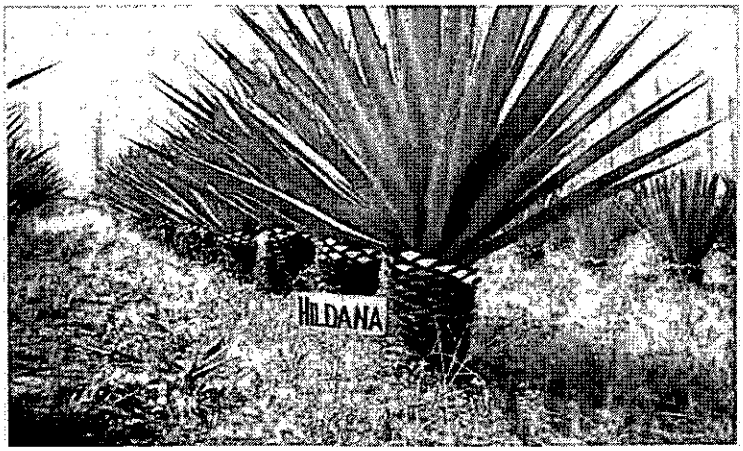


Plate 14. Hildana at Nakuru

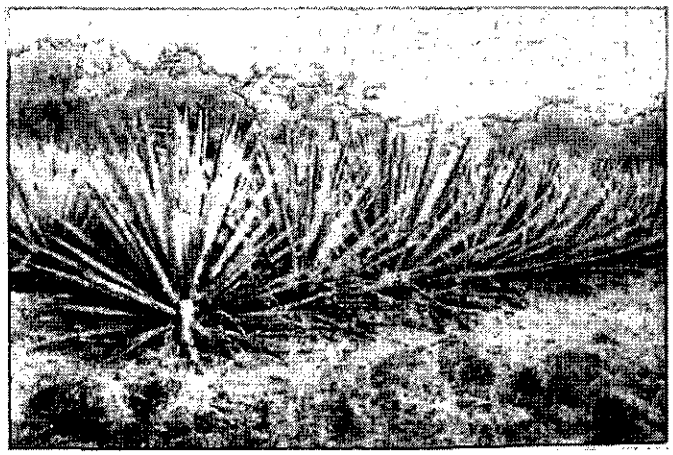


Plate 15. Agave Amaniensi at Kibwezi

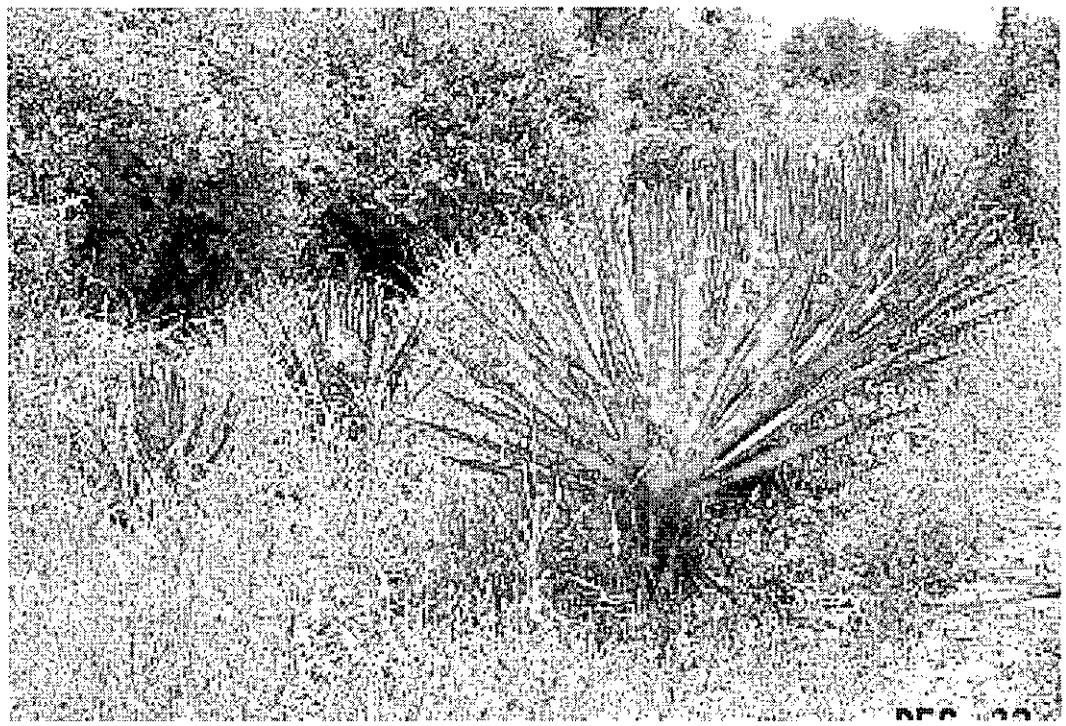


Plate 16. Mlola 487 at Kibwezi

SISAL DISEASES

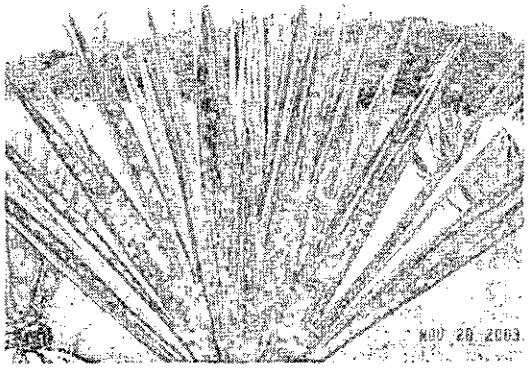


Plate 17. Sun Scotch on hybrid 1300 at Malindi

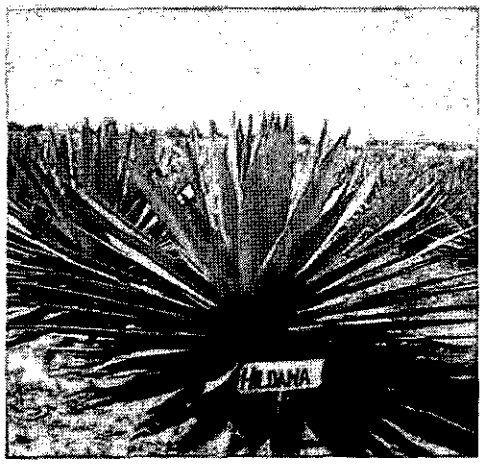


Plate 18. Sun scotch on Hildana at Nakuru

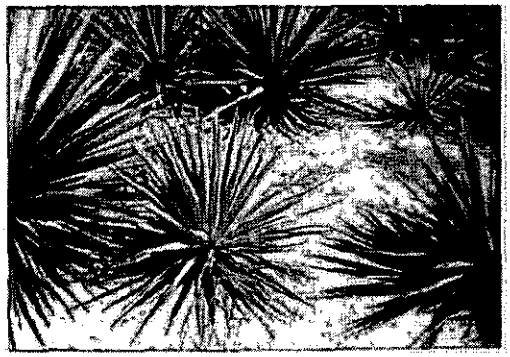


Plate 19. Dry bole rot on hybrid 11648 at Malindi

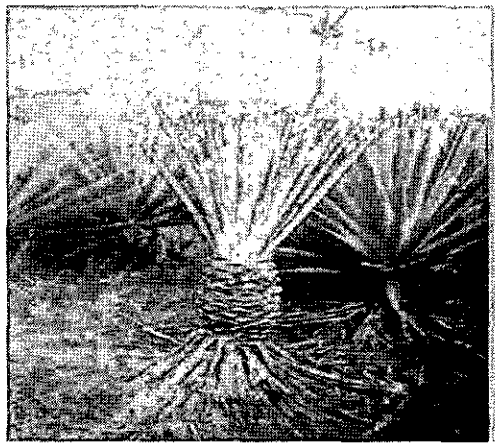


Plate 20. Soft bole rot on hybrid 11648 at Kibwezi

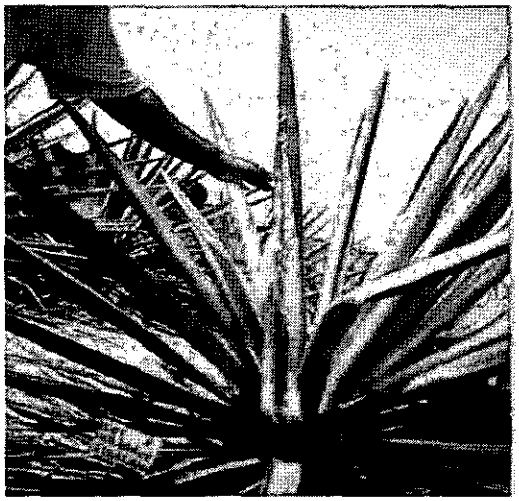


Plate 21. Fungal attack on *Agave sisalana* at Malindi

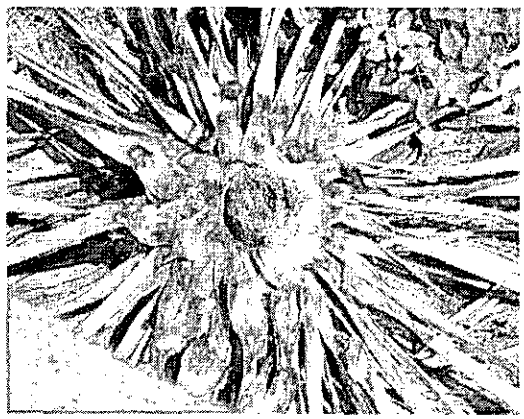


Plate 22. Soft bole rot on Mlola 487 at Malindi

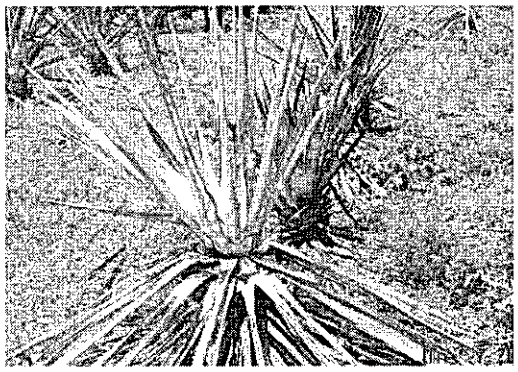


Plate 23. Soft bole rot on Agave sisalana at Malindi

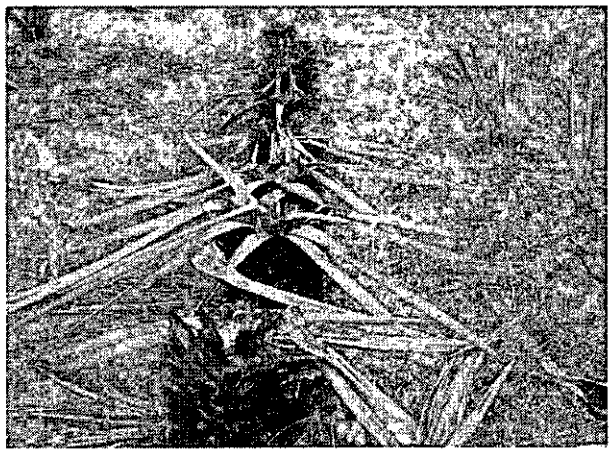


Plate 24. Agave amaniensis wiped out by soft bole rot at Malindi

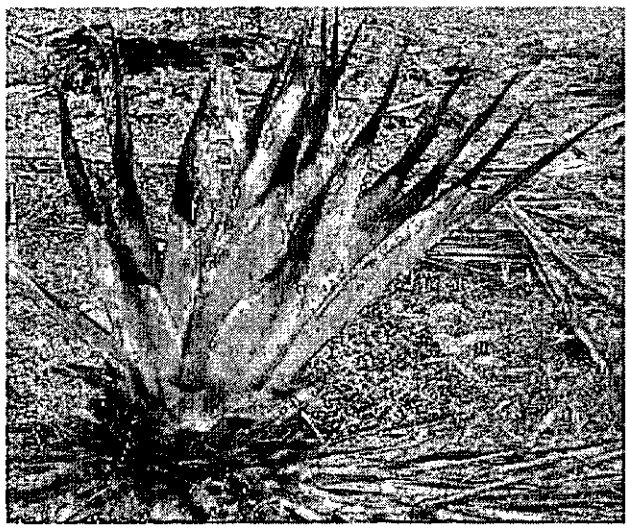


Plate 25. Purple leaf tip roll on ML1 at Malindi

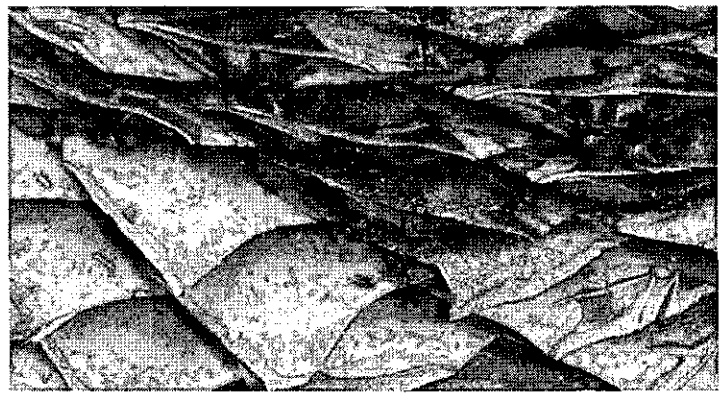


Plate 26. Fresh bole rot infection through leaf scars after harvesting

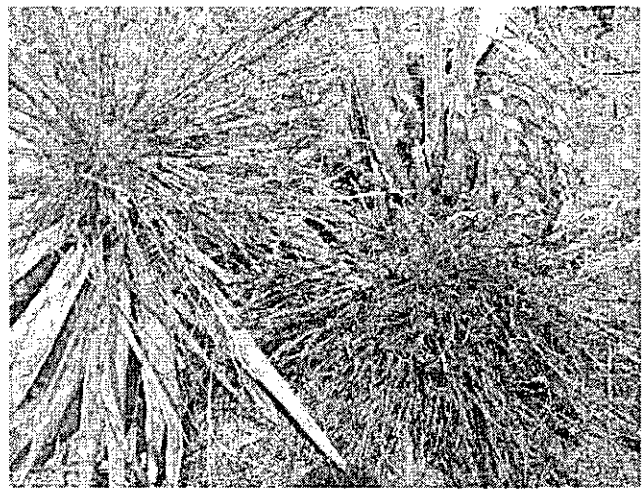


Plate 27. Roots of a sisal plant affected by dry bole rot

SISAL PESTS AND THEIR EFFECTS ON SISAL

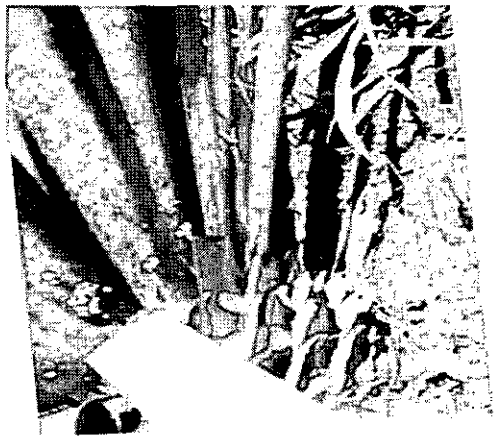


Plate29. Scales on Sisal leaves

Plate 30. Sisal weevils on a rotting bole

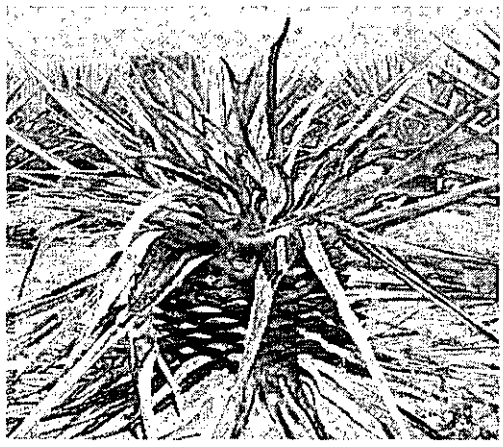


Plate 31. Sisal plant completely destroyed by sisal weevil

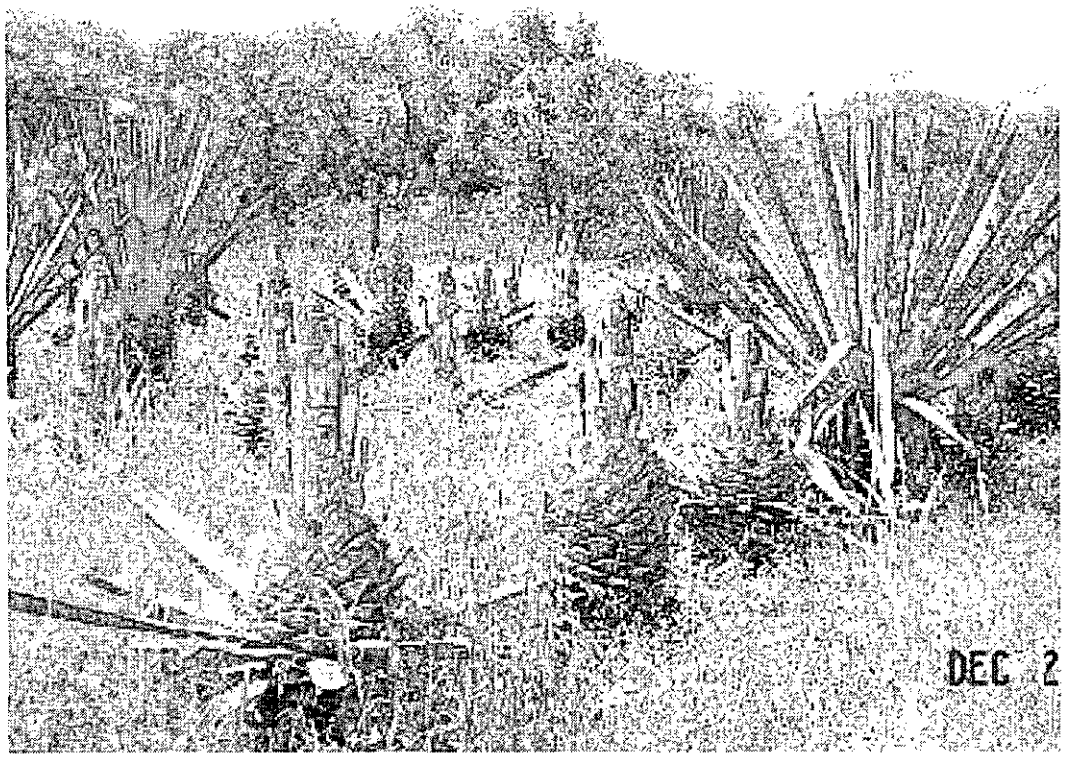


Plate 32. Baboon damage at Kibwezi

Plate 34. Agave angustifolia pole with green and albino bulbils

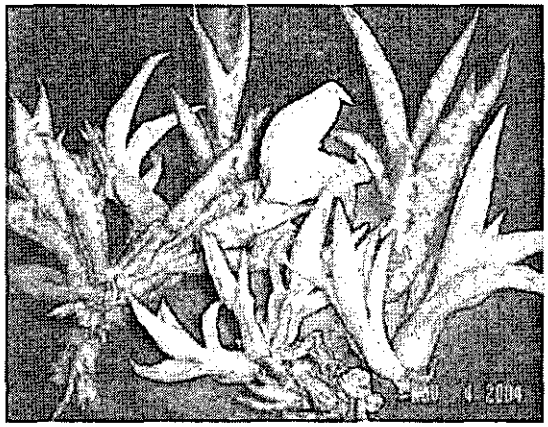


Plate 35. Albino and normal bulbils from the same pole

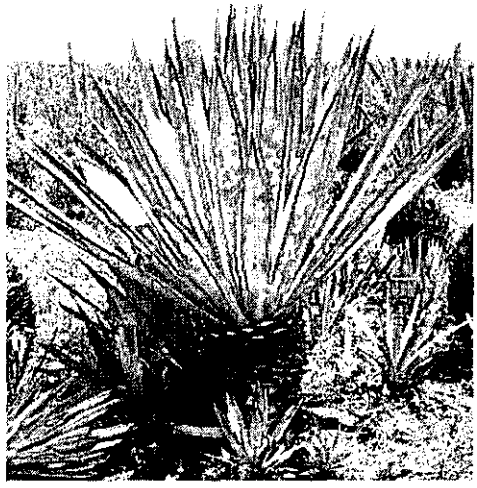


Plate 36. Variegated mutants of hybrid 11648 at Alphega estate in Nakuru

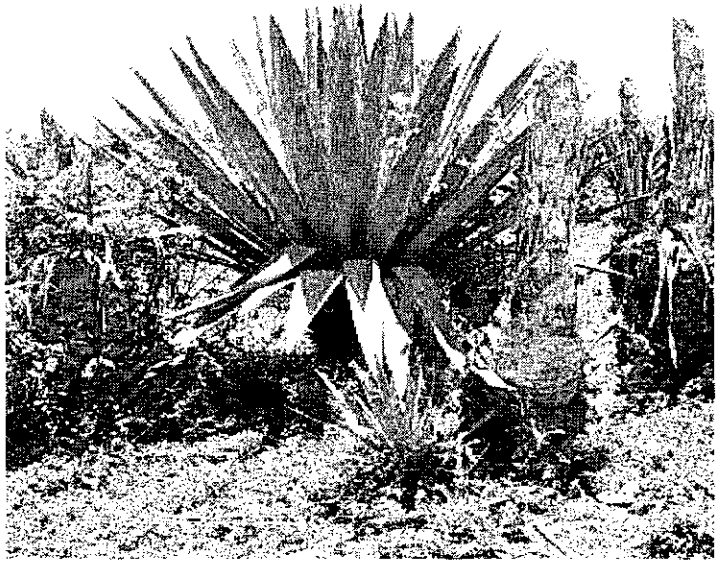


Plate 37. Giant plant found in an old cut out field of Hybrid 11648

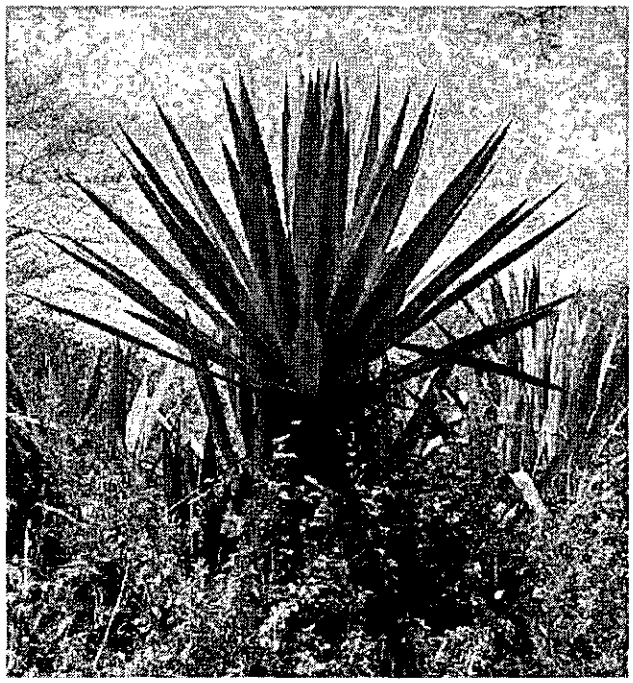


Plate 38. Hildana plant in a long-abandoned plantation

SOME ADVANTAGEOUS CHARACTERISTICS OF SISAL.

Plate 39. Sisal water harvesting ability - note the wetness at base of plant

Plate 40. Soil conservation by Sisal plants

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