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USAID

OUTLINE RESEARCH PROGRAMME

VERNONIA GALAMENSIS

Submitted by:

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ANNEX 1 REFERENCES

1.0 INTRODUCTION

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The potential of *Vernonia galamensis* as an industrial oil was identified by the USDA over 25 years ago. However, the cost of production and low product price did not justify its use or generate any interest from industry until recently. *Vernonia* oil is naturally expoxidised and is a potential substitute for some of the oils used by the paint industry which are under pressure from environmental legislation.

The objective of the current trials in Kenya is to stimulate production of the oil by evolving rainfed production systems, and providing commercial samples of oil for end user evaluation. *Vernonia galamensis* is indigenous to East Africa. If successful the crop could provide a valuable new cash crop for smallholder farmers of East Africa, with significant implications for employment generation. Attempts to grow it in the US have not been successful as the plant has failed to set seed.

1.1 CTS INVOLVEMENT TO DATE

In 1990 and funded by Cargill East Africa, CTS carried out a review of the literature describing the agronomy of the plant and visited Zimbabwe, Kenya and Ethiopia where small trial plots had been grown over several years.

Observation trials were hurriedly planted under irrigation on a Government Horticultural Research Station in Kenya. Unfortunately the plants failed to reach maturity due to a high incidence of disease linked to previous intensive cropping. Availability of viable seed was and still is a major constraint. Despite the poor trial results a tenfold increase in seed available to CTS was achieved. One litre of oil was produced and 80 lbs of seed made available for subsequent planting.

Preliminary analysis of the US market for *Vernonia* oil shows a demand of 54,000 tons annually by 1998 for a variety of coatings, plastics, inks and other applications. A price range of 30-70 US cents per pound was identified which equates to a bulk price of approximately US$ 600/MT FOB Mombasa.

For the market study CTS was able to tap into the resources of the Cargill Chemical Products Division, a major supplier of chemical resins to the US industrial coatings industry. The Cargill Research Centre in Minnetonka, Minnesota works on polymers and resins to meet the changing demands of industry and are thus already in contact with the potential customers for *Vernonia* oil. Availability of oil for functionality testing by industry has been a major constraint and one of the initial objectives of the programme in Kenya will be to make commercial samples available for analysis in the Cargill laboratories, the Coatings Research Centre in Michigan and other interested users.

In August 1991, USAID funded further work in Kenya to study the crops potential. The objectives of this on-going work are:

- to maintain the viability of the seed held in Nairobi through planting as storage has not been successful in the past;

- to bulk the available seed and provide general observations on its growth pattern;

- to evaluate the results and update the current best production technique;

- to prepare a formally structured research programme which might be funded for the 1992 crop season.

Suitable land was identified on the coast where the rainfall is expected to last longer than elsewhere in Kenya. Small plots have already been planted and the results are expected in early 1992. Therefore this proposal only addresses the last of the objectives listed above.

1.2 RELEVANT PAST EXPERIENCE

Cargill Technical Services Limited have previous experience in the development of wild plants for successful commercial production. The same methodology will be applicable to the development of *Vernonia* as a new cash crop for Kenya.

A wild plant found in the jungles of Indonesia, Thailand and China was taken by CTS to a government research station in Malaysia. The plant required shade and oil palm was selected for inter-cropping trials. For eight years CTS and the government research staff worked together to develop the most appropriate farming system and commercial quantities of the processed crop are now being exported regularly from Malaysia.

1.3 APPROACH

A similar approach is proposed for *Vernonia*. The Kenya Agricultural Research Institute (KARI) have the necessary expertise and facilities to run a series of agronomic trials at several sites. This will provide the information on the optimum farming system for the crop and can be practical and farmer orientated. It is important that KARI are involved at an early stage in the detailed design of the trials and in discussions with potential funding agencies.

The principal objective of the research programme will be to develop *Vernonia* as a crop in Kenya suitable for growing in semi-arid areas, with or without irrigation and on small or large farms. For the crop to be successful, the oil produced must be suitable for the identified markets, at prices which will permit the crop to compete with other cash crops such as cotton. The project is therefore market led with emphasis on oil quality and the economics of production.

2.0 BACKGROUND

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The scientific and technical literature relating to *Vernonia* is limited as would be expected of a plant and oil in the very early stages of development. In a comprehensive review of information on *Vernonia* and its uses Perdue and Ayoride (1989) quote twenty references. A list of these references on *Vernonia* is contained in Annex 1. Of these ten relate directly to *Vernonia* oil and its utilisation. The other ten papers relate to the botany and agronomy of *Vernonia galamensis* and the potential of the plant as an agricultural crop. Six of these ten papers were either written by Robert E. Perdue Jr. (alone or with collaborators) or are based upon his work. Dr. Perdue of the Agricultural Research Service of the United States Department of Agriculture is a leading authority and promoter of the development of *Vernonia*. The other four papers relate to agronomic research in Pakistan (Aziz et al, 1984), systematic botany (Gilbert, 1986, and Jeffrey, 1988) and photoperiod research in the USA (Phatak et al, 1989).

The two key papers which embody the majority of scientific facts relating to the agronomy of *Vernonia galamensis* are Perdue et al (1986) and Perdue et al (1989). Therefore the following review is based principally on these two papers, formatted to assist the reader in identifying key items of information.

2.1 SCIENTIFIC INTEREST AND COLLECTION OF *VERNONIA* SPECIES

During the mid-1950s the USDA Agricultural Research Service initiated plant screening programmes to identify new sources of industrial raw materials, especially new and unique plant constituents that would not compete with those then in adequate supply and that could be used to satisfy existing needs or anticipated needs. The goal was to identify plants that might be developed as new crops for agricultural diversification to replace those in surplus.

One programme focused on the discovery of unusual seed oils for which new industrial markets might be created or that might recapture markets lost by agricultural products to petro-chemicals. Seeds were screened for oil content and those with substantial amounts (>20 per cent) were evaluated to identify oils with unique fatty-acid composition, distinctly different from oils of peanut, cottonseed, soyabean, linseed, or other domestic crops.

2.1.1 *Vernonia anthelmintica*

Oil content of seed of *Vernonia anthelmintica* (L) Willd. obtained from the Indian Agricultural Research Institute (IARI), New Delhi, was 26.5 per cent (Earle et al., 1960). Preliminary evaluation of the oil indicated that it contained 67 per cent of an epoxy oleic acid. Vernolic acid was subsequently isolated from the seed supplied by IARI (Smith et al., 1959). Since substantial quantities of epoxy oils were then, and still are, used by industry to manufacture plastic formulations, protective coatings, and other products, prospects seemed good that a naturally occurring epoxy acid could enter these markets and

perhaps others developed following further utilisation research on the oil. Thus, a programme was initiated to introduce and evaluate *Vernonia anthelmintica* germplasm. The objective was to develop new varieties suited to American agriculture. In parallel, another programme was initiated to conduct utilisation research on the oil and its components.

2.1.2 *Vernonia galamensis* and Other Species

In order to broaden the germplasm base for the hybridisation programme based on *Vernonia anthelmintica*, Mr. C.E. Smith Jr. visited Africa where all other species of *Vernonia* section *Stengelia* (to which *Vernonia anthelmintica* belongs) occur. The visit made from December 1966 to March 1967 included Ethiopia, Kenya, Uganda, Tanzania and South Africa. Seed of stengeloid and other *Vernonias* was collected. Analysis of seed for oil content showed that the stengeloid samples were not impressive compared with five lots of seed from non-stengeloid plants collected in the Kenya highlands.

2.2 BOTANY AND DISTRIBUTION OF *VERNONIA* SPECIES

The most comprehensive review of the botany of *Vernonia* is found in Perdue et al (1986).

2.2.1 Description

Herbaceous, usually annual, rarely persisting for more than one growing season; varying from small ephemerals 20 cm tall with a single flower head, to robust, rather diffusely branching, somewhat shrubby plants to 5m tall with many flower heads; stems never branching from the base, branching only after the first flower head is formed; the inflorescence consisting of a terminal flower head with lateral flower heads from the uppermost axils, subsequently, if moisture is sufficient for continued growth, the lateral branches of the inflorescences overtopping the first formed inflorescence. Leaves alternate, sessile, membraneous, 0.6 - 5.0 cm wide, up to 25 cm long, acuminate at the tip, cuneate at the base, margins toothed, surface puberulous to pilose. Characters otherwise as typical of *Vernonia*, separated by Gilbert (1986) into 6 sub-species, primarily by characters of the phyllaries.

2.2.2 Taxonomy

Jones (1981) developed a synoptic classification of Old World *Vernonia* that relied strongly on pollen characteristics, but reflected phytochemistry, cytotaxonomy, cytogenetics and morphology to the extent such information was available. *Vernonia galamensis* belongs to subgenus Orbisvestus (which is restricted to the Old World tropics and sub-tropics), section Orbisvestus, and is the type species of sub-section Centrapalus. Species of this sub-section are coarse annuals to perennial herbs or semi-shrubs of grasslands and successional habitats from south of the Sahara into South Africa. They can be distinguished from other African species with similar pollen by their brownish pubescent achenes.

Wild (1978) studied *Vernonia* of the Flora Zambesiaca area and first recognised the subject species as *Vernonia pauciflora* (Willd.) Less. Subsequently he (Wild 1978, errata) accepted *Vernonia galamensis* (Cass.) Less. as the correct name for this species.

More recently, prompted by the new interest in *Vernonia galamensis* as a potential new vernolic acid source, Gilbert (1986) studied this species in greater depth. He concluded that within the complex formerly called *Vernonia galamensis*, a locally endemic population in northern Tanzania should be segregated as a new species *Vernonia filisquama* M. Gilbert, and plants earlier recognised as *Vernonia afromontana* R.E. Fries are better considered as a sub-species of *Vernonia galamensis*. According to Gilbert's concept of *Vernonia galamensis*, this widely distributed species includes six sub-species, one of which includes four varieties:

1. ssp. *galamensis*

   a. var. *galamensis*
   b. var. *petitiana* (A.Rich) M. Gilbert
   c. var. *australis* M. Gilbert
   d. var. *ethiopica* M. Gilbert

2. ssp. *nairobensis* M. Gilbert

3. ssp. *lushotensis* M. Gilbert

4. ssp. *mutomoensis* M. Gilbert

5. ssp. *afromontana* (R.E. Fries) M. Gilbert

6. ssp. *gibbosa* M. Gilbert

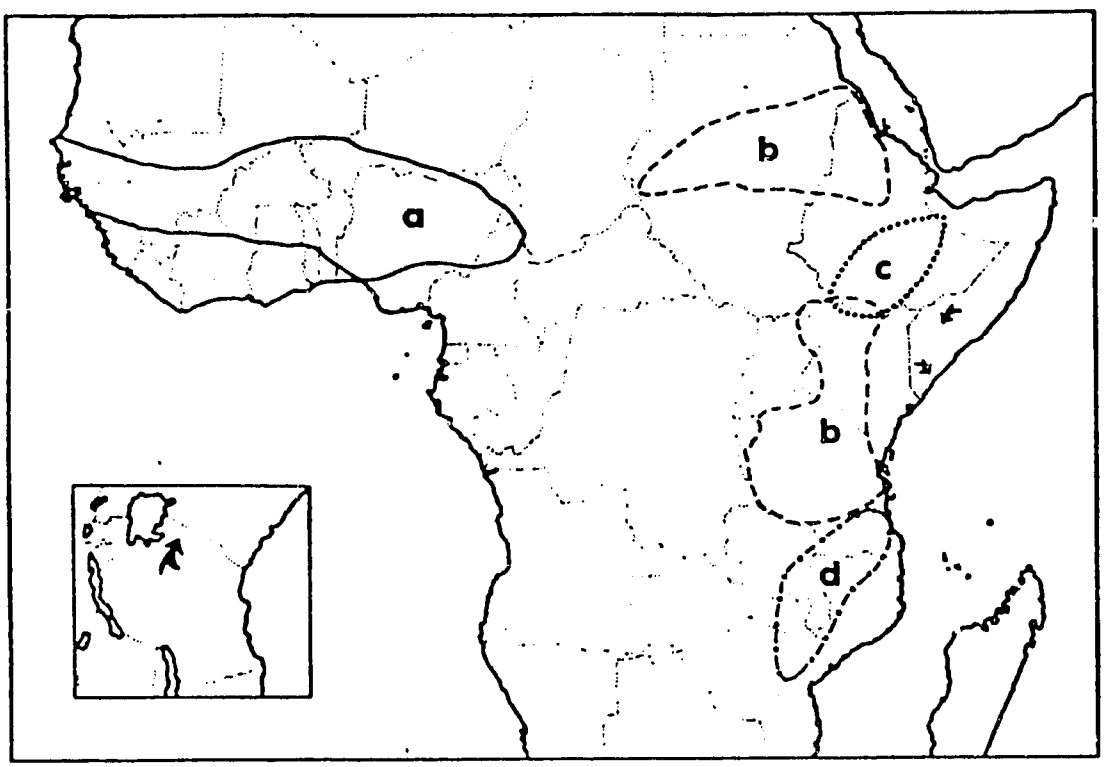
2.2.3 Distribution

The distribution maps are based on specimens at Kew Herbarium and the East African Herbarium (EA), Nairobi, Kenya. Figure 2.1 shows distribution of *Vernonia filisquama* and the four sub-species of *Vernonia galamensis*; Figure 2.2 shows distribution of the other sub-species. It is evident from Gilbert's treatment that this widely distributed species is highly diverse and its centre of diversity is in East Africa.

Within ssp. *galamensis* Gilbert defines four varieties that seem fairly well separated geographically and/or ecologically. The West African var. *galamensis* (west of 14°E) is found only in areas of lower rainfall. Var. *petitiana* is in Ethiopia, Kenya, Somalia, Sudan, Tanzania and Uganda; var. *australis* is distributed from southern Tanzania through Mozambique to eastern Zimbabwe, each reaching about 19° distant from the equator. Var. *ethiopica* occurs in southern and eastern Ethiopia at elevations of 1,250 - 2,075m, on the whole at higher elevations than those recorded for var. *petitiana* (mostly 750 - 1,500 m).

Ssp. *nairobensis* is a common plant in the uplands (1,300 - 2,250 m) of Kenya and northern Tanzania, a ruderal of forest margins and clearings. Ssp. *gibbosa* is endemic to a small area northeast

Figure 2.1



Distribution of *Vernonia filisquama* and *V. galamensis* subsp. *galamensis*. *V. filisquama* is recorded from several locations in northern Tanzania (arrow, box, lower left). *V. galamensis* subsp. *galamensis* includes 4 varieties distributed from West Africa, east to Sudan and Ethiopia, then south to Zimbabwe and Mozambique. a. var. *galamensis*. b. var. *petitiana* (arrows show 2 isolated records in Somalia). c. var. *ethiopica*. d. var. *australis*

Figure 2.2

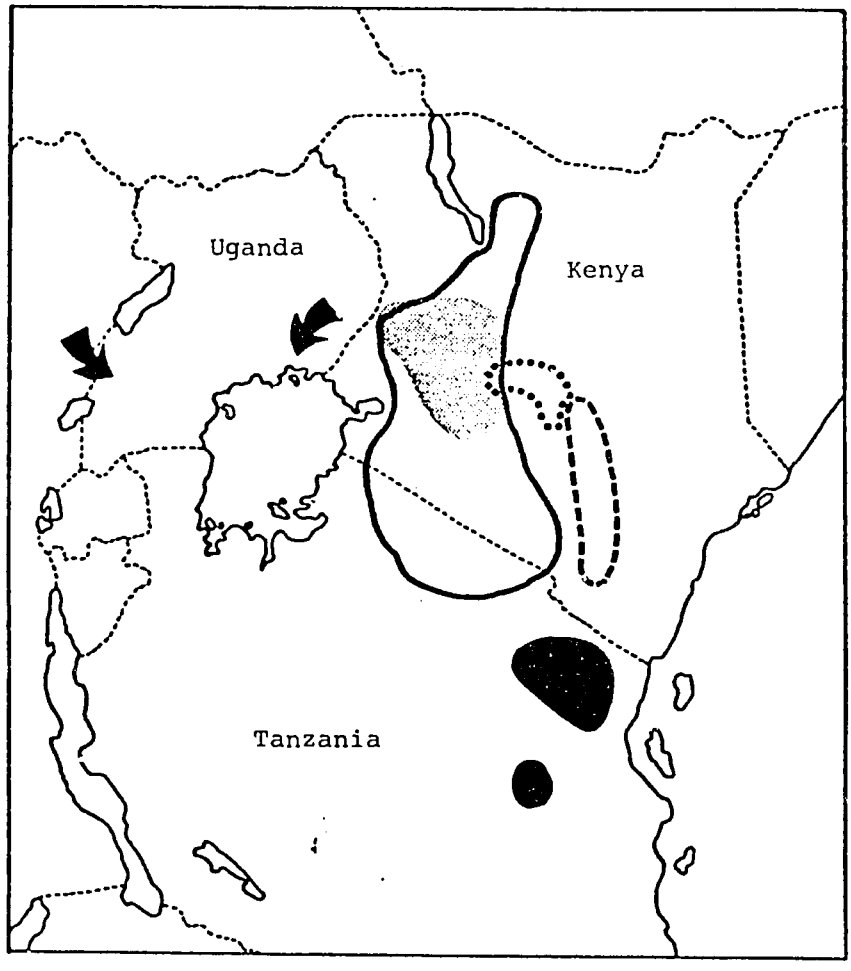


Fig. Distribution of 5 subspecies of *Vernonia galamensis* found only in East Africa (Uganda, Kenya, and Tanzania), the center of diversity of this species: subsp. *nairobensis* (solid line), subsp. *afromontana* (stippled), subsp. *gibbosa* (dotted line), subsp. *mutomoensis* (dashed line), subsp. *lushotoensis* (black; arrows show isolated collections in Uganda).

of Mt. Kenya. Ssp. *afromontana*, one of the most distinct segregates, occurs in montane forests or former forest areas (1,900 - 2,400 m) of central and western Kenya, often under trees. Ssp. *mutomoensis* is endemic to the Ukambani-Taita area of Kenya where it is largely associated with basement complex inselbergs at substantially lower elevations (700 - 1,150 m). While ssp. *lushotoensis* does occur at isolated points in Uganda (3 records), it is by far most common as a ruderal in wet forest areas of eastern Tanzania, primarily in Lushoto District in the Usambara Mountains.

The *Vernonia galamensis* segregates occur in areas with annual rainfall as low as 50 cm, occupied by *Acacia-Commiphora* bushland/woodland, to rich forested areas with annual rainfall of 185 cm, but no sub-species occurs through a large proportion of this ecological range. Ssp. *mutomoensis* and ssp. *galamensis* are restricted to drier habitats and avoid areas without a well-defined and severe dry season. Ssp. *nairobensis* and ssp. *gibbosa* occur in areas characterised by dry evergreen forest often dominated by *Brachylaena* or *Olea* with members of the Rutaceae, especially *Teclea*, *Vepris* and *Calodendrum*, forming an important component. In these areas rainfall is bimodal but is distinctly higher and more reliable than in the areas occupied by *Acacia-Commiphora* bushland/woodland. Ssp. *Afromontana* and ssp. *lushotoensis* occur in the areas of highest rainfall, which rarely have a prolonged dry period, and where the natural vegetation is tall forest rich in epiphytes. All the sub-species are restricted to rather open situations and are very much favoured by disturbance. They are usually most conspicuous in ruderal situations and characteristically occur on porous, well-drained soils.

2.3 EARLY ATTEMPTS TO DEVELOP *VERNONIA* AS A CROP

2.3.1 *Vernonia anthelmintica*

During the late 1960s substantial agronomic research was devoted to *Vernonia anthelmintica* in the USA. The goal was to develop varieties suitable for cultivation in the United States. The germplasm base consisted of nine accessions from India and Pakistan, where the plant is valued for its medicinal properties and is cultivated or allowed to persist in or around the borders of cultivated fields. Some accessions were collected from cultivated or semi-cultivated plants; others were market samples. Although the germplasm base was not as broad as desirable, there was substantial genetic diversity.

Agronomists developed improved lines with shorter stature, more uniform seed maturity, and higher oil content, but showed that yields were limited by poor seed retention. Plants branch diffusely and produce many flower heads, up to about 1.5 cm in diameter. But those formed first lose their seed before those formed later mature. While the total seed crop was heavy, it was not adaptable to mechanical harvest because seed did not mature uniformly.

2.3.2 *Vernonia galamensis*

Trials in the USA

Seed from the Perdue 1964 collection were planted at Experiment, Georgia, USA. Plants grew to 1.2-1.5 m tall and produced a few flowers but no seed. Leaves were discoloured and appeared diseased. Seed was subsequently increased in a greenhouse at Glenn Dale, Maryland. Plants flowered in November and seed matured in December. However, by that time there was no interest in this species as a potential new crop for the United States.

Trials in Kenya

In July 1975, African Highlands Produce Company, Kericho, Kenya, planted seed, increased from that collected in Ethiopia. Plants initially formed single unbranched stems and subsequently branched above, after terminal flower heads were formed. Seed was harvested in March 1976 and contained 40 per cent oil with 80 per cent vernolic acid, about the same as the original seed from Ethiopia. A much larger planting at Kericho was made in early July 1977; the crop was harvested in late February. Even though average annual rainfall at Kericho is 185 cm, almost three times that of the area of Ethiopia where seed was initially collected, there was no evidence of disease, insect, or other problems. No data on seed yield are available but it was the success with the Kericho planting that prompted new interest. African Highland Produce Co. supplied substantial seed, source of the oil used to establish the value of this product in the manufacture of coatings (Carlson et al, 1981).

Following the successes at Kericho, small plantings were established at Mombasa by Mr. R. Haller. Oil yield was up to 29.7 per cent with up to 78.2 per cent vernolic acid. These samples were identified as sub-species of *Vernonia galamensis*.

Trials in the Caribbean

In the early 1980s small plantings were established at Cayey, Puerto Rico, Isabela, Puerto Rico and at five locations in Jamaica. The Cayey plantings produced substantial amounts of seed and there was no evidence of disease, insect, or other problems. The Isabela and Jamaica plantings failed.

At Isabela, in 1982 and 1983, plants grew to a height of about 0.6 m, the leaves turned brown and the plants died. Specimens from the 1982 planting, including roots from which soil had been removed, were examined by specialists at Beltsville, Maryland, for evidence of insects, disease, and nematodes. None could be found. Additional specimens were obtained from the 1983 planting; these included balls of soil around the roots and these too showed no evidence of parasites or pathogens. Absence of insects, nematodes, or disease suggests failure was due to a physiological disorder probably associated with excessive soil moisture. The response in Jamaica was similar to that at Isabela; plants tended to die off, root rot was observed and a Fusarium was identified as the possible causative agent. At one Jamaica site, soil was "heavy clay"; soils at the other four were "medium textured silty to clay loams".

Trials in Zimbabwe

In 1984, Perdue observed a small planting of *Vernonia galamensis* at the Botanic Garden, Harare, Zimbabwe, from seed increased from the original collection in Ethiopia. Seed was sown under glass on 28th June 1983. Plants 30 cm tall were transplanted 15th September. The first flower heads appeared 19th September. In January, plants were luxurious and profusely branching, about 1m tall, with many immature flower heads terminating the branches. But on each plant, about 30 cm above ground level, there was a fully mature flower head and other fully mature flower heads were at levels 45-60 cm above ground level. Seed was dead ripe. Involucral bracts had spread completely open and were beginning to reflex but no seed had been shed. The plants had been over-watered and were growing on the site of a former compost pile. The luxurious growth seemed due to excessive moisture and fertility. Perdue commented that had these plants been subject to severe moisture stress soon after initial flowering the plants would have produced few flower heads, all of which would have matured and retained their seed. Here, seed retention by the first-formed flower heads was striking.

The Department of Research and Specialist Services (R & SS), Ministry of Agriculture, began research work with *Vernonia galamensis* in 1983. Seed was provided by Dr. Perdue and was progeny of the original collection made in Ethiopia in 1964. Initial trials were planted in Harare and at four R & SS field stations in different parts of the country (including Chiredzi in the S.E. Lowveld at 420 m, Inyanga in the northern part of the Eastern Highlands at 1,860m, and Chipinga in the southern part of the Eastern Highlands at 1,130 m - Figure 3.1). Plants grew well at Harare, Chiredzi and Chipinga. At Inyanga the plants grew vegetatively well but did not set seed, possibly due to low temperatures (average minimum temperatures in September are 6-7°C and absolute minimum temperatures for that month can reach freezing point).

Based on the encouraging observations on plants grown at Harare, Chiredzi and Chipinga, further experimental plantings were established for Chiredzi and Chipinga. The trials programme continued for several years. In 1983-84 trials on time of planting were grown to confirm photoperiodicity, on topping to prevent excessive vegetative growth. These trials were grown at Chipinga and Chiredzi but in later years were restricted to Chiredzi in the lowveld.

Time of planting, row spacings, topping, fertilisers and weed control were variously tested over a six year period and the effects of the various treatments on oil content were measured. After the second year all the trials were irrigated to ensure even germination and good stands.

Seed yields between 2 and 2.5 tonnes per hectare were obtained with an oil content of 38 per cent of which 75 per cent was vernolic acid.

Trials in Ethiopia

The properties and potentials of *Vernonia galamensis* have been well publicised in universities and research institutions in Ethiopia initiated by the efforts of Robert Purdue. The level of awareness has recently been enhanced as the result of distribution of information supplied by the University of Michigan.

To date efforts towards research and development of the plant have largely been taken up by individuals on an ad hoc basis through personal contacts made by Purdue and Gilbert. However, in September 1989 a National Committee was formed comprising key government departments, agencies and research programmes. This committee has a mandate to research and develop oil-bearing crops, and *Vernonia galamensis* has been identified as one to be included in the programme.

The National committee is headed by the Minister for Industry and has representatives appointed from:

- the Plant Genetics Resource Centre
- the Ministry of State Farms
- the National Chemical Corporation
- the University of Addis Ababa

As yet there has been no clear strategy identified.

3.0 TRIALS PROGRAMME

3.0 TRIALS PROGRAMME

The following outline trials programme should form the basis for discussions with KARI officials who must be intimately involved at an early stage in the detailed planning.

This early involvement will cover the types of trials to be grown, the statistical designs, proposed locations, the funds, equipment and extra support which KARI will need during the project. KARI will also define the supervisory staff which would be allocated to the project.

3.1 LOCATIONS

It is proposed that the trials programme will continue for three years beginning in 1992. In the first year locations could include the KARI stations comprising:

- the oilseed centre at Mwea Tabere
- Katumani research station and the substations of Katui and Kibwezi

Additional locations could be included following discussion with KARI and then in 1993 further modification could be made in the light of the first year's experience.

3.2 TIME OF PLANTING

It is expected, as *Vernonia galamensis* grows wild in Eastern Africa, that optimal times of planting will be at the beginning of the rainy seasons. It is to be hoped that in areas of bimodal rainfall two crops a year will be possible. This, however, needs to be checked experimentally, because in other countries there have been problems, most probably because of daylength sensitivity.

The following is proposed.

A serial planting experiment - At two week intervals, starting from the first rains in April for a period of six weeks. Where there is a bimodal rainfall pattern these trials should be done in both rainy seasons starting in April and again in October.

Plot size should be about 12 m^2 and the plants should be grown with and without a standard fertiliser application comprising NPK compound 10:20:10 at 150 kg per hectare.

Design should be 3 times of planting x 2 (fertiliser/no fertiliser) x 4 replications.

Hand weeding should be done before planting, and probably the whole trial should be weeded before each planting.

3.3 SOWING METHODS

The seed of this crop is very small: 1,000 seeds weight is 5 grammes. This complicates sowing methods, as there will always be a tendency to use excess seed and thus much thinning will be needed. Previous work has indicated a seed rate of 4 kg per

needed. Previous work has indicated a seed rate of 4 kg per hectare, and the optimum plant population as 80,000 plants per hectare ie 8 plants per m^2.

An experiment is suggested with the following treatments:

a. Seed sown by hand without admixture
b. Seed mixed with soil and then sown by hand
c. Seed mixed with sand and then sown by hand

In each of the treatments a stated weight of seed would be mixed with a stated weight of soil or sand. Probably in the form:

Seed	+	Sand	or	Soil	Seed only
1	+	1	or	1	2
1	+	2	or	2	1
1	+	3	or	3	0.5

The trial should be replicated and detailed observations will be required on time to germination; growth data; time to first flowering; time to first harvest etc.

3.4 OPTIMUM SPACING/POPULATION DENSITY

Because of the small seed oversowing will be normal, particularly if germination testing has not been possible. The literature suggests that 8 plants per m^2 is an optimal spacing, but this needs to be checked by experiment. Previous work also suggest that thinning may not be necessary, because in a high population, quick growing individuals rapidly shade out weaker individuals and that this process tends to continue until an optimal population is reached. Again this needs to be checked by experiment.

It is suggested that a duplicate of the sowing methods trial could be used to gain this information, beginning with different seed rates and then introducing thinning and no thinning as an additional treatment.

For both the sowing and thinning trials a decision needs to be made on whether the trails will be broadcast or sown in rows. This will probably depend on normal practice on the research station and this will be acceptable for the first year. In the second year, trials should be initiated to resolve whether broadcasting or row cultivation has any advantage. It may be, for example, that self thinning is much more effective in a broadcast situation than in row sowing, where edge effect may be more important.

3.5 APICAL DOMINANCE

The literature indicates that in the wild the species exhibits apical dominance; as the plant grows it does not produce lateral branches until the apical bud has matured and produced a flower. The apical flowers then mature before the lateral flowers and harvesting of the crop has to be spread over several weeks.

Work done in other countries shows that if the plants grow too vigorously they may lodge later in their life cycle. To avoid

this plants were topped and it was found that in the topped plants apical dominance was broken, many branches being formed, on which all the flowers tended to mature at the same time. This latter situation may result in smaller plants; a short term crop and a harvest more suited to mechanical harvesting. This also needs to be investigated under experimental conditions.

It is suggested that the treatments would be:

a. Control - no treatment
b. Topping at 30 cm above ground
c. Topping at 45 cm above ground
d. Topping at 60 cm above ground

The trial could be split for fertiliser versus no fertiliser.

There is no knowledge of when topping should actually take place and in the first season's trials an arbitrary date should be fixed, probably about two weeks after the plant has reached the required height. In subsequent seasons dates of planting and dates of topping should be incorporated into a more complex trial.

3.6 FERTILISER

Fertiliser should be included in some replications of all the trials in the first season, so that levels of response can be calculated. One of the hopes for this crop is that it will give reasonable yields without fertilisers, but it is possible that in high rainfall areas the application of fertiliser will be economic. Refinement of any fertiliser used should be left until later in the programme.

In 1992 it is proposed that an NPK compound 10:20:10 at a rate of 150 kg per hectare should be standard for all the trials.

3.7 PESTS AND DISEASES

Pests and diseases have not so far been a problem, but only small areas of the crop have been grown. This aspect of the experimental programme will need vigilance so that there can be a quick response. Rapid identification of pests or diseases will be necessary to ensure that control can be implemented. Should serious pest or disease outbreaks occur, the trials programme will be modified for 1993 and 1994.

3.8 HARVESTING

Data on time of harvesting and crop life tables under different conditions will accumulate from all the trials being done.

Seed is produced inside flower heads and the seed is not visible. Regular daily samples will be needed throughout the period of crop maturation and flower head drying to determine when seed heads are actually mature and ready for harvest. The literature suggests that at least some varieties retain the seed in non-shattering seed heads until they are fully ripe; this would have considerable advantages and needs to be confirmed.

There will be a need to determine the relationship between weight of seed head and weight of mature seed. This will be very important in determining the price to be paid to farmers, who will probably be expected to harvest seed heads, dry them further if necessary and sell them without threshing.

3.9 POST HARVEST SEED REQUIREMENTS

Investigations will have to be done on the processing of seed heads after harvest. Drying may be required and this will be followed by threshing. It will be necessary to determine whether this can reasonably be done by individual farmers, or whether it must be a mechanised operation. The literature mentions that in the seed heads, in the remains of the flowers, there are numbers of irritating hairs, which may be enough to make threshing by hand unacceptable. The irritating hairs would also interfere with the winnowing process which will be quite difficult with such a small seeded crop.

From the experimental programme there will be a need for the weighing of seed head samples from individual plots, threshing them, cleaning them and weighing the mature seeds. Following on this will be the need to extract the oil and to note the quantity and quality.

3.10 OIL ANALYSIS

Seed samples will be taken from all the trials plots for oil analysis. During the initial discussion with KARI it will be determined if suitable laboratory facilities could be made available for oil extraction from the trial samples. The samples of oil will then be tested in Cargill laboratories in the USA for industrial suitability and market response.

During 1993 and 1994 larger samples of oil will be produced which will enable commercial testing to take place in the USA to confirm the small scale market tests from the trials. This aspect of the project will be most critical for the determination of the marketability of the oil and thence the potential success of the crop in Kenya.

3.11 ANIMAL FEEDS

The oilseed cake residues from the samples used for oil analysis will be used for laboratory tests on palatability and nutritional content, for animal feeds. KARI will be in a position to advise on the most suitable laboratories to cooperate in this aspect of the project. If the initial laboratory tests indicate that there is potential for the residues to be used for animal feed a series of field trials will then be planned for ruminants and non-ruminants. It is thought that the feed value of the cake will be 80-90 per cent of the feed value of soybean meal. However, no trials have been carried out to check for the presence of toxins.

3.12 ECONOMIC ANALYSES

During the second and third years of the project a socio-economic study will be started to investigate how and where the crop will

fit into the existing farming systems. These investigations will emphasise the role of women in the growing of the crop, the likely impact on the environment and the possibilities of growing *Vernonia* as a catch crop in the higher rainfall areas.

It is anticipated that the impact on the environment could be beneficial if the crop replaces others such as cotton which presently receive large quantities of chemicals for pest control.

Economic analyses will be made to determine the returns per man day from growing the crop. This will be an essential pre-requisite for the introduction of the crop into the Kenyan farming systems to demonstrate to farmers that worthwhile returns to their labour can be made.

3.13 PLANT SOURCING AND CULTIVAR TESTING

After the first year of the trials programme sufficient information should be available to decide if a further search for wild types should be made and if a selection programme for cultivars should begin.

The species of *Vernonia galamensis* is widespread in Africa and has recently been studied taxonomically by Gilbert (1986) who, partly because he was aware of the commercial interest, decided to split the species into six subspecies, one of which, *Vernonia galamensis* ssp *galamensis* was further split into four varieties. This classification allows for a comprehensive study of the characteristics of the nine taxa, to determine whether they have any worthwhile commercial characters, either on their own or in combination.

The requirements for an adequate programme will be:

a. Seed collection throughout the range of the species
b. The growing of the various taxa and selection of promising material
c. The assessment of desirable characters in each of the taxa and the planning of how these may best be used
d. The planning and implementation of a selection programme designed to produce the most commercially rewarding form of *Vernonia galamensis*.

Such a programme should be for a minimum of five years, because the production of improved varieties will need successive crosses etc over a number of generations. The seed collection phase can probably be completed in two years.

For plant collection it will be possible to employ staff from the Herbarium at the National Museum who already know the sites where previous collections were made and who are quite familiar with the range of varieties. They also have good contact with officials in Tanzania, Uganda and Ethiopia.

The availability of suitable land should be investigated in the Athi River area, because:

The availability of suitable land should be investigated in the Athi River area, because:

a. The area is very convenient to Nairobi, with all its facilities
b. There are ample facilities for irrigation
c. There are many private farms along the river
d. Athi River is about the mid point, in altitude, of the range of habitats of the varieties of *V. galamensis*.

ANNEX 1

REFERENCES

ANNEX 1

REFERENCES ON VERNONIA BOTANY AND AGRONOMY

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