Industrial Utilization of Pyrethrum

Workshop Proceedings

Dar es Salaam, Tanzania 29-30 May 2000

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Preface

Increasing use of pesticides in agricultural production has been a matter of serious concern for the environmentalists. The inherent danger of using Persistent Organic Pollutants (POPs), especially insecticides, has led a number of international initiatives from United Nations to regulate, control and reduce the distribution of dangerous chemicals in international trade. The void created by withdrawal of hitherto popular pesticides has to be suitably filled by making available cost-effective, safe insecticides for the success of these global initiatives.

Pyrethrum with its glorious past had been successfully used for a wide range of insect control. The properties of pyrethrum lend themselves well to promote its use in today's context. It possesses a very low mammalian toxicity, rapidly degrades in the environment, and does not leave any harmful residue to contaminate food or water chains.

The world production of pyrethrum has never been able to meet its demand, a situation that kept its supply and price unpredictable and erratic. Fortunately, the poor countries of the world are bestowed with geographical and climatic conditions ideally suited to provision of a commercial production of pyrethrum.

The changed situation in pest management has led the way for adoption of biopesticides, which were previously unable to compete as regards price and availability.

These considerations attracted the attention of the International Centre for Science and High Technology, and resulted in their hosting a two-day workshop in Dar Es Salaam on 'Industrial Utilization of Pyrethrum' on 29-30 May 2000, in an attempt to revamp the slackening pyrethrum industry of East Africa. Unfortunately, pyrethrum production in East African countries was in decline, despite growing international demand.

The workshop invited participants from the pyrethrum industry, research institutes, governmental agencies and farmers associations to debate and recommend action for encouraging pyrethrum production and processing in traditional strong bases in Kenya, Rwanda and Tanzania.

It gives me immense pleasure and satisfaction to publish the proceedings of this workshop, which was unique in providing a common platform for all stakeholders in the pyrethrum industry to discuss problems of the industry, resolve a common action plan and catalyze productive initiative.

Gennaro Longo
Area Director
Earth, Environmental and Marine
Sciences and Technologies

Acknowledgements

The Area of Earth, Environmental and Marine Sciences and Technologies of ICS-UNIDO is grateful to the participants in the workshop who gave wholehearted support to the ICS initiative of promoting production and utilization of pyrethrum in the East African region. We would not have succeeded in this endeavour without the support of the UNIDO Field Representation in Tanzania, who agreed to collaborate in holding this workshop. The efforts of the UNIDO Field Representation, its staff and especially the UNIDO Representative, Mr Felix Ugbor, are gratefully acknowledged for their efficient organization and conduct of the workshop.

Special thanks go to Mr. Francesco Pizzio, Managing Director of ICS-UNIDO, for his constant support and encouragement throughout the activities mentioned here, and to the ICS scientific, secretarial and publications staff for guidance, compilation, preparation and editorial work.

Contents

1 Introduction

The workshop on Industrial Utilization of Pyrethrum focused on the potential of promoting pyrethrum production in the East African region to benefit the most deserving poor farmers in developing countries. Any discussion on this topic must address the issues of exploration of more effective production technologies, marketing strategies, research needs and quality improvement measures for pyrethrum. In order to provide practical solutions to the issues outlined, the International Centre for Science and High Technology (ICS), in collaboration with the UNIDO Representative's office in Dar es Salaam, hosted a two-day workshop on 'Industrial Utilization of Pyrethrum', 29 to 30 May 2000, at the Sheraton Dar es Salaam Hotel, Tanzania.

1.1 Objectives of the Workshop

The efficient management for sustainable production of any crop has become essential for meeting the growing demands in market. With the increasing threat of insect pest to agricultural crops and deleterious side effects of synthetic insecticides there is a shift towards using environment-friendly natural products in the world. But the gap between their demand and supply is very wide. In order to narrow down this gap there is a need for increasing the pyrethrum production.

Workshop participants sought to define strategies for increasing production and marketing opportunities for pyrethrum with the following objectives:

- Assess the present status and formulate future strategies that would promote pyrethrum production in the East African region;
- Explore more effective production technologies, i.e. emerging agricultural techniques to improve the yield and pyrethrins content of the flower, development of improved varieties and cultivars, value addition through simple steps at point of origin, advances in the production and extraction of pyrethrins, marketing strategies, research needs and quality improvement measures for the pyrethrum crop.

1.2 Background

The use of natural products in pest management is a long-established folk practice. People in many parts of the world even today use plant products to protect their food and food crops from harmful insects. The need to develop products to check the growth of harmful insects and pests has been felt ever since the evolution of human society. Inquisitive human nature provided the first answer to this need of developing society. As a result, a number of plants were discovered to possess insecticidal properties in different parts of the world. These became the first insecticides to be used by man. *Nicotiana, Ryania, Derris,* sabadilla, pyrethrum and neem are some of the plants with established insecticidal properties. Developments especially during the first half of the 20th century drifted the focus towards synthetic insecticides, which was spearheaded by the discovery of dichlorodiphenyltrichloroethane (DDT). Insect poisons were discovered and used, some of them indiscriminately, causing irreparable damage to the environment. Their long persistence in the environment, toxic effects on non-targeted insect species and animals posed a serious threat to the biosphere. The increasing awareness for protection of the environment and understanding of the complications of using toxic but non-degradable chemicals, demanded discovery of novel means of pest control. This resulted in a prodigious revival of interest in plant products for their much better acceptance in the environment.

In pest control management, one insecticide, pyrethrum has ever outshone in the history of insecticides. The insecticidal use of pyrethrum derived from *Chrysanthemum coccineum* Willd. was a long-established practice in the Caucasus region and northwest Persia. The flower powder, later termed Persian or Caucasian insect powder, was known to possess rapid insecticidal action coupled with low mammalian toxicity. By the beginning of 19th century, the insecticidal efficacy of pyrethrum was so well established that the supply reaching Europe was insufficient to meet the demand. In around 1840 a more potent species *Chrysanthemum cinerariaefolium* Vis. (syn. *Tanacetum cinerariifolium* (Trevir.) Sch.Bip.) native to coastal mountains of Croatia, Bosnia and Herzegovina was identified. It became the major source of pyrethrum. It was first introduced in the United States in 1855. Pyrethrum is also known as Dalmatian Insect Flower, as Dalmatia had dominated the pyrethrum trade over a long period till World War I, to be replaced by Japan, which held the control until World War II.

Technically pyrethrum refers to dried flower heads of *Chrysanthemum cinerariaefolium* Vis., *C. coccineum* Willd. and *C. marshallii* Aschers. But principally the first species, which is also the best in containing higher percentage of pyrethrins, is the source of commercial supplies of pyrethrum. The plant is cultivated in Kenya, Tanzania, Rwanda and Ecuador. Smaller amounts are also grown in Brazil, India and Japan. The United States of America is the principal consumer of world supplies of pyrethrum.

2 Recommendations

Pyrethrum is an ideal insecticide in today's context. It is produced from a natural source, displays safety to mammals, degrades quickly and does not leave harmful residue in the environment. These characteristics make pyrethrum a safe and environment-friendly insecticide. World preference for use of plant-derived products has further increased interest in pyrethrum. Interestingly, 90 per cent of world production is achieved in East Africa, Kenya, Tanzania and Rwanda, which export 85 per cent of their production to the world market.

The estimated present demand for pyrethrum stands at 20,000 metric tonnes (MT) per annum of dried flowers, against current world production of less than 12,000 metric tonnes. The concern for the declining trend of pyrethrum production in these countries despite increasing world demand prompted the International Centre for Science and High Technology (ICS), a centre within the legal framework of the United Nations Industrial Development Organization (UNIDO), to organize this workshop to promote the production and industrial utilization of pyrethrum in East African countries. The workshop was organized in collaboration with the country UNIDO Office in Tanzania. Experts from industry, academia, the agricultural sector and farmers associations participated to deliberate on different issues involved in the production of pyrethrum, a crop which can have a profound effect on the economy of East African countries. Key issues were discussed at length and experts agreed to make the following recommendations to be taken up for follow-up at different levels:

- There is an immediate need to revamp the pyrethrum industry by increasing agricultural production to tap fast-expanding world demand.
- All possible help should be rendered to farmers to increase production and yield per hectare from the current 250 to 500 kg per hectare, and pyrethrins content from the present 1.2 to above 2.0 per cent.
- To achieve this, research should be encouraged to multiply suitable clones through tissue culture facilities, which should be amply supported by bulking centres with greenhouses located at strategic places, managed by contract farmers on a commercial basis.
- Farmers should be motivated to increase overall production through access to improved planting material on credit, better price for farmers' produce, prompt payment to farmers and timely analysis of their produce to facilitate the payment of the second instalment.
- Extension services should be strengthened to include awareness programmes for farmers education on crop management using radio, television, documentaries, and print media. The farmers should be made aware of the importance of picking the flowers at the right time, using better drying techniques to prevent loss of pyrethrins, proper pack-

aging and packaging material to avoid fermentation and loss of pyrethrins during transport, effecting timely deliveries at processing centres. Extension staff should be motivated through incentives and good remuneration.

- The current achievable capacity at the only processing plant in Tanzania is 3,000 metric tonnes per annum of dried pyrethrum flowers. However, the 20 year old dilapidated plant is based on old conventional technologies, which employ large quantities of organic solvent to extract flowers. High solvent consumption results into high production costs and hence less money to the farmer. The workshop make recommendations to: rehabilitate the existing plant; adopt new and cleaner production technologies; monitor closely process operations for improved efficiency; put in place preventive maintenance measures as well as human resource development programmes; request the governments to review taxes and utility tariffs in favour of the industry; expand existing processing facilities and/or encourage new investments to include diversification of products (i.e. powder, refined extract, formulated products, cattle feed and manure); encourage the use and strengthening of existing R& D facilities in the country; and establish R&D centre at the processing plant.
- Although the present supplies are inadequate to meet current world demand, new markets must be developed to absorb envisaged increase in future production. The workshop made recommendations to: strengthen existing markets in the West and identify new markets in Asia and the Far East, and to encourage local consumption of pyrethrum-based products by popularizing its advantages over synthetic insecticides.
- As 90 per cent of world production is located in Kenya, Tanzania and Rwanda, there is a need for closer cooperation among these countries in areas of research, product development, marketing and development of improved processing technologies. These countries should develop uniform quality benchmarks for pyrethrum products in conformity with latest world standards.
- The existing research and development facilities in these countries should be strengthened to develop high yield synchronous clones; complete agronomical packages; improved processing technologies; high-tech pyrethrum products for markets in developed countries; and low-cost drying techniques like solar dryers.

3 The Workshop

3.1 Opening of the Workshop

The workshop was formally opened by Mr. Reginald A. Mengi, Chairman of the National Environment Management Council (NEMC), Tanzania. Introduction and general house-keeping matters were presented by Mr. Felix Ugbor, UNIDO Representative in Tanzania. He welcomed the participants to the two day forum and introduced Dr. John Liwenga, the Chairman of the Tanzania Pyrethrum Board, noting that he was to moderate and chair the workshop. Dr. Liwenga took the chair and went on to invite Mr. Ugbor for the opening remarks.

Mr. Ugbor welcomed the participants and on behalf of the workshop organizers, ICS-UNIDO, extended a note of thanks to the guest of honour, Mr. Mengi, who despite his busy schedule and the short notice accepted to officiate the opening as the guest of honour. He highlighted the comparative advantage that Kenya, Tanzania and Rwanda have on account of being leading pyrethrum producers in the world. He called on participants to view the workshop as the first step towards revamping the industry and ultimately turning the local comparative advantage into a competitive one. He underscored the role of 'new' and stressed the importance of environmentally sustainable industrial development, which demands integrating environment goals with those of industrial development without sacrificing industrial growth. Mr. Ugbor noted with great irony the one million deaths caused by malaria in Africa, when the East Africa provides most of the pyrethrum, which could be used to combat malaria without adverse health risks. He went on to conclude his remarks by assuring participants that UNIDO is ready to support the effort of Tanzania, Kenya and Rwanda to take maximum advantage of this resource.

Mr. Gennaro Longo - Director of the Area of Earth, Environmental and Marine Sciences and Technologies, ICS-UNIDO, Trieste, Italy - welcomed the principal guests and participants to the workshop. He gave an account of ICS, emphasizing its mission of promoting sustainable industrial development through transfer of know-how and technology. The target beneficiaries are developing countries. He underscored the importance of target beneficiaries defining their problems in very clear terms. ICS goals are pursued through a wide set of projects, promoted with partner institutions in beneficiary countries. Awareness-building programmes, similar to the present workshop on industrial utilization of pyrethrum, normally support them. He assured the participants that ICS will collaborate with partner institutions in Rwanda, Tanzania and Kenya in implementing workshop deliberations and concluded his remarks by wishing the participants fruitful discussions.

H. E. Mr. A. Matacotta Cordella, Italian Ambassador in Tanzania extended a word of invitation to participants and thanked ICS and UNIDO for organizing the workshop.

Mr. Mengi delivered the keynote address. He started by thanking the UNIDO Representative, Mr. Ugbor, for inviting him to officiate at the opening of the workshop of great importance, not only in revitalizing pyrethrum production but also for its potential impact on environment conservation. He further noted that world demand for food certified to have been grown biologically is increasing fast, allowing farmers in East Africa great opportunities for pyrethrum cultivation, not only as a cash crop but also as a principal pesticide. He added that more access to the international markets and utilization of pyrethrum in growing organic food will create immense opportunities in the near future.

3.2 Key Issues Raised in the Workshop

3.2.1 Plenary Session

The following issues relevant to improve pyrethrum production were raised by the participants.

Improved Seeds
Availability of high yield planting materials would maximize output and generate more income to the farmers.

Processing Efficiency
The existing processing facilities at Mafinga need to be upgraded as a measure towards enhancing processing efficiency and reducing costs.

Producer Prices
The reason why farmers in the north of Tanzania, who get a far better price than those in the south, was queried by participants. The crux of the problem is the growing dissatisfaction and impact it might have on pyrethrum farming in the South. Two participants, both farmers, called for a price review that could ensure more financial returns to pyrethrum farmers.

Extension Services
Lack of regular and adequate support to farmers in good crop husbandry, especially in regions where pyrethrum is not a major cash crop, was another serious constraint observed by several participants.

Pyrethrum Research
Supportive research is non-existent. This is attributed to understaffing, inadequate funding and lack of research facilities.

Driers
A participant made a suggestion to reintroduce mobile driers to cut down drying time and improve product quality. Another participant apprehended loss of pyrethrins during sun drying.

Strategic Planning

There is a world-wide growing demand for pyrethrum. A participant asked if stakeholders were ready to take up the challenge of increasing production, in order to meet the demand. He called on participants to identify existing bottlenecks and formulate appropriate solutions that will maximize the production.

Technical Assistance

One participant suggested that we should first identify our problems and then decide on what do we want to achieve, before seeking external technical assistance.

Commercial Farming

The UNIDO Representative was of the opinion that improved production methods should be at the centre of any meaningful plan for pyrethrum development. He went on to suggest commercial farming of pyrethrum.

RWATAKE Spirit

A participant invited Rwanda, Tanzania and Kenya to enhance cooperation and move away from the notion of being potential competitors in the pyrethrum industry. World demand is far greater than the total combined production of these countries and is unlikely to change in the near future.

The Pyrethrum Board was called upon to take the lead in setting up, organizing and increasing research for the entire industry. A suggestion was made that a system of collecting information pertaining to the industry should be established. It could be forwarded to ICS for publication and dissemination. The UNIDO Representative informed the workshop that he was soon going to invite proposals on viable investment projects, particularly on agro-processing.

3.2.2 Group Discussions

Group A: Agriculture

The group made the following observations:

- ❑ Production has been declining. From 6,000 metric tonnes in 1966-67 it has come down to 1,000 metric tonnes at the end of this season;
- ❑ There are 2,000 registered farmers cultivating pyrethrum on 8,000 hectares in the Southern Highlands and 200 pyrethrum growers associations and primary societies;
- ❑ In the Northern Highlands, there are 240 registered farmers working on 120 hectares;
- ❑ Pyrethrum cultivation can also be introduced in new areas such as Uwino in Ruvuma, Kasulu in Kigoma and some parts of Kagera region;
- ❑ The pyrethrum sector is currently faced with the constraints of lack of supportive research; lack of extension services; lack of high-yield planting material; inefficient drying techniques; poor storage and transportation facilities; and low price for agricultural produce.

Group B: Processing

The group addressed two questions. First, whether the current achievable capacity of 3,000 metric tonnes of dried pyrethrum flower at the Mafinga extraction plant is fully utilized? Secondly, could the extraction capacity be a bottleneck, if we think of encouraging farmers to grow more pyrethrum?

In answering these two questions, the following observations were made:

- There is inadequate supply of flowers to the plant;
- The quality of flowers is poor (low pyrethrins content, fermented and caked);
- The plant machinery is dilapidated. The processing plant which produces only two products (crude extract and dry marc) has high solvent consumption and inefficient extraction, resulting in low pyrethrins content of extract leaving more pyrethrins in marc, inadequate percolation cycle, faulty design and high production cost;
- Inadequate use is made of existing national research institutes;
- There is a lack of R&D facilities at factory level.

Group C: Marketing

The group made the following observations:

- The pyrethrum market is huge and fast growing;
- There is inadequate supply of pyrethrum on the world market;
- Prices are good, emphasis should be on agriculture to improve production;
- There is a need to explore new markets especially in the Far East;
- There is inadequate product development and innovation;
- The local market is flooded with cheap, substandard products made from synthetic pyrethroids;
- The local market is not fully liberalized; and it has very few dedicated players.

3.3 Summary of Presentations

3.3.1 Pyrethrum - A Perspective

Speaker: K. Vasisht

The paper covered various aspects of pyrethrum, starting with its origin, its chemical constituents and the most common pyrethrum products, namely powder, crude extract and pure pyrethrum extract. The speaker discussed key insecticidal properties of pyrethrum, namely:

- Quick knockdown effect;
- Repellent in very low concentrations;
- Very low mammalian toxicity;
- Low incidence of insect resistance;
- Very short life in environment and quick biodegradation.

Other positive aspects of pyrethrum were highlighted, namely, safety ratio to mammals, non-polluting to food and water chains and environment-friendly. This was followed by an account of pyrethrum uses, and leading producers of pyrethrum in the world. The impact of pyrethrum being a natural product, its use is allowed in the cultivation of fruits and vegetables under biological production methods.

Emphasis on botanical insecticides, world preference for use of organics and the need for environment-friendly insecticides has created new prospects for pyrethrum-based products.

In conclusion, strong emphasis was laid on the following:

- Provision of high yield clones, access of farmers to improved seeds and saplings, better drying, storage and extraction techniques;
- Processing and refining facilities at source, product development and innovation;
- Liberalized marketing policies with more returns to farmers.

3.3.2 Industrial Potential of Pyrethrum: Research Overview

Speaker: J. H. Y. Katima

The discussion pointed out that about 85 per cent of the world's pesticide consumption is used in agriculture and about three quarters of pesticides are used in the developed countries. In addition, the pesticide market in developing countries is dominated by insecticides with higher toxicity than herbicides, which dominate the developed countries. Increasing concern for health risks associated with the persistent organic pollutants (POPs) and recent world focus on protection of the environment, have produced tremendous interest in botanical pesticides, especially pyrethrum, which has been proved effective and less toxic to humans. In recognition of this potential, a holistic review of the industry has to be made in order to optimize yields and hopefully maximize production. The proposed review should take into account the farming, harvesting, handling of fresh flowers, drying, extraction of the product, purification of the crude extract, formulation and marketing.

The importance of pyrethrum as an insecticide can be emphasized by listing its outstanding properties, which include rapid action, low mammalian toxicity, lack of insect immunity, broad spectrum of activity, environment friendly and its repellent and flushing action.

3.3.3 Pyrethrum Production in Tanzania

Speaker: E. R. Mhekwa

The speaker gave an overview of historical development of pyrethrum production and research in Tanzania. He started by discussing requirements for raising pyrethrum crop, which is cultivated for its flowers containing insecticidal properties. Then he highlighted the results of research experiments on breeding, cultivation, post-harvest care and other agronomical factors affecting yield and pyrethrins content of the crop. This was followed by production trends of pyrethrum in Tanzania.

The production has been declining over the years. From 6,000 metric tonnes in 1966 it fell to about 400 metric tonnes in 1999. The main reasons for the decline were lack of planting material, the low crop price and the shift in preference of farmers to high-value horticultural crops. The average annual yield of dried flowers per hectare was 260 kg in 1974. Since then, the yield has been falling as a result of adverse climatic conditions and failure to replace aged plants. Current average annual yields are 200 kg per hectare. The optimum yield is between 500-800 kg per hectare. On the other hand, the pyrethrins content of dried flowers, which is dependent on a number of factors, including quality of planting material, climatic conditions, altitude, efficiency of drying and marketing operations, has remained fairly stable at around 1.2 per cent. Pyrethrum production also suffered owing to inadequate research support and lack of good quality planting material. Poor extension services, lack of efficient drying facilities, institutionalized marketing of pyrethrum, deterioration of soils and soil-borne diseases contributed to the problem.

In his conclusion the speaker elaborated on key issues to be considered in revamping pyrethrum production in Tanzania. The capacity building in research, improved planting material, better producer prices, improved drying facilities and extension services were suggested as measures to increase the pyrethrum production.

3.3.4 Pyrethrum Production and Its Industrial Utilization in Rwanda

Speaker: S. Nzabagamba

Pyrethrum was introduced in Rwanda soon after World War II, by the Belgians. In 1968, a farmer's cooperative society (ASPY) was established, followed by an extraction plant and a processing organization (USINEX) in 1972. Prior to that, bales of dried pyrethrum flowers were being exported to Kenya for processing. Pyrethrum production registered significant growth from 1972 to 1976 and the production steadily rose from 1,174 metric tonnes in 1972 to 1,500 metric tonnes in 1976. In 1978, ASPY and USINEX merged to form OPYRWA (Office du Pyrethre au Rwanda). Assisted by UNIDO, the new organization built a refinery in 1978. Owing to defective designs the refinery has never been operational. The speaker highlighted the internal reasons for the ups and downs in pyrethrum production in Rwanda between 1978 and 1993. The tragic incidence of genocide in 1994 brought pyrethrum production to practically nil. Since 1999, OPYRWA is focusing all its efforts on revamping the pyrethrum sector in the country. At present, it is providing good clonal material through nurseries. Prices have been reviewed upwards and extension services have been reinforced through agronomists as an incentive to the farmers. The speaker concluded his presentation with a call to UNIDO for a sustained assistance in Rwanda in making available high-yield strains, rehabilitation of drying facilities and the processing factory.

3.3.5 Industrial Processing of Pyrethrum in Tanzania

Speaker: W. J. Swai

The speaker started by discussing the history of industrial processing of pyrethrum in Tanzania. The first processing plant was established in Arusha that went into operation in 1962. The plant had a nominal capacity of 6,000 metric tonnes per annum of dried pyrethrum flowers. Following the increase in pyrethrum production, the need for additional processing capacity became evident in the 1970s and new extraction facilities were installed at Mafinga, in the Southern Highlands, where 70 per cent of total production of flowers was being cultivated. The new plant went into commercial production in 1982 and had a capacity of 4,500 metric tonnes per annum. The Arusha plant is no longer operational, owing to low production of pyrethrum flowers in the region. The Mafinga plant was privatized in 1998 and is currently operating under the name of Tanzania Pyrethrum Processing and Marketing Company Limited (TPPMCL), a subsidiary of M/s International Chemical Producers of South Africa. The speaker also discussed the manufacturing processes at TPPMCL. The process employs organic solvent to extract flowers to produce crude pyrethrum extract. The dried pyrethrum marc is also used. He then gave a detailed description of unit operations and process stages starting with flower procurement at the factory to milling, extraction, evaporation, storage, shipping of finished products and handling of by-product. On plant efficiency the speaker explained that recovery at the TPPMCL factory currently lies between 85 to 90 per cent and depends on pyrethrins content of the feed. Hence farmers were encouraged to supply high quality flowers.

He concluded his presentation by thanking ICS and UNIDO for organizing the workshop.

3.3.6 Industiral Utilization of Pyrethrum in Kenya

Speaker: R. K. Shah

In his introduction, the speaker highlighted man's continued need to control harmful insects to protect himself, his crops, food reserves and animals. He is in perpetual need of suitable insecticides with high degree of biological efficiency, low environmental impact, minimal risks from its use to non-target insect species and animals. Pyrethrum has long been considered the safest insecticide in terms of safety and toxicity. It has been the ideal choice of insecticide manufacturers and users of household insecticides. The speaker gave an outline of primary products of pyrethrum processing, i.e. pyrethrum extract, powder and marc. Uses of these products were also discussed in the lecture.

He finally dwelt on the marketing of their pyrethrum products and noted that the local market is centred on mosquito coils as they are readily available, relatively cheap and effective in repelling mosquitos. The use of expensive aerosols, vermin powders and vapour mats is restricted to middle and upper class. The company (Coils Products (K) Limited) exports mosquito coils to Japan,Malawi, Sudan, Tanzania, Uganda and Zimbabwe, has been unable to tap the American and European markets owing to the high cost of obtaining the requisite registration of finished products. Almost all of the pyrethrum extract produced in this region is exported to America and Europe. Total demand surpasses current production. Local processors should strive to sell finished products and not crude extract.

3.3.7 Marketing of Pyrethrum in Tanzania

Speaker: E. J. Materu

The speaker started with an overview of the world's production of pyrethrum, listing Kenya, Rwanda, Tanzania and Tasmania as the world's leading growers of this commodity. Small amounts are currently being grown in Papua New Guinea, Ecuador, India and more recently in Uganda. Most of these countries export over 80 per cent of their production largely in the form of crude extract. USA is the largest importer of pyrethrum products. In the East African region, only Kenya and Rwanda have refineries to produce high-value refined pyrethrum extract. Powdered pyrethrum flowers are used in the manufacture of mosquito coils.

Currently the world demand for pyrethrum stands at 20,000 metric tonnes of dried pyrethrum flowers per annum. World preference for use of organic and natural insecticides predicts further increase in demand for pyrethrum. The current products offered by the Tanzanian pyrethrum processors are: pyrethrum extract concentrate, exported to the world's largest consumer USA; pyrethrum extract (standard), traded locally in small quantities for application in farm sprays; super fine pyrethrum powder, exported mainly to Japan and the Far East and a substantial amount also sold locally to mosquito coil manufacturers; dry pyrethrum marc, also exported but a larger portion traded locally mainly to ranches.

Tanzania has only one producer of pyrethrins aerosols (Mansoor Daya Chemicals Limited) and one manufacturer of pyrethrum-based mosquito coils (Dawa ya Mbu Limited).

This was followed by an account of RWATAKE - a regional group made up of pyrethrum stakeholders from Rwanda, Tanzania and Kenya, which meets regularly to exchange notes on production, pricing, marketing and other related issues pertaining to pyrethrum development in the member states.

He concluded his presentation with a call to grow more pyrethrum, increase investments in processing facilities, refinery and aerosol manufacturing plants. Research should also be encouraged in ascertaining the wider use of pyrethrum marc in fighting the stalk borer in maize, as already demonstrated by farmers in the vicinity of the Mafinga extraction plant.

3.3.8 New Opportunities for Natural Pyrethrum Products in Europe

Speaker: V. de Rinaldini

The speaker discussed the origin and development of marketing opportunities for pyrethrum-based products which are fast appearing in Europe. They are a direct result of the renewed and growing demand for natural products and those produced by biological production methods. Pyrethrum being a natural product is used in the cultivation of fruits and vegetables under biological production methods. It is considered as an insecticide that cannot be compared with products of synthetic origin, even if at the end of the day, they have the same function. This has generated additional demand for pyrethrum where public opinion is growing more sensitive to solutions which care for the environment and public health.

There are new opportunities for pyrethrum in Europe and they offer great growth potential. They have to be nurtured and not destroyed. The only obstacle is the limited availability and the high cost of natural pyrethrum. A positive response from producing countries to this stimulus is to maximize the production.

4 Presentations

4.1 Overview of Pyrethrum Industry

4.1.1 Pyrethrum - A Perspective

by K. Vasisht

Pyrethrum is the dried flowers of *Tanacetum cinerariifolium* (Trev.) Schultz Bip. [synonyms: *Chrysanthemum cinerariaefolium* (Trev.) Vis. and *Pyrethrum cinerariaefolium* Trev.] [1] of family Asteraceae. The use of pyrethrum against insects dates back to antiquity when it was obtained from *Tanacetum coccineum* (Willd.) Grierson [synonyms: *Chrysanthemum coccineum* Willd, *Chrysanthemum marschallii* Asch.ex O. Hoffm. and *Chrysanthemum roseum* Adams].[1] This species was the first source of pyrethrum and is no longer important as the commercial crop is now raised from the former species.

There is some difference of opinion regarding the origin of insecticidal use of pyrethrum. Some believe it to be in China where it was used as early as first century before it spread to East Asia. But most believe it to have originated in Persia where a less potent *Chrysanthemum coccineum* was used. The use of crushed dried flowers of this species, known as Persian or Caucasian insect powder, was a long-established folk practice in the Caucasus and northwest Persian region. The product had well established by eighteenth century and became an important article of commerce from Persia. By the beginning of nineteenth century it became so much popular in Europe that the supply was always insufficient to meet the demand. During this period one trader in Armenia succeeded in learning the production of Persian insect-flower and started manufacturing the powder on a large scale in 1828.[2] Around 1840, *Chrysanthemum cinerariaefolium* was discovered to be a richer source of insecticidal constituents and became commercial source of pyrethrum. This species indigenous to the Adriatic coastal mountains of Croatia, Bosnia and Herzegovina was popularly known as Dalmatian insect-flower. Dalmatia (the coastal region of Croatia) dominated the trade until World War I, which disrupted the supply channels and Japan took over the trade control where the species was introduced around 1880. During World War II, pyrethrum became available from East Africa where it was introduced first in Kenya in 1928. Kenya produced first commercial crop in 1933 and by 1938 started producing 2,000 metric tonnes of the pyrethrum flower and since that time it has dominated the world market to stay the major producer of pyrethrum. History is witness to the strength of pyrethrum, which has survived numerous challenges in ever-changing programmes of pest management.

Pyrethrum Plant

Chrysanthemum once genus of over 200 species is known for vast complexity, which ultimately led to a division of the genus.[3,4] Many species of *Chrysanthemum* have now been moved to closely related genera. The pyrethrum species has been moved under the genus *Tanacetum* and *Chrysanthemum cinerariaefolium* is now *Tanacetum cinerariifolium*. The genus *Tanacetum* includes about 70 to 150 species in different classifications.

Pyrethrum is a tufted perennial plant, which in its native temperate regions grows at low altitude. In ex-situ adaptation, it grows very well at high altitudes of tropics. The plant can persist for number of years but commercial crops are optimally obtained for 3 to 4 years and maximally for 5 to 6 years. The plant has numerous fairly rigid stems that grow upto 50 to 80 cm in height with blue-green deeply divided leaves that are covered on both sides by a dense wooly material.[5] It has very deep roots, which pulverize the soil and deplete it of nutrients. In its natural habitat, it flowers only a few weeks in a year but at or near the equator and at high altitude the plant flowers throughout the year. In Kenya, for example it flowers from 7 to 11 months in a year. Technically each pyrethrum flower is an assemblance of numerous tiny florets. The florets like other plants of family Asteraceae are arranged in condensed inflorescence called capitulum so as to give it an appearance of one flower. The yellow centre of capitulum is comprised of disc florets, which is surrounded by white ray florets.

Cultivation of Pyrethrum

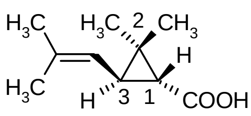
The plant needs a reasonably dry weather. An annual rainfall of 100 to 150 cm distributed over a period of 8 to 10 months is desirable. It prefers well-drained sunny slopes of loamy soils of good fertility and altitude placement between 1,500 to 3,000 meters. The flowering is reduced below 1,500 meters and insecticidal content are inversely related to temperature. A study in Kenya has reported an increase of 0.15 per cent of pyrethrins with altitude elevation of every 360 meters. The plant can tolerate temperature as low as $-12\ ^0C$ and prefers 2 to 3 months of dry season.

Pyrethrum is planted in the fields as seedlings or splits of an old plant. The seed sowing is impracticable for number of reasons including very small size of seeds with low and uneven germination; lack of genetic purity in seeds exhibiting unreliable yields; longer period of over three weeks for germination and slow growth of seedlings. As a result, in all pyrethrum-producing countries vegetative propagation is preferred. A good amount of research has been carried out on nutritional requirements of the plant and an adequate amount is necessary for optimal plant growth. However, specific doses of fertilizer elements can only be determined after assessing the nutrient status of the soil. A positive correlation has been observed with the application of phosphorus.[6,7]

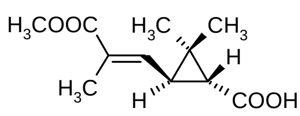
The best crop of flowers is produced in the second year and to harvest highest quality of flowers they are hand-picked at proper stages of development. Both early and delayed harvesting results in significant losses of pyrethrins.[8] An ideal stage of flower plucking is when 2 to 3 rows of disc florets have opened. Harvesting should be followed with immediate drying and wherever possible artificial drying should be employed to preserve pyrethrin content of flower. Pyrethrins are thermolabile and any drying operation should be so planned to keep the temperature below 50 ^{0}C. Pyrethrum flowers fast lose their activity on storage, which necessitates the processing of flowers for extraction of pyrethrins at the earliest possible time.

Chemical Constituents of Pyrethrum

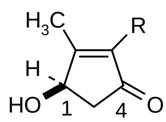
The active constituents of pyrethrum are combination of six monoterpenoid esters, which are collectively termed as pyrethrins. These are pyrethrin I and II; cinerin I and II; and jasmolin I and II. The concentration of pyrethrins ranges from 0.5 in wild and poorly managed crops to over 2 per cent in select high-yield clones under cultivation and is subject to genetic, climatic, geographical and ontogenetic variations. Pyrethrin I, cinerin I and jasmolin I are the esters of chrysanthemic acid (chrysanthemum monocarboxylic acid) with pyrethrolone, cinerolone and jasmolone respectively, whereas pyrethrin II, cinerin II and jasmolin II are the esters of pyrethric acid (chrysanthemum dicarboxylic acid) with same alcohols. These esters have a key structural unit of substituted cyclopropane nucleus in their acid portion. The configuration of cyclopropane at C-1 is (*R*) and C-3 is (*S*) and orientation of the isobutenyl moiety is *trans* to the acid group. Chrysanthemic acid derived from natural source is always *1R* and *1S* structures are always non-toxic to insects. The three alcohols are collectively called rethrolones. They have in common a methylcyclopentenolone nucleus supporting side chain at C-3, which differs only in length and saturation in different pyrethrins.



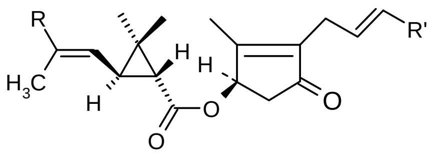
Chrysanthemic acid



Pyrethric acid



Cyclopentenolones



	R	R^1
Pyrethrin I	CH_3	$CH=CH_2$
Pyrethrin II	$COOCH_3$	$CH=CH_2$
Jasmolin I	CH_3	$CH-CH_3$
Jasmolin II	COOCH3	$CH-CH_3$
Cinerin I	CH_3	CH_3
Cinerin II	$COOCH_3$	CH_3

Pyrethrins are found in all aerial parts of the plant but useful concentrations are found only in the flowers. Even in the flower they are not uniformly distributed and the maximum concentration is found in the ripening ovaries. Pyrethrin I and II constitute the dominant portion of total pyrethrins and the two together make up more than two thirds of total esters.

Table 1 lists the concentration of pyrethrins in flower[9] and Table 2 lists the distribution of pyrethrins in different parts of the flower.[10] Pyrethrins are oily, water-insoluble unstable liquids. They are readily hydrolyzed and oxidized and the half-life of natural pyrethrins under daylight is estimated at no more than about ten minutes.

Table 1: Pyrethrins concentration in dry pyrethrum flowers

Compound	Per cent concentration
Total pyrethrins	2.00
Pyrethrins of type I	0.92
Pyrethrins of type II	1.08
Pyrethrin I	0.65
Pyrethrin II	1.08
Cinerin I	0.18
Cinerin II	0.26
Jasmolin I	0.09
Jasmolin II	0.10

Table 2: Pyrethrins concentration in flower parts

Part of the flower	Per cent weight of flower	Per cent of total pyrethrins
Achenes	34.2	92.4
Receptacles	11.3	3.5
Involucral scales	1.08	2.0
Disc florets	0.65	Trace
Ray florets	1.08	Trace

As most of the studies have concentrated on the insecticidal constituents of pyrethrum flowers only a few studies are available addressing other components of the flower. In addition to pyrethrins, the crude extracts of pyrethrum also contains small amounts of carotenoids, β-amyrin and taraxasterol.[11] A number of sesquiterpenoid lactones including cadinene, farnescene,[2] chrysanin, chrysanolide,[12] tatridin A and B and their analogues have been reported from pyrethrum flowers.[13]

Biological Properties of Pyrethrins

Natural pyrethrins possess some of the most desirable insecticidal attributes. They are toxic to wide variety of insects, possess quick knock-down effect, are repellent in very low concentrations, have exhibited very low incidence of insect resistance, possess ultra short life in environment before being degraded to non-toxic and non-residual components and have a very high degree of safety to humans and other warm-blooded animals. Their safety can be judged from their comparison to organophosphorus insecticides, which are only 33 times more toxic to insects in comparison to mammals, whereas pyrethrins are 4,500 times more toxic to insects than to mammals. The character of their high safety to mammals and being non-polluting to food and water chains has made them one of most desirable pest control agents in context of increasing awareness for the protection of environment

Pyrethrin I is mainly responsible for the kill, whereas pyrethrin II exerts knockdown activity. The insecticidal activity of the pyrethrum extract increases with the increased ratio of pyrethrin I/pyrethrin II, which varies from 0.9 to 1.3 depending on the origin. Pyrethrins are repellent in concentrations as low as ten times of their insecticidal activity.

Pyrethrins in insects acts as nerve toxins and they kill insects by disrupting normal functioning of the nervous system. In insects, as also in other animals including humans, nerve impulse travels along nerves by generation of action potential. This is achieved when sodium channels are momentarily opened allowing entry of sodium ions across the nerve membranes. Pyrethrins disrupt functioning of these 'gates' keeping them open and allowing entry of sodium ions longer than desired. This results in multiple nerve impulses and release of neurotransmitter at muscle junction leading to hyperactivity, loss of muscular coordination, paralysis and ultimately death. The warm-blooded animals unlike insects are rich in esterases, which quickly degrade these esters into inactive acids and alcohols. The lowest lethal oral dose of pyrethrum is 750 mg per kg for children and 1,000 mg per kg for adults.[14]

Uses of Pyrethrum

Pyrethrum products are used as insecticides or repellents and are ideal household insecticides against flies, fleas, cockroaches and other insects. They are also used in human and animal ectoparasites besides their use in animals against alimentary endoparasites. Pyrethrum is an insecticide of choice in pre and post-harvest protection because of its safety to mammals and its degradation to non-toxic components during storage. Its use in processed food and preservation, where storage in dark enhances the life of pyrethrins has an added advantage. Despite excellent qualities of natural pyrethrins, their instability in light and air has restricted their out-door application. They had never been serious contenders for agricultural insecticides, which was further restricted by their exorbitant price.

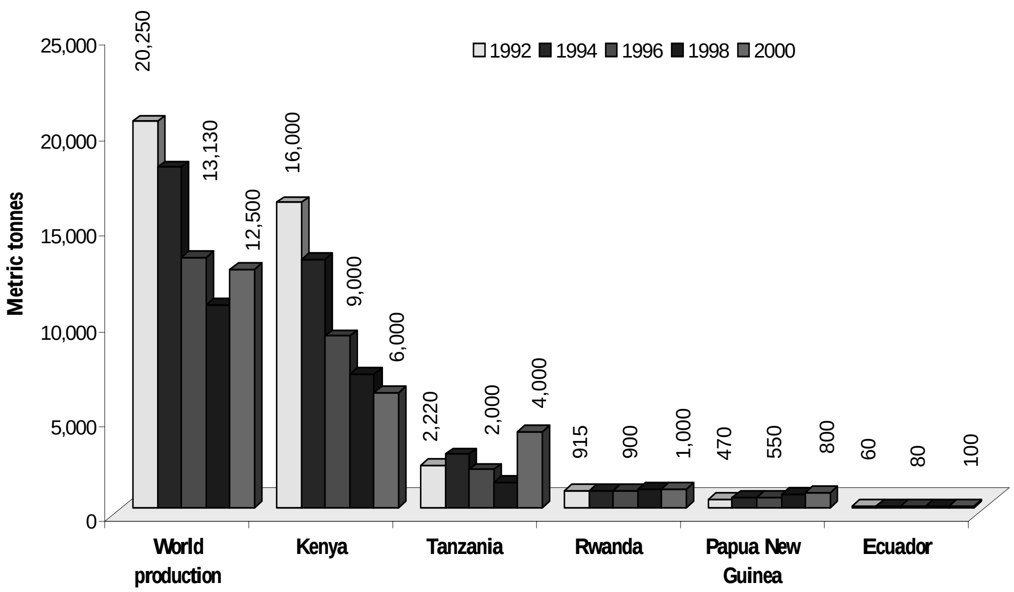
To increase their activity and stability, it is customary to use pyrethrins in combination with synergists (like piperonyl butoxide, sesamin and myristicin) and antioxidants (tannic acid and hydroquinone). Of late there is a growing concern for the use of piperonyl butoxide because of its carcinogenic properties. Although the activity of both pyrethrins is increased by the use of synergists, but activity of pyrethrin II is increased to a greater extent. It is also known that as the pyrethrins are purified, their stability decreases. Pure pyrethrin I and pyrethrin II are least stable, are very expensive and available only for laboratory use.

Pyrethrum is available as pyrethrum powder, crude extract and purified pyrethrum extract. The purified pyrethrum extract is used for dispensing into aerosols, sprays, creams, ointments and other high value products. Crude extract is used in the manufacture of number of insecticidal products. Pyrethrum powder is largely used for making mosquito coils. Pyrethrum dust prepared by impregnating pyrethrum extract on inert carrier contains 0.3 to 0.5 per cent of pyrethrins and is used to control insects in horticulture crops.

Pyrethrum Production

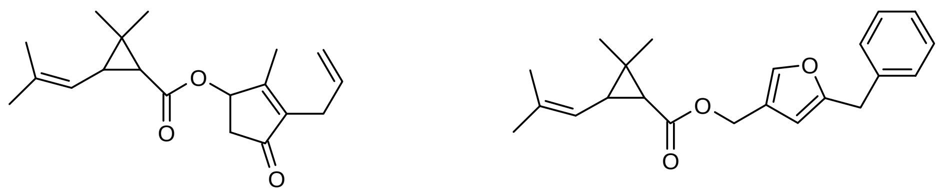
Kenya, Tanzania, Rwanda, Ecuador, Papua New Guinea and Australia are some of the countries, which contribute significantly to the world production of pyrethrum. Kenya has dominated the world production ever since it started commercial production in 1933. Australia started commercial production in 1983 and by 1992 had 1,200 hectare of land under cultivation. Australian production of 60 metric tonnes of refined product in 1992 was second only to Kenya. What is most significant is the declining trend of pyrethrum production in the East African countries in the last decade despite increasing world demand. The world production has come down from 20,250 metric tonnes in 1992 to 10,500 metric tonnes in 1998, which has marginally improved to 12,500 metric tonnes by the turn of the century.[15] The production of pyrethrum was always insufficient to meet its global demand that maintained its prestigious status in the world market.

Figure 1: Pyretrhrum production in some important countries



Synthetic Pyrethroids

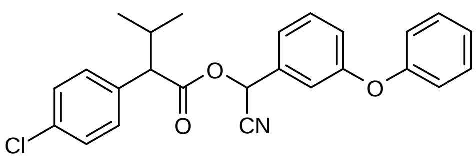
The efficacy and lack of toxicity of natural pyrethrins on one hand and their high cost



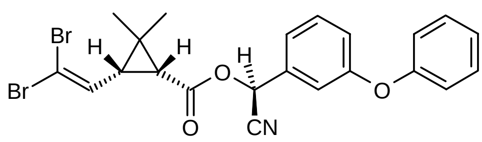
Allethrin   Resmethrin

and low stability on other hand always inspired chemists to synthesize improved analogues of pyrethrins. The earlier efforts concentrated on finding suitable substitute for photolabile alcohol of natural pyrethrins. As a result of these efforts, allethrin became the first synthetic analogue of pyrethrins to reach the market in 1949. Numerous more analogues were synthesized and tested. Conventially, all synthetic insecticides developed on the template of natural pyrethrins are called pyrethroids. A major achievement in the field of pyrethroids was the synthesis of resmethrin (1967) and its isomer bioresmethrin, which had distinctly higher insecticidal activity, 20 and 50 times more than natural pyrethrins and less toxicity towards mammals.

Later the development of 3-phenoxybenzyl alcohol and its alpha cyano derivative in the early 70s marked a very significant step in the history of pyrethroids to overcome the photolability of alcohol portion with consistent results. Thereafter, the research interest shifted towards improving the acid part. It resulted in the synthesis of fenvalerate and deltamethrin, which were marketed in 1974 and 1975 respectively. Deltamethrin proved to be the most toxic insecticide synthesized by man and was patented and marketed as a single isomer unlike others, which were marketed as racemic mixture of isomers. The number of synthetic pyrethroids has steadily increased over the years producing many generations of synthetic pyrethroids. Most modern pyrethroids are variations of permethrin or fenvalerate.



Fenvalerate



Deltamethrin

Pyrethrin insecticides are broadly categorized in two classes. Type I contains pyrethrins and many of the older pyrethroids. Type II is ill defined in terms of chemical structure. They specifically contain a cyano-3-phenoxybenzyl alcohol and some commercially important Type II pyrethroids have an altered acid portion of the molecule. The poisoning syndromes for the two types of compounds are different. Type 1 pyrethroids produce hyperexcitability and convulsions in insects and have negative temperature coefficient. Type II pyrethroids cause predominantly ataxia and incoordination with positive temperature coefficient i.e. increased kill with increase in temperature.

Future Prospects of Pyrethrum

The production of pyrethrum had always under-sustained its market demand and throughout its production for over 150 years the supplies had been irregular. It came to be used when no safe insecticide was available and knowledge of man to synthesize organic compounds was limited. The world wars disrupted trade channels of pyrethrum and also augmented its world demand. This period saw the advent of a number of synthetic insecticides as a result of increased research emphasis. Then followed widespread use of man made poisons leading to unrealized and irreparable loss to our environment.

Indiscriminate use of persistent organic pesticides necessitated the reassessment of pest control programmes and use of many insecticides was banned. The growing concern for the environment protection and consumer awareness resulted in tremendous interest in botanical insecticides, which has further been strengthened by growing popularity of biologically produced or organic products. The emphasis is to use biological measures, keep insect population under check, use environment friendly insecticides with non-residual effects and minimal effects on the non-target species. The chemical insecticides as a result got a serious setback in the recent past, whereas the market potential for products like pyrethrum has correspondingly increased and is expected to improve significantly in the coming years.

Pyrethrum has suffered because of its irregular production and supply cycles. The national bodies in pyrethrum producing countries entrusted with promotional policies failed to produce significant impact. The lack of supportive research and more important the failure to deliver research results to farmers, lack of any trusted support to farmers and use of old processing facilities have resulted in poor performance of pyrethrum industry in spite of ready market demand. The research results of improving planting material and agrotechniques in the East African countries could not reach the farmers. Financial crisis in these countries in updating their processing facilities and adding value to their product before exporting it out proved counterproductive for the farmers. The low prices offered to farmers shifted their interest to alternative crops and the production steadily declined over the years. The introduction of synthetic pyrethroids, which were highly successful further dampened the spirit. Asynchronous flowering and quality dependence on stage of flower development, extreme post-harvest care and unfavourable conditions at the buying centres made pyrethrum production unattractive for the African farmers. Lack of refining units, old technologies at the pyrethrum processing plants, political instability further contributed to the problems of pyrethrum industry.

At present USA and Japan are the biggest consumers of pyrethrum. The USA alone uses 75 per cent of world supply and East African farmers provide 85 per cent of pyrethrum to the world market. The vast world market is yet to open for this most promising insecticide of the future. With e-commerce getting in place, it will not be far from now to see booming world market for pyrethrum products from all corners of the world. Already there had been so much interest in the pyrethrum that 'World Pyrethrum Forum' is available on the internet (http://www.pyrethrum.de/) to answer all queries related to pyrethrum. The forum aims to establish exchange of information on export, import, supply, development, research, technology, information on pyrethrum growing, processing, marketing, buying and producing industries besides many more useful links related to pyrethrum. The scientific literature published in 20 volumes (1948 to 2000) of *Pyrethrum Post*, a journal solely devoted to pyrethrum is available on CD ROM.

It is a right time that steps be initiated to resurrect the declining trend of pyrethrum production in East African countries. Research to develop high-yield clones with synchronous flowering, making available to farmers the improved planting material and agrotechniques including better drying, storage and transportation facilities, revamping extraction facilities, setting up of refining facilities for value addition before exportation, liberalized marketing facilities to return more benefits to farmers are some of the measures that can gear up the pyrethrum industry to meet the emerging challenges.

Summary and Conclusions

Among the potenial plants grown in Africa, pyrethrum is one that can have tremendous impact on the economy of East African countries. Demand for pyrethrum has always stayed, even when other once popular insecticides were being phased out of the market. The market for natural products is getting more and more attractive. The interest of developed world to favour use of naturals has generated new opportunities for plant-based products. At the same time market is getting more and more competitive. Product designs, marketing innovations were never so important and quality parameters were never so stringent as one finds them today. With everything in place a product can still fail in the market because of the more aggressive marketing approach of its not so good competitors. Pyrethrum with long and glorious past enjoys definite edge over its competitors. Though patented pyrethroids can boast of retaining goodness and overcoming shortness of natural pyrethrins, but they do not carry the most sought after tag of being natural. This situation is clearly poised to favour use of pyrethrum and if properly nurtured the trend can help poorest of the poor in African continent. Though pyrethrum can be produced in most part of the world, but commercial crops can be raised in fewer countries situated in or near the equator. Crop improvement and newer agrotechnologies are more productive for these countries, which are naturally favoured for pyrethrum production. Better initiatives are expected to result from the present workshop.

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4.1.2 Industrial Potential of Pyrethrum: Research Overview

by J. H. Y. Katima

Background

Pyrethrum is a beautiful daisy that is hardy and blooms throughout the spring and summer. Its flower heads are used to make probably the best natural pesticide available.[1] Fast knock-down time, rapid environmental degradation and low mammalian toxicity are a mark of pyrethrum advantages.[2] Pyrethrins chemically break down into harmless compounds within 24 hours of application.[3] These facts make pyrethrum's future more promising than any time before. The world has witnessed the negative impact of some pesticides. Pyrethrum, which has been successfully used over the years as an environmentally safe and effective insecticide, could easily take over the market if proper strategies are put in place. This presentation examines the potential of the pyrethrum industry.

Current Pesticide Spectrum and Global Use

Several hundred pesticides (active ingredients) are currently used world-wide. The Pesticide Manual[4] contains a total of 751 chemical and biological pest control agents, of which 33 have been classified as extremely hazardous to human health by the World Health Organization (WHO class Ia[5]); 48 as highly hazardous (class Ib); 118 as moderately hazardous (class II); and 239 as slightly hazardous (class III); 149 pesticides were considered as unlikely to cause acute hazard in normal use (WHO class IV); while 164 of the Pesticide Manual's chemical entries have not yet been classified according to acute health hazard by WHO.

Figures on the global production of pesticides in terms of sales value are abundant, whereas information on production in terms of weight or volume of active ingredient is extremely scarce. The Annual Production Yearbook of the Food and Agriculture Organization (FAO) of the United Nations includes data from only a very small number of countries. In addition, published figures are neither uniform in character nor updated regularly. FAO has recently initiated a database on pesticide consumption.[6] This database is still at a very early stage. Nevertheless, the combined sales value in 1998 for the ten largest manufacturers (in decreasing order Novartis, Monsanto, DuPont, Zeneca, AgrEvo, Bayer, Rhone-Polenc, Cyanamid, Dow Agro and BASF)[7] was more than US$ 27,000 million or 90 per cent of the global sales value. In the world agrochemical market in 1995, US$ 17,000 million out of US$ 33,000 million (51 per cent) were spent on generic (non-proprietary) pesticides. The global market for generics is estimated to increase to US$ 27,000 million out of a forecasted total of US$ 39,000 million (69 per cent) by the year 2005.[8]

In 1995, world pesticide consumption reached 2.6 million metric tonnes of active ingredients with a market value of US$ 38,000 million. Roughly 85 per cent of this consumption was used in agriculture. About three quarters of pesticide use occurs in developed countries, mostly in North America, Western Europe, and Japan. Although the volume of pesticides used in developing countries is small relative to that in developed countries, it is nonetheless substantial and is growing rapidly. In addition, the pesticide market in developing countries is dominated by insecticides, with a higher acute toxicity than herbicides, which are predominantly used in the developed countries.[9] Table 1 shows worldwide estimated annual pesticidal consumption in different regions during mid 1990s.[10]

Table 1: Estimated annual pesticide consumption in different regions of the world

Region	Consumption (1000 MT)	Per cent consumption
Europe	800	32
United States of America	500	20
Canada	100	04
Other Industrialized Countries	500	20
Asia	300	12
Latin America	200	08
Africa	100	04
TOTAL	2,500	100

The world crop-wise consumption at about the same time in per cent was:[11] fruits and vegetables 26, cereals 15, maize 12, rice 10, soybeans 9.4, cotton 8.6, sugar beet 2.8, rape oil seed 1.6 and other crops 14.

Pesticides of International Concern

Rachel Carson, author of Silent Spring (1962), identified a number of pesticides causing adverse effects on the ecosystem (Rachel Carson's Dirty Dozen).[12] In 1985, the Pesticide Action Network launched a campaign called *The Dirty Dozen* to draw attention to a selection of hazardous pesticides. The original dozen now includes 19 pesticides.[13] A third dirty dozen is the current group of persistent organic pollutants (POPs), identified by the United Nations Environment Programme (UNEP).[14] This dozen includes 9 pesticides and 3 other chemicals. A fourth group of potentially hazardous pesticides is covered in the joint prior informed consent (PIC) initiative by UNEP and FAO, recently reshaped into the Rotterdam Convention.[15] The convention initially covered a selection of 21 pesticides. The three dirty dozens and the PIC initiative together cover 39 pesticides of international concern (Table 2).

Areas of Major Concern

Synthetic pesticides are more of a threat to man than the insects themselves. As each generation of insects becomes more immune to the pesticide, stronger and more potent insecticides are used. An example is that of the POPs which are characterized by their high stability in the environment (in other words persistent), potential bioaccumulation, toxicity and ability to travel long distances from potential sources. The health risks associated with POPs include cancers, birth defects, fertility problems, susceptibility to disease, and diminishing intelligence.

In August 1999, negotiators from 115 countries met in Geneva, Switzerland, for the third round of United Nations-sponsored negotiations to develop an international treaty on POPs. During the session, governments agreed to eliminate and phase out eight of the twelve POPs chemicals targeted for action by the United Nations. Government negotiators in Geneva agreed

Table 2: Thirty-nine pesticides of international concern

Pesticide	"Rachel Carson's Dirty Dozen" (1962)	Pesticide Action Network's "Dirty Dozen" (1985)	UNEP's POPs and goals for international negotiations (1999)	Pesticides in Rotterdam Convention on P. I. C. (1999)
Aldicarb	-	+	-	-
*Aldrin**	+	+	C. E.	+
Amitrol	+	-	-	-
Binapacryl*	-	-	-	+
Camphechlor (Toxaphene)*	+	+	C. E.	+
Captafol	-	-	-	+
Chlordane	+	+	P. E.	+
*Chlordimeform**	-	+	-	+
*Chlorobenzilate**	-	-	-	+
Chlorpropham (CIPC)	+	-	-	-
DDT	+	+	use limited to vector control	+
1,2-Dibromo-3-chloro-propane (DBCP)	-	+	-	-
1,2-Dibromoethane (Ethylene dibromide, EDB)	-	+	-	+
*Dieldrin**	+	+	P. E.	+
*Dinoseb**	+	-	-	+
*Endrin**	+	+	C. E.	-
Ethylene oxide	-	-	-	-
Fluoroacetamide	-	-	-	+
Heptachlor	+	+	P. E.	+
Hexachlorobenzene	+	-	P. E.	+
Hexachlorocyclohexane (HCH) mixed isomers	+	+	-	+
Isobenzan (Telodrin)*	+	+	-	-
Lindane	+	+	-	+
Mercury compounds	-	-	-	+
Methamidophos	-	-	-	+[1]
*Mirex**	+	-	P. E.	-
Monocrotophos	-	-	-	+[1]
Paraquat	-	+	-	-
Parathion	-	+	-	+[2]
Parathion-methyl	-	+	-	+[3]
Pentachlorophenol	-	+	-	+
Phosphamidon	-	-	-	+[4]
Propham (IPC)	+	-	-	-
2,4,5-T*	-	+	-	+

*Pesticide considered to be obsolete / superseded / discontinued

[1] SL formulations above 600 g/l

[2] All formulations except CS formulations

[3] EC formulations 19.5 per cent and above and dusts containing 1.5 per cent or more

[4] SL formulations above 1,000 g/l

C. E. stands for Complete Elimination

P. E. stands for Partial Elimination

to eliminate production and use of aldrin, endrin and toxaphene without exemptions. They also agreed to phase out chlordane, dieldrin, heptachlor, mirex and hexachlorobenzene, considering limited country-specific exemptions. Significant controversy remains regarding the elimination of the remaining chemicals on the list: polychlorinated biphenyls, dioxins and furans, as well as DDT, which is still registered for public health purposes in approximately 20 countries. Negotiators also discussed criteria by which new POPs will be added to the action list, and technical and financial assistance for phase-outs and related activities for POPs. Table 3 depicts the tendencies and forecasts in global pesticide use.

Table 3: Tendencies and forecasts in global pesticide use

Year	Tendencies and forecasts
1993	The last two years have seen a stagnation in the global agrochemical market.[16] The stagnant and stable market in the major pesticide consuming regions and lack of novel chemicals will increase the tendency in the agrochemical industry to look to export markets and sales in developing countries, particularly Latin America, Asia and the Middle East.[17]
1996	World pesticide market expands. The South American market, particularly Argentina and Brazil, recorded the highest growth, with pesticide sales increasing 13 per cent. Markets in Asia fell despite growth in China, India, Indonesia and the Philippines. Africa's share of the world market shrank.[18]
1997	Global agrochemical market up 1.3 per cent Latin America was again the fastest growing region with an increase of 18 per cent.[19] World agrochemical market growth slows down.[20]
1998	Global agrochemical market up 0.9 per cent. Latin America was again the fastest growing region with a 12.5 per cent increase.[21]
1999	Global sales down 3.1 per cent.[22]
2000	Global market decline to continue. [23]

It should be noted that aldrin, chlordane and heptachlor are registered for use in Tanzania. However, aldrin and chlordane are restricted while heptachlor is not. Dieldrin and toxaphene were withdrawn by registrants while mirex and endrin have never been registered for use in Tanzania.

Natural Products

It can be seen that several pressures have accelerated the search for more environmentally and toxicologically safe and more selective and efficacious pesticides. It should be noted that most commercially successful pesticides have been discovered by screening compounds synthesized in the laboratory for pesticidal properties. The average number of compounds that must be screened to discover a commercially viable pesticide has increased dramatically. The increasing incidence of pesticide resistance is also fuelling the need for new pesticides. Thus, natural compounds, mainly of plant origin, have increasingly become the focus of research and development.

Throughout history, plant products have been successfully exploited as insecticides, insect repellents, and insect antifeedants. Probably the most successful use of plant product as an insecticide is that of the pyrethrum.[2] The insecticidal properties of the several *Chrysanthemum* species were known for centuries in Asia. Even today, powders of the dried flowers of these plants are sold as insecticides.

After elucidation of the chemical structures of the six terpenoid esters (pyrethrins) responsible for the insecticidal activity of these plants, many synthetic analogues have been patented and marketed. Synthetic pyrethroids were preferred because they have better photostability and are generally more active than their natural counterparts.

Factors Influencing Development of Natural Pesticides

Tens of thousands of secondary plant metabolites have been identified and there are estimates that hundreds of thousands of these compounds exist. There is growing evidence that most of these compounds are involved in the interaction of plants with other species - primarily the defence of the plant against plant pests. Thus, these secondary compounds represent a large reservoir of chemical structures with biological activity. This resource is largely untapped for use as pesticides; however, it takes a while and efforts to establish a viable pesticide even although the need is urgent.

Unlike compounds synthesized in the laboratory, secondary compounds from plants are virtually guaranteed to have biological activity and that activity is highly likely to function in protecting the producing plant from a pathogen, herbivore, or competitor. Thus, a knowledge of the pests to which the producing plant is resistant may provide useful leads in predicting what pests may be controlled by compounds from a particular species. Isolation and chemical characterization of the active compounds from plants with strong biological activities can be a major effort compared to synthesizing a new synthetic compound. However, the assurance of biological activity and improvement in methods of purification and structural identification is shifting the odds in favour of natural compounds.

Considering the probability of secondary plant metabolites being involved in plant-pest interactions, the strategy of randomly isolating, identifying, and bioassaying these compounds may also be an effective method of pesticide discovery. Biologically active compounds from plants will often have an activity against organisms with which the producing plant does not have to cope. Many secondary compounds described in the natural products have not been screened for pesticidal activity. This is due, in part, to the very small amounts of these compounds made available for screening.

The discovery process for natural pesticides is more complicated than that for synthetic pesticides. Traditionally, new pesticides have been discovered by synthesis, bioassay, and evaluation. If the compound is sufficiently promising, quantitative structure-activity relationship-based synthesis of analogues is used to optimize desirable pesticidal properties. The discovery process with natural compounds is complicated by several factors.

First, the amount of purification initially conducted is a variable for which there is no general rule. Furthermore, secondary compounds are generally isolated in relatively small amounts compared to the quantities of synthetic chemicals available for screening pesticidal activity. Therefore, bioassays requiring very small amounts of material will be necessary for screening natural products. A number of published methods for assaying small amounts of compounds for pesticidal and biological activities are available in the allelochemical and natural product literature. At some point in the discovery process, structural identification is essential, which can be quite difficult for some natural products. Despite these problems, modern instrumental analysis and improved methods are reducing the difficulty, cost and time involved in each of the above steps.

The toxicological and environmental properties of the compound must be considered. Simply because a compound is a natural product does not ensure that it is safe. The most toxic mammalian poisons known are natural products and many of these are plant products. Introduction of toxic natural compounds into the environment that would never be found in nature could cause adverse effects. However, evidence is strong that natural products generally have a much shorter half-life in the environment than synthetic pesticides. After a promising biological activity is discovered, extraction of larger amounts of the compound for more extensive bioassays can be considered.

Before a decision is made to produce a natural pesticide for commercial use, the most cost-effective means of production must be found. Although this is a crucial question in considering the development of any pesticide, it is even more complex and critical with natural products. Historically, preparations of crude natural product mixtures have been used as pesticides. However, the potential problems in clearing a complex mixture of many biologically active compounds for use by the public may be prohibitive in today's regulatory climate. Thus, the question that will most probably be considered is whether the pure compound will be produced naturally or by traditional chemical synthesis.

From the above analysis it can be seen that those natural insecticides which have been proved effective, like pyrethrum, are poised to capture the market at short notice.

The Future

History tells us that use of the crushed dried flowers of the daisy *Chrysanthemum coccineum* Willd. as an insecticide was a long-established folk practice in the Caucasus region and North-west Persia. The powder, termed Persian or Caucasian insect powder and now known as pyrethrum, combined the attributes of rapid insecticidal action and low acute toxicity to humans. Modern analysis shows that it contains 68 per cent of the very effective insecticides pyrethrin I and II, along with four minor, closely related insecticides, jasmolin I and II and cinerin I and II, which are collectively referred as pyrethrins.

During the 18th century, this Persian powder became an article of trade exported by caravan from that region, which is now called Iran. By the beginning of the 19th century, the insecticide's efficacy had become so apparent that the supply reaching Europe was insufficient to meet the demand.

The situation changed, however, when an Armenian trader succeeded in learning the identity of the plant and started manufacturing the powder on a large scale in 1828. Even so there were constraints on the supply because hand collection of the flowers has always demanded low labour costs and dictated its major growing regions.

Starting in 1840, pyrethrum began being produced from the more potent *C. cinerariaefolium* Vis., a species native to the Adriatic coastal mountains of Croatia, Bosnia and Herzegovina. Dalmatia dominated the control of this trade until World War I, when it was replaced by Japan, which held control until World War II, when trade patterns were disrupted and supplies cut off.

During the war years, prior to the development of DDT, farmers, public-health officials and householders in the West had only a few effective inorganic and botanical insecticide alternatives. The importance of pyrethrum and rotenone to agriculture became evident by their absence when wartime shortages forced farmers from the developing world to turn back to much less effective and often more dangerous insecticides used in the 19th century, including nicotine and arsenic compounds that were extremely poisonous to humans and livestock.

In response to the need to find additional alternative botanical herbicides, research was begun during the war, and continued through the 1970s. In this period two other substances were added - ryania and neem extract - to the very short list of botanicals that could compete with the chemist's synthetic products. Some of the other potential leads for botanical insecticides that turned up in the research period from 1940 to 1970 may be worth re-evaluating in view of the concern about the persistence of synthetic pesticides.

What Needs to be Done to Improve the Market Share of Pyrethrum?

Having seen that the pyrethrum is well placed to attract users both in East Africa and abroad, a holistic review of the industry should be made in order to optimize the yields and if possible expand production. The review should take into account the farming, harvesting, handling of fresh flowers, drying, extraction of the product, purification of crude extract, formulation and marketing. Inefficiencies at any one step in the production chain would mean reduced income to the farmer.

After hearing the presentations on current production practices and marketing issues, this workshop will probably issue recommendations on how to revamp the pyrethrum industry. However, the following points may be considered while listening to the other presentations:

- ❑ Ways to improve the yield to increase income per unit hectare and to reduce losses during harvesting.
- ❑ Are the current handling practices of unprocessed flowers, i.e. harvesting, transportation and drying, efficient? What needs to be done to improve them?
- ❑ Is the extraction process of pyrethrins effective? Do we know the efficiency of the extraction? Is there a way of improving the extraction efficiency? Is the current solvent per unit product optimal? Is the current installed capacity fully utilized? Could the extraction capacity be a bottleneck, if we think of encouraging farmers to grow more pyrethrum? Can it be improved?
- ❑ Is the current practice of exporting crude extract for purification cost effective? What needs to be done to purify the crude extract on site so as to minimize the handling charges and thus increase the profitability of the operation?

- Has the product been effectively utilized? This could be looked upon from the perspective of number of products on market. Is there a possibility of expanding the present product line? What needs to be done to increase the local market base of the product, i.e. in form of having more end users?
- Are private entrepreneurs aware of the potential of the plant? Is there a way to awareness-build and encourage investment in the industry?
- Are the financial institutions aware of the potential of the pyrethrum industry?
- What are the barriers and incentives on the part of farmers that need to be addressed if the full potential of the plant is to be realized.

Sustainable pyrethrum industry will depend on well articulated intervention strategy that will ensure that the communities growing the plant enjoy the benefits accrued from the industry.

Conclusions

Pyrethrum is a complex insecticide with outstanding properties of rapid action and low mammalian toxicity, lack of insect resistance, broad spectrum of activity, powerful repellent and flushing action and environment-friendly nature.

From a commercial perspective, the major disadvantage of pyrethrum is that its products are unpatentable and produced by small companies, many of them in the developing world. It lacks the sponsorship and major drive that could promote it to the leading insecticide on the world market. However, the time is right, and suitable interventions now will make the pyrethrum stand a chance of becoming a major forex earner.

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4.2 Overview of Pyrethrum Production

4.2.1 Pyrethrum Production in Tanzania

by E. R. Mhekwa, B. E. G. Kiwovele and G. M. Mbeyela

Introduction

Pyrethrum (*Chrysanthemum cinerariaefolium* Vis.) is a perennial tropical cross-pollinated plant belonging to family Compositae. The plant is cultivated for its flowers, which contain insecticidal chemicals known as pyrethrins.[1] The plant originated from the Dalmatian coast of Yugoslavia. Seeds of this plant were brought to Kenya and later to Tanganyika (now Tanzania), in the late 1930s. In Tanganyika, pyrethrum was first introduced in the northern regions on the slopes of mount Kilimanjaro and mount Meru. By 1941 the crop was already in the Southern Highlands of Tanganyika as a cash crop and by 1949 the country was able to export 274 metric tonnes to the world market.[2,3] Prior to 1957, production in Tanganyika was almost entirely confined to non-African farms and estates.[1]

In 1960, the Tanganyika government decided to establish the Tanganyika Pyrethrum Board (TPB) with the purpose of pyrethrum development and formation of different pyrethrum projects, such as construction of a pyrethrum processing factory.[3] Apart from this, the Board was given full autonomy and was mandated to:

- Formulate and give advice to the minister of agriculture on different strategies to develop and protect the pyrethrum crop;
- Receive and advice the minister on how to develop the pyrethrum farming and hence increase production;
- Advise the crop director on issues related to the distribution of pyrethrum growing licences to farmers;
- Develop, run and finance pyrethrum research;
- Announce the success of pyrethrum development;
- Solicit and ensure good prices for the farmers;
- Have overall control and guidance on all aspects concerning pyrethrum development.

Despite this full autonomy and power, as stipulated above, the Board had no permanent working staff. Day-to-day issues were conducted by the Tanganyika Extract Company Limited (TECO) of Arusha. The Dar es Salaam Chamber of Commerce was the Secretariat in this structure. In 1971, the Pyrethrum Board modified the government act of 1960, in order to obtain permanent workers, as a strategy of increasing pyrethrum production in the country. The permanent staff was established for the first time in 1973.

From 1931 to 1963 all pyrethrum produced in Tanganyika was transported to Kenya for processing.[3] TECO constructed in Arusha took over processing of flowers from 1964. This factory had a capacity to process 6,000 metric tonnes of dry flowers. In 1973-74 the research on pyrethrum development forecasted pyrethrum production to reach 14,000 metric tonnes by the year 1977-78. This increased production was expected from the Southern Highlands, particularly in the Iringa and Mbeya regions. Therefore a new pyrethrum-processing factory was constructed at Mafinga in Iringa, which became fully operational in 1982. Pyrethrum production in the northern province continued to decline, and this ultimately led to the closure of the factory. The overall production trend over the last 30 years has been declining as shown in Figure 1 and Table 1.

Figure 1: Trends in pyrethrum production (metric tonnes) in Tanzania from 1950-54 to 1995-99

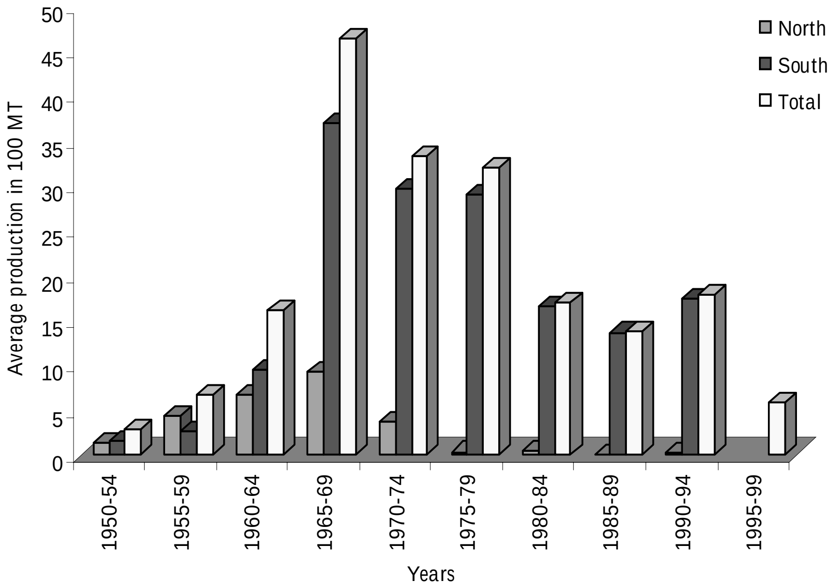

Table 1: Pyrethrum production (metric tonnes) with distribution and percentage between Northern area and Southern Highlands during 1949/50-1953/54 to 1994/95-1998/99

Years	Total production (MT)	Production (MT) from North	Production (MT) from South	Per cent production from South
1949/50-1953/54	291.60	133.20	158.50	54
1954/55-1958/59	677.80	426.00	251.80	37
1959/60-1963/64	1,618.80	667.80	951.00	59
1964/65-1968-69	4,630.20	931.80	3,698.40	80
1969/70-1973/74	3,331.20	377.20	2,954.00	89
1974/75-1978/79	3,204.20	316.40	2,887.80	90
1979/80-1983/84	1,693.00	41.00	1,652.00	98
1984/85-1988/89	1,376.60	11.60	1,365.00	99
1989/90-1993/94	1,773.80	35.60	1,738.20	98
1994/95-1998/99	578.00	-	-	-

Where North means Arusha and Kilimanjaro regions, South means Iringa and Mbeya regions.

The crop is currently grown by small land holding farmers in the Southern Highlands. About 20,000 farmers cultivate nearly 8,000 hectares of land. The majority of these farmers have one quarter of a hectare or less under pyrethrum cultivation and produce comparatively poor flower yields. The fact that the crop is perennial, with flower picking at two-week intervals, makes the crop attractive to small-scale farmers in terms of providing a steady monthly income. A few farmers have restarted pyrethrum growing in the northern regions. The crop-raising requires altitude of 1,800 - 2,000 m, well drained fertile soil and annual rainfall of 900 to 1,800 mm.[1,4] The rains should be well distributed in the growing season. The flowers must be picked at the correct stage of maturity and dried to a moisture level of 8 to 10 per cent to avoid losses of pyrethrins. Flowers should be transported as soon as possible to a factory where flowers are processed, to produce a crude extract which is subsequently marketed without refining.

Apart from the Southern Highlands, pyrethrum cultivation can be extended to other regions in Tanzania having similar climatic conditions, such as west Kilimanjaro, Ruvuma, Rukwa and Kagera Regions. However, the socio-economic changes taking place now in these areas should be considered prior to introducing pyrethrum cultivation.

Research Review of Pyrethrum

Research before 1963

Up to 1959 the Tanganyika and Kenya pyrethrum growers worked largely together and shared many services including agronomic research.[5] Growers in the northern region appeared to have relied on experimental results of Kenya, while in the southern region experimental work was done by the District Agricultural Officer in Uwemba-Iringa. Trials on general husbandry problems (spacing, planting time, fertilizers, weeding, etc.) were carried out. Breeding programmes were also initiated. The clones appearing in Table 2 are the result of this early breeding programmes in the Southern Highlands between 1950-56.

Table 2: Characteristics of the pyrethrum clones released into production in the breeding programme

Clone	Dry matter yield (kg/ha)	Per cent pyrethrins content
59/347	500	1.55
59/346	560	1.62
59/351	400	1.87
59/358	450	1.44
60/362	650	1.36

In the northern regions a clonal selection programme was also initiated in 1960. Testing of the selected plant material was carried out by Mr. Brown of Maua Limited and at Tengeru Research Centre B to develop the clones.

Research after 1963

In 1963 pyrethrum research was concentrated in the south, which is now the Igeri Experimental Station, Njombe-Iringa.[6] In 1973 pyrethrum research moved to ARTI (now Agricultural Research Institute, ARI-Uyole, Mbeya), which became the main pyrethrum research centre in the country. Uyole situated at an altitude of 1,800 m has four testing sites, viz. Igeri (2,300 m), Ujuni (2,500 m), Kinyika (2,600 m) and Kikondo (2,300 m).[7]

Since privatization of the pyrethrum industry from 1998, pyrethrum research has been supervised by the Tanzania Pyrethrum Board. Funds are sourced by all stakeholders. The Ministry of Agriculture meets personnel and other administrative costs.[8]

The objective of pyrethrum research is to improve pyrethrum production in the country through developing and dissemination of improved technologies in agronomy, and breeding clones of high yield and pyrethrins content. The following are some of the successes so far achieved for use in pyrethrum production.[7]

Breeding - Clonal Selection

In the clonal selection programme considerable attention has been given to the pyrethrum clones with high fresh flower yield, dry matter (DM) and pyrethrins content, in order to establish their effects in relation to total pyrethrum yield. Pyrethrins content and yield of clones produced as a result of clonal selection work are shown in Table 3.

Table 3: Characteristics of the pyrethrum clones released into production in the clonal selection programme

Clone	Dry matter yield (kg/ha)	Per cent pyrethrins content
	Section I	
60/70	700	1.70
65/166	800	1.60
65/194	900	1.50
	Section II	
78/94	977.1	1.88
79/78	852.5	1.92
79/71	756.5	1.89
78/111	739.3	2.07

In 1985, the clones (Table 3, Section I) were released to the Tanzania Pyrethrum Board (TPB) for multiplication and distribution to farmers in altitude ranging from 1,800 - 2,400 m.[7]

Other promising lines, which are a result of clonal selection, have shown quite outstanding superiority to the former clones in terms of dry flower yield and pyrethrins content. They can be grown from 1,800 to 2,600 m in the Southern Highlands of Tanzania. However, these clones have not reached the farmers' fields due to lack of a system for rapid multiplication and distribution of clones in large quantities. The characteristics of these improved clones are summarized in Table 3, Section II.[7,9] In some locations, depending on soil condition and other environmental factors such as rainfall, altitude and temperature these clones have the potential to yield up to 1,500 kg per hectare of dry flowers.

Hybridization

Some of the characteristics of the two crosses produced as a result of hybridization, using clones from the selection programme, are shown in Table 4. Most correlation coefficients between progeny characters were negative.[6,7,10] Progenies in both populations were uniform and similar in agronomic characteristics. Most of the progeny had a pyrethrins content below that of the parents. Only four plants had a pyrethrins content above 2 per cent. The crossing of clones resulted in plants with wide variation in pyrethrins content. Polycrossing might prove better in the future.[7,9,10]

Table 4: Hybrid characters in two pyrethrum crosses

Crosses	Flower stalks	Lateral shoots stalk	Height (cm)	Lodging (scale 0-5)	Weight of 100 flowers (g)	Max. pyrethrins content
60/70 x 65/166	39.1	5	51.3	1	18.5	2.18
65/194 x Mporoto local	42.8	6	52.6	1	17.3	2.26

Pyrethrum Propagation and Variability in the Field

The conventional propagation of pyrethrum is by sexual means through seed and asexually through vegetative propagation of splits.[1] Shortage of planting materials is the most limiting factor in pyrethrum production.[11]

Splits

A split is a vegetatively divided plant by mitosis from the mother plant. At the base of the pyrethrum plant, it forms a crown of divisible small plants like tillers from the roots. The term split is a special term in pyrethrum, synonymous to tillers in other crops.[1] It denotes the multiplication capability of pyrethrum. Research at Uyole has found most clones to have limited multiplication of between 10-20 splits per plant.[6,7]

The splits are used for field planting. In the field they take 3-4 months for flowering. The bulky nature of splits and the logistics involved when a large area has to be planted is another factor to be considered. This makes the use of splits an expensive, laborious, time and resource-consuming exercise.[7] However, it is the only method that maintains plant purity in terms of yield and pyrethrins content because they are true to type from the mother plant.[9]

Seeds

Pyrethrum is self-sterile, and has to be cross-pollinated to produce viable seeds.[1] Pyrethrum seeds have low germination percentage due to presence of non-viable (unfertilized) seeds. The out-crossing nature of pyrethrum results in seedlings of variable genetic constitutions that vary greatly in their pyrethrins content. Despite the fact that using seeds as propagating material is easier compared to splits, the existence of variability in pyrethrins content in seeds varieties has made breeders switch to vegetatively propagated clones.[2,9]

In view of the above, a continuous breeding and agronomy research leading to improved flower yield and increased pyrethrins content has to be strong within the industry.[9] The use of other modern technological approaches to remove or alleviate some of the production constraints, such as shortage of planting materials through in-vitro micropropagation of pyrethrum clones must be addressed.[5]

Agronomy

Agronomic factors for increased pyrethrum production have been studied. The following are some of the results.[7,9]

Fertilizers

Experimental field studies at Uyole and Igeri have shown the use of phosphorus in pyrethrum production as essential to sustain flower production. Yield increase of 20 to 40 per cent was observed with phosphate application. A rate of 40 kg phosphorus per hectare was found to be optimal for most soils in Njombe and Mbeya districts but smaller rates could be used in more fertile areas. Some nitrogen should be applied when phosphorus is used. A rate of 60 kg nitrogen per hectare in Njombe and less in other areas was found suitable. Nitrogen 80 kg per hectare is recommended in nursery to stimulate the formation of splits.

The effect of potassium and micronutrients, such as copper, magnesium, molybdenum and boron on yield and pyrethrins content were included in other studies.[7,9] Application of potassium has no noticeable effect on yield and pyrethrins content. The response to micronutrients was generally inconsistent. In some cases a negative effect was noticed, especially with magnesium. Beneficial effects have been obtained with copper and molybdenum application in the Southern Highlands, where these elements are deficient. The interaction effects that were noted for some micronutrients warrant re-evaluation and quantification, particularly in the case of molybdenum and boron. Difference in response to micronutrients amongst clones was negligible. The pyrethrins content was unaffected by micronutrients.

Nematodes

As early as 1956, Tackett in an unpublished work reported nematodes in pyrethrum in Uwemba, Njombe district. Later, work in Kenya identified the species as *Meloidogyne hapla* in the roots and soil, and showed that a severe attack could result in heavy reduction in yield of flowers and pyrethrins. These findings were confirmed by research at Uyole. The research[6,7,9] showed that the flower yield reduction due to nematode attack was more severe under conditions of moisture stress. Yields were reduced by 20 to 40 per cent even in years of sufficient rainfall, depending on the degree of nematode attack in the root system. Even when there is no moisture stress and nematode attack is minimal, yields fall off sharply in the third year after planting. Preventive treatment with nematicides is undesirable because of environmental concern. Control by improving management practices is preferable, for example by crop rotation with cereals and legumes (but not with potatoes, which are also susceptible to nematode attack) to check the nematode population.[6,9]

Weeding

Weeding in pyrethrum is a laborious activity, which needs attention as labour availability is constantly decreasing. To alleviate this situation, a combination of technologies had to be found. An alternative method is the use of herbicides.[7,9] In a study at Uyole it has been shown that Galex 500EC at 0.60-0.70 litre per hectare, Gesagard 500FW at 1.75-2.50 litre per hectare and sencor (metribuzin) 70 WP at 0.52-0.60 kg per hectare can be used for broad leaf and some grass weed control in pyrethrum production without detrimental effect to the crop. However, for stubborn and noxious weeds, a combination of hand weeding and herbicides will result in complete weed control.

Inter-cropping

Study on inter-cropping technique in pyrethrum production for medium altitude (1,700-1,800 m) was made between pyrethrum and beans (*Phaseolus vulgaris* L).[7] Depending on farm conditions, such as land pressure, markets and choices in an area, pyrethrum and beans can be grown as companion crops without detrimental inter-species competition, especially for non-trailing bean varieties.

Pyrethrum or beans when grown individually as pure stand give more yield than when these two are inter-cropped. However, the monetary gain per unit area is more in the inter-crop practice. The best crop spacing for pyrethrum and beans, which gives farmers profit and good utilization of land, was found to be 60 cm x 30 cm for pyrethrum and 30 cm for beans giving a land equivalent ratio (LER) of 1.40.

Losses During Storage and Marketing

Studies on storage have shown that the pyrethrins of the flowers tend to decrease with time after picking.[11] Storage conditions and the containers used for the dried flowers affect this loss. The loss of 3 per cent pyrethrins per month is considerable. Delay in extraction arises from any one of several causes, such as delay in delivering the flowers from the farm to the buying centre during the peak farming season, problems at buying centres, lack of transport, cooperative or private buyer procedures and priorities.[11] For these reasons, the pyrethrum production becomes uneconomical for small land holders.

Pyrethrum Products Utilization

Farmers in the Southern Highlands have been using fresh pyrethrum leaves to control the maize stalk borer in their maize farms for quite a long time. The leaves are simply crushed or squeezed and the liquid material is applied on the funnel of the maize plant.[7]

Some research work on the use of pyrethrum marc or grist as botanical insecticide in the field and in storage of maize and beans has been done through collaborative efforts between pyrethrum research for plant protection and post harvest research programmes.[7] A non-governmental organization, Hifadhi ya Mazingira (HIMA), in collaboration with Uyole is now working with farmers in the Iringa region, through on-farm trials. About 200 to 500 maize farmers around the Uyole Research Institute have been using pyrethrum marc since three years to control the maize stalk borer. The results are quite encouraging. Both crushed fresh pyrethrum and pyrethrum marc are effective in controlling the maize stalk borer. However, refining of the application methodology is needed. Some farmers are using pyrethrum marc or grist to control cutworms in crops such as cabbage, tomatoes and onions.[7] Livestock keepers, living around the pyrethrum factory, benefit by using pyrethrum marc to deworm their animals.

Technology Transfer

Outputs from research to farmers are transmitted through demonstration plots. The pyrethrum demonstration plot programmes, which existed from 1975 to 1979, involved three steps.[9]

The training plots were equal to demonstration plots, but were being used for training the Field Officers. The training was supervised by staff from the District Agricultural Office and staff from the Uyole Research Institute, in Mbeya. This system helped much to transfer different technologies developed during the research. The system no longer exists in pyrethrum production. An effective research-extension linkage should be established for the research findings to reach the farmers.

Research Funds and Staff Position

For the last 37 years, operational research funds came from the Tanzania Government, Nordic countries, World Bank and Finnish International Development Agency. Consistent funding was rare and inadequate to maintain experimental trials. For instance, between 1987 and 1999, the total research budget requirement was 142 million TZS (US$ 0.18 million) and only 10 per cent of this was obtained.[7]

Inadequate staffing has negatively affected pyrethrum research programmes. There is a need to consolidate pyrethrum research. A total staff of five people since 1999 (two diploma holders, one graduate and one post-graduate in agronomy), is far from being sufficient to allow any meaningful research to be conducted.[7]

Pyrethrum Production

Commercial cultivation began in the 1930s and up untill 1957 it was on large farms and estates owned by European or Asian settlers in west Kilimanjaro and Arusha, and in the Southern Highlands particularly in Mbeya and Iringa. In general, pyrethrum cultivation increased steadily in the southern region. All dry pyrethrum flowers were transported to Kenya, which had the extraction plant.[12]

After 1960 Africans began to grow the crop in small plots. The farmers were encouraged by the free distribution of planting material and the provision of extension and marketing services.[7] Thus production of dried flowers expanded from 2,300 metric tonnes in 1963 to over 6,000 metric tonnes in 1967. The production increased more in the southern region than in the northern due to availability of land.[3] At least six regions in the country are engaged in pyrethrum production, including Arusha, Kilimanjaro, Rukwa and Ruvuma. The country became the second largest producer of pyrethrum in the world next to Kenya, which is now the leading producer. Pyrethrum production in Tanzania since 1949-50 to 1999-2000 between Northern Areas and Southern Highlands, with distribution and percentage is given in Figure 2 and Table 5.

After 1967, a gradual decline began in pyrethrum production, which fell below 2,000 metric tonnes in 1979. The situation grew more critical in 1994-95 when production fell drastically from 2,500 metric tonnes in the preceding year to a mere 500 metric tonnes. This sharp decline was caused by the farmers' refusal to release their flowers on credit and others

Figure 2: Trends in pyrethrum production in Tanzania during the period 1949-50 to 1999-2000

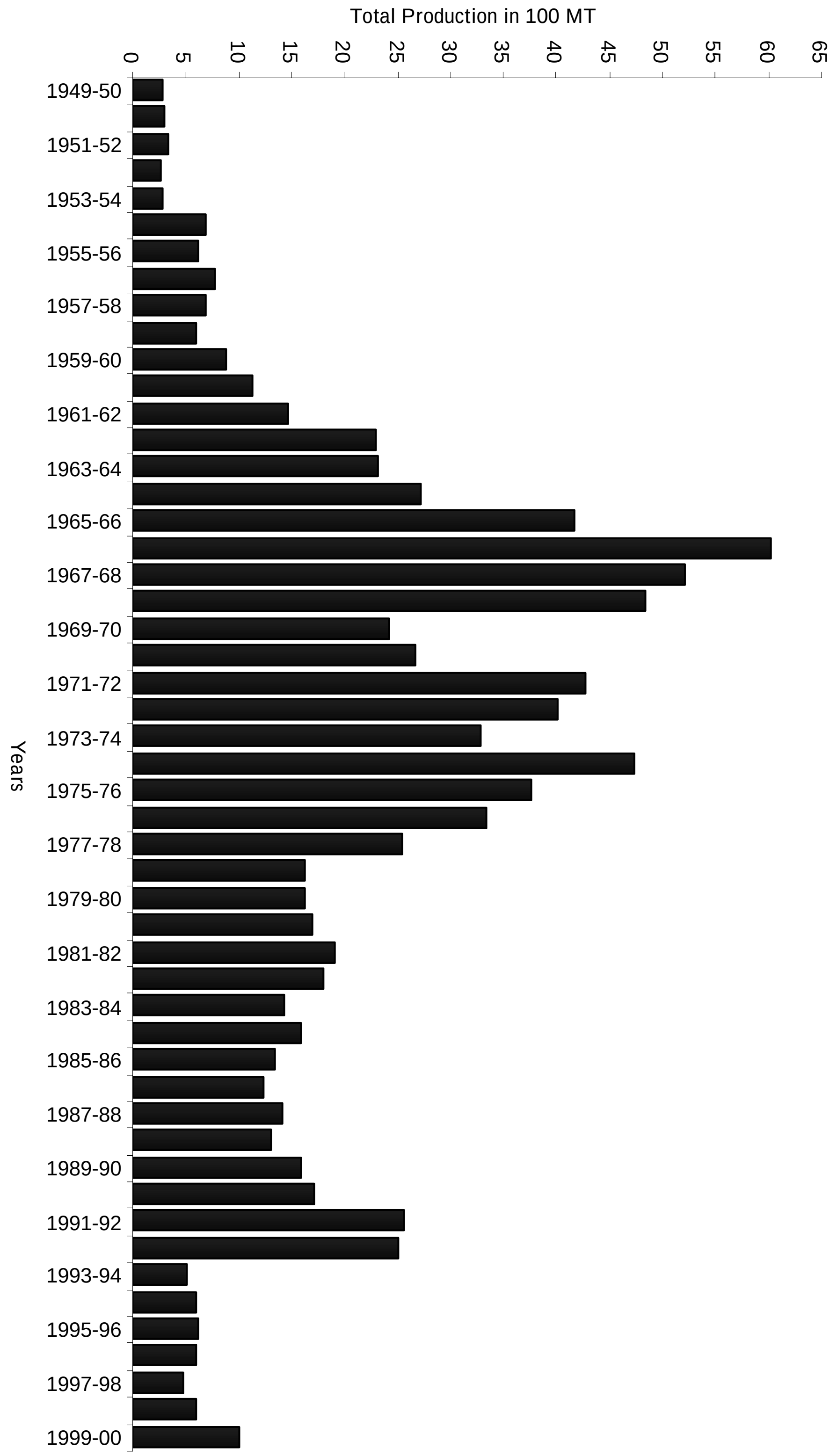

Table 5: Pyrethrum production in Tanzania since 1949-50 to 1999-2000 with distribution and percentage in Northern and Southern Highlands

Year	Total Production (MT)	Production from North (MT)	Production from South (MT)	Per cent production from South
1949-50	274	91	183	67
1950-51	298	147	151	51
1951-52	330	165	165	50
1952-53	272	126	146	53
1953-54	286	137	149	52
1954-55	691	454	237	34
1955-56	616	386	230	37
1956-57	779	489	290	37
1957-58	695	433	262	38
1958-59	608	368	240	39
1959-60	880	556	324	37
1960-61	1,132	582	550	49
1961-62	1,466	520	946	65
1962-63	2,299	1,010	1,289	66
1963-64	2,317	671	1,646	71
1964-65	2,718	953	1,765	68
1965-66	4,160	961	3,199	77
1966-67	6,015	1,023	4,992	83
1967-68	5,216	1,014	4,202	81
1968-69	4,842	708	4,134	85
1969-70	2,416	373	2,043	85
1970-71	2,666	287	2,379	89
1971-72	4,276	438	3,838	90
1972-73	4,016	361	3,655	91
1973-74	3,282	427	3,855	87
1974-75	4,741	437	4,304	90
1975-76	3,766	506	3,260	86
1976-77	3,335	388	2,947	88
1977-78	2,546	173	2,373	93
1978-79	1,633	78	1,555	95
1979-80	1,624	25	1,599	98
1980-81	1,702	59	1,643	96
1981-82	1,899	69	1,830	96
1982-83	1,801	32	1,769	98
1983-84	1,439	20	1,419	98
1984-85	1,582	21	1,561	98
1985-86	1,351	12	1,339	99
1986-87	1,231	12	1,219	99
1987-88	1,408	5	1,403	99
1988-89	1,311	8	1,303	99
1989-90	1,589	8	1,581	99
1990-91	1,705	17	1,688	99
1991-92	2,555	43	2,512	98
1992-93	2,510	69	2,441	97
1993-94	510	41	469	92
1994-95	600	40	560	93
1995-96	610	5	605	99
1996-97	600	12	588	98
1997-98	480	-	-	-
1998-99	600*	-	-	-
1999-2000	1,000*	-	-	-

Where North means Arusha and Kilimanjaro regions, South means Iringa and Mbeya regions.
* Estimates

abandoning the production of pyrethrum altogether.[8] Since that time, annual production has hovered around 500 metric tonnes per annum.

Reasons for the Decline in Pyrethrum Production

From the 1970s to 1990s, the world market for pyrethrum dropped drastically because many countries switched to synthetic pyrethroids, which were cheaper than pyrethrins, and led to unattractive prices being offered to farmers.[8] Introduction of competitive crops with attractive revenues, such as cabbage, maize, round potatoes and horticultural crops, like tomatoes in the suburbs, have replaced pyrethrum,[13,14,15] which is another reason for the decline in pyrethrum production. For instance, the Mbeya suburban area, once a pyrethrum area, has now changed to intensive agriculture of horticultural crops. In the 90 km stretch from Njombe to Kipengere mountains in Iringa region, the area has been replaced by maize and round potatoes. The Eastern part of Mufindi district, Iringa region, is now planted with tea, maize and round potatoes.[16]

Change in the farming systems in areas, such as the Uporoto-Umalila highlands, situated at 1,700-2,000 m in the Mbeya region has also contributed to a decline in pyrethrum production.[13,14,15] Diagnostic survey and participatory rural appraisal (Kirway 1988, Nalitolela 1990, Kiara, 1995 and Mussei 1998) indicated a complete change of the farming system in areas which had the potential for pyrethrum growing. The reports showed an increase from 45 to 62 people per square km in year 2000. Thus population growth is causing land pressure and an area decrease of 2 per cent per annum per person. As a result, farmers grow many crops in a continuously subdivided land.

Some farmers have introduced inter-cropping between pyrethrum and maize or beans, while others in parts of Ileje and Umalila in the Mbeya region practice annual cropping whereby pyrethrum is allowed to flower only one season instead of the recommended three years before uprooting.

Yields and Pyrethrins Content

Pyrethrum comes into full flower production in the second and third year and then production declines rapidly. In view of the soil pulverizing effect of the crop and the hazards of root knot nematodes, it is necessary to uproot the crop every third year, and to rotate with either a grain crop or a period of fallow.[9] Flower picking is 9-10 months at an interval of 10-14 days. Cutting of dead flower stocks is done annually, either at the onset of long rains, or immediately after the long rains.

According to a survey of small holders carried out in 1974, the average annual yield of dried flowers per hectare was 260 kg. Since then yield has been falling as a result of adverse climatic conditions and because of aging of plants in the absence of replanting. Current average annual yields for a farmer are put at 200 kg per hectare, with yield of 100 kg in the first year and 250 kg in both second and third year. The optimum yield should be 500-800 kg per hectare.[16]

The pyrethrins content of dried flowers, which is measured prior to processing, depends on the quality of the planting material, climatic conditions, altitude and the efficiency of drying and marketing operations.[9] For a period of 16 years, 1962 to 1977, pyrethrins content remained fairly stable around an average of about 1.20 per cent. However, a sample survey of 933 farmers carried out from 1979 to 1987 showed a pyrethrins content between 1.30 and 1.69 per cent.[7] It reflects that individual farmers are able to dry their flowers properly to maintain good flower quality.

Efforts to Raise Pyrethrum Production

The Tanzanian Government, under National Agricultural Development Program (NADP I & II) planned to raise pyrethrum production from 3,000 metric tonnes in 1973-74 to 14,000 metric tonnes by year 1983-84. The pyrethrum factory in the north (Tanganyika Extract Company), with installed capacity of 6,500 metric tonnes per annum was expected not to cope with the targeted increase in production.[16] Thus a new factory (which became operational in 1982) with a capacity of 4,500 metric tonnes was constructed in the south, at Mafinga, where expansion programme of pyrethrum production was concentrated due to availability of land and labour.

The European Economic Community (EEC) and the World Bank funded the pyrethrum development programmes between 1978 and 1985. These programmes concentrated on:

- ❑ Research and training;
- ❑ Bulking centres for multiplication of clonal materials;
- ❑ Seed farms and nurseries for production of seeds and seedlings;
- ❑ Improvement of infrastructure - roads and bridges;
- ❑ Improvement of pyrethrum drying.

Bulking Centres

In an effort to ensure enough good planting clones to growers, TPB under financial assistance from the World Bank project (1980-85), established about nine bulking centres in the growing areas. Eight of them were in the Southern Highlands, while the northern region had one bulking centre. In these centres, selection of high yield clones was carried out. The selected clones and sometimes clones from research were being multiplied further at TPB's farming before final distribution to farmers. These nurseries were organized and run by TPB. Every bulking centre had an Assistant Production Officer (APO). They were successful in faster dissemination of good pyrethrum plants to farmers. However, the bulking centres were expensive to manage and when the World Bank and EEC (1978-85) stopped funding, the multiplication centres had collapsed.

Production of Seed and Seedlings

TPB had seed farms at the Wattle Company - Njombe, Dabaga (Iringa), Ilindi (Mbeya) and at Mafinga (Iringa). EEC sponsored training for field officers at Uyole (Mbeya), in order to make TPB self sufficient in field staff. Seed farms became non-functional after the EEC assistance was withdrawn.[3]

Improvement of Infrastructure

The World Bank offered assistance for the rehabilitation of feeder roads and bridges in the pyrethrum growing areas, in order to make transportation of pyrethrum flowers possible during rainy periods. The World Bank constructed storage go-downs for storing pyrethrum for short periods before they were delivered to the factory for processing.

Farm Services Centres

TPB established farm services centres in pyrethrum areas. Various goods, especially building materials, were used. Tractors were given on hire. The goods and services were given on a credit basis and payments were deducted during the sales of pyrethrum. To some extent, this assistance stimulated pyrethrum production.

Flower Picking and Drying

Flower picking and drying is laborious and expensive. It remains a family business. Today the young people have migrated to towns and flower picking is left to the old people. This aspect has an impact on the cultivation/expansion of pyrethrum.

Quick drying of pyrethrum flowers after picking is essential. Moisture content must be reduced from 80 to 10 per cent and affecting minimum loss of dry matter and pyrethrins, which are thermolabile and vulnerable to oxidation. Quick drying with minimum heat is desirable. Many farmers use to sun dry on mats or bare ground. Some use wire mesh raised above ground. Where there is limited sunshine and prolonged wet weather, natural drying is difficult. In such areas, farmers dry pyrethrum in the kitchen over a cooling fire.

A programme was initiated to make 400 portable box driers, which were given on loan to farmers; this reduced the drying time from 12 days to 10 hours or less. The artificial drying was constrained by scarcity of fire wood and global environmental concern on deforestation. Solar driers were tried, but the initial costs proved high. Attempts were made by EEC (1982-84) to buy wet flowers in place of dry flowers. This system was disliked by farmers, owing to price changes.[17] Farmers were paid 25 per cent of the price that they were getting for dry flowers. Also the wet flowers never received second payments.

Institutional Involvement in Pyrethrum Purchase

Between 1930 and 1960, all pyrethrum dry flowers were transported by settlers/farmers to Kenya where there was an extraction plant.[12] In 1964-65 the Tanganyika Extract Company, which was established at Arusha in Tanzania, bought all pyrethrum flowers from farmers. In the 1970s, regional co-operative unions took over the purchase and delivered them to TECO. From the early to late 1980s, TPB was the only buyer of all flowers and thereafter co-operative unions were allowed again to buy pyrethrum. TBP and co-operative unions continued the purchases until the mid 1990s. TPB was privatized in 1998 and all commercial activities of pyrethrum *viz.* procurement, processing and export were taken over by the Tanzania Pyrethrum Processing and Marketing Company Limited (TPPMCL), a subsidiary of a South African firm known as M/s International Chemicals Producers.

The pyrethrum market liberalization policy has allowed private companies to purchase the crop from farmers as agents of TPPMCL, which processes the flowers into crude extract. This free market economy is likely to improve the marketing system. TPB at present remains as a government regulatory body on pyrethrum-pertaining issues. Other roles of TPB now are to fund research and supervise the extension services.[8]

Major Bottlenecks and Constraints in Pyrethrum Promotion and Recommendations for Revamping Pyrethrum Production in Tanzania

Research

The main constraints on pyrethrum research are lack of continuity, competent staff, research facilities, adequate funds, transport facilities and professional training.[7]

Efforts should be directed towards improving research technology, backed by motivated staff and modern equipment, including tissue culture and adequate funding.

Pyrethrum Producer Price

The producer price in pyrethrum had been unattractive for many years.[7] The producer price per kg received in 17 years (from 1981 to 1997) ranged between TZS 6.50 and TZS 300 per kg, less than US$ 1. From 1997 the price has been increased to TZS 350. This price offered is for grade V. Few farmers qualify for grades 1V - 1 and hence do not get bonuses or second payment.

The prices should be revised upward in favour of the farmers.

Planting Materials

After the closure of the bulking centres and seed farms it has been difficult for farmers to obtain enough planting materials of high yield clones with high pyrethrins content.

Provision should be made to make available improved planting materials to replace the old materials developed in earlier years. Bulking centres and seed farms should be revitalized at district council level.

Extension Services and Land Management

Farmers are inadequately assisted in carrying out proper agronomical practices and good crop husbandry. Pyrethrum plants are heavy feeders. Pyrethrum cultivation is done mainly in uplands on undulating lands. Soils are not conserved and are washed away by rains. This is combined with the fact that pyrethrum plants feed heavily and, without replacement of nutrients, most pyrethrum farms have deteriorated and are infertile. Old pyrethrum fields have yet another problem of accumulating soil-borne diseases, caused by nematodes.[6]

Soil conservation is important in all pyrethrum fields since most of them lie in the uplands. Dedicated extension workers should be at the farmers' disposal to guide them on good crop husbandry practices, control of diseases, and soil management.

Drying Facilities

Farmers depend on sun drying, which is unreliable in many places. As a result, most pyrethrum flowers rot. This is the main reason why many farmers keep small plots, of roughly 0.4 hectares per household.

In order to obtain better quality flowers with high pyrethrins content, appropriate artificial driers should be designed and given on credit to farmers.

Institutionalized Marketing System of Pyrethrum

For many years farmers have not had the chance to control the pyrethrum market. Rather, institutions dictated both marketing and prices.[8]

It is necessary to improve marketing system in the free market economy backed up by active primary societies or pyrethrum growers associations. Farmers will be motivated by better prices and availability of inputs on loan.

Summary and Conclusions

Pyrethrum production in Tanzania has been declining over the years. From 6,000 metric tonnes in 1966 it touched a dismal 400 metric tonnes in 1999. Among other factors, lack of potential planting materials, poor price and incorrect packaging adopted by farmers contributed to the decline. Changing agricultural policies and roles of different institutions in purchase of pyrethrum at other times lowered farmers' morale for growing pyrethrum.

Pyrethrum research in Tanzania was not effective enough to revamp pyrethrum production in the country, although it started some 40 years ago. This failure is attributed to understaffing, lack of adequate funds and research facilities.

The future of pyrethrum is bright and if all the bottlenecks explained in the foregoing section are addressed, production may pick up to 3,000-4,000 metric tonnes per annum within the next few years (2003-05). Opportunities to learn from past mistakes, the present free market economy, possibility of land expansion, dedicated managers and farmers, give a possibility to increase pyrethrum production in the near future.

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4.2.2 Pyrethrum Production and its Industrial Utilization in Rwanda

by S. Nzabagamba

Pyrethrum was introduced in Rwanda after World War II by the Belgian colonels in the northern regions of Rwanda, along the volcano chain. In 1963 the government of Rwanda became interested in the new cash crop and ordered local authorities to seek land and extend the pyrethrum cultivation.

In 1968, a planter's co-operative (ASPY) concerned with pyrethrum was born and a processing pyrethrum extraction plant (USINEX) was built in 1972. Before this date, Rwanda used to export bales of dried flowers to Kenya. The assistance had been provided by the United Nations Development Programme (UNDP), with financial assistance from the European Development Fund.

The period of 1972 to 1977 was one of the sustained high yields of production with 1,174 metric tonnes in 1972; 1,427 metric tonnes in 1973; 1,301 metric tonnes in 1974; 1,753 metric tonnes in 1975; 1,500 metric tonnes in 1976 and 1,136 metric tonnes in 1997.

In order to promote and strengthen the production of pyrethrum, the government of Rwanda decided in May 1978 to merge the two existing entities, ASPY and USINEX, into one entity named OPYRWA (Office du Pyrethre au Rwanda). The first project undertaken by OPYRWA was to build a refinery. The contract was granted to the Australian Company VEW in 1978. The decision to build the refinery through an Australian company, supported by UNIDO, alienated OPYRWA's most important customer, McLanghlin Gormley King (MGK) Company, who took most of Rwanda's crop from 1974 to 1977. The company declined to take the crop altogether in 1978-79.

During 1978 to 1981 pyrethrum production fell to 935 metric tonnes in 1978, 772 metric tonnes in 1979, 938 metric tonnes in 1980 and 955 metric tonnes in 1981. After two years, VEW finally admitted that it could not get the refinery to work. In the meantime, a shortage of natural pyrethrum had developed and the price for the crude extract increased in 1980. OPYRWA was unable to benefit from that price, because the extract was kept with the intention of subjecting it to the process of refining. When a decision to sell was finally taken, it was too late because demand and prices had fallen.

From 1982 to 1984 flowers production was 1,087 metric tonnes in 1982, 1,218 metric tonnes in 1983 and 1,149 metric tonnes in 1984. In the meantime, further problems arose in 1983, when new evaporators were ordered for the extraction plant, but a dispute over the contract resulted in a refusal by the supplier to install the new evaporators. As a result, the production of the whole year was lost. From 1985 to 1989, the production dropped owing to a very poor sales situation. It came down 786 metric tonnes in 1985; 586 metric tonnes in 1986; 499 metric tonnes in 1987; 582 metric tonnes in 1988; and 790 metric tonnes in 1989. This led to a very unfavourable exclusive distributor-ship, signed with Briddle Sawyer, a trading company who simply resold the extract to the main buyers, MGK, SC Johnson Wax and Prentiss. The sales contract was unfair in the sense that Briddle Sawyer had complete freedom to accept or reject

OPYRWA's extract, whereas OPYRWA could not sell it to any other customer and the price offered was extremely low.

In late 1985 Mitchell Cotts, a British Company, took on the job of refurbishing the refinery and completely redesigned the process. From the day Mitchell Cotts staff left OPYRWA, the process failed to produce any saleable pale extract, because the OPYRWA's technicians were not well trained. In spite of this, the refinery was accepted and Mitchell Cotts declined to accept further responsibility. In late 1986, OPYRWA went bankrupt. Sales were at an uneconomic price, because of the monopolistic exclusive sales agreement with Briddle Sawyer. The morale in the office was at its lowest. The farmers had not been paid for a year and as a consequence, flower production dropped to 586 metric tonnes. Much good clonal material had been uprooted and all agronomic research abandoned.

In March 1987 the government decided to cut its losses with OPYRWA, but first sent in auditors, who revealed serious errors in the management. They gave detailed proposals for reduction of overheads and improvement in the procedures. Legal action was taken against various individuals and suppliers and most of the recommendations were adopted. The result was a remarkable turnaround for OPYRWA. Although flower deliveries actually fell in the first twelve months, largely because of a shortage of planting material, they increased in 1990 until 1993, despite the war that arose in October 1990.

In the period of 1994 to 1998 pyrethrum production was practically nil. This was the result of the tragic events of genocide in 1994 and the insecurity, that arose from 1996 to 1998. OPYRWA was able to survive on the basis of the stock of crude extract realized in 1992 and 1993. This had been sold to AgrEvo and PBK during the post-war period. Since 1999, OPYRWA has been focusing all its efforts on relaunching of the pyrethrum production by collecting some clonal material and installing nurseries. OPYRWA has set up some incentive measures for the farmers, increasing price and maintaining near the growers a reinforced team of agronomists, in order to keep the interest of the growers for pyrethrum cultivation. In this respect, OPYRWA calls upon all pyrethrum producers and in particular UNIDO for sustained assistance in Rwanda. This assistance could consist of selection of high-yield clones, their reproduction and distribution to the growers, as well as the rehabilitation of the drying areas and the factory.

4.3 Overview of Pyrethrum Processing and Marketing

4.3.1 Industrial Processing of Pyrethrum in Tanzania

by W. J. Swai

Introduction

Pyrethrins, naturally occurring insecticidal principles in the flowers of *Chrysanthemum cinerariaefolium* Vis., are the world's most widely used botanical insecticide. It is considered the safest insecticide because it is almost non-toxic to warm-blooded mammals while being highly toxic to a wide range of insects. Pyrethrins decompose when exposed to light leaving no residual effect, thus rendering the atmosphere and its surroundings free from hazardous pollution, a very significant advantage over other insecticides.

Technologies for obtaining pyrethrins from flowers are varied. Widely used conventional methods employ organic solvents to extract flowers. A recently pioneered process uses liquid carbon dioxide ($C0_2$). It is claimed to be cost effective and yields a pale, transparent, solvent free concentrate of pyrethrins in a one-step process.

Industrial processing of pyrethrum in Tanzania can be traced back to the 1960s. The first processing plant in Tanzania was established in Arusha, northern Tanzania under the company name of Tanganyika Extract Company Limited (TECO), which became operational in 1962. Pyrethrum was extracted in a pot extractor using n-hexane as solvent to produce a 'concentrate pyrethrum oleo-resin' and marc as a by-product. Products traded were pyrethrum extract, pyrethrum dried marc, pyrethrum powder and pyrethrum marc powder. The plant had a nominal capacity to process 6,000 metric tonnes of dried flowers per annum.

During the 1970s, in response to changing circumstances in the pyrethrum industry, it was felt that the TECO plant might not have sufficient capaciy to process all flowers of future production, and another extraction plant was planned for installation in the Southern Highlands of Tanzania, producing 70 per cent of the total country production. As the outcome of feasibility studies undertaken by a mission sent by FAO Investment Centre, Rome, Italy, and later updated by the consulting firm Dalgety Associates, a new extraction plant was installed at Mafinga in the Iringa region of southern Tanzania. The new plant with a capacity to process 4,500 metric tonnes of dried pyrethrum flowers in a year in 250 working days and operating on 3 shifts, went into commercial production in April 1982. The Arusha extraction plant, in all probability, has been closed down permanently. The main reason for its closure was a low production of pyrethrum flowers in the Arusha region, with ever-declining trend since 1966-67.

This paper discusses the processing technology used at the only existing and active pyrethrum factory in Tanzania, located at Mafinga. The status today is that the TECO's Arusha plant has been brought to a safe and possibly permanent shutdown.

The Company Ownership

The plant operates under the name of the Tanzania Pyrethrum Processing and Marketing Company Limited (TPPMCL). Ownership has changed hands from a government-managed parastatal organization to a private company. On 6 February 1998, TPPMCL was officially sold and handed over to M/S International Chemical Producers (ICP) of the Republic of South Africa, under a privatization programme of the Government of Tanzania.

Manufacturing Process

General Description of the Process

The dried flower heads of the *Chrysanthemum cinerariaefolium* Vis. are extracted with solvent to produce a crude concentrate pyrethrum extract containing active constituents, pyrethrins; the dried exhausted marc constitutes a by-product of the process.

The dried pyrethrum flowers are milled and the ground material is called 'grist'. The grist is mixed and extracted with n-hexane to obtain the hexane extract called 'miscella'. The hexane is evaporated under vacuum from the miscella to get pyrethrum crude extract, a semi-finished product. The pyrethrum marc that is left after solvent extraction is dried to a by-product.

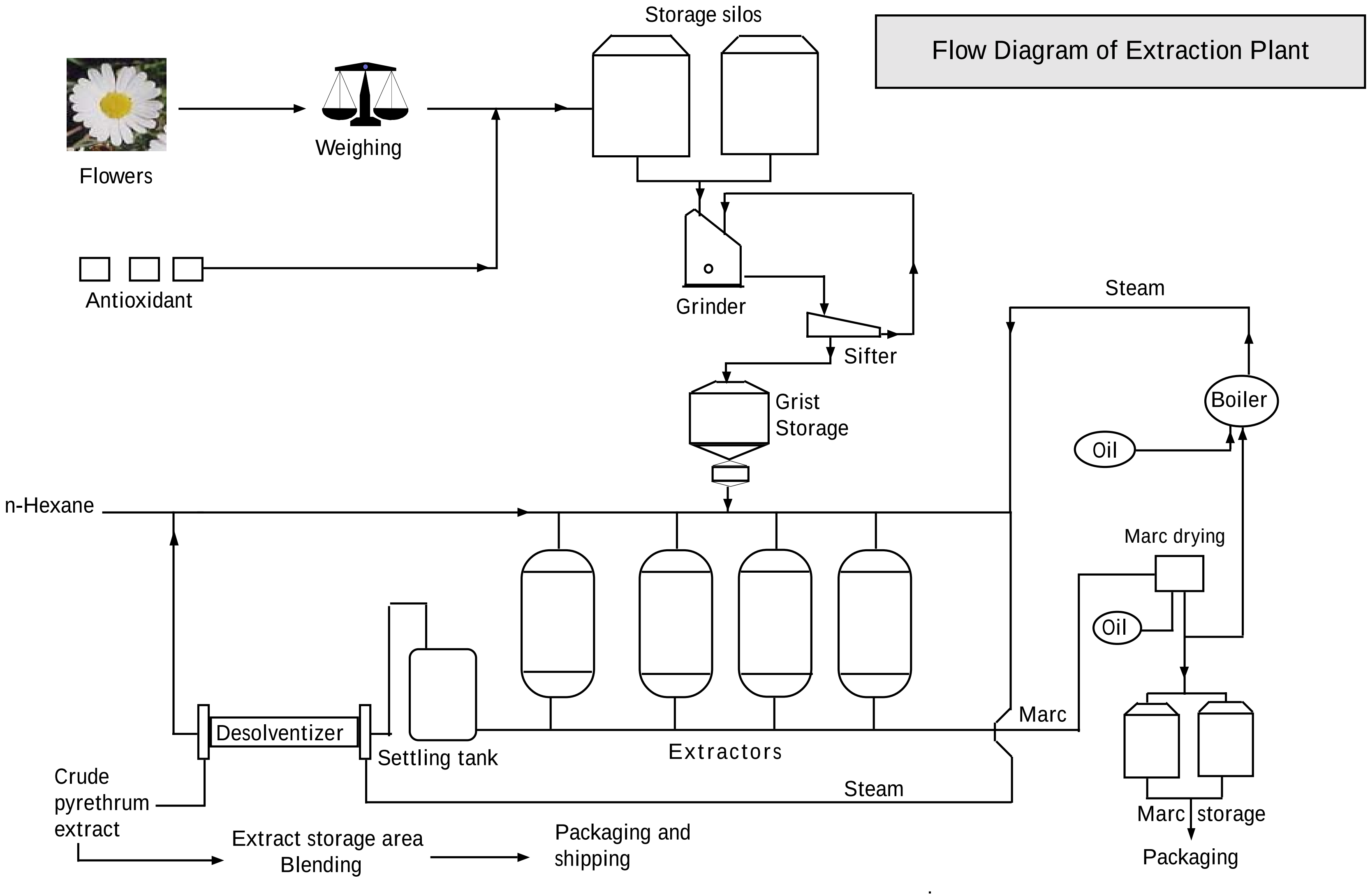
Production of the crude pyrethrum extract and pyrethrum dry marc is shown in the flow diagram of extraction plant. The main unit operations and the various stages of the process are described below.

Detailed Description of Process

Flower Reception and Storage: The raw material for the processing plant is pyrethrum flowers dried to an average moisture content of 10-12 per cent by weight. The active pyrethrins in the dried flowers are expected to be 1.3 per cent. The dry flowers coming to the plant are taken in from the farmers. They are weighed and sampled, and a food-grade antioxidant (butylated hydroxytoluene, 0.4 kg per metric tonne) is added to the dried flowers. The flowers are then pneumatically conveyed to the vertical flower storage silos.

Milling: The milling unit takes in whole flowers from the storage silos and turns out ground flowers in particle size suitable for solvent extraction. The hammer mill is fitted with screens of 2 mm perforations. The grist from this mill is fed to a grist classifier fitted with 500 micron sieves. Grist that passes the sieves is conveyed to a grist storage bin. The oversize is cycled back. The purpose is to produce a grist with maximum possible even size closest to 500 microns. In no case should more than 5 to 10 per cent of the grist pass a 250 micron sieve.

Extraction: The extraction plant consists of pot extractors, tanks, evaporators, pumps, desolventizers, heat exchangers, refrigeration unit and other ancillary equipment for carrying out the solvent extraction of the powdered dried pyrethrum flowers. The grist is charged into extractors. There are ten pot extractors all inter-connected and piped, so that solvent of miscella can be pumped from the bottom of the one to the top of the next or from the bottom of the last,


Flow Diagram of Extraction Plant
Storage silos
Flowers
Weighing
Antioxidant
Grinder
Sifter
Grist
Storage
Steam
Boiler
Oil
n-Hexane
Marc drying
Oil
Desolventizer
Settling tank
Extractors
Marc
Steam
Crude
pyrethrum
extract
Marc storage
Packaging
Extract storage area
Blending
Packaging and
shipping

back to the top of the first. The order of charging with grist and the direction of pumping solvent is such as to allow counter-current percolation with the solvent. In this way, the freshest grist is being extracted with pyrethrins-enriched miscella from the extractor that had been in the extraction process for the longest period. The grist in the outgoing extractor is being washed with fresh solvent.

At any given time, the extraction operation is carried out with six extractors connected in series. The remaining four are in different stages of solvent drainage, de-solventizing, emptying, cleaning and recharging.

As solvent passes through the various extraction vessels containing grist, it becomes progressively rich in pyrethrins and other hexane solubles. At the end it contains approximately 4 per cent of total solubles and is pumped to one of two intermediate settling tanks, where it is allowed to stand for entrained fines or water particles to settle down. This intermediary extract is called 'miscella'.

Evaporation: The clear hexane extract from the settling tanks is transferred to an evaporation system, where solvent stripping takes place in two stages. In the first stage, a falling film evaporator, operating under reduced pressure, removes the bulk of the solvent. In the second stage, last traces of solvent are removed under high vacuum in a thin film evaporator.

Normal hexane vapours leaving the two evaporators are condensed and recirculated in the process. After final solvent removal the concentrated extract is called 'pyrethrum crude extract', and contains approximately 30 per cent of the insecticidal pyrethrins. The product is pumped from the extraction area to a storage and handling building.

Finished Product Handling: The crude extract from the process block is pumped directly into the security tanks from where it is drained into a scale tank for weighing once a day. After weighing, the extract is drained into mixing vessels where it is blended into a homogeneous lot for one batch. Blended extract is packed into lacquered drums and shipped from the factory. Purchasers often refine this extract at their end to produce defatted and decolourized material suitable for use in the manufacture of aerosols and household sprays.

By-Product Handling: After extracting pyrethrins from the grist, the exhausted extractor in the series is disconnected. Solvent is drained from the extractor under gravity and recirculated into the process. The last traces of solvent from the extractor are removed by introducing steam at low pressure from the bottom of the extracting vessel. The steam and solvent vapours are condensed, and water and hexane mixture is passed through a separator. The hexane is returned to the process and water goes to the drain.

After removal of the last traces of solvent from the exhausted grist, the spent material or marc is discharged from the extraction vessel from a bottom manway into a hopper through a chain conveyor. From here the wet marc passes through a pneumatic drying and conveying system to a fluidized bed dryer. The fluidized bed dryer removes the last traces of moisture from the marc which is then fed to the storage silos.

The by-product pyrethrum dry marc is handled in one of two ways, packed in bags and shipped from the factory or used as a fuel for the boiler in the factory. The spent marc contains only traces of pyrethrins (0.05-0.08 per cent weight basis) and about 12 per cent proteins. It is used for making mosquito coils and employed as livestock feed. Other applications include its use as a crop protectant, in control of the maize stock borer and other crop insects, and as a farm manure, especially when it is wet and semi-decomposed.

Plant Efficiency (Pyrethrins Recovery)

In any pyrethrum plant, a high pyrethrins recovery is essential. Pyrethrins recovery is expressed as a percentage and calculated by:

$$\frac{\text{weight of pyrethrins in product}}{\text{weight of pyrethrins in feed}} \times 100$$

Recovery at TPPMCL factory currently lies between 85 to 90 per cent. The plant design guaranteed a minimum recovery of 94 per cent from flowers containing 1.30 per cent or more of pyrethrins.

Plant efficiency increases with increase in pyrethrins content of the feed. It is for this reason that the farmers are encouraged to supply high-quality flowers.

Acknowledgements

We are thankful to ICS-UNIDO for having organized this useful workshop and giving an opportunity to our company to present this paper. We look forward to many such workshops/ seminars organized by ICS-UNIDO in the future.

4.3.2 Industrial Utilization of Pyrethrum in Kenya

by R. K. Shah

Introduction

Man realized the need to control the growth of harmful insects, long before the dawn of civilization. He needed to protect: himself from insects, which apart from being a nuisance, are known to transmit a wide range of diseases affecting man; crops from a wide range of insect pests that feed on them, causing irreversible damage and reducing yields; food stores that are damaged by insects causing substantial loss, a primary concern to man; domestic animals from diseases that are transmitted by insects.

To achieve this, a suitable insecticide was needed with high degree of biological efficacy, low impact on the environment, low danger or risk arising from its use to non-target insect species and animals, and low mammalian toxicity.

The active ingredient used is therefore of primary concern. In this regard, pyrethrum stands head and shoulders above all other available actives in terms of safety and toxicity. It is therefore an ideal choice of manufacturers of insecticides and of end-users of household insecticides.

The insecticide used has also to be appropriately formulated and packaged for ease of use and handling. The types of formulation currently available include aerosols, powders, emulsifiable concentrates, vapour mats and mosquito coils.

Pyrethrum as Raw Material

The following primary products of pyrethrum are available to formulators and manufacturers:

Pyrethrum extract

This is a product of solvent extraction of dried pyrethrum flowers. It is available either as a highly refined concentrate, commonly referred to as pale extract or as a semi-refined concentrate, referred to as oleoresin. Standardized extracts contain 25 or 50 per cent of pyrethrins. The pale extract is used in the manufacture of the following high-value products.

- Aerosols: The East African market alone currently stands at seven million cans per year. Unfortunately, 70 to 80 per cent of these contain synthetic chemicals as active ingredient.
- Emulsifiable concentrates: These include home and garden sprays and pet shampoos. Half of the total pet shampoos used in Europe and America are formulated using pyrethrum, due to its low mammalian toxicity.
- Powders: The pyrethrum extract is impregnated onto a carrier material to produce an insecticidal powder for use against crawling insects. Since these powders are used in dwelling and eating places, the low mammalian toxicity of pyrethrum is a strong desirable advantage.

- ❑ Vapour mats: This is a relatively new concept in terms of its operation, where the active ingredient is impregnated onto a cellulose mat, and then volatilized into the air by use of a vaporizing device that works by heating the mat.

Pyrethrum Powder

This product, also known as mosquito coil powder, is obtained by pulverizing the dried pyrethrum flowers into a fine powder, which is subsequently standardized to a predetermined content of active ingredient. The powder is predominantly used to manufacture mosquito coils, which are perhaps the most widely used domestic insecticidal product in the coastal and lake regions of Africa and South-East Asian countries.

Pyrethrum Marc

This is a by-product left after solvent extraction of the pyrethrum flowers. The product has a very low content of pyrethrins, and is used as filler material in the manufacture of mosquito coils. Pyrethrum marc is also used in the control of storage pests such as weevils, and as cattle feed. It has been found to contain a high level of digestible crude protein.

Marketing of Pyrethrum Products

The local market is centred on mosquito coils since they are readily available, relatively cheap and have proven efficacy in keeping away mosquitoes, the most common pest in this region. Products such as aerosols, vermin powder and vapour mats are predominantly used in middle and upper class homes.

Coil Products (K) Limited, besides supplying the local market, exports mosquito coils to Tanzania, Uganda, Sudan, Zimbabwe, Malawi and even Japan. It is, however, difficult to penetrate the American and European markets, owing to the high cost of obtaining the registration of finished products. Almost all of the pyrethrum extract produced in the region is exported to America and Europe. Their demand actually surpasses our current production levels. The extract is used in formulating products, such as pet shampoos and aerosols, which are very popular owing to the high level of environmental and safety concern in those countries.

The ideal solution for a better local utilization of pyrethrum would be to process the flowers into semi-finished and finished products.

There is a huge influx of imported products into the East African region from all over the world. These products, using synthetic active ingredients, are relatively cheaper than locally manufactured products, owing to the lower costs of production in the source countries.

4.3.3 Marketing of Pyrethrum in Tanzania

by E. J. Materu

Introduction

The pyrethrum plant, *Chrysanthemum cinerariaefolium* Vis., was first introduced to the East African region between the late 1920s and early 1930s. Pioneers of pyrethrum cultivation in Kenya enthusiastically organized growing of the crop and formed the Kenya Pyrethrum Growers Association in the early 1930s. Several legislations were passed ensuring careful inspection, grading and quality maintenance. Licences were issued to planters and the entire organization and marketing was kept under tight control.

In Tanzania, an ordinance was passed by the legislative assembly to create the Tanganyika Pyrethrum Board (TPB) in 1939, which operated on similar lines to the Kenyans. The TPB issued licences to growers, and advised farmers on good crop husbandry through agricultural extension services.

In Kenya and northern Tanzania, pyrethrum was grown largely on estates until the mid 1960s. From the late 1960s small land holders of between 4 to 8 hectares of land started the pyrethrum cultivation. Presently about 20,000 families in Tanzania are involved in pyrethrum cultivation over a total of 3,200 hectares of land.

Until 1998, all pyrethrum activities, starting from the supply of seeds and seedlings to the farmers, procurement of dried pyrethrum flowers, processing and marketing of its products were undertaken by the TPB. With the advent of privatization of the parastatals in Tanzania, the commercial activities of the board were diversified and are now in the hands of a private firm. The TPB is now left only with regulatory functions.

World Production of Pyrethrum and Prices for Pyrethrum Products

World production of pyrethrum is normally measured in metric tonnes of dried flowers and pyrethrins content. The pyrethrins content varies from 0.8 to over 2.0 per cent. Table 1 lists the amounts produced in the leading growing countries in the late 60s and early 70s. At present, the world's leading producers are Kenya, Tanzania, Tasmania in Australia and Rwanda. Smaller amounts are produced in Papua New Guinea, Ecuador and India. Uganda is also joining the club.

Most of these countries export over 80 per cent of their produce, largely in the form of crude extract. At present, only Kenya and Rwanda have refineries where they can produce refined pyrethrum extract, a high value product. Apart from the export of crude pyrethrum extract and the refined product suitable for direct inclusion in aerosols, most of the producer countries also export ground flowers for the world's mosquito coil market.

World production in 1967-68 was approximately 2,500 metric tonnes in excess of demand. During this period, the existence of unsold stock coupled with the considerable publicity on the development of synthetic pyrethroids led to a general decline in the world production during the following 3-4 years. History shows that there is a general 10-year cycle in pyrethrum peak and low seasons.

Table 1: Comparative pyrethrum production (metric tonnes) in different countries during the period 1967-68 to 1971-72

Country	Production (MT)				
	1967-68	1968-69	1969-70	1970-71	1971-72
Kenya	11,059	7,300	5,909	9,747	14,400
Tanzania	5,102	4,757	2,416	2,665	4,300
Ecuador	1,609	1,744	1,457	1,241	1,100
Japan	950	838	700	600	380
Rwanda	120	200	640	800	1,000
Others	700	620	600	580	600
TOTAL	19,540	15,459	11,722	15,633	21,780

The United States of America (USA) is the largest importer of pyrethrum products. Very strict regulations on importation are in force in that country. With stronger action by the US government against persistent insecticides that were alleged to pollute the environment and which were categorically harmful to humans and mammals, the US Environmental Protection Agency (EPA) issued a mandate for all stakeholders in the industry to obtain clearance from the EPA before any product was imported into the USA. The exporter can obtain the authorization from the EPA once the analysis of the solvents used in the extraction process are certified. The analyses are carried out in various scientific and research stations in the USA. The cost of carrying out these analyses is borne by the merchants.

Currently, the annual world demand for pyrethrum stands at 20,000 metric tonnes of dried pyrethrum flowers. The targeted production of world demand has not been achieved. Shifting trends to organic and natural insecticides predict that the world demand is bound to increase.

As shown in Table 2, Tanzanian production figures show an irreversible downward trend from the mid 1970s to the present date except for a short period in 1991-92 and 1992-93. There are a number of factors that affected production in Tanzania. In the mid 1970s, the villagization programme initiated in Tanzania, whereby whole populations were moved to live in new collectivized areas, affected production especially in the Southern Highland of the country. Urban migration and low prices paid to farmers also contributed to the low production. Many countries switched to synthetic pyrethroids, which were cheaper to produce than natural pyrethrins.

Historically, extremes of climate in East Africa also had a bearing on agricultural production. In Tanzania there is a serious drought approximately every 10 years, and a less serious one every 3 to 5 years. Although in the pyrethrum growing highlands drought may not be an important factor, cultivation of food crops will be more attractive in view of the ready market and higher prices offered during the drought period.

During the 1960s the price of dried flowers was TZS 1.10 per kilogram, which increased to TZS 5.40 in the 1970s, TZS 12.00 to 29.00 in the 1980s, and to the present price of TZS 350.

The production in Tanzania for the years 1996 to 1999 (Table 2) are frighteningly low, to say the least. Apart from the El Nino phenomenon, which devastated many areas of agricultural production, cold weather persisted in the northern hemisphere for a longer period even during the summer, inhibiting the breeding of insects, which resulted in very little sales in those areas. At the same time, the TPB was under deprivation by the government. Regular publicity of the exercise frightened the farmers as they were not sure where they would sell their crop. We are hopefully making a new turn now.

Table 2: Region-wise pyrethrum production (metric tonnes) in Tanzania during the period 1972-73 to 1999-2000

Year	Production (MT)			
	Southern Zone		Northern Zone	TOTAL
	Iringa	Mbeya	Arusha,Kilimanjaro	
1972-73	2,364	1,291	361	4,016
1973-74	1,904	951	425	3,280
1974-75	2,244	2,060	437	4,741
1975-76	2,130	1,130	506	3,766
1976-77	1,918	1,029	388	3,335
1977-78	1,730	643	173	2,546
1978-79	1,125	430	78	1,603
1979-80	962	637	25	1,624
1980-81	1,213	430	59	1,702
1981-82	1,108	722	69	1,899
1982-83	1,234	535	32	1,601
1983-84	950	469	20	1,439
1984-85	981	580	21	1,582
1985-86	848	491	12	1,351
1986-87	706	513	12	1,231
1987-88	804	599	5	1,408
1988-89	744	559	8	1,311
1989-90	799	782	8	1,589
1990-91	671	1,017	17	1,705
1991-92	914	1,598	43	2,555
1992-93	700	1,741	69	2,500
1993-94	45	424	41	500
1994-95	124	436	40	600
1995-96	250	355	5	610
1996-97	300	288	15	600
1997-98	-	-	-	480[1]
1998-99	-	-	-	600[2]*
1999-2000	-	-	-	1,000*

*Estimates
[1] Actual quantity collected at the factory in 1997-98 was 137.46 metric tonnes
[2*] Actual quantity collected for 1998-99 season was 317.08 metric tonnes

Production and Prices of Pyrethrum Products in Tanzania

Until the 1970s, the bulk of pyrethrum production in Tanzania was carried out in the Northern Highlands of the Arusha and Kilimanjaro regions. The other pyrethrum-producing regions were Iringa and Mbeya in the Southern Highlands of Tanzania. A processing factory was built in

Arusha and commissioned in 1960. This private limited company, the Tanganyika Extract Company Limited (TECO), processed pyrethrum flowers to produce crude extract. The factory had an installed capacity of processing 6,000 metric tonnes of dried pyrethrum flowers per annum. A separate milling plant was also built to grind dried pyrethrum flowers into pyrethrum powder for the mosquito coil market.

Prior to 1960, all pyrethrum flowers produced in Tanzania used to be exported to Kenya. The procurement of dry pyrethrum flowers was organized through the co-operative unions. The TECO had representatives working with the unions to undertake procurement of flowers and transportation of flowers to the factory in Arusha. This was the arrangement until 1974, when the factory was nationalized. From 1976 the TPB took over all procurement activities and marketing of the pyrethrum products at the Arusha factory. Concurrently, a new factory was built in the Southern Highlands of Tanzania at Mafinga in the Iringa region. The factory was commissioned in 1982. This factory with planned capacity to process 4,500 metric tonnes of dried pyrethrum flowers was conceived in the mid 1970s to co-operate with the Arusha factory, in view of the anticipated increase in production. It was envisaged that the production would reach approximately 14,000 metric tonnes by the mid 1980s. As it turned out, the production slackened instead of going up. With the advent of low prices paid to the farmers and the farmers not being paid on the spot, they shifted to alternative crops, mainly Irish potatoes, which fetched better prices and were less laborious to grow.

In Tanzania, all flowers are procured dry and are collected in jute gunny bags of 30 kg and transported to the factory. The individual farmer is registered with a licence number. This is done because the second payment to the farmer is made on the basis of the pyrethrins content in the flowers. Recycling of the gunny bags is also usually undertaken and these are sent back to the co-operative unions for re-use. Payment to farmers is provided on the spot, at the collection centres. This payment is regarded as the first instalment to the farmer. Once the flowers are received at the factory and the analyses carried out to determine pyrethrins content in the flowers, which in turn is also verified by the importer, the second instalment of payment is made to the farmer, calculated on the basis of pyrethrins content. Table 3 shows the prices offered to farmers for different grades. Table 4 shows the sale figures of pyrethrum product from 1981 and 1999. Table 5 illustrates characteristics of products produced and marketed by TPB.

Approximately 98 per cent of the pyrethrum extract concentrate is exported to the USA in steel drums containing 100, 50 or 25 kg of net extract. The lack of facilities to refine crude pyrethrum extract in Tanzania denies the country's access to wider market of refined products. On the other hand, Kenya and Rwanda earn profit from the sale of high value product. The pyrethrum extract standard 25 per cent w/w is a concentrate material diluted in kerosene and marketed locally in small quantities for application in farm sprays by ultra low volumes (ULV) techniques. Superfine pyrethrum powder is exported to Japan and the Far East. A substantial volume is also sold locally to the mosquito coil industries. Dry pyrethrum marc is also exported, but a larger portion is marketed locally mainly to ranches. An appropriate mixture of dry marc and maize bran has proven to be a good cattle feed. The small pyrethrins residue contained in the dry marc helps in deworming the cattle. It is also apparent that a good number of farmers in the vicinity of the pyrethrum factory use the marc to fight the stalk borer in maize.

Table 3: Price structure for the purchase of dried pyrethrum flowers for selected years/seasons in Tanzania

Year	Price of dried pyrethrum flowers (TZS/kg)				
	Grade I (>1.40% pyrethrins)	Grade II (1.30-1.39% pyrethrins)	Grade III (1.20-1.29% pyrethrins)	Grade IV (1.00-1.19% pyrethrins)	Grade V (<1.10% pyrethrins)
1983-84	18.50	16.80	15.40	14.50	12.60
1984-85	29.29	23.50	21.60	19.60	17.60
1986-87	43.30	29.40	36.20	32.80	29.50
1996-97	-	-	-	-	300.00
1999-2000	-	-	-	-	350.00

Table 4: Sales performance of pyrethrum crude extract and dry marc from TPB during the period 1981-82 to 1998-99

Year	Crude Extract (MT)	Dry Marc (MT)
1981-82	3,395.44	102.83
1982-83	44,701.47	1,101.48
1983-84	31,909.50	1,151.29
1984-85	45.22	1,151.29
1985-86	33.25	833.84
1986-87	38.92	972.28
1987-88	44.64	1,020.28
1988-89	39.98	974.24
1989-90	48.80	785.70
1990-91	48.65	505.92
1991-92	58.19	465.56
1992-93	38.34	438.73
1993-94	26.01	308.92
1994-95	24.61	152.52
1995-96	16.23	1.68
1996-97	4.25	-
1997-98	3.81	-
1998-99	12.80	-
TOTAL	563.70	9,966.56

As mentioned above, the USA is the largest user of pyrethrum products. Because of the chemical nature of the product, the merchants, i.e. the exporter to the USA and the importer in the USA, are required by law to conform to certain regulations, in order to sell pyrethrum products on the US market. The EPA has proposed a labelling requirement for all pyrethrum products entering the US market. This was initiated as a measure to safeguard the consumer from using chemicals that are harmful to humans and domesticated animals. The Chemical Specialities Manufacturers Association (CSMA) in the USA and other key players in the pyrethrum industry have formed a task force that gives the necessary data on pyrethrum to the EPA. At present the fee contributed by each key players ranges from a high of US$ 100,000 to 38,000 per annum.

Table 5: Characteristics of pyrethrum products produced and marketed by TPB

	PYRETHRUM PRODUCT				
	Afrisect Pyrethrum Extract or Concentrate	*Afrisect Pyrethrum Extract: Standard 25 % w/w Pyrethrins*	*Afrisect Superfine Pyrethrum Powder: 1.30 or 0.60 %*	*Pyrethrum Dried Marc*	*Pyrethrum Marc Powder*
PHYSICAL CHARACTERISTICS					
Appearance	Viscous liquid with minute clear emulsifiable bubbles	Mobile liquid with spherical bubbles	Powder	Coarse powder	Powder
Color	Dark brown	Dark brown	Bright yellow to pale brown	Dark brown with yellow tinge	Yellow to dark brown
Odor	Aromatic and little pungent	Aromatic and very little pungent	Chocking	Sweet smelling	Sweet smelling
Specific gravity (at 25.2°C)	0.975 (approximately)	0.030 (approximately)	-	-	-
Flash point	Above 100 °F (avarage 110.38 °F)	Above 100 °F	-	-	-
Solubility:					
Kerosene	Soluble (bright-yellow solution)	Soluble (bright-yellow solution)	-	-	-
Water	Sparingly soluble forms emulsion	Sparingly soluble forms emulsion	-	-	-
Organic solvents & oils	Very soluble (bright-yellow solution)	Very soluble (bright-yellow solution)	Insoluble but organic components extracted to give pale yellow extract	-	-
Freon Insolubles	Traces	Traces	-	-	-
Volatility	Less than 3% on avarage	Less than 3%	-	-	-
Moisture Content	-	Less than 0.1%	Less than 6%	Less than 5%	Less than 5%
Particle Size	-	-	100 or 200 BS Mesh	Approximately 1/16 inch	100 or 200 BS Mesh
CHEMICAL CHARACTERISTICS					
Total Pyrethrins	28-32% w/w	24.5-25.5% w/w	-	0.06-0.08% w/w	0.06% w/w
Acidity	Mildly acidic, pH 5.5-5.8	Mildly acidic, pH 5.5-5.8	-	-	-
Other components (fatty acids, carotenoids, chlorophylls and alkanes, etc.)	Very small quantities	Traces	-	-	-
APPLICATION					
	After refining product is used against wide range of flying insects and other household pests, e.g. flies, cockroaches, bugs, fleas, etc.	Farm sprays as crop protectants	Pest control (e.g. bugs, fleas, etc.) crop insecticide and manufacture of mosquito coils	Manufacture of mosquito coils, cattle feed ingredients (13% protein content) and farm manure, especially when wet	Manufacture of mosquito coils as diluant for pyrethrum powder

The task force at present has the following members:

- ❑ Aventis: Environmental Science USA/Europe;
- ❑ Botanical Resources Australia, Tasmania, Australia;
- ❑ S.C. Johnson & Sons Incorporated, Racine, Wisconsin, USA;
- ❑ McLanghlin Gormley King Company, Minneapolis, USA;
- ❑ OPYRWA, Rwanda;
- ❑ Prentiss Incorporated, New York, USA;
- ❑ Pyrethrum Board of Kenya, Nakuru, Kenya;
- ❑ Tanzania Pyrethrum Board/Tanzania Pyrethrum Processing & Marketing Company, Tanzania.

Pyrethrum products are marketed through negotiations between the buyer and seller. The pyrethrum producers in East Africa have formed a club called RWATAKE (Rwanda, Tanzania and Kenya) and meet regularly to exchange notes on production in member countries, prices to be paid to the farmers and general market situation. RWATAKE also follows the developments in the area of synthetic pyrethroids and other botanical products that could compete with pyrethrum. It can be noted that at the moment, research on neem products obtained from the tree *Azadirachta indica* A. Juss., which have a knockdown effect on insects is gaining momentum and can add pressure on pyrethrum.

These and other relevant topics are discussed at the RWATAKE meetings. The two producers, Kenya and Rwanda, have an edge over Tanzania as they have the refineries that assure benefit from a wider world market of refined products. The efforts of Tanzania to establish a refinery began in the late 1970s, but it was never realized owing to lack of funds.

In Tanzania, the only known formulator and producer of pyrethrum-based aerosol is a private company, Mansoor Daya Chemical Limited (MDCL), based in Dar es Salaam. Because of the lack of refined pyrethrum material in Tanzania, MDCL buys crude pyrethrum extract in Tanzania and exports it to the refineries in Kenya or the United Kingdom. The refined material, ready for formulation, is re-imported. Two more private companies are involved in the manufacture of pyrethrum-based mosquito-coils in Tanzania: Dawa ya Mbu Limited, based in Dar es Salaam, still in the pyrethrum business, and Africa Flowers Industries in Moshi, which stopped manufacturing in the early 1990s.

Pyrethrum and the Environment - The Tanzanian Experience

Pesticides are heavily used in the agricultural sector in Tanzania, including animal health for control of ticks and flies. A small percentage is used in public health programmes, including mosquito control to curb the spread of malaria and control of flies to improve sanitation. The main categories of pesticides used in Tanzania are insecticides, fungicides and herbicides. Insecticides are used widely in farm agricultural production. Several of the pesticides currently in use in the country are banned or severely restricted in many other countries of the world.

In 1993, the Journalist Environmental Association of Tanzania (JET), with the assistance of Swiss Aid Tanzania, commissioned the Department of Chemistry at the University of Dar es

Salaam to examine the extent of DDT and other hazardous pesticides in use in the country. The JET discovered that accessing information on pesticides, particularly regarding their importation, distribution and use in Tanzania is extremely difficult. However, research revealed without doubt that DDT is being imported, formulated and distributed for sale and use to farmers throughout Tanzania. This is despite the fact that DDT was declared a restricted substance in Tanzania in 1990. A two-year grace period was granted to dispose of surplus stock before it was finally banned in 1993.

Farmers are unaware of the long-term environmental hazards of DDT, not to mention the dangers of not wearing protective gear while applying pesticides. There is a need to publicise the safer alternatives to DDT by offering special education programmes to the users. All available information on pyrethrum shows that it has no associated health hazards. It does not depress cholinesterase, or induce other harmful actions in mammals. It degrades rapidly in the environment and leaves no residual effect.

Marketing Contraints of Pyrethrum Products

The following may be cited as constraints in the marketing of pyrethrum products:

- ❑ Stringent requirement of the EPA and high fees payable to support the analyses cost to obtain clearance for export to the USA.
- ❑ The lack of refining facilities and the lack of consumers of refined products in Tanzania. Only one company formulates refined products into aerosols in the country.
- ❑ Although a member of RWATAKE, Tanzania contributes very little to *Pyrethrum Post*, a scientific and research magazine published quarterly.

A change in the policy of Tanzanian Government on investments in the country and the fact that commercial activities regarding pyrethrum are now privatized should mean that this is an opportune time not only to expand cultivation of pyrethrum, but also to invite investors to invest in a refinery and aerosol manufacturing industries. Researchers could also take the opportunity, following the expanded market, to research in the use of pyrethrum marc for controlling the stalk borer in maize, an application already exhibited by the farmers in the factory area.

Pyrethrum extract is a natural product derived from Chrysanthemum flowers and has been used safely and effectively as an insecticide for centuries. Tanzania is endowed with vast arable land where pyrethrum can flourish. With the prevailing economic climate and a good governance, there is a very good possibility for Tanzania and the East African region in general to abandon the use of dangerous insecticides in favour of safer natural chemicals.

4.3.4 New Opportunities for Natural Pyrethrum Products in Europe

by V. de Rinaldini

The insecticidal properties of pyrethrum have been known for centuries. Commercial use of pyrethrum powder dates back to the middle of the 19th century. In 1919 the oily extract of pyrethrum began to be used in the production of insecticides. Products derived from extracts, as opposed to the powder form, began to be accepted during the 1920s, and their use increased rapidly up until World War II. Towards the end of the 1940s, the worldwide scene changed. The demand for insecticides, for both agricultural as well as domestic and industrial use, increased enormously, but at the same time competitive synthetic products started appearing on the market. First of all was DDT, used extensively for agricultural and mass external use. Then organophosphorus, paradichlorobenzene, gamma benzene hexachloride, and the synthetic pyrethroids appeared on the scene. The two phenomena had reciprocal effects. The wide availability and low cost of the synthetic products satisfied the growing demand and this, in turn, meant that larger and larger sectors were involved and the number of ways in which it could be used increased.

Pyrethrum, which in any case could never have satisfied the demand of the time, did not seem to suffer from this situation. Demand stayed at a good level and production was still able to increase. In fact, it was at this point that the slowing down phase began. Market shares of pyrethrum decreased. Agricultural use disappeared altogether.

As far as domestic use was concerned, the increase was almost exclusively due to industrial products. There were more profits for the manufacturers of the active principles, it was easier to find, and cheaper to buy for the end users. The crisis, which hit the production of East Africa towards the end of the 1990s, could have been the last chapter in the story, but now many more opportunities are coming into view, as we shall see.

The story of pyrethrum seems to follow the path, albeit over a longer time span, of the marketing life of any product: the initial stage of its creation, the development phase - first rapid then slowing down, the maturity phase and then its decline. In fact, while on one hand the crisis develops, on other hand new opportunities appear. If appropriate advantage is taken and correctly interpreted by the producers, this can lead to a new phase of growth.

The present opportunities come from appreciation of the fact that pyrethrum is a natural product; this characteristic means that its derivatives cannot be compared with those containing synthetic products, although they have similar properties. This confers a special status to pyrethrum. In fact, more opportunities have come from a renewed and growing demand for natural products throughout the world, which varies only in degree at different locations.

The demand is more intense in the industrialized countries where public opinion is more sensitive to solutions for environment and health care. The comparison of risks, which result from indiscriminate use of synthetic chemicals, weighs heavily in favour of safer natural counterparts. In practical terms, what interest us, is the origin and development of this tendency. It is important because we are now dealing with markets with higher purchasing power that can generate, in a short time, a sizeable demand.

A rapid exploration of the opportunities appearing on the horizon for pyrethrum in Europe (and else where also) lead us to examine three sectors:

- ❑ Products for biological agriculture;
- ❑ Products of natural origin for domestic use;
- ❑ Some special products.

Products for Biological Agriculture

This sector is particularly important because it has been coded and regulated in a precise manner by the European Union with the introduction of applicable norms in all the member states, and it is rapidly increasing. In 1991, the Council of the European Community, in consideration of the fact that consumers are increasingly demanding for agricultural products and food stuffs grown biologically and that this phenomena is creating a new market for agricultural products, adopted a regulation number 2092/91. The regulation deals with the biological production methods of agricultural products, and establishes all the norms that must be respected, in order to claim an agricultural product or a product destined for human consumption, consisting of one or more vegetable ingredients, produced with biological production methods. In particular, it establishes that in biological production methods only those products made up of substances listed in an attachment to the decree can be used as phytosanitary products, detergents, fertilizers, etc. The section of this attachment dedicated to phytosanitary products, listed as insecticides, exclusively admits:

- ❑ Azadirachtin extracted from *Azadirachta indica* A. Juss (neem tree);
- ❑ Extract (aqueous solution) of *Nicotina tabacum* L.;
- ❑ Vegetable oils;
- ❑ Pyrethrins extracted from *Chrysanthemum cinerariaefolium* Vis.,
- ❑ Quassia extract from *Quassia amara* L.;
- ❑ Rotenone extracted from *Derris, Lonchocarpus* and *Thephrosia* species;
- ❑ Gelatin.

Only pyrethrins, quassia and vegetable oils are without restrictions.

Decree 2092/91 includes vegetable products and foodstuff, which consist of one or more vegetable ingredients. This means that it is applicable not only to fruit and vegetables as such, but also to their products, such as flour, bread, pasta, baked products, wine and jams. In this case, to claim them as biologically produced, they must use exclusively ingredients that have also been produced biologically.

Pyrethrum therefore becomes an important insecticide because its use is allowed in the cultivation of fruit and vegetables, which are consumed directly, as well as in the production of fruit juices, jams, wine; in the conservation of cereals to be used for the manufacture of bread, pasta, bakery items and products of similar nature.

In 1999, the Council of the European Union adopted a new regulation (No. 1804) which completed the preceding regulation 2092/91 and extended the norms on biological production methods to animals, non-transformed animal products, transformed agricultural animal products destined for human consumption consisting of ingredients of animal origin, animal feed, mixed animal feed and the raw materials for animals foodstuffs.

The attachment of phytosanitary products admitted has been confirmed, increasing the scope to use pyrethrum. It is one of the very few products that can be used in the production of the raw materials for animal foodstuffs or for products used directly as animal feed in raising animals for meat production. A further opportunity for pyrethrum arises from the same decree, where it establishes that products cited in the same attachment can only be used for the elimination of insects and parasites on the premises and the equipment.

The European Union regulations citation has been incorporated into national legislations by individual member states. They had also to indicate which of their own national organizations are responsible for checking compliance to the norms of biological production methods.

These norms have also been adopted by some countries which are not part of the European Union, such as Argentina, Australia, Czech Republic, Hungary, Israel and Switzerland for products they wish to export to countries of the European Union under the label of biological product.

Products of Natural Origin for Domestic Use

In the past, the increase in demand for insecticides for domestic use has almost exclusively been covered by products made from synthetic principles. These have partially replaced products made from natural pyrethrum extract. The manufacturers of these products have given preference to the use of synthetic insecticides, expecially when they were making the raw materials. This was also the case when they were the only purchasers and end-users. It is easier and cheaper to buy, synthetic pyrethroids, for example, from a big chemical company than to buy an extract of pyrethrum at its original source or from an importer. Normally, the synthetic product is available immediately and in any quantity, the product characteristics are constant, and, in recent years, it was also cheaper.

It is therefore natural that manufacturers of insecticide coils, sprays and powders for domestic use preferred synthetic materials. However, market demand has started to turn against this tendency not only because of the wish to rediscover everything 'natural', but there is a definite demand for insecticides made from natural active ingredients. It has been seen that some manufacturers, especially those who have good market share for their synthetic products, were consequently obliged to offer a similar 'green' line of products made from natural extracts.

If we look at our own sector in the market, we can find products from the same manufacturer, under the same brand name and packaging but in different colour and price. As regards insecticide sprays, these can be found made from synthetic pyrethroids and a 'green' spray made from natural pyrethrum extract. The same is true for coils (normally red or yellow), made from synthetic pyrethroids and from natural pyrethrum (green), and many more such products.

It is admittedly a restricted market that cannot be compared with the vast market for synthetics. But in its own way, it is significant because it demonstrates that there is a spontaneous demand for natural products with great growth potential.

The main obstacle for its development is probably the limited availability and high cost of natural pyrethrum.

Special Products

Amongst the opportunities for pyrethrum, some special products deserve mention. Although the quantum of their demand is low, they are of interest because they meet the demand of special and exacting end-users, e.g. insecticides in the form of shampoo or fine powders for pets, products for the treatment of indoor plants, insecticides used in trailers for race horses, perfumed moth-killer pads and so on. There may not be a real necessity to use natural products but this is what the consumer wants. They want to feel safer when using such products in their houses from a health point of view.

At present there is only limited demand for these products, but they deserve our attention because they recognize the fact that pyrethrum possesses a reliable safety property and this is what some end-users are looking for. These clients are likely to be faithful and often have high spending power.

Conclusions

New opportunities are presenting themselves for pyrethrum-based products. The market calls for natural products, as well as those produced in a natural way using biological methods. Demand for these products is growing. Pyrethrum is a natural product and its use is allowed in animal and vegetable production under biological production methods. The image of pyrethrum has therefore been elevated. It used to be a product with insecticidal properties subject to competition from any other product with the same characteristics, but now it is looked upon as an insecticide that cannot be compared with products of synthetic origin even if, at the end of the day, they have the same function.

Therefore, new opportunities that offer a large growth potential for pyrethrum have arisen. However, they must be nurtured and at the moment this is a difficult task, considering the irregular availability of pyrethrum and its price instability.

A positive response from the producers to this stimulus, which derives from a growing market demand, must be regarded as a priority for the future.

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