

# PYRETHRUM RESEARCH: A REVIEW OF PAST ACHIEVEMENTS AND CONSTRAINTS TO PRODUCTION IN THE SOUTHERN HIGHLANDS OF TANZANIA

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## ABSTRACT

*The overall trend in pyrethrum production in Tanzania has been poor for the past 30 years. The reasons are simple. Farmers big and small have found the enterprise uneconomic, and consequently have shifted their resources and management skills elsewhere. To reverse this negative trend, it is strongly recommended that emphasis should be given to improving agronomic and management factors. If these improvements were made, total production could be doubled within three years, without the cost being too much to bear even for resource-poor smallholders. The breeding of improved cultivars of pyrethrum is important even if it is costly and time consuming, because there are long term tangible benefits for smallholder farmers. Yet plant breeding has only a limited contribution to make to the total extracted pyrethrin.*

## INTRODUCTION

Pyrethrum (*Chrysanthemum cinerariifolium*) is a tropical perennial cross-pollinated plant belonging to the Composite family. The pyrethrin extracted from its flowers are valued for their insecticidal properties, especially since they are harmless to people and warm-blooded animals and do not accumulate in the environment. The plant has been grown in the Southern Highlands of Tanzania as a cash crop since 1931 (McGregor, 1940). To day it is among the top ten export crops in the country, bringing in an average of TSh 30 to 50 million annually in foreign exchange. Production trends over the last 27 years are shown in Table 1.

The crop is all grown by smallholder farmers in the Southern Highlands. About 20,000 farmers cultivate a total area of about 8,000 hectares (TPB, 1989). The majority of these farmers have one-quarter of a hectare or less under pyrethrum and produce comparatively poor flower yields. The fact that the crop is perennial, with flower pickings at two week intervals makes the crop attractive to small scale farmers in terms of providing a steady monthly income.

In general the crop does well above 2000 m in fertile well-drained soils where the annual rainfall is 900 mm. Water-stress is one of the most critical factors in pyrethrum production. Equally important is the fact that the flowers must be picked at the correct stage of maturity and dried quickly at the correct temperature to a moisture level of less than 10% to avoid losses of pyrethrin. The flowers should be transported as soon as possible to a factory. There the flowers are ground to a fine power and the pyrethrin extracted by chemical means to produce a crude extract which is subsequently marketed.

Uyole Agricultural Centre (UAC) is the only institution in the country which does pyrethrum research. This paper reviews past research achievements, describes farmers' production practices, mentions constraints to the adoption of improved technology, and indicates priorities and future strategies for increased production.

Table 1. Yields of dry flowers for extractable pyrethrins in Tanzania from 1965/66-1991/92

	Iringa	Mbeya	Northern zone	Total
1965/66	2 163	1 063	961	4 160
1966/67	2 236	1 756	1 023	6 015
1967/68	2 864	1 338	1 014	5 216
1968/69	2 747	1 387	708	4 842
1969/70	1 279	764	373	2 416
1970/71	1 484	960	288	2 731
1971/72	2 333	1 505	438	4 271
1972/73	2 364	1 291	361	4 016
1973/74	1 904	951	425	3 282
1974/75	2 244	2 060	437	4 741
1975/76	2 130	1 130	506	3 946
1976/77	1 918	1 029	388	3 335
1977/78	1 730	643	173	2 547
1978/79	1 125	430	48	1 603
1979/80	962	637	25	1 624
1980/81	1 213	730	59	2 002
1981/82	1 108	722	69	1 899
1982/83	1 034	535	32	1 601
1983/84	950	469	20	1 439
1984/85	891	581	21	1 532
1985/86	848	491	12	1 351
1986/87	706	513	12	1 231
1987/88	804	499	5	1 408
1988/89	744	559	8	1 311
1989/90	799	782	8	1 589
1990/91	700	1 000	10	1 710
1991/92	1 000	1 200	25	2 225

## RESEARCH REVIEW

The total yield of extractable pyrethrin from one hectare is a product of the fresh flower yield (number and size of fresh flowers), the dry matter content of the flowers and the pyrethrin content of the dry flowers.

Any factor that affects any of these three parameters will have an effect on the total yield of pyrethrin. The main factors that influence final yield are the structure and fertility of the soil, the rainfall amount and distribution, the temperature, and the quality of the cultivars being grown. Research on pyrethrum over the past 15 years has given considerable attention to these four factors, to establish their effects and relation to total pyrethrin yield.

## Breeding

Pyrethrum can be raised either from vegetatively propagated clones split from the parent plant or from seeds obtained from mature flowers and sown in nurseries.

**Clone selection.** A large number of clones have been selected, tested and evaluated in several agro-ecological zones over a number of years for various desirable characteristics. The most recently recommended clonal selections that have been released to the Tanzania Pyrethrum Board (TPB) for multiplication and distribution to farmers are shown in Table 2. Clones 60.70 and 65.166 are suitable for high and medium altitude zones and were handed over to TPB in 1985, clone 65.194 yields better than these two clones at relatively low altitude. The yields of other promising clones that could be recommended are shown in Table 3.

Table 2. Characteristics of three recommended clones from Uyole, 60.70, 65.166 and 65.194 (values are means of five years' data from four sites ranging in altitude from 1800 to 2400 m above sea level)

	60.70	65.166	65.194
Yield (kg ha <sup>-1</sup> )	15 000-4 000	1 800-5 000	2 000-5 000
Pyrethrin content (%)	1.47-1.75	1.35-1.60	1.30-1.50
Single flower weight (mg)	73	76	89
'Blindness' (%)	30	25	10
Lodging (scored 1 min. to 5 max.)	2	1	2
Bud diseases (scored 1 min. to 5 max.)	2	2	2
Rosette size (scored 1 min. to 5 max.)	3	3	2
Frost tolerance (scored 1 min. to 5 max.)	4	4	4
Plant survival rate (%)	90	80	90
Height at flowering (cm)	55	65	60
Dry matter content (%)	22.1	22.0	22.7
Ratio pyrethrins I: pyrethrins II	-	1.17-1.48	-

Table 3. Yields of selected pyrethrum clones at Kinyika (2600 m) and Igeri (2400 m)

	Yield (kg ha <sup>-1</sup> )
79/78	6205
78/94	5850
82/3	3470
82/11	2377
65/166	2247
59/347	1153

Research at UAC has shown that:

- clonal differences in any one environment are not particularly large, indicating a fairly high degree of adaptation;
- first year yields always tend to be low because of poor planting management and timing;
- selection for flower yield must be accompanied by selection for pyrethrin content since there is an inverse correlation between these two factors;
- moisture stress at any time decreases flower yield;
- optimal field management techniques have a considerable beneficial effect on flower yield, but little effect on the content of dry matter or toxins;
- the higher the altitude the higher the pyrethrin content because of lower temperatures. The correlation equation is close to  $Py = k - bx$ , where  $Py$  is pyrethrin content,  $k$  and  $b$  are constants (1.503 and - 0.035, respectively) and  $x$  is the temperature. An increase in altitude of 500 m could increase pyrethrin content by nearly 30% regardless of genotype (Parlevliet, 1970);
- flower weight is positively affected by altitude;
- over-drying of the flowers results in losses of pyrethrin of up to 20%;
- pyrethrin content can vary considerably within the same clonal material over one season.

**Hybridization.** Two years ago a small hybridization programme was initiated using four superior clones from the selection programme. Some characteristics of the two crosses are shown in Table 4. Most correlation coefficients between progeny characters were negative. Progenies in both populations were uniform and similar in agronomic characteristics. Most of the progeny had a pyrethrin content below that of the parents. Only four plants had a pyrethrin content above 2%. Flower yield was not evaluated. The crossing of clones produced plants with wide variation in the toxin content. There seemed to be a negative correlation between vigour and pyrethrin content. Poly-crossing might prove better.

Table 4: Evaluation of some characters of progeny lines arising out of two pyrethrum crosses.

Crosses	Flower starts	Lateral shoots stalk <sup>-1</sup>	Height (cm)	Lodging (scale 0 min., 5 max.)	100 flowers weight (g)	Max. pyrethrin 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

### Fertilizer trials

The results of fertilizer trials at two locations are shown in Table 5. The following are the main conclusions to date.

**Table 5.** Effects of phosphorus and nitrogen on pyrethrum flower yields (kg ha<sup>-1</sup>) at two sites

	Uyole	Igeri
Control (no fertilizer)	3910	2489
20 kg P ha <sup>-1</sup>	4330	2594
40 kg P ha <sup>-1</sup>	3496	2064
75 kg N ha <sup>-1</sup>	3440	2648
20 kg P ha <sup>-1</sup> + 75 kg N ha <sup>-1</sup>	3192	1618
40 kg P ha <sup>-1</sup> + 75 kg N ha <sup>-1</sup>	3957	2120
LSD (P<0.05)	264	NS

NS, not significant.

- The use of phosphate in pyrethrum production is essential if flower production is to be sustained. Yield increases of between 20 and 40% were observed when phosphate was applied.
- A residual effect was noted in the season following phosphate application but not subsequently.
- A rate of 40 kg P ha<sup>-1</sup> was found to be optimal for most soils in Njombe and Mbeya Districts, but smaller rates could be used in the more fertile of Ujuni and Kinyika.
- All of the phosphorus should be applied at planting time in the hole.
- Triple superphosphate was better than single superphosphate or rock phosphate as a source of phosphorus.
- Some nitrogen should be applied when phosphorus is used. A rate of 60 kg N ha<sup>-1</sup> in Njombe, less in other areas, would suffice.
- Nitrogen should be used in the nursery to stimulate the formation of splits, at the rate of 80 kg N ha<sup>-1</sup>.
- Application of potassium has no noticeable effect on yield.
- So far clonal differences in response to fertilization have been small.
- Pyrethrin content has not been affected by fertilization.

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 parts of 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. Differences between clones in their response to micronutrients were negligible. The content of toxins in the flowers was unaffected by micronutrients.

The response of pyrethrum to organic manures has also been studied (Table 6). The use of farmyard manure on pyrethrum was not immediately reflected in increased yield. In some cases the application of poultry manure reduced yields in the first year. In subsequent seasons however, there were

considerable beneficial effects on yields, especially in the second season with poultry manure. Pyrethrin content was unaffected by the use of organic manures. Use of mulch improved the survival rate of splits. No increase in flower yield was noted with mulching, at least initially, although in the long term an increase could be expected. The type of mulch used made no difference, although in the long term leguminous mulches would appear to be the most beneficial.

Table 6. Response of pyrethrum fresh flower yields (kg ha<sup>-1</sup>) to organic manuring at Igeri

Farmyard manure (t ha <sup>-1</sup> )	Yield	Poultry manure (t ha <sup>-1</sup> )	Yield	Yield with mulch	Yield without mulch
0	235	0	3402	Yr 1 1646	1519
1	1057	2.5	3872	Yr 2 6586	4700
2	815	5.0	3303	Yr 3 7158	6275
3	940	7.0	3383	Mean 5163	4165
4	1354	10	3240	LSD (P<0.05) NS	
5	1502	LSD (P<0.01)	144	CV (%) 9	
LSD (P<0.05)	NS				

### Nematodes

As early as 1956 Tuckett in an unpublished mimeograph 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 yield reduction in flowers and pyrethrin (Parlevliet, 1970). These findings were confirmed by research at UAC (Table 7). The main conclusions from this research were:

- Flower yield reduction, due to nematode attack, is more severe under conditions of moisture stress.
- Yields were reduced by between 20 and 40%, even in years of sufficient rainfall, depending on the degree of nematode attack on 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. Farmers use splits from existing plants to provide new planting material so that nematodes are always present.
- Preventative treatment with nematicides is undesirable because of environmental concerns. 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 and so maintain the nematode population).

Table 7. Effect of nematode infection on yield (kg ha<sup>-1</sup>) of pyrethrum at UAC

	Yield of dry flowers
Healthy plants and clean soil	1152.7
Healthy plants and infested soil	1146.1
Infested plants and uninfested soil	970.5
Infested plants and infested soil	958.5
LSD (P<0.05)	75.1
CV (%)	4

### Losses during storage and marketing

Work elsewhere (Jones and Stephenson, 1959) has shown that the pyrethrin content of the flowers tends to decrease with time after picking. Storage conditions and the containers used for the dried flowers affect this loss. The results from a storage trial at UAC are shown in Figure 1. The loss of 3% pyrethrin per month is considerable, and at current prices could easily amount to a 40% loss in earnings. Delays in extraction arise from any one of several causes such as delays in delivering the flowers from the farm to the buying centre during the peak farming season, problems at buying centres, lack of transport, laboratory failures, and co-operative procedures and priorities. For smallholders this results in pyrethrum production becoming uneconomic.

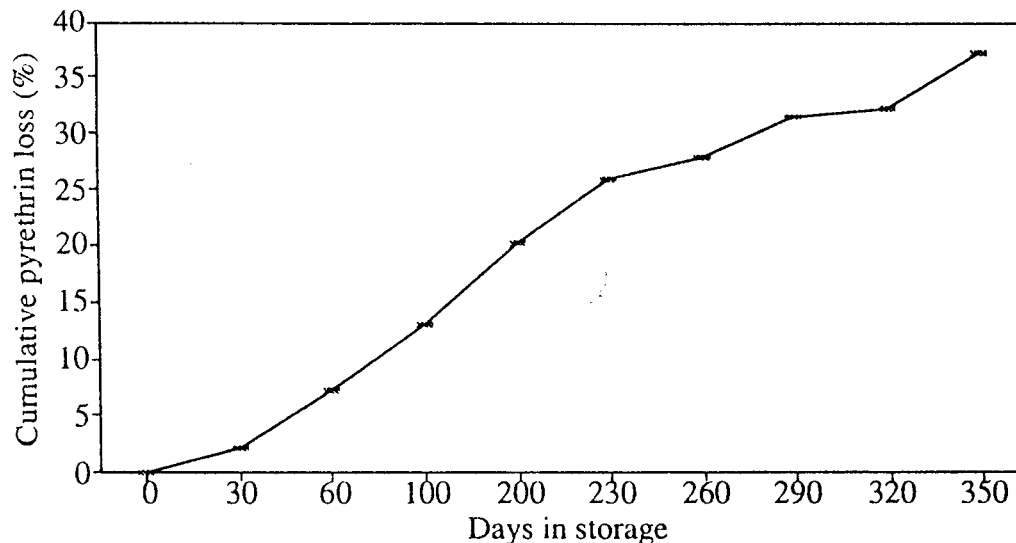


Figure 1. Losses in total pyrethrin content resulting from prolonged storage of dried pyrethrum flowers

### ACHIEVEMENTS AND CONSTRAINTS

There has been a steady decline in pyrethrum production for almost 30 years. Managers of the pyrethrum industry have been concerned about this for the last 10 years but have failed to reverse the trend. One of the most serious consequences is that since its commission the extraction plant has been operating at only 30% of its capacity. Five years ago the industry mounted a campaign in the main growing areas to try and increase production and the area planted. The uptake of recommended practices and the reasons why farmers fail to adopt recommendations was studied at UAC by means of informal discussions with individual farmers (or groups) in their fields or at home at that time. The results are shown in Table 8. The clear message is that 'small farmers are not fools'. The main constraints to production were as follows:

- The better clones have not yet reached the farmer. The multiplication process is tedious and it takes many years to provide sufficient numbers of improved plants for distribution to farmers.
- Inputs are unavailable, arrive at the wrong time come in insufficient amounts, or are of the wrong kind. The little fertilizer that is obtained is required for other crops.
- Full payment to the farmer for the crop is unreliable.
- Picking is tedious and labour intensive. Young people have migrated to towns and the few old people remaining are of limited help.

- Drying requires fuel and driers. De-forestation has limited the supply of fuelwood.
- Fields are sited far away from home and too small for rotation to be practicable.
- Smallholders have no effective say on such matters as marketing and co-operative procedures.

Despite this list of constraints some of the recommended practices have been adopted, as Table 8 indicates. The potential for increased crop yields is considerable if management practices can be improved.

Table 8. Estimated farmer adoption of recommendations for pyrethrum production

Recommendation	Adoption rate (%)	Comments
Preference to be given to the use of released clones	60	Preference often given to farmer's own selections
Large rather than small splits to be used	40	Number of splits available often limited
Spacing of 60 x 30 cm or 90 x 30 cm	80	Sometimes closer spacing is used
Use of phosphorus at planting	20	Fertilizer expensive and usually unavailable
Flowers to be picked at correct stage of maturity only	7	School children are used at weekends
Two week picking interval	50	Other crops demand labour
Cutting back after planting	90	
Weeding once a month during the rains	30	Other crops demand labour and weeds grow too fast
Fast drying of flowers	40	Fuel limitation and weather
Quick transportation to the factory	10	No transport, difficult roads, broken bridges
Use of farmyard manure at 5 t ha <sup>-1</sup>	5	Farmyard manure unavailable
Use of mulch 5 cm deep between the rows or in furrows	20	Grass is required for thatching houses
Adopt a three to four year rotation	50	Small fields too far apart
Irrigate once a week	0	No facilities and fields too far apart
Use nematicide in the nursery	0	Nematicide unavailable
Remove all blind plants in the first year in the field	0	Always ignored so that the number of splits available is reduced in the following season
Avoid shaded fields	60	Fields are few and small and trees provide fuel
Use nitrogen in the nursery often	20	Insufficient fertilizer for all crops
Use nitrogen soon after cutting back	0	Farmer has no fertilizer in stock at this time
Frequently request pyrethrum extension advice from UAC	60	Advice distributed through extension service and regional seminars

## SEQUENCE OF ADOPTION

An increase in the yield of total pyrethrin extracted can be achieved by increases in flower yield or in the pyrethrin content of the flower head, or both. The factors that can contribute to increased yield are listed in Table 9, together with an estimate of their potential contribution. These estimates should only be taken as a general guide; there may be other factors involved. However, the conclusions from Table 8 are that: improved agronomic practices have the greatest effect on flower yield (68%); efficient management and handling procedures have the greatest effect on the yield of pyrethrin extracted (40%); and climatic and breeding aspects can make an equal contribution to reducing the content of toxin (30% each).

The most logical strategy for achieving a rapid improvement in pyrethrum production in the Southern Highlands is to concentrate on improving the agronomic factors of production. Those that are likely to be the most rewarding and that are relatively easy and inexpensive for smallholders are: correct plant densities, even with using local selections; careful preparation and planting of splits; planting at the right time at the beginning of the main rainy season; ridging properly before planting; careful weeding once a month during the main rainy season; use of organic manures and mulching; and crop rotation with cereals and pastures (this would improve soil quality as well as helping with pest control). Harvesting and post-harvest management can be improved by picking at the correct stage of flower maturity once a fortnight and rapid drying and selling of flowers by the small farmer. The flowers should be transported from the village collection centre to the factory once a week. The flowers should be processed within the same week, although this is outside the control of the farmers. The storage of dried flowers should be minimized at all stages of handling; the total storage time should not exceed two weeks.

If successfully applied, these measures could more than double current capacity in less than three years, with little investment required. The development of new clones and cultivars takes about five to seven years before new recommendations can be released. Although the search for improved cultivars should be continued, it should not be allowed to dominate the efficiency of the pyrethrum industry as a whole.

Table 9. Estimated contribution (% of total contribution) of a number of factors to increased yield and pyrethrin content in pyrethrum

	Influence on flower yield	Influence on pyrethrin content
Temperature	10	20
Rainfall	10	10
Soil quality	10	0
Fertilization	5	0
Micronutrients	3	0
Plant population	10	0
Weeding	5	0
Ridging	5	0
Rotation	3	0
Quality of splits	7	0
Pest control (all)	10	0
Time of planting	7	0
Organic manures	3	0
Picking time	3	20
Drying	0	10
Storage	0	5
Transport	0	5
Cultivar	10	30

## PRIORITIES FOR THE FUTURE

Research priorities should include investigations into techniques to improve soil quality, for example, erosion control, green manuring, moisture retention and fertilization; the possibilities for irrigation; pest control by means of integrated pest management; farming systems to identify farmer priorities and opportunities that could be exploited, for example integration of pyrethrum production with livestock and pastures; more efficient drying techniques, for example, solar driers and central drying facilities; afforestation issues to improve the sustainability of the system; and improved linkages with extension workers.

Extension priorities should include education for farmers; improved linkages with research; improvements in the multiplication and distribution of existing planting materials and cultivars; advice to farmers on selecting their own planting material from their fields, those of neighbours, or joint nurseries; the organization of field days to encourage pyrethrum farmers to visit other villages and/or research centres; more emphasis on pyrethrum in the training of extension workers in the Southern Highlands.

Government policy on the pyrethrum industry has been changeable, confusing producers and the associated institutions. More attention should be given by policy makers to encouraging the adoption of the measures already described. Issues that need to be addressed include a price review mechanism to ensure stable prices; payment of the second instalment to producers; efficient transportation; minimal storage of flowers throughout the marketing process; individual marketing of flowers from a village, rather than one 'village bag' as at present, since quality varies from producer to producer; separate pyrethrum and maize co-operative societies.

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