PHENOTYPIC VARIATION IN FLORAL DEVELOPMENT AND PYRETHRIN CONTENT IN GENETICALLY DIFFERENT CLONES OF PYRETHRUM *Chrysanthemum cinerariefolium* vis.

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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TO

MY PARENTS

WAMWITHA AND JACKSON IKAHU

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ABSTRACT

Pyrethrum, Chrysanthemum cinerariae folium vis, is an important insecticide producing plant propagated vegetatively by splits and shoot cuttings. The objectives of the study were to determine the pattern of pyrethrins and dry weight net accumulation during the entire flowering cycle, the duration of transition in days from one stage to the other during the flowering cycle and to determine the optimum picking time for six recommended pyrethrum clones (Ma/70/1013, Ma/71/423, 4331, SB/66/107, Ks/71/6 and Ks/70/64. The experiment was laid out in split-plot block design with three replicates. During the 1985/86 growing season three plants from each fully established clone were randomly selected and labelled. From each plant three flower heads were randomly selected and labelled at bud stage. The date when the selected bud had just started to open was noted and the number of days from there on to reach each of the eight stages of development were counted in each clone. Sampling for dry weight and pyrethrins content was done January, June and September

There were highly significant differences

amongst the clones in pyrethrins content and 100 flower dry weight at different stages of flower development. Lack of interaction between clones and developmental stages in both pyrethrins content and 100 flower dry weight suggested the pattern of dry weight and pyrethrins net accumulation was similar in all pyrethrum clones.

The 100 flower dry weight increased from closed bud (Stage I) and reached a maximum at the late overblown stage (Stage VII) in all the clones. The pyrethrins in the flower head generally increased from closed bud (Stage I) to a maximum when nearly all disc florets were open (Stage V) in all the clones except clone Ma/71/423 which had a maximum pyrethrins content at Stage IV. The pyrethrins yield increased from a closed bud (Stage I) to a maximum at Stage VI in clones Ks/70/64 and Ma/71/423 while clones SB/66/107, Ks/71/6 and Ma/70/1013 had a maximum pyrethrins yield in Stage VII. Clone 4331 showed slight changes in pyrethrins yield from Stage V to VII. The time lapsed from closed bud (Stage I) to nearly all disc florets open (Stage V) when most of the clones had maximum pyrethrins content varied from 18 to 21.2 days except for clone 4331 which varied from 11 to 19.5 days.

Results suggested that the optimum picking stage for clones SB/66/107, Ma/70/1013, Ks/71/6 should be in Stage VI, while clones Ks/70/64 and Ma/71/423 in Stage V. Clone 4331 can be picked in Stage IV to VII as it showed very slight changes during these stages.

1. INTRODUCTION

Pyrethrum, Chrysanthemum cinerariaefolium vis, is the Kenya's fourth most important export crop. Kenya produces about 80% of the world's pyrethrum supply. Pyrethrum is grown for its flowers, which are picked by hand and then dried and ground. Extract prepared from pyrethrum powder contains pyrethrins which have unique properties when compared with synthetic insecticides. They have high degree of suitability for combination with synergists (Chadwick, 1963) and have repellent, knockdown and toxic effects for a greater variety of insects (Van Rijn, 1974). They are however practically non-poisonous to mammals (Griffin, 1973). They have a rapid breakdown and no persistence of residues and hardly any build up of resistance in insect population (Busvine, 1960; Fine, 1963).

These properties permit the use of pyrethrins against pests in the house, on crops (even

when treatment is required just prior to harvest), stored food and livestock. Because of an increasing consciousness of the risks associated with widespread use of many synthetic insecticides, like toxicity to mammals, persistence of residues and insect resistance, the demand for pyrethrins is growing.

Synthetic compounds resembling some of the six constituents of natural pyrethrins have been manufactured (Elliot, 1967). Even though these synthetics are more toxic to insects, it is unlikely that they will replace natural pyrethrins in the near future, because the latter are effective against wider range of insects, more suitable for combination with synergists (Chadwick, 1963) and less expensive (Winney, 1973).

Although pyrethrum is essentially grown for its insecticidal properties, pyrethrum marc is used as a cattle feed (Griffin, 1974).

Commercial use of pyrethrum probably

originated in Persia with Chrysanthemum cocineum which was sold as Persian powder in 1820's. This genus being of low flowering ability and low pyrethrins content was replaced in "1840" in Europe with Chrysanthemum cinerariaefolium vis. It flowers better and it has a higher toxic potency. Dalmatia (Yugoslavia), the centre of origin of this genus, was the leading world producer, before it spread from there to France, Switzerland, the United States and Japan. Japan was for a long time the world's largest producer until replaced by East Africa in the second world war (Glyne, 1962).

In Kenya, pyrethrum was introduced in 1928. A Kenyan farmer, Captain G. Walker obtained some seeds from Dalmatia and established a commercial field on his farm at Subukia, Nakuru district (Chandler, 1948; Le Pelley, 1973; Tuikong, 1984). In 1929, T.J. Anderson, an entomologist at National Agricultural Laboratories brought some seeds from England, and used them for experimental purposes. Both introductions reached many farmers

and by 1945 Kenya was the world's leading producer a position she maintains today. There have been fluctuations in the production level due to market price and unfavourable weather condition (appendix 4 and 5).

Only 2% of Kenya production is used locally while the rest is exported to United States, United Kingdom, Italy and Germany.

Other countries which produce pyrethrum include Tanzania, Equador, Rwanda, Japan, New Guinea, Brazil, Zaire, Indonesia, India, U.S.S.R., Taiwan, Zimbabwe, Yugoslavia and South Africa in order of declining importance.

Pyrethrum grows well in deep, well drained soils, preferably of volcanic origin (Kroll, 1962; 1963). Double superphosphate fertilizer is applied at planting time. For flower bud initiation to occur some degree of chilling is required (Glover, 1955). Such conditions in Kenya are met in highlands over (1800 metres) above sea level where rainfall is also over (1000mm) a year. The main producing areas, are highlands of Kisii district,

east and west of Rift Valley, foothills of Aberdares and Mount Kenya and the high regions of Kiambu District (Parlevliet and Brewer, 1971).

Over 95% of pyrethrum is grown by small scale farmers on pieces of land ranging from less than a quarter to one hectare. This is unlike earlier days when it was grown mainly by white settler farmers on a large scale (over 10 hectares).

Routine work on pyrethrum field includes keeping the field weed free (Mwakha, 1974 ; 1979) and picking of pyrethrum flowers at the right time (Head, 1966; Parlevliet, 1970a). The control of diseases and pests in pyrethrum like thrips, red spider mites and root-knot nematodes Meloidogne hapha; (Bullock, 1961; Robinson, 1963; Parlevliet and Brewer, 1971; Parlevliet, 1971).

To strengthen the position of natural pyrethrins on the market, it is of outmost importance to decrease their cost by increasing the annual production of pyrethrins per unit area. Yield is determined by several components, such as the

number of flowers per plant, the size of the flowers, the percentage of dry matter and pyrethrins content in the flower head.

The breeding of pyrethrum in Kenya is based on the selection for improved hybrids or polycross varieties and clones (Parlevliet, 1975). The main objective of the breeding programmes is to increase fresh flower yield and the pyrethrins content which determine the pyrethrins yield per unit area.

Since the selection for superior clones started in 1962 (Contant, 1963a) about 13 clones have been recommended for commercial growing (Appendix 6). The general recommendation is, to pick the flowers at two to three weekly intervals. However clones differ in the rate at which flowers mature, the pyrethrins content and dry weight accumulate at different stages of floral development. The main objectives of this study were:-

- To determine the pattern of pyrethrins and dry weight net accumulation during the entire flowering cycle.

- To determine the duration of transition in days from one stage to the other during the entire flowering cycle.

- To determine the optimum picking time for each clone.

2. LITERATURE REVIEW

2.1 Botanical Aspects of Pyrethrum.

Pyrethrum, Chrysanthemum cinerariaefolium vis, is a member of the Compositae family. It is a small perennial herb with a tendency to form a woody base. Pyrethrum is propagated vegetatively by splits and shoot cutting. The practical importance of propagation by splits has been indicated by several authors (Drain and Shuey, 1934; Martin and Tattersfield, 1934; Cormark, 1935; Chamberlain and Procter, 1947; Osbourn, 1961; Contant, 1963a; Brown, 1965). The use of shoot cuttings has also been reported by many authors (Drain and Shuey, 1934; Cormack, 1935; Chamberlain and Procter, 1947; Colling-well and Contant, 1963). Pyrethrum is also propagated by seeds.

Figure 1 A - C show the morphology of an inflorescence, a ray and disc florets. The capitulum is borne on the peduncle and consists of a slightly convex receptacle, sheathed by green in-

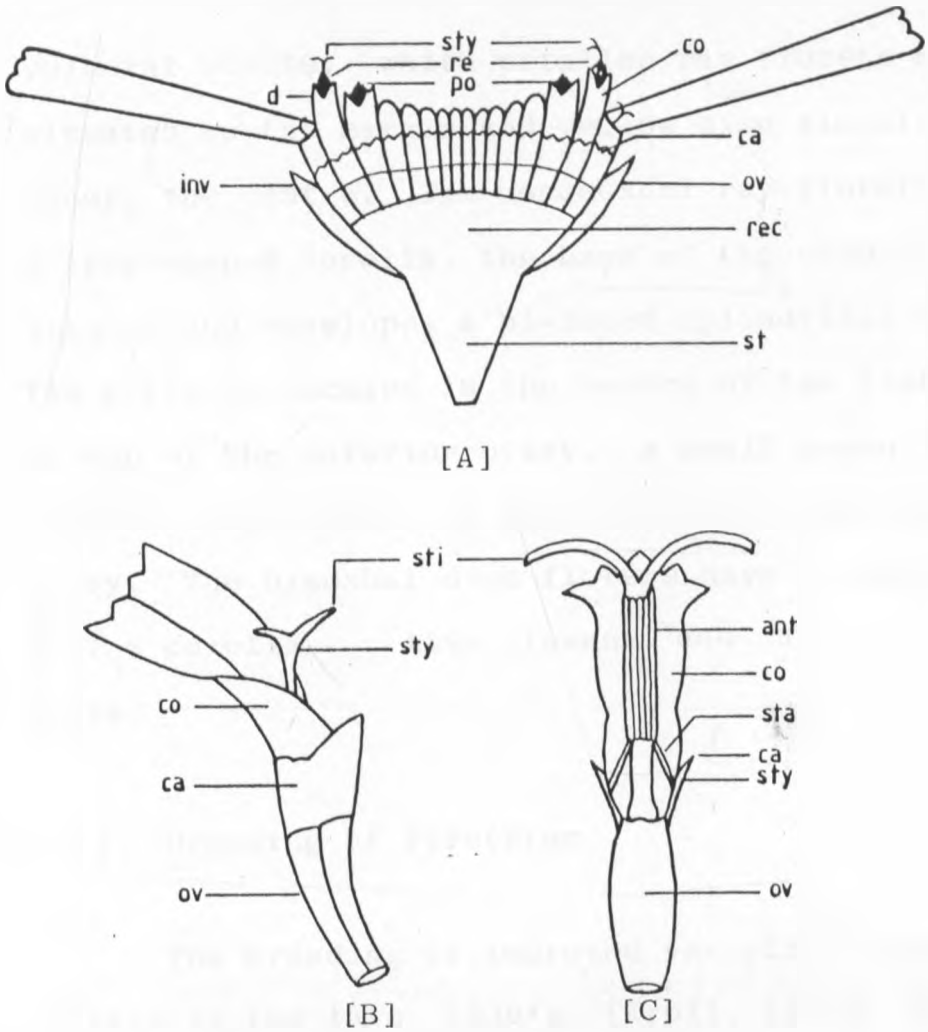

Fig. 1. The morphology of an inflorescence (A), ray florets (B) and a disc floret (C).

Ca	-	calyx	Po -	pollen	st - stalk
Co	-	carolla	r -	ray floret	sta - stamen
d	-	disc floret	re -	rest anther	sti - stigma
inv	-	involucre	rec-	receptacle	sty - style
ov	-	ovary			

volucral bracts; white petalled ray florets are situated on the margin and yellow disc florets occupy the centre. The monosexual ray florets have a trap-shaped corolla, the base of the corolla is tubular and envelopes a bi-lobed cylindrical style. The style is located in the centre of the florets on top of the inferior ovary. A small green irregular shaped calyx is attached to the pentagonal ovary. The bisexual disc florets have a tubular yellow corolla, five stamens and a style.

2.2 Breeding of Pyrethrum.

The breeding of improved varieties in Kenya started in the late 1930's (Kroll, 1958). Phenotypically outstanding plants were selected and compared in single line observation trials for three years. The best clones were crossed to form hybrids which were tested in replicated trials at various locations. Several good hybrids were produced as well as some outstanding clones.

Drain and Shuey (1934) and Cormack (1935) reported that selection and multiplication of

superior clones could provide a better method of improvement than the production of hybrids. The actual selection for superior clones started in 1962 (Contant, 1963b). The selection scheme was fairly simple. Phenotypically outstanding plants were selected, split and planted in single line observation trials. After one year the best clones were planted in a replicated trial which lasted for two to three years. This was followed by adaptability trials at several sites. The best clones were recommended for commercial growing.

Contant (1963a; 1963b) also introduced the polycross system to test the general combining ability of selected clones. Clones with high combining value were then crossed in pairs to produce hybrids, which were tested as described by Kroll (1958).

The methods used earlier have now been refined to improve the selection response (Tuikong, 1984). Two interrelated breeding programmes are being pursued namely varietal and clonal breeding (Figure 2).

Varietal breeding deals with the production of improved hybrids or polycross seed for commercial growing and has four selection cycles (Figure 2). Clonal breeding deals with the selection of outstanding plants for yield trials and subsequent clonal multiplication for commercial growing. It has five selection cycles (Figure 2).

In both programmes, the objective is to develop clones and varieties with high yields of pyrethrins per unit area, over a wide range of environmental conditions (Parlevliet, 1969). The clones should be non-lodging, easy to split, re-establish and tolerant to root-knot nematodes (Parlevliet, 1971). The clones should also be resistant to major pyrethrum diseases and pests like thrips, red spider mites and root-knot nematodes, Meloidogne hapla. (Nattrass, 1950, Bullock, 1961; Robinson, 1963; Parlevliet and Brewer, 1970; 1971). Plant height and flower size have also gained great importance due to the ease in picking of flowers (Anonymous, 1983).

2.3 Identification Methods used in Pyrethrum.

Flower traits like the flower size, shape and distribution of ray florets are often used in

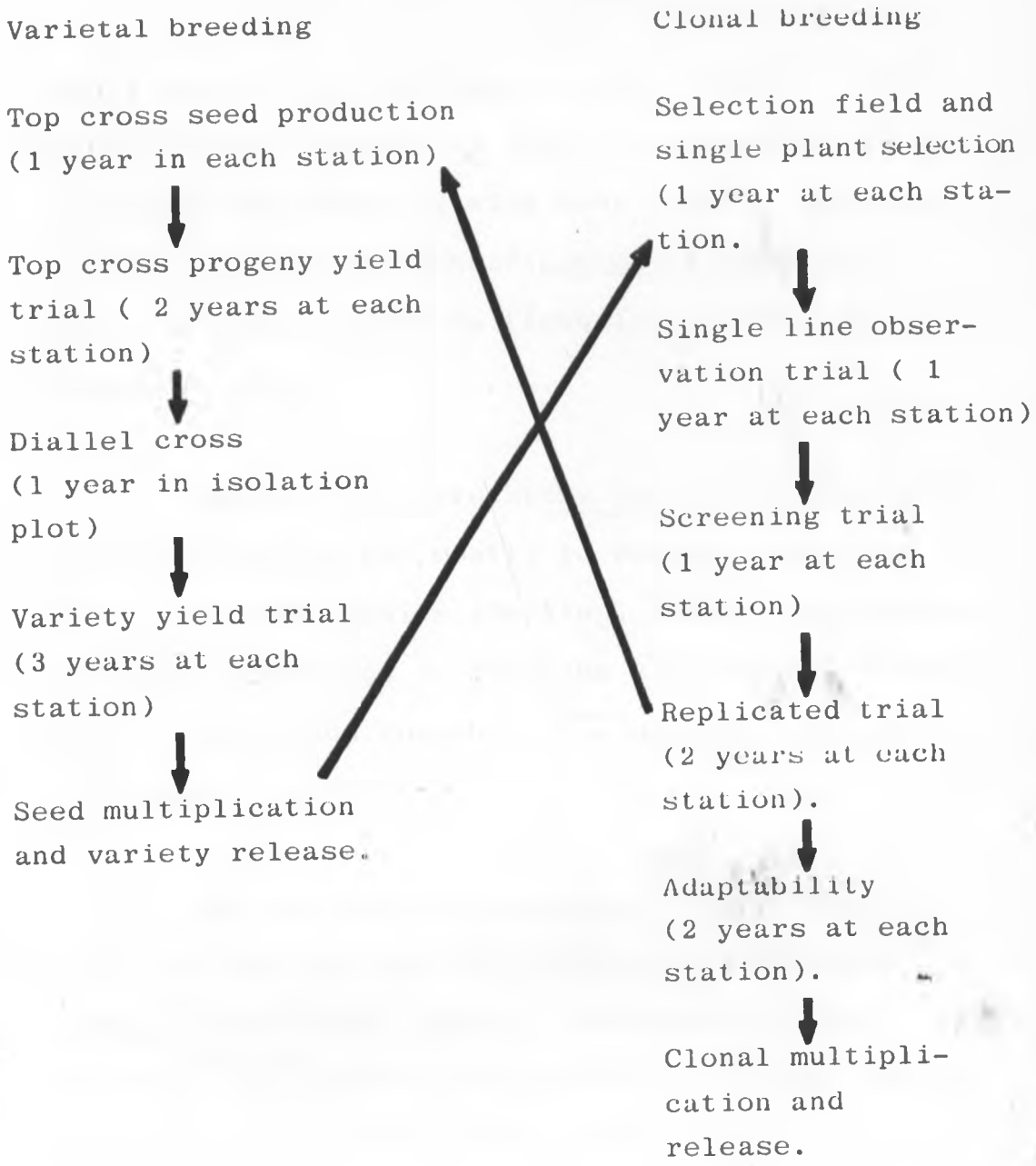

Figure 2. Selection stages in the breeding of pyrethrum currently practiced at the National Pyrethrum and Horticultural Research Station, Molo.

identification of different clones. However, this method does not result in complete identification especially when dealing with many clones. The use of flower traits in identification of pyrethrum clones is also limited to flowering periods only (Chandler, 1951).

Analysis of pyrethrins content is also used in identification but mostly to confirm identification by flower traits (Beckley, 1950). This works only when the clones in question are known to differ much in pyrethrins content. Its use is limited to flowering period.

The analysis of pyrethrin I/ pyrethrin II ratio can also be used for identification of different clones (Head, 1967). The method can be used where distinction on the basis of flower traits and pyrethrins content prove inconclusive.

Incompatibility is a more reliable method (Brewer and Parlevliet, 1969). In pyrethrum, a sporophytic incompatibility system operates. Most clones are strongly self-incompatible. Identical

genotypes gives a reciprocal incompatible reaction and differing genotypes give a compatible reaction. This test is reliable but takes three to four days to be completed and it is highly sensitive to environmental influences (Brewer, 1973).

Currently, under uniform growing conditions, pyrethrum clones can be identified satisfactorily by their peroxidase electrophoretic pattern (Tuikong and Gupta, 1985). The technique gives result in less than eight hours and can also be used to distinguish between large number of clones even if they were closely related because of a high degree of polymorphism of the peroxidase bands (Tuikong and Gupta, 1985).

2.4 Pyrethrins.

The pyrethrins are esters which are derived from two acids (chrysathemic and pyrethric acids) and three alcohols (pyrethrone, cinerolone and jasmolone). Chrysanthemic acid comprises pyrethrin 1, cinerin 1 and josmolin 1 (commonly termed pyrethrin 1) while pyrethric acid

comprises, pyrethrin II, cinerin II and josmolin II (commonly termed pyrethrin II).

Pyrethrins are present throughout the whole plant but only the flowers are suitable for economic extraction of the resin. Head (1966) in his study of the insecticidal constituents in the flower head and their distribution in clone 1708 found that the achenes contain 93.7% of total pyrethrins (Figure 3). This is in close agreement with 92.4% reported by Gnadinger and Corl, (1930) and 94% by Brewer, (1973). The yellow corolla, comprising the style and anthers (perianth) and white corolla of the ray florets including the style contain 2% pyrethrins (Head 1966, Brewer, 1973).

Chandler, (1951; 1954; 1955; 1956), Notcutt (1955) and Brewer (1973) identified two types of secretory tissue which contains pyrethrins. These are the oil glands which are external multi-celled bodies found on the achene and corolla of the florets and the secretory ducts which are found within (Figure 3 A - B, 4E).

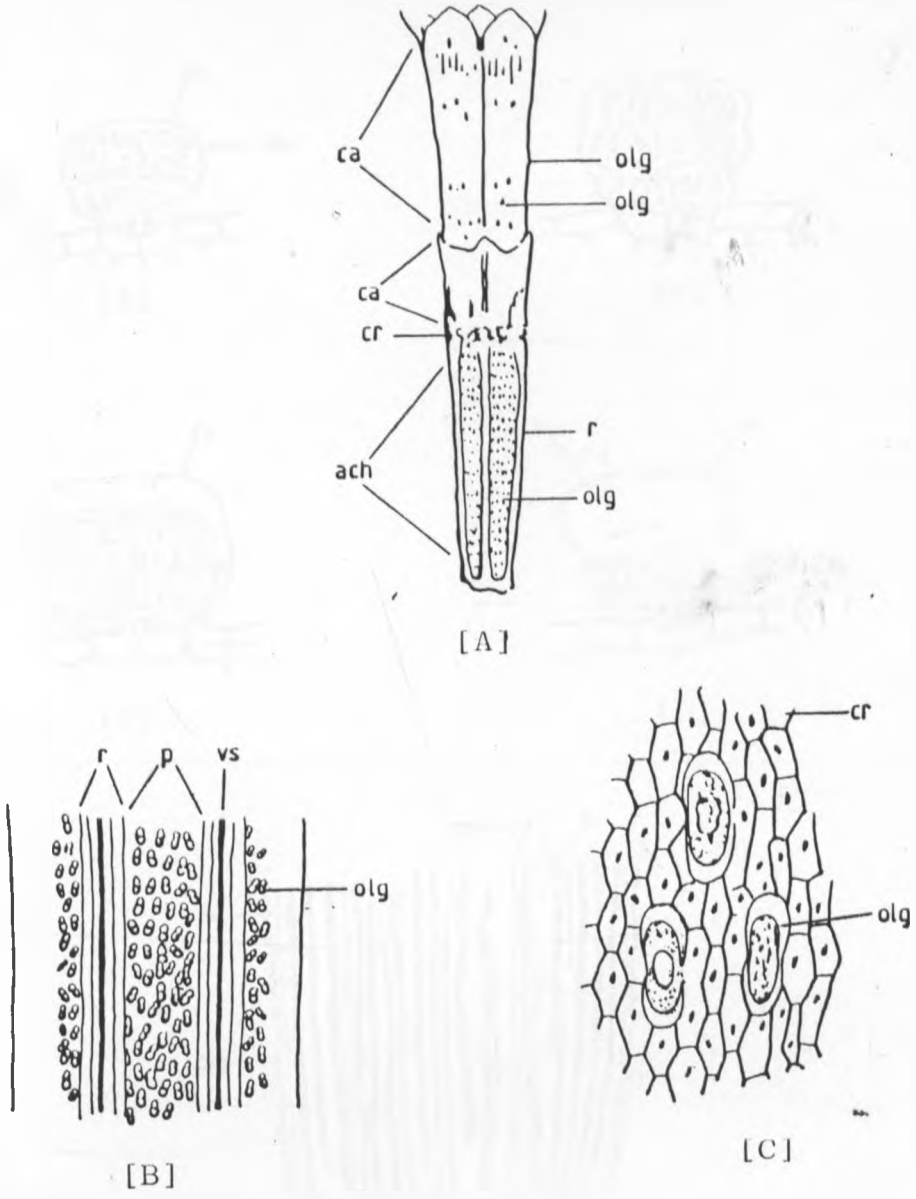

Fig. 3. The disc floret with oil glands (A.), ovary surface view (B) and panel of ovary surface showing three oil glands (C).

olg - oil glands
ach - achene
cr - crown of ovary
r - crest of rib
p - panel
vs - vascular strand.

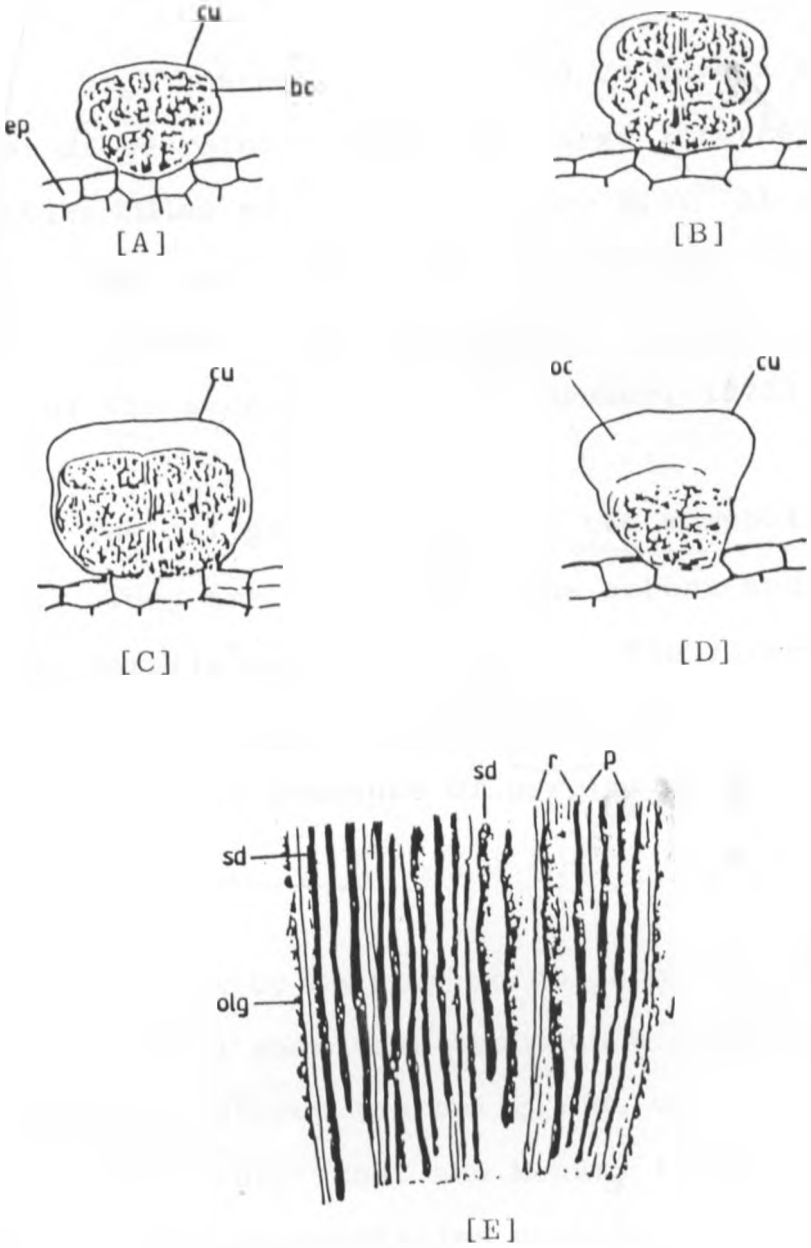

Fig. 4. (A - D) oil glands in successive stages of development, (E) inner surface of ovary wall showing secretory ducts.

bc - body cells
cu - cuticle
oc - oil cavity
ep - epidermis of ovary wall
sd - secretory ducts
r - rib
p - panel

High content flowers tend to have a thick layer of secretory tissue and large intercellular cavities filled with resin (Figure 4E). Although largely impracticable selection of high pyrethrins content flowers would be possible through examination of the secretory tissue (Brewer, 1973).

The oil glands represent two morphological forms. They are attached to the achene and the yellow corolla (Chandler, 1955). The former group contain small amount of pyrethrins while the latter do not show the presence of pyrethrins (Brewer, 1973).

Studies by Beckley in collaboration with Notcutt (1955) show that there is a strong positive correlation between the oil glands count and pyrethrins content. Bhat and Menary (1979) found that increase in pyrethrins content were low at bud stage when the glands were not fully developed reaching a maximum when the glands were fully developed (Figure 4 A - D). This is in agreement with finding of Beckley' et al (1938)and Head, (1966) that pyrethrins content varies with the stage of flowering. Bhat and

Menary (1979) found that the oilglands appeared collapsed when the pyrethrins content had declined at overblown stage. However, they also reported that in some genotypes the glands did not collapse and there was no decrease in pyrethrins at the over-blown stage. Parlevliet (1970b) reported that genotypes like Ma /63/1889, Ma /65/99, Ks/63/11 and Ks/63/299 had no decrease in pyrethrins content even at the overblown stage.

2.5 Yield Components and their Relation to Environment.

The most economically important factor in pyrethrum production is the quantity of pyrethrins harvested per unit area (Contant, 1963a; Parlevliet and Contant, 1970; Parlevliet, 1969; 1974a). The pyrethrins yield is determined by four yield components viz, number of flowers in the plant, the flower size (measured as the fresh weight of 100 flowers), the dry matter content of the flowers and the pyrethrins content of the dry flowers. The flower size, dry matter content and pyrethrins content have an important effect on picking, drying,

transportation and extraction costs (Parlevliet and Brewer, 1971).

Fresh flower yield is dependent upon the flower size (fresh weight of 100 flowers), number of flowers per stem and number of stems produced over the growing period (Parlevliet, 1974). In pyrethrum breeding programme the ultimate objective is to combine attractive level of expression for each of these traits into one strain which would result in high pyrethrins production per unit area (Appendix 6).

Kroll (1958) reported that the number and size of the flowers were negatively correlated as were flower yield and pyrethrins content. Parlevliet (1974) reported that flower size was negatively correlated with dry matter content and flower yield, while the pyrethrins content did not have any relationship with either flower yield or flower size. Bhat and Menary (1986) found that pyrethrins yield was positively correlated to flower yield, pyrethrins content, number of flowers per plant and 100 flowers dry weight. They also reported

that flower yield was more dependent on the number of flowers per plant than on 100-flower dry weight. Pyrethrins content was not significantly correlated with any of the other traits (Bhat and Menary, 1986).

Flower size, dry matter content, pyrethrins content and resultant amount of pyrethrins per flower head vary strongly with rainfall (Parlevliet, 1970a). During the rainy spells the flowers become bigger, the dry matter content lower and the pyrethrins content and pyrethrins per flower head higher. During the dry spell the reverse occurs. Most clones show similar pattern, although the amplitude may differ slightly among clones (Parlevliet, 1970b).

The effect of altitude on flower yield is very difficult to assess. Other factors like soil type, planting time, rainfall, care of the crop, introduces such a variation that differences in yield due to altitude may be covered (Parlevliet and Brewer, 1971). Experiments carried at Subukia (2300 m) and Marindas (2800 m) over a series of years when the same clones were compared,

suggested that within the range of "2300 m to 2800 m)" the yield potential is not very much different (Parlevliet and Brewer, 1971; Muturi et al., 1969).

2.6 Pyrethrins Yield at Different Stages of Floral Development.

To harvest the maximum pyrethrins per unit area, the flowers have to be picked only at a certain stage of development. Studies carried out at Molo National Pyrethrum Research station indicate that pyrethrins yield is highest at two to three weekly picking intervals when flowers could not develop to an overblown stage (Anonymous, 1953; 1956; 1957). Therefore, the general recommendation is to pick all flowers from the stage with horizontal petals onwards with intervals between picking, which should allow only a very limited number of overblown flowers. If, however, for any reason picking has to be postponed, all overblown flowers should be picked too, as they contain still a large amount of pyrethrins and, left on the plant, the presence of maturing seeds in the over-

blown flowers tends to reduce the number of newly initiated flowers (Anonymous 1953; 1956; 1957; Parlevliet and Brewer, 1971).

The general belief as evident from literature, is that the pyrethrins reach peak level when 75% of the disc florets have opened, may be true for a highly variable seed population (Beckley et al., 1938; Head, 1966). When individual clones are studied, not all the clones conform to this general pattern, each clone has a pyrethrins net accumulation pattern of its own (Bhat and Menary, 1979; 1984; Parlevliet, 1970b).

Parlevliet (1970 b); Bhat and Menary (1984) found that some clones had peak level at the beginning of the flower opening while others showed it at the overblown stage. In view of these differences it was therefore found necessary to investigate the pattern of pyrethrins net accumulation for some of the recommended clones for the entire flowering cycle. Head, (1966) carried out such a study but his conclusions were based on performance of only one clone which represents a very narrow

gene base within a highly variable population. Bhat and Menary, (1984) in Tasmania studied six clones individually but only up to the stage when all the disc florets were open.

This informtion would have an important bearing on the timing of field operations, especially the picking time, picking cost, drying, transportation and the extraction cost in pyrethrum production.

3. MATERIALS AND METHODS

3.1 Plant Material.

The present study was based on six of the thirteen Kenyan commercially recommended clones. They were obtained from the reference collection of clones at National Pyrethrum and Horticultural Research Station, Molo. A brief description of the material is given below.

	Clone	Characteristics
I	Ma/70/1013	Released in 1979 for commercial growing in areas above 2200 m. It has a flower yield potential of about 1000-1200 kg/ha/year and an average pyrethrins content of 1.9%. The pyrethrins yield per hectare per year is between 20.9 - 22.8 kgs.

II Ma/71/423 ✓

Released in 1978 for commercial growing in areas above 2000 m. It has a flower yield potential of about 1000-1100 kg/ha/year and an average pyrethrins content of 1.8%. The pyrethrins yield per hectare per year is between 18 - 19.8 kgs.

III 4331 ✓

Released in 1964 for commercial growing in areas above 1800 m. It is the most popular among farmers. It has a flower yield potential of 1000-1200 kg/ha/year and average pyrethrins content of 1.6%. The pyrethrins yield per hectare per year is 16 - 19.2 kgs.

IV Sb/66/107 ✓

Released in 1976 for commercial growing in areas above 2200 m. It has a flower yield potential

of about 900 - 1000 kg/ha/year and an average pyrethrins content of 2%. The pyrethrins yield per hectare per year is 18 - 20 kgs.

V Ks/71/6

Released in 1978 for commercial growing in areas above 1700 m. It is a low altitude clone. It has a flower yield potential of about 900 - 1000 kg/ha and an average pyrethrins content of 1.7%. The pyrethrins yield per hectare per year is 15 - 17 kgs.

VI Ks/70/64

Released in 1979 for commercial growing in areas above 1700 m. It is a low altitude clone. It has a flower yield potential of about 1000 - 1100 kg/ha/year and an average pyrethrins content of 1.9%. The pyrethrins yield per hectare per year is 19 - 21 kgs.

3.2 Site Description.

The study was carried at Limuru Sub-station of the National Pyrethrum and Horticultural Research Station, Molo, Kenya 1'08'S and 36° 40' E. The farm is situated 2300 m above sea level and receives a mean annual rainfall of 1100 mm. Rainfall pattern is bimodal with short rains starting in October and long rains in March. Between May and September there is a cold cloudy dry spell with night temperatures going below 10°c. A hot spell occurs between December and March. Annual minimum and maximum temperatures are 10.8°C and 20.8°C, respectively. However, sometimes day temperatures may rise up to 25°c during the hot months. The soil is red clay loam of volcanic origin with good drainage. The pH ranges between 4.5 and 5.5. A fine seedbed was prepared by ploughing twice, rotavating once and finally removing weeds with forked hoes.

3.3 Planting and Spacing.

The experiment was planted in October, 1985. The six clones were planted at the spacing of 60 cm between rows and 30 cm within rows. Double super-

phosphate (P_2O_5, 46%) fertilizer was applied at the rate of 200 kg/ha (one spoonful per hole) and thoroughly mixed with the soil to reduce direct contact of fertilizer with plant roots. The splits were placed in the holes with their roots straight and the soil was filled in and firmly pressed around them.

3.4 Experimental Design.

The experiment was laid out in a split-plot block design. There were six treatments (clones), replicated 3 times. Each of the six treatments were planted in a single row of 30 plants and replicated 3 times. Two rows of 4331 were platned on the free ends of the experiment as guard rows. Other routine field maintenance practices like weeding at four week intervals, spraying against thrips and mites were carried out with rogor or metasystox especially during the dry periods when they attain damaging levels.

Data collection was started when the plot contained flower heads at all stages of development.

3.5 Data collected and Observations.

3.5.1 Variation in floral development.

During the 1985/86 growing season three plants

from each fully established clone were randomly selected and labelled. From each plant three flower heads were randomly selected and labelled at bud stage. The date when the selected bud had just started to open was noted and the number of days from there on to reach each of the eight stages of development were counted. These stages were essentially those described by Head (1966). (Plate I - VIII).

Stage	Description
I	Well developed closed bud. (Plate I).
II	Ray florets vertical (Plate II).
III	Ray florets horizontal, first row of disc florets open. (Plate III).
IV	Approximately three rows of disc florets open. (Plate IV).

V	An inflorescence with nearly all disc florets open (Plate V).
VI	Early overblown condition, colour of disc florets diminishing but ray florets still intact. (Plate VI).
VII	Late overblown condition, little colour remaining in disc florets but still intact, ray florets dried out. (Plate VII).
VIII	Disc florets fallen, stem dry 2 cm below the flower head - suitable for collection for seed.

3.5.2 Dry Weight.

Hundred flowers at each of the eight stages of development were randomly picked from each clone and replicate and their fresh weight determined. The samples were put in an oven at 80°C for two hours and

then at 50°c until completely dry. Drying was stopped when four out of five flowers shattered easily when squeezed between the thumb and fore finger. The samples were allowed to cool and weighed again to obtain the dry weight. Sampling was done in June and September under relatively wet growing condition. The last sampling was done in January under very dry growing conditions.

3.5.3 Pyrethrins content (%)

The pyrethrins content was determined using the Beckley's U.V. spectrophotometric method (Beckley, 1950). The analysis was carried out at the Pyrethrum Board Chemistry Laboratory, Nakuru. The analysis was done for eight developmental stages, for each clone, replicate and sampling.

4. RESULTS

4.1 Flowers Development in Pyrethrum.

Table I shows the mean number of days taken by six clones to reach the eight stages of flower development. On the average, the clones took 52 days to complete the flowering cycle, that is opening of bud (Stage I) to seed stage (Stage VIII). Clone Ma/70/1013 took the longest period (57 days), while clone SB/66/107 took the least time (50 days).

Stages IV and V, when the pyrethrum content in the flower head are generally expected to be at their peak was reached within 11 and 20 days respectively (Table I). However, clonal differences were observed in the number of days taken to reach a particular stage of development (Table I).

Clone Ma/71/423, 4331 and Sb/66/107 were regarded as early maturing as they took less time to reach stage IV and V as well as Stage VIII,

Table 1. Number of days taken to reach different stages of flower development in six pyrethrum clones (Stage 1* taken as the starting point).

Clone	Days from stage 1 to stage						
Stage	II	III	IV	V	VI	VII	VIII
Ma/70/1013	9.0	10.3	12.8	21.0	23.7	31.8	56.7
Ma/71/423	6.8	9.0	10.7	19.2	21.8	29.2	50.8
4331	7.0	8.0	10.8	19.5	21.2	28.7	51.3
SB/66/107	4.2	5.7	8.8	18.0	21.2	28.2	50.5
Ks/71/6	6.5	9.5	12.2	20.5	24.0	31.0	53.0
Ks/70/64	7.3	10.7	12.7	20.7	23.3	30.8	53.5
Mean	6.8	8.9	11.3	19.8	22.5	29.9	52.6

*For description of the various stages, refer Appendix plate I - VIII.

compared to the late maturing clones as Ma/70/1013, Ks/71/6 and Ks/70/64 which took much longer time to reach these three stages of development (Table 1).

The time duration of eight stages of flower development differed with clones. Change from stage I to II took (7 days) on the average. Clone Sb/66/107 took(4 days) compared to clone Ma/70/1013 which took about(9 days). The shortest duration was between stages II to III which took approximately (2 days). The longest duration was between stages VII-VIII which lasted about(23 days) (Table II).

4.2 Dry Weight of 100 Flower Heads.

Table III shows the analysis of variance for 100 flowers dry weight in six clones at eight stages of flower development. There were highly significant differences amongst the clones for 100 flower dry weight. Table III also shows that there were highly significant differences amongst the various developmental stages in clones in respect to 100 flower dry weight. There was no interaction

Table II. Duration of transition in days taken by flower from one stage of development to the other (stage 1* taken as the starting point)

Clone	Duration of transition (days)					
Stage	II-III	III-IV	IV-V	V-VI	VI-VII	VII-VIII
Ma/70/1013	1.3	2.5	8.3	2.5	8.2	24.8
Ma/71/423	2.2	1.7	8.5	2.2	7.8	21.7
4331	1.0	2.8	8.7	1.7	7.5	22.7
SB/66/107	1.5	3.2	9.2	3.2	7.0	22.3
Ks/71/6	3	2.7	8.3	3.5	7.0	22.0
Ks/70/64	3.3	2.0	8.0	2.7	7.5	22.7
Mean	2.1	2.5	8.5	2.6	7.5	22.7

*For description of the various stages, refer to Appendix Plate I - VIII.

Table III. Analysis of variance for 100 flowers dry weight in six pyrethrum clones at eight stages of flower development.

source	df	ms
Subplot	143	
Main plot	17	117.6
Block	2	83.3
Clones	5	287.9**
Main plot error	10	39.3
Development stages	7	317.2**
Stages x Clones	35	6.9^{NS}
subplot error	84	21.88

L.S.D. = 11.4 at 5%

CV = 15.3

*,** = Significant at 0.05 and 0.01 probability level, respectively.

NS = Not significant.

between the 100 flower dry weight at different stages of development and clones.

Figure 5 shows the 100-flower dry weight at eight stages of flower development in six clones. The 100 flower dry weight increased through stage I to II with a sharp decline in stage VIII. This trend was observed for all the clones (Appendix I).

Figure 5 shows that there was a sharp increase in 100 flower dry weight from stage I to II, a slow increase from stage II to V and then a sharp increase in 100 flower dry weight from stage V to VII, except for clone 4331 which was very gradual, followed by a sharp decrease from stage VII to VIII.

Clone Sb/66/107 had the highest dry weight at all stages of flower development. This was followed by Ma/70/1013, Ks/70/64, Ks/71/6, Ma/71/423 and 4331 respectively (Figure 5).

Other notable feature was that the 100 flower dry weight at stage VIII was much higher than at stage I, II and III (Figure 5) for all the clones.

4.3 Pyrethrin Content (%).

Table IV shows the analysis of variance for pyrethrins content in six clones at eight stages of flower development. There were highly significant differences amongst the clones in pyrethrins content. Table IV also shows that there were highly significant differences amongst the various developmental stages in respect to pyrethrins content. There was no interaction between pyrethrins content at different stages of flower development and clones.

Figure 6 shows that mean pyrethrins content (%) of six clones at eight stages of flower development. It was observed, that the pyrethrins content (%) increases through stage I to V with a sharp decline in content from stage V to VIII (Figure 6). However this trend was not consistent in all clones. For example, clone Ma/71/423

Table IV. Analysis of variance for pyrethrins content of six clones at eight stages of flower development

Source	df	ms
Subplot	143	
Main plot	17	0.104
Blocks	2	0.026
Clones	5	0.262**
Main plot error	10	0.04
Development stages	7	0.75**
Stages x clones	35	0.008^{NS}
Subplot error	84	0.01

L.S.D. = 0.36 at 5%

C.V. = 12.9

*,** - Significant at the 0.05 and 0.01 probability level, respectively.

NS = Not significant.

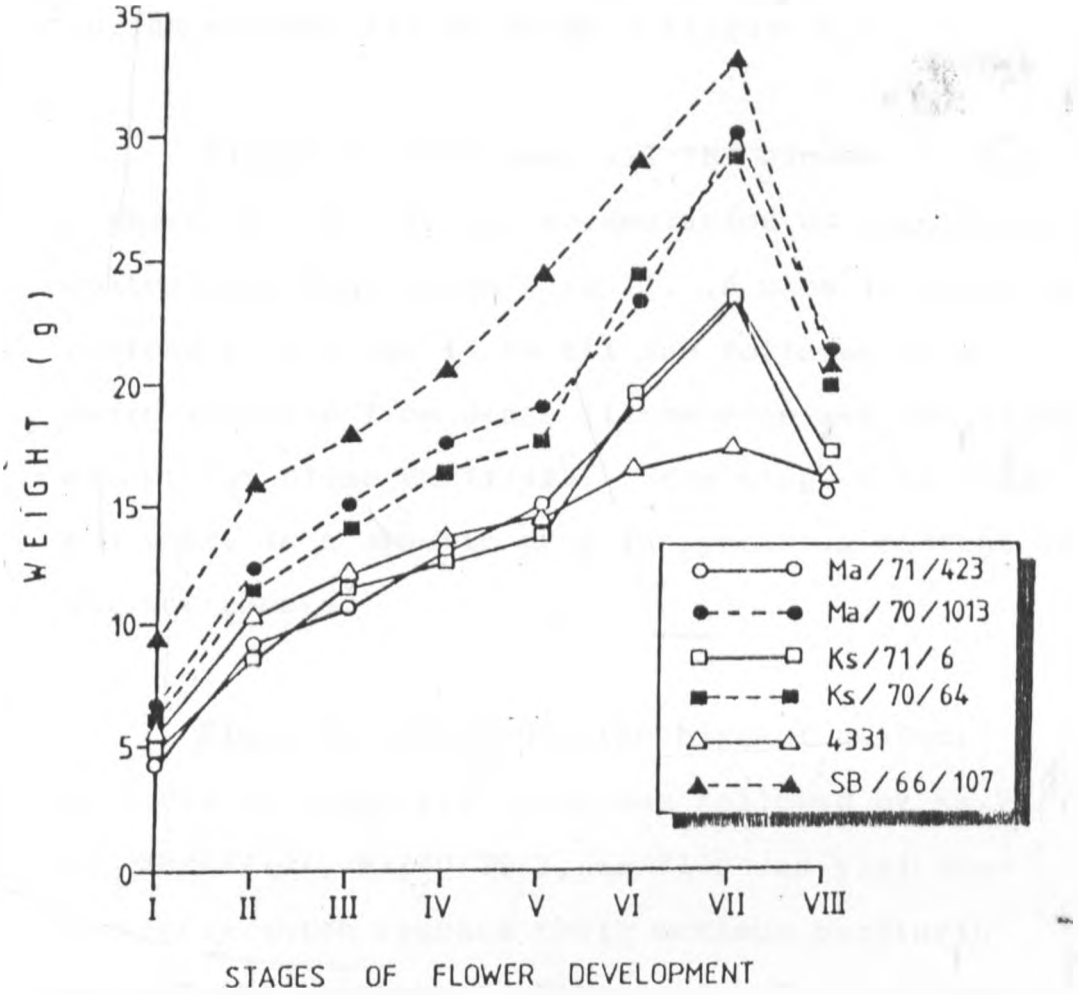

Fig 5. Dry weight of 100 flowers at eight stages of floral development in 6 different clones of pyrethrum.

reached its maximum pyrethrins content at stage IV while all the rest reached the highest pyrethrins content (%) at stage V (Figure 6).

Figure 6 shows that all the clones had a sharp increase in net accumulation of pyrethrins content (%) from stage I to II. A slow increase in content from stage II to III was followed by a sharp increase from stage III to V in all the clones except for clone Ma/71/423. From stage V to stage VIII there is a drastic drop in pyrethrin content in all the clones.

Clone Ma/71/423 had the highest content of 1.96% at stage IV. This was followed by Ks/70/64, SB/66/107, Ma/70/1013, Ks/71/6 and 4331 respectively which reached their maximum pyrethrin content (%) at stage V (Figure 6). The difference between the clone with the highest content, Ma/71/423 and the lowest in clone 4331 was .32%.

The pyrethrins content (%) at bud stage 1 was generally higher than at stage VIII (seed

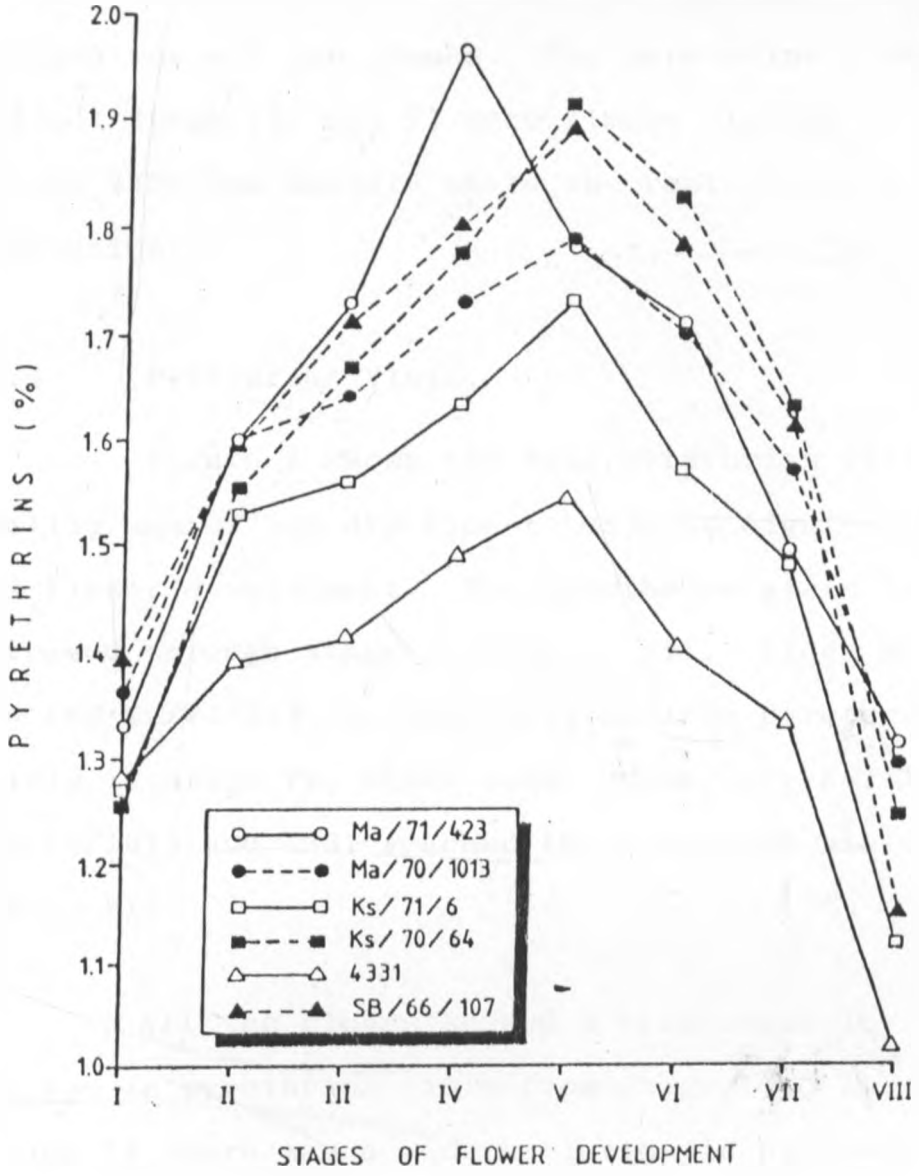

Fig 6. Pyrethrins content at eight stages of floral development in 6 different clones of pyrethrum.

stage) for all the clones. The pyrethrins content (%) at stage III and VI were almost similar in clone 4331 and Ks/71/6 while the rest showed a wide variation.

4.4 Pyrethrins Yield.

Figure 7 shows the mean pyrethrins yield in milligrams of 100 dry flower heads at eight stages of flower development. The pyrethrins yield increased through stage I to VI or VII. Clone KS/70/64 and Ma/71/423 reached their maximum pyrethrins yield in stage VI, while clone Sb/66/107, Ks/71/6, Ma/70/1013 and 4331 reached their maximum yield at stage VII.

All the clones showed a very sharp increase in pyrethrins yield from stage I to II. From stage II there was a wide variation in pyrethrins yield increase among the clones. For example, clones Sb/66/107, Ks/70/64 and Ma/70/1013 showed very high net accumulation of pyrethrins yield as compared to Ma/71/423, Ks/71/6 and 4331. Clone 4331 showed very slight change in pyrethrins.

yield from stage V to VII which is not displayed by any other clone (Figure 5).

Clone Sb/66/107 had the highest pyrethrins yield at all stages of flower development except at stage VIII (Figure 7). Clone 4331 had the least pyrethrins yield from stage III to stage VIII (Figure 7).

Clone Sb/66/107 had nearly double pyrethrins yield to that of 4331 at all stages of development. Pyrethrins yield at stage VIII was higher than at stage I and II for all the clones except for clone Sb/66/107.

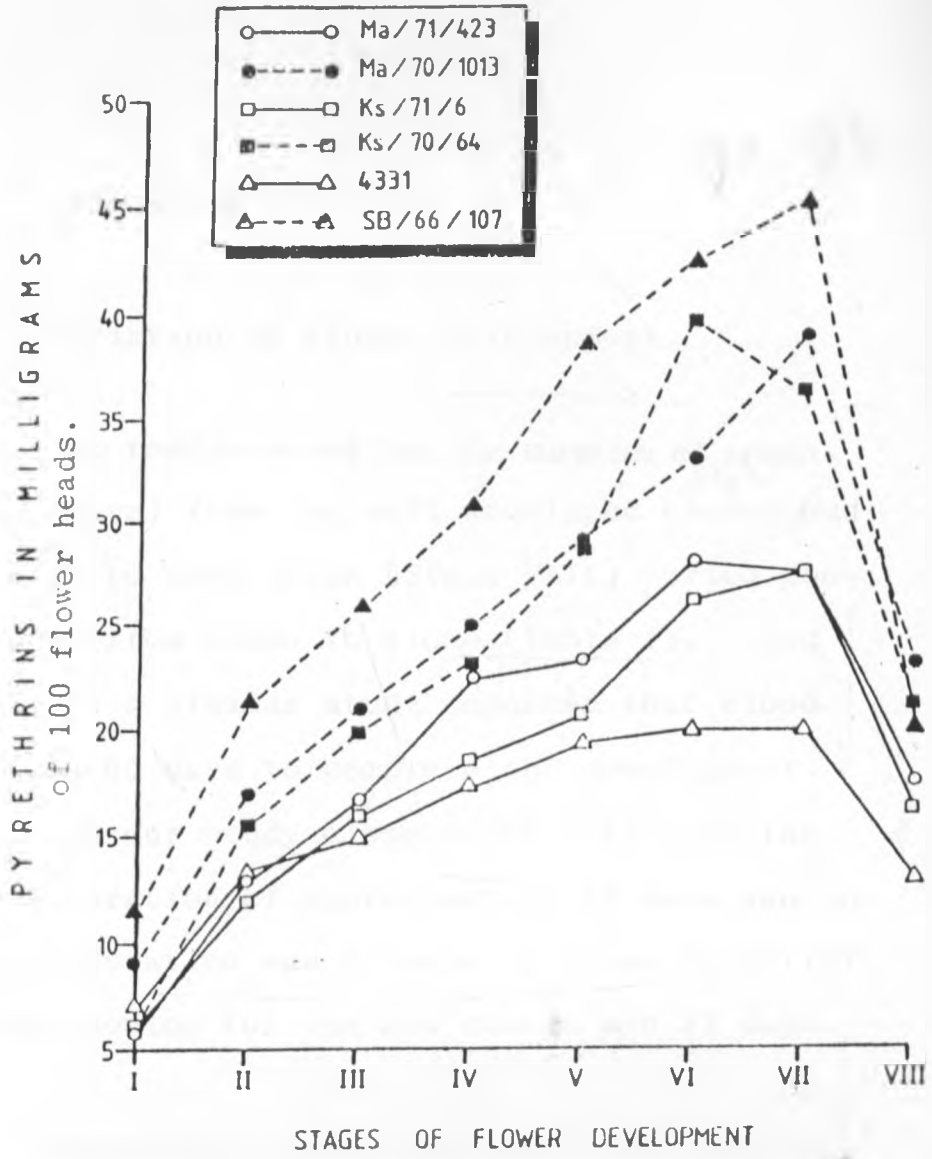

Fig. 7. Pyrethrins yield in mg of 100 flower heads at eight stages of floral development in 6 different clones of pyrethrum.

5. DISCUSSION

5.1 Variation in Flower Development.

The results showed that the duration of transition in (days) from the well developed closed bud (Stage I) to seed stage (Stage VIII) varied considerably from clone to clone (Table I). Head (1966), in a similar study reported that clone 1708 took 60 days to complete the development cycle. In our study clone Ma/70/1013 took the longest duration of approximately 57 days and the shortest duration was 50 days in clone Sb/66/107. The mean period for the six clones was 53 days.

Interstage transition period was shortest from stages II to III as it took on an average of 2 days. In clone Ks/70/64 it took approximately 3 days (Table II). This finding agrees with the results of Head (1966) of 4 days in clone 1708, while Bhat and Menary (1984 reported that it took on average 2.8 days in six different clones. Interstage transition from stage

III-IV took approximately 2.5 days for all the clones while clone Sb/66/107 took the longest period of 3.2 days. Head (1966) reported that the interstage transition period from Stage IV-V took 2 days. Our study shows that it took approximately 8.5 days. This big difference could be attributed to the environmental factors or the sampling methods, since all clones in our study showed a range between 8 days and 9.2 days.

The time lapse from a well developed closed bud (Stage I) to fully overblown (Stage V) when most of the clones are expected to have maximum pyrethrins content (Appendix 2) varied from 18 - 21.2 days in the six clones with a mean value of 19.8 days. Parlevliet (1970b) in a similar study reported that the period varied from 14 to 21 days. Head (1966) also reported that it took 21 days in clone 1708. Bhat and Menary (1984) in a similar study reported 27.9 - 32.7 days. All these studies show that the interstage transition period from a well developed closed bud (Stage I) to fully overblown (Stage V) took about

20 days for most of the clones. Bhat and Menary (1984) findings can be explained by the fact that flowering cycle in Kenya is shorter by about 9 days than observed in Tasmania (Bhat and Menary, 1984).

Parlevliet (1970) and Bhat and Menary (1984) considered only Stage I to V. The results of our study probably differ from that of Head (1966) because his conclusions were based on the performance of a single clone which represents a very narrow gene base within a highly variable population.

5.2 100 Flower Dry Weight in Different Pyrethrum Clones at Eight Stages of Flower Development.

There were highly significant differences amongst the clones for 100 flower dry weight and also at different stages of development. Lack of interaction between clones and developmental stages in 100 flowers dry weight shows that the pattern of dry weight accumulation is similar in all

pyrethrum clones ((Table III).

As expected, there was a gradual increase in 100 flowers dry weight from Stage I to Stage VII followed by a drastic drop in weight from stage VII to VIII (Figure 5) in all clones studied.

Parlevliet (1970), Bhat and Menary (1984), reported increase in dry weight from Stage I to V. Head (1966), reported a sharp increase in dry weight from Stage I to II followed by a slow increase from Stage II to III and then a sharp increase from Stage III to VII in clone 1708. A similar pattern was observed in this study (Figure 5).

The initial sharp increase in Stage I to II was due to the fast cell division during early stages of flower development. The slow increase from Stage II to III was probably due to the fact that dry matter content drops slightly before it starts to increase, probably due to fast cell

expansion in early stages of flower development. (Parlevliet and Brewer, 1971).

Parlevliet (1970) and Bhat and Menary (1984) reported the dry weight increases to a maximum in Stage V as they did not continue beyond this stage. Our study and that of Head (1966) confirms that maximum dry weight is realised in Stage VII of flower development in all the clones. From Stage VII there is a drastic drop in dry weight. This is due to the fact that the ray florets and disc florets have fallen and also the loss of water in the flower head as the flower dries (Plate 8).

5.3 Pyrethrins Content (%) in Different Clones at Eight Stages of Flower Development.

The pattern of pyrethrins net accumulation was followed for each of the six clones individually at eight stages of development (Table 6). Beckley *et al*. (1938); Head, 1966: Parlevliet, 1970b; Bhat and Menary (1979 and 1984) reported

the pyrethrins content net accumulation in the flower head vary with clone and the stage of development. Our study supports their finding in that highly significant differences existed amongst the clones in pyrethrins content and also at different stages of flower development. Lack of interaction between clones and development stages in pyrethrins content suggested that the pattern of pyrethrins net accumulation is similar in all pyrethrum clones (Table IV).

Figure 7 shows that there was a sharp increase in pyrethrins content (%) from Stage I to II followed by a slow increase from Stage II to III and then a sharp increase up to a maximum in Stage V except for clone Ma/71/423 which had attained a maximum pyrethrins content at Stage IV. The initial increase in pyrethrins content (%) is due probably to the fast synthesis of pyrethrins as cells in the flower head at this stage are characterised by a fast cell expansion (Parlevliet, 1970b).

Beckley et al (1938), Head (1966), reported that the flower head had a maximum pyrethrins content (%) when 3 to 4 rows of disc florets were opened (Plate 4), and that the yield of pyrethrins did not appreciably increase beyond this stage. Head, (1966) confirmed the results obtained by Beckley et al (1938), that clone 1708 reached maximum content of 1.89% in Stage V.

Parlevliet (1970b) Bhat and Menary (1984) reported that pyrethrins content in different clones generally increases to a maximum pyrethrins content (%) when most of the florets have opened but individual clones showed significant deviation from this pattern. Our study supports their finding as 5 out of 6 clones studied had a maximum content in Stage V (Figure 6).

From Stage V there was a sharp decline in pyrethrins content up to Stage VIII. Various theories have been proposed to explain the decline in pyrethrins content from Stage V to VII.

Parlevliet (1970b) suggested that decrease in pyrethrins content during the latter stages of flower development is associated with the rapid increase in dry matter, the increase in total pyrethrins being retarded. Bhat and Menary (1979), found with scanning electron microscope that, when the pyrethrins content reach their maximum the oil glands looked fully expanded (Stage V). The shrunken appearance of the glands at latter stages may be due to the glands stopping producing any secretions, presumably pyrethrins which were getting stored in the oil glands chamber or the content were being lost due to the metabolic conversion to some other products or due to the transfer to the secretory ducts. Brewer (1973) reported a shift in the oleoresin from the achene wall towards the ovule as the flower matured.

5.4 Weight of Pyrethrins (milligrams) in Different Clones at Eight Stages of Develpment.

Studies carried out at National Pyrethrum and Horticultural Research Station, Molo, indicate that pyrethrum yields were highest at two to three weekly picking intervals. The study also showed that pyrethrum yields were reduced by about 10 per cent when picking was done at three and four weekly intervals due to the presence of a considerable number of overblown flowers (Anonymous, 1953; 1956; 1957). Parlevliet (1970b) also suggested that the presence of maturing seeds in pyrethrum plants tends to reduce the number of newly initiated flowers.

Figure 7, shows that clone Ma/70/1013, Sb/66/107 and Ks/71/6 reached their maximum pyrethrins yield in Stage VII while clone 4331, Ks/71/64 and Ma/71/423 reached their maximum pyrethrins yield in Stage VI. These results suggests that the optimum picking stage should be a stage before the

stage of pyrethrins yield decline; for example clone Sb/66/107, Ma/70/1013 and Ks/71/6 in stage VI while clones Ks/70/64 and Ma/71/423 in stage V. Clone 4331 can be picked from stage IV-VII as it shows very slight changes during these stages.

The results obtained in our study show that for clone Sb/66107, Ma/70/1013 and Ks/71/6 to reach their optimum picking stage it takes 21.2, 23.7 and 24 days respectively. For clone Ks/70/64 and Ma/71/423 it took 20.6 and 19.2 days respectively to reach stage V, while clone 4331 took 10.9 days to reach stage IV. This is in agreement with Parlevliet (1970b)that the optimum picking for clone 4331 is at two weekly intervals while the rest of the clones in his study showed a maximum pyrethrins yield at 3 weekly intervals. It can therefore be generalised that the optimum picking interval for the clones in our study varies from 18 - 24 days except for clone 4331.

Our study, therefore showed that it is

possible to differentiate clones with similar yield potentials in terms of their maturity, 100 flower dry weight, pyrethrins content and pyrethrins yield at different stages of flower development. Our study also showed that it is possible to recommend on the optimum picking stage for each clone. This is not feasible today as the farmers do not only grow the recommended clones but also other varieties of unknown origin. This has lead to farmers being given a blanket recommendation of picking all the flowers with horizontal petals (Stage III) or picking at two to three weekly intervals. Our finding is, therefore, important if in future farmers grow a limited number of clones. It will also be possible for breeders to give individual recommendation for optimum picking stage for each clone, for example, clone Ks/71/6 can be picked after 24 days while clone 4331 can be picked after only 11 days.

5.5 CONCLUSION

The method presented in our study for following the rate of flower development, the 100 flower dry weight, the pyrethrins content and pyrethrins yield in the flower head in six different clones at different stages of development individually is not limited to these clones only but can also be applied to other clones.

Our study shows that, highly significant differences exist amongst the clones in terms of both pyrethrins content and 100 flower dry weight and also at different stages of flower development. Lack of interaction between clones and developmental stages in both pyrethrins content and 100 flower dry weight shows that the pattern of dry weight and pyrethrins content (%) net accumulation is similar in all pyrethrum clones.

From our study, it can be concluded that each pyrethrum clone under similar growing conditions

has a characteristic dry weight, pyrethrins content (%) and pyrethrins yield net accumulation pattern of its own. It can also be concluded that, under uniform growing conditions, the interstage transition period is characteristic of a particular clone. It is therefore an important consideration in determining the optimum timing of picking for each clone individually.

Results obtained in our study clearly show that it is possible to differentiate and characterise clones in terms of their maturity, dry weight, pyrethrins content (%) and pyrethrins yield at different stages of development.

Our results show that it is possible to characterise and determine the optimum time of picking for each of the recommended clones individually rather than having a blanket recommendation as practiced today. Picking at the optimum time will go a long way in boosting the pyrethrum industry and benefit farmers who are paid by the amount of kilograms of pyrethrins delived to the Pyrethrum Board of Kenya.

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Appendix 1. Mean dry weight of 100 flower heads (grammes)of six pyrethrum clones at eight stages of development.

Stage	Clone	Dry weight of 100 flower heads (g)						
		Ma/70/1013	Ma/71/423	4331	SB/66/107	Ks/71/6	Ks/70/64	Mean
I		6.4	4.5	5.5	8.4	4.9	5.7	5.8
II		10.9	8.3	9.3	13.6	8.2	10.1	10.0
III		13.0	9.7	10.7	15.2	10.2	12.2	11.9
IV		14.6	11.6	11.6	17.3	11.3	14.0	13.4
V		16.2	12.9	12.6	20.5	12.0	15.0	14.6
VI		19.6	16.3	14.2	24.0	16.8	21.5	18.7
VII		25.0	18.6	14.9	27.4	18.7	22.4	21.1
VIII		18.0	13.5	13.7	17.6	14.6	17.1	15.8
Mean		15.5	11.7	11.6	18.0	12.0	14.8	13.9

Appendix 2. Mean pyrethrins content of six pyrethrum clones at eight stages of flower development.

	Pyrethrin content %						
Stage / clone	Ma/70/1013	Ma/71/423	4331	SB/66/107	Ks/71/6	Ks/70/64	Mean
I	1.36	1.33	1.28	1.38	1.27	1.25	1.31
II	1.60	1.60	1.39	1.59	1.53	1.55	1.54
III	1.64	1.73	1.41	1.71	1.56	1.67	1.62
IV	1.73	1.96	1.49	1.8	1.63	1.78	1.73
V	1.79	1.78	1.54	1.89	1.73	1.91	1.77
VI	1.70	1.71	1.40	1.78	1.57	1.85	1.67
VII	1.57	1.49	1.33	1.66	1.48	1.63	1.53
VIII	1.29	1.31	1.01	1.15	1.12	1.24	1.19
Mean	1.59	1.61	1.36	1.62	1.49	1.61	1.55

Appendix 3. Pyrethrins yield in milligrams of 100 flower heads at eight stages of floral development.

Stage	Clone	Pyrethrins yield in milligrams of 100 flower head						
		Ma/70/1013	Ma/71/423	4331	SB/66/107	Ks/71/6	Ks/70/64	Mean
I		8.68	5.93	7.0	11.52	6.19	7.11	7.74
II		17.44	13.20	12.89	21.64	12.5	15.76	15.57
III		21.42	16.71	15.1	26.03	15.97	20.44	19.28
IV		25.24	22.66	17.36	31.1	18.39	24.92	23.28
V		29.07	23.0	19.4	38.71	20.78	28.76	26.62
VI		33.32	27.87	19.81	42.71	26.33	39.78	31.65
VII		39.22	27.76	19.80	45.43	27.66	36.61	32.75
VIII		23.26	17.66	13.84	20.24	16.33	21.23	18.75
Mean		24.71	19.35	15.65	29.68	18.02	24.33	21.96

Appendix 4. Pyrethrum production in Kenya from 1935 to 1984 in metric tons of dry flowers.

Period	Flower production	Period	Flower production
1934/35	327	1960/61	9312
1935/36	1095	1961/62	10931
1936/37	1005	1962/63	3511
1937/38	1894	1963/64	5269
1938/39	1915	1964/65	6256
1939/40	5954	1965/66	7876
1940/41	5856	1966/67	10698
1941/42	5557	1967/68	11237
1942/43	4173	1968/69	7423
1943/44	6652	1969/70	6005
1944/45	7528	1970/71	9748
1945/46	6848	1971/72	14414
1946/47	3970	1972/73	10698
1947/48	1582	1973/74	13722
1948/49	1541	1974/75	15034
1949/50	2211	1975/76	14267
1950/51	2266	1976/77	11428
1951/52	1781	1977/78	8437
1952/53	2356	1978/79	7450
1953/54	2591	1979/80	10423
1954/55	3527	1980/81	15702
1955/56	3477	1981/82	18900
1956/57	3933	1982/83	8000
1957/58	4596	1983/84	3200
1958/59	4912		
1959/60	6604		

Source: Pyrethrum Board of Kenya Production figures.

Appendix 5. Yearly production in metric tons of dry flowers and their corresponding producer prices from 1965 to 1983 in Kenya.

Period	Flower production	Producer prices Ksh/kg of pyrethrins
1964/65	6256	368
1965/66	7876	423
1966/67	10698	411
1967/68	11237	375
1968/69	7423	311
1969/70	6005	333
1970/71	9748	375
1971/72	14414	379
1972/73	10698	408
1973/74	13722	430
1974/75	15034	472
1975/76	14267	530
1976/77	11428	630
1977/78	8437	905
1978/79	7450	1200
1979/80	10423	1200
1980/81	15702	1200
1981/82	18900	1200
1982/83	8000	1200
1983/84	3200	1200

Source: Pyrethrum Board of Kenya
Production figures.

Appendix 6: Recommended Clones in Kenya.

Clone	Year of release	Flower yield potential kg/ha/year	Pyrethrins content (%)	Pyrethrins yield potential kg/ha/year	Altitude
4331	1964	1000-1200	1.6	16-19.2	1800-3000
SB/66/107	1976	900-1000	2.0	18-20	2200
Ma/70/1013	1979	1100-1200	1.90	20.9-22.8	2200
Ks/70/64	1979	1000-1100	1.90	19-20.9	2200
Ma/71/423	1979	1000-1100	1.80	18-19.8	2200
Ks/75/313	1979	1100-1200	1.60	17.6-19.2	2000
Ks/72/43	1980	900-1000	2.10	18.9-21	2200
L/72/26	1980	1100-1200	2.10	23-25.2	2200
Kr/74/443	1982	1000-1100	2.10	21-23	1800
Kr/74/223	1982	900-1000	1.95	17.55-19.5	2200
Kr/74/122	1982	900-1000	2.10	18.9-21	2200
Mo/70/1124	1979	900-1000	1.90	17-19	2200
Variety P_4	1970	600-800	2.0	12-16	2100

Source: Recommendation from the National Pyrethrum Research station Molo, Kenya.

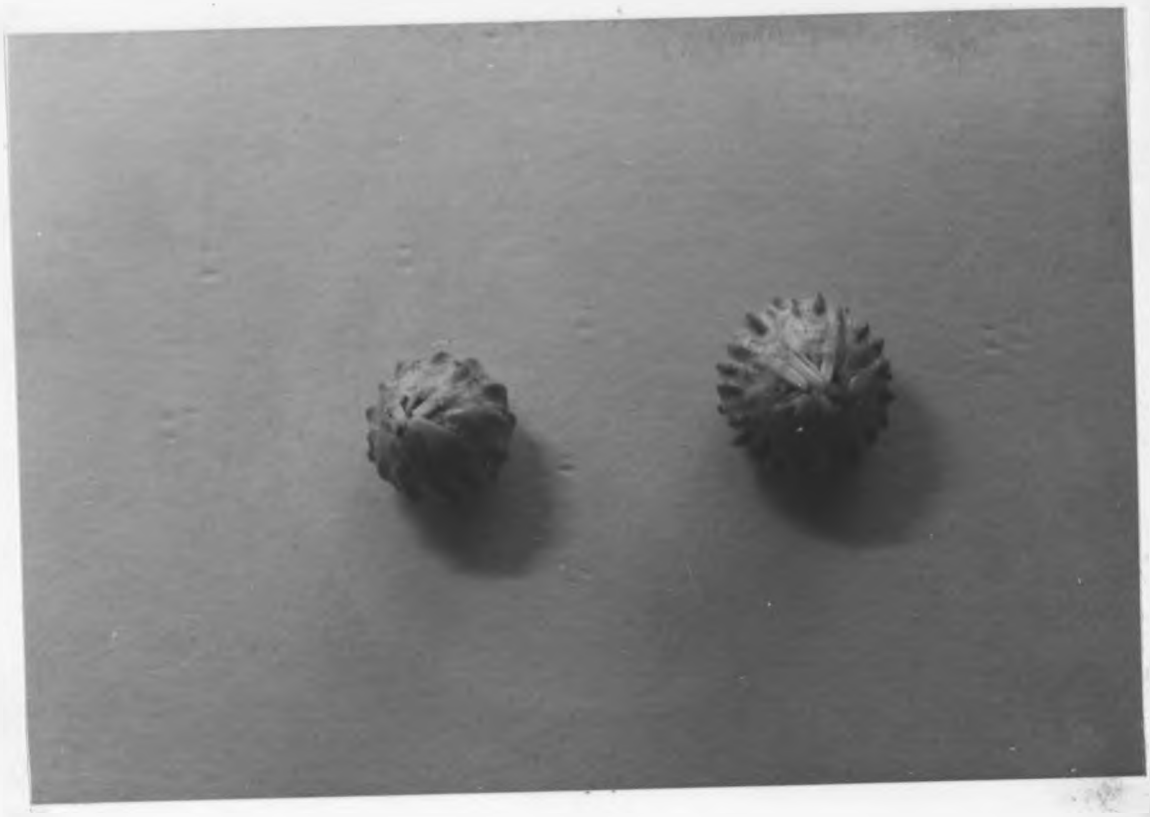

Plate 1. Well developed closed bud.

Plate 2. Ray florets vertical.

Plate 3. Ray florets horizontal, first raw of disc florets open.

Plate 4. Approximately three rows of disc florets open.

Plate 5. An inflorescence with nearly all disc florets open.

Plate 6. Early overblown condition, colour of disc florets diminishing but ray florets still intact.

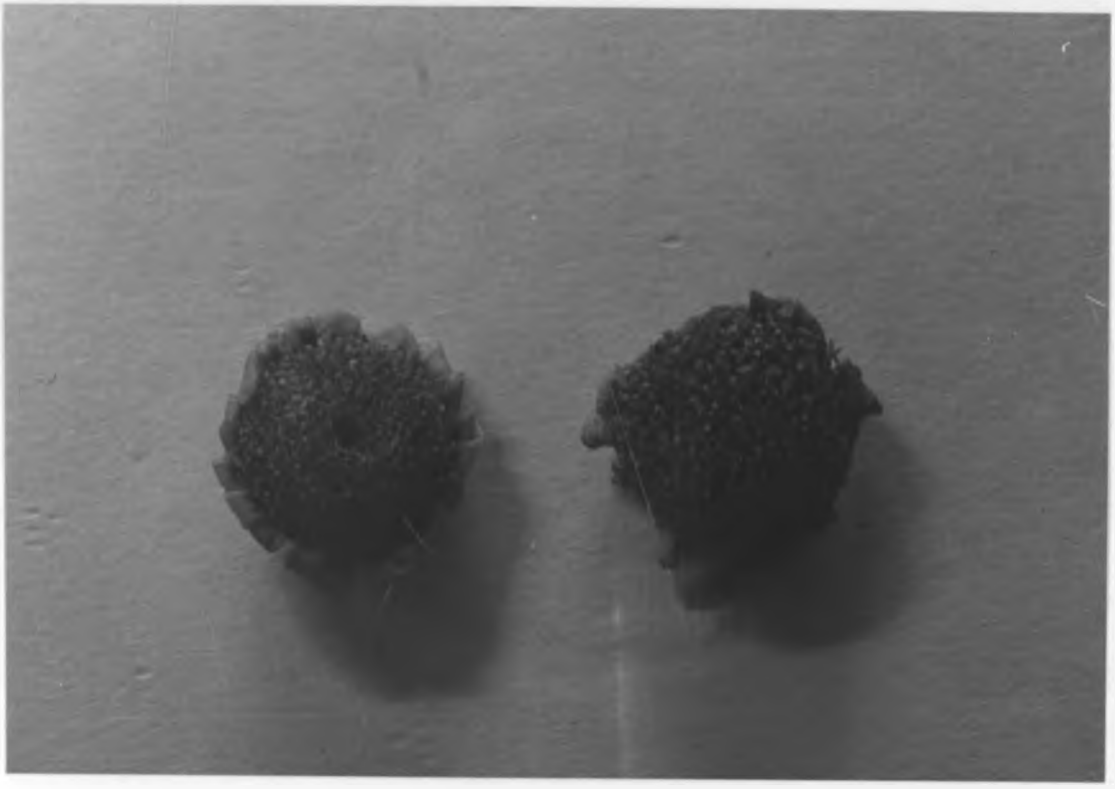

Plate 7. Late overblown, little colour remaining in disc florets but still intact, ray florets dried out.

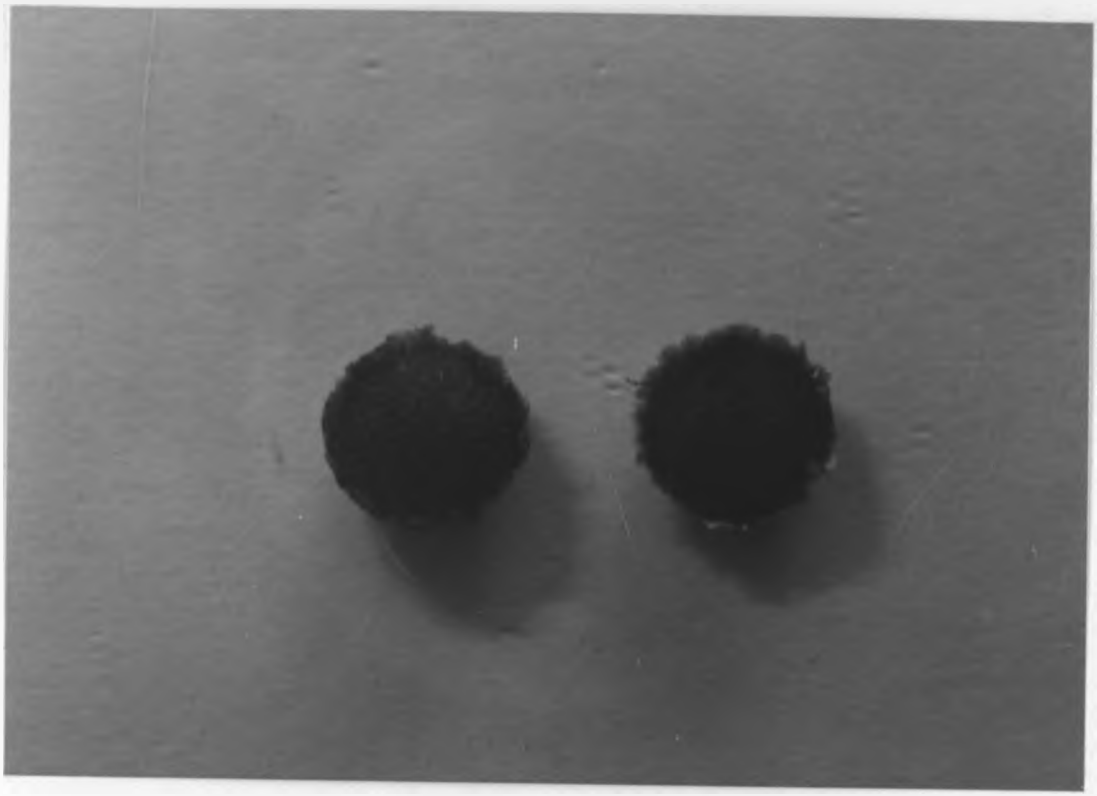

Plate 8. Disc florets fallen, stem dry 2 cm below the flower head - suitable for collection for seed.