PLATE 1.—*Pyrethrum trials at Aiyura.*

PYRETHRUM IN THE HIGHLANDS OF NEW GUINEA

A. J. SCHINDLER.

Pyrethrum is a crop which has created a thriving industry in the Equatorial Highlands of East Africa. The author, who studied African pyrethrum production at first hand, has been in charge of the pyrethrum experiments of the Department of Agriculture, Stock and Fisheries of the Territory of Papua and New Guinea. Mr. Schindler describes methods of cultivation and selection of soils, which best suit New Guinea conditions. He reviews the firm market prospects for pyrethrum, despite the spectacular development of synthetic insecticides. His conclusion is that pyrethrum offers good possibilities, both for European and native planting in the Territory's Highlands. Mr. Schindler is Agronomist-in-Charge, Highlands Agricultural Experiment Station, Aiyura, Eastern Highlands.

A DAISY-LIKE plant, *Pyrethrum cinerariifolium,* of the Chrysanthemum group of the Compositae family, is the source of the valuable insecticide, pyrethrum. The plant has a flower head made up of a cluster of tiny flowers, consisting of an outside ring of "ray" florets and an inner mass of "disc" florets. The active constituents, or pyrethrins, are formed in glands at the base of the florets and are obtained when the flowers are crushed.

Pyrethrum has unique and important properties which enable it to withstand the competition of modern synthetic insecticides. It is one of the few insecticides which is completely harmless to man and animals. The active pyrethrins also have a quick knock-down power when applied to most insects. This knock-down is not completely lethal and some insects can make a recovery.

However, recent discoveries have introduced other substances, which although not lethal in themselves greatly increase the lethal power of the pyrethrins. These are known as synergists. One of the most common is piperonyl butoxide.

About 85 per cent. of pyrethrum is used domestically, about 10 per cent. goes to industry and the remainder is used in agriculture. Com-

mercial sources say that if the price of pyrethrum could be reduced the market could be expanded. In the last decade, there has been some pessimism about selling the world's pyrethrum crop in the face of competition from synthetics, but pyrethrum is, in fact, holding its own.

The price paid to farmers for dry flowers of 1.5 per cent. pyrethrin content varies from 2s. 6d. to 3s. (Aust.) per lb., and the yield an acre varies from 300 to 1,000 lb. of dried flowers. From an acre, the producer would expect to gross a return of £A40 to £A150. One pound of pure pyrethrum sells for about £A18 which allows roughly £A8 for manufacturing costs plus profit to the manufacturer.

The establishment of an extraction plant in Kenya has been the main factor contributing to the profitable production of pyrethrum in East Africa. The extraction plant at Nairobi was built about 1940 and a new plant is now being built at Nakuru. Before 1940, baled flowers were shipped abroad. These consignments lost weight during the sea voyage, the pyrethrin content deteriorated and little margin of profit was left to the grower. Now the extract is exported at concentrations of 15 to 20 per cent. pure pyrethrin and can be carried by air-freight. Previously, very careful picking was the rule at weekly or closer intervals. But picking can now be spaced at fortnightly or three-weekly intervals and this has brought about a big reduction in costs.

Soil and Climatic Conditions

Pyrethrum can thrive on a great variety of soils, if they are fertile. In Kenya, the soils of the pyrethrum-growing areas are derived from volcanic rocks, rich in plant food, and on the acid side of the pH range. Best conditions in East Africa are found on the recent volcanic soils and ashes around Lake Kivu, in the Belgian Congo and near the Kilimanjaro and Meru mountains in Taganyika. However, in Dalmatia, which is said to be the natural habitat of pyrethrum, the soil is light and calcareous.

Slopes liable to erosion are not suitable for pyrethrum because clean-weeding is essential and the bare soil is exposed to wind and water erosion for the three or four years the crop is in the ground. Flat or gently-sloping land is best.

An evenly-distributed rainfall is important for good pyrethrum yields and a healthy crop, because the plant is affected by drought or continuous hot and dry winds. Pyrethrum is also harmed by "wet feet" and where this is likely to occur drainage will be necessary.

Soils with natural free-draining textures are ideal for pyrethrum. They are found in many parts of the Highlands of New Guinea, although they do not necessarily occur over large areas. These soils can usually be cultivated easily and are often fertile. They therefore coincide with areas of heaviest population density.

The largest expanse of these open-textured soils is developed around Mount Hagen, and there are other significant areas in the upper Asaro Valley. Smaller areas are found in the Wabag area, on the Ramu-Purari divide, where the land is also quite hilly, in the valleys running into the Middle Wahgi from the north and south and in the valleys of the Finisterres. This survey excludes other Highland areas, such as those in Papua, which are unknown to the author.

Extensive trials will provide information about the usefulness of other soil types, such as the heavy clays of the Eastern Highlands, which do not possess good draining textures. No recommendation can yet be given for pyrethrum on these soils, because they are liable to waterlog in the wet and to cake hard in the dry season.

More information is also needed about pyrethrum possibilities on the organic soil of the pitpit swamp areas, which can be drained fairly easily, and which occur in many parts of the Highlands.

Optimum Altitudes

Close to the equator, pyrethrum produces best at altitudes of 8,000 feet or more. The limits of altitude are stated to be from 6,000 feet to 9,000 feet. The New Guinea Highlands lie about six degrees south, so favourable conditions should be found between 5,000 feet and 8,000 feet, with 7,000 feet and above as the optimum. However, verification of this will depend on the results of investigations into the response of pyrethrum in the Territory. The following table

shows how altitude and pyrethrin content are related to the effect of differences in mean temperature.

TABLE I.—Altitude, Temperature and Pyrethrum Content, Kenya Crop in 1956

Altitude in feet.	Mean Temperature Degrees F.	Pyrethrin per cent.
8,500	57.0	1.53
7,500	59.2	1.45
6,500	62.8	1.37

Much depends also on the particular temperatures prevailing about flowering time and it has been found that in general a rise in mean temperature by one degree results in a fall in pyrethrin content of 0.03 per cent.

Selection and breeding work is now under way at Aiyura with the object of producing strains capable of being grown outside the present altitude limits.

Yields

Preliminary plantings of many strains have shown that pyrethrum grows well at the Highlands Agricultural Experiment Station at Aiyura. Early extraction results from bulk flowers have also indicated that pyrethrum from Aiyura has a useful content of pyrethrin. It is expected that yields at Aiyura, which lies at an altitude of 5,400 feet, will average about 500 lb. of dry flowers per acre per year and that strains will be developed to yield more than 1.5 per cent. pyrethrin. On good soils at about 7,000 feet, crops of 1,000 lb. per acre should be expected. The expectation at 6,000 feet is 700 lb. per acre and at 5,000 feet 400 lb. is as much as could be expected. Confirmation of yields will depend on pilot plantings.

Preparation of the Land

(*a*) *Selection*

Choose flat or gently sloping land for pyrethrum. On flat land, even if the soil is of good open type, ridge planting will be necessary to provide drainage during wet periods. Where the land is gently sloping, some degree of protection from soil erosion will be necessary, together with ridge planting. On steep slopes special attention must be paid to erosion control measures and this work over a large area may be too costly. Pyrethrum is a suitable crop for planting immediately after grass has been ploughed out as long as the soil has not been ruined by former erosion or continual firing. Forest soils are, of course, also suitable.

(*b*) *Eradication of grass and weeds*

The preparation of the land is aimed mainly at the elimination of the hard stoloniferous grasses such as couch and kikuyu. They must not be allowed to build up again during the three years or more that pyrethrum is cultivated. Where such grasses exist several ploughings and cultivations will be necessary, followed by hand digging to extract the pieces of grass which remain. Where only tussocky native grasses are found, there would be no need for these measures. Where fields are to be only a few acres, as in early trial plantings, all the preparation of the land could be done by hand.

(*c*) *Anti-erosion measures*

On small areas, anti-erosion measures are hardly necessary but even so it would be wise to plan the field on the contour principle, so that the rows are level. If the soil is not porous the rows should slope slighly to allow the soil to drain easily. The field must also be protected at

PLATE 2.—*The pyrethrum flower.*

the top by a drainage channel to prevent wash from higher land. A convenient slope for the drainage channel is a foot in 200 feet with a triangular cross-section 18 inches deep, three feet wide on the surface sloping to a point at the base. Where very heavy falls of rain are expected and channels are about 1,200 feet long, the cross-sectional area is increased and an early slope of 1 : 200 may be increased to 1 : 100 along the channel to carry off large volumes of water.

A basic line at the top of the field is run out by dumpy level or by striding level (A-frame) and marked at intervals. To obtain the slope, one leg of a six-foot A-frame has a piece of wood a third of an inch thick nailed to the bottom of it. If a slope of 1 : 100 is required, the piece of wood should be two-thirds of an inch thick. The basic line is followed when making the protection drain. The same line is followed when running out the first planting ridge.

Where larger areas are planned, consideration must be given to further anti-erosion measures. The extent of these measures depends on the slope of the land, the nature of the soil and rainfall. The first operation is to decide where to run off the water, the second is to find the average slope of the field and the third is to mark the position of each drainage channel. The frequency of the drainage channels determines the quantity and velocity and hence the erosive power of the run-off water. The table on the next page will give an indication of the spacing between the drainage channels.

(*d*) *Throwing up the ridges, fertilizing*

The field should be ready when the nursery plants are four to five months old. Final cultivation should be done in the week before transplanting, when the ridges should be thrown up.

Overseas experiments have shown that on grassland soils, phosphate at the rate supplied by two to three hundredweight of 18 to 20 per cent. superphosphate an acre will increase the yield of flowers over the three years by up to 20 per cent. The superphosphate must be applied to the soil under the pyrethrum rows just before planting and before throwing up

PLATE 3.—*Ridged cultivation of pyrethrum at Aiyura.*

the ridges. However, fertilizing in Papua and New Guinea cannot yet be recommended until field trials have been made to test its value.

The ridges are made by following the drainage channel and using it as a guiding trace to build parallel ridges so that the furrows between the ridges act as drainage ways with a slight slope similar to the channel. If a considerable area has been prepared and more than one drainage channel crosses the field, then the ridges on the upper half of the field are made parallel to the upper drainage channel and the ridges on the lower half are made parallel to the lower channel. The untouched spots are worked in later. This preparatory work should be done accurately, particularly if mechanical cultivation for later weeding is planned. The ridges for double row planting are made two feet wide. If single row planting is proposed, the ridges are made one foot wide.

TABLE II.—Intervals Between Channels.*

Slope of land feet per 100 feet	Vertical drop between channels feet	Distances between channels in feet	Lineal feet of channel to give an acre between channels
2	3	150	300
4	4	100	430
6	5	83	520
8	6	75	570
10	7	70	610
12	8	66	650
14	9	64	670
16	10	62	700

(* Adapted from Table 10, "Soil Erosion and its Control", Ayres, McGraw-Hill).

In East Africa, pyrethrum is planted at rates of from 14,500 to 22,000 plants an acre. The higher density should suit the New Guinea Highlands, where drought is usually not a problem. The best method of planting is to have the plants in double rows on a low ridge and to have the ridges four feet apart. The plants in each row go in one foot apart, staggered into the double row as in triangular planting. This system leaves three feet of working space between the double rows for either a small cultivating machine or a machine which straddles a double row, while operating two or four cultivating attachments on its tool bar.

Another method of spacing to give the same number of plants per acre is to have single rows two feet apart with the plants again spaced in the row at one foot apart.

Establishing the Crop

Planting Material

The first introduction of a new variety of pyrethrum to a plantation is usually by seed. This must be from a high-yielding strain, proven by chemical analysis and of good agronomic character, uniform and not subject to lodging.

Further multiplication may be done from splits of the existing proven high-yielding plants. A well-grown vigorous plant will split into five or ten pieces for planting. To extract splits from a mature field, the old field must be examined and all weakly, sickly, lodged and non-flowering plants dug out. Three or more acres of old field will probably provide enough splits to plant ten acres of new field. The plants remaining are dug out with forks during favourable weather and the old flowering stems and half the foliage is cut off. When dividing the plants ensure that each split retains many roots. Splits have a certain advantage over seedlings when conditions are wet as the slender seedlings may be overwhelmed by surface water. Splits also flower earlier than seedlings.

Seedlings, with a strong root system do better in dry weather. For their production a nursery is necessary. If it is proposed to plant a second time by seed, it is necessary to go back to the cross between the original parents of the variety, as the seed produced by the second generation in the field will not produce the same high quality plants as those which come from the original cross.

Nurseries

The viability and germination percentage of seed can vary and hence the amount of seed required will also vary. Forty per cent. germination can be expected from good seed and at this rate three-quarters of a pound will plant an acre. The seed is planted in the nursery bed at an ounce to 100 sq. ft. of nursery. The requirement, then, for one acre in the field is 1,200 sq. ft. of nursery bed.

The nursery should be established where there is well-drained rich soil with a water supply close by. Usual nursery bed technique should be observed. The beds should be four feet wide separated by paths 18 inches wide. The soil

should be cultivated to a fine tilth and raked level. The seed should be drilled in rows across, or along the bed, at the rate of about ten seeds to the inch if the drills are four to five inches apart.

The seeds are slightly covered by fine soil and grass mulch should be laid on the surface. Avoid over-watering. The seed starts to germinate in ten days and all viable seeds are germinated within a month of planting. At first, as the plants develop, frequent light waterings should be made. Later heavier and less frequent applications are necessary to encourage good rooting. When germination commences, the grass mulch must be removed. In some seasons a light shade canopy will help the young plants. The shade if used should be removed after the seedlings have made a month of growth.

At four to five months old, the seedlings are ready for transplanting to the field in suitable weather.

early April in the Highlands. The land should not be too wet or it will become puddled as labourers continually tramp it down. The nursery plants are dug out deeply to avoid root damage and are carried to the field in baskets or bags. The planter is armed with his planting stick, which is also used for measuring as described above. With this he makes the holes as he goes along the ridge, carrying at the same time his bundle of plants. He drops the roots of each plant into the hole, taking care not to curl them up, and firms the soil around them with his foot. It is certain that a few plants will fail to take and these must be replaced without delay by new and well-grown plants.

Care and Cultivation

Weed growth, if not prevented after planting, will soon ruin the field. Weed growth at any time will greatly reduce the yield. Ridged fields can be weeded in the furrow by the tractor ridging attachment running through and throwing some soil back over the ridge. Hand weeding will be necessary among the plants on the ridge. Any invasion of couch grass must be dug up and removed by hand.

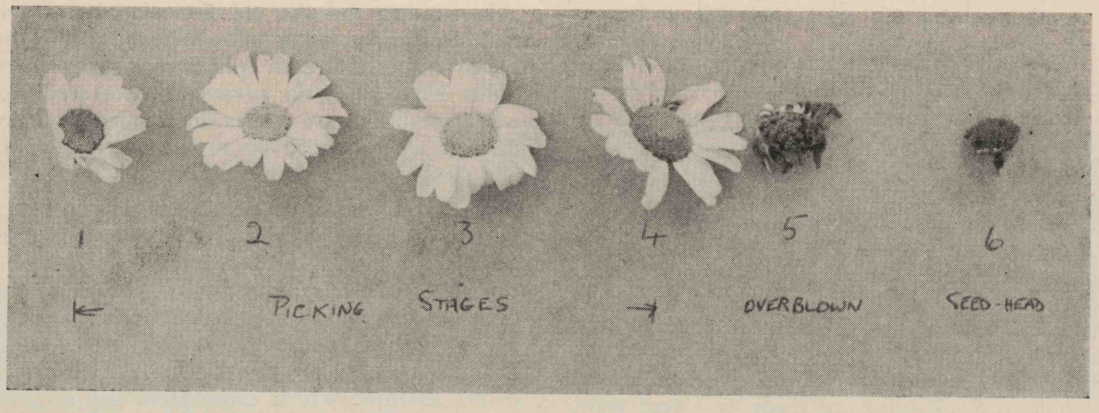

PLATE 4.—*Stages of Pyrethrum flowering.*

Transplanting—(a) Marking Out

Accuracy is unnecessary as the plants on the ridge itself must be weeded by hand. Each planter carries a stick to show him the distance between the plants. If he is planting single row, the stick is a foot long. If he is planting double row, the stick is 14 inches long and the planter must be taught to lay it down diagonally from plant to plant. The sticks should be strong and at least an inch in diameter and sharpened so they can also be used for digging.

(b) Planting

Generally, good transplanting weather would be almost any time between early December and

Once a year, the old flowering stalks which remain behind after the flowers have been picked must be cut back as far as the level of the foliage with a sickle or a pair of hedge clippers.

Pests and Disease

Pyrethrum until recently has been very free from diseases and it is expected that there would be few problems with the crop in New Guinea for some time.

In 1946, in Kenya, a fungus *Ramularia bellunensis* began to attack pyrethrum, and has become rather troublesome. It attacks the flower heads, causing them to twist and become deformed and all affected buds fall off before maturing.

Individual plants in a field may develop root rot but this is not serious except in old fields.

Nematodes may become serious in some fields and in many places their presence makes rotation essential.

Harvesting and Processing

Picking

There are several stages recognized in the ripening of the flowers. After the bursting of the bud the immature flower stands with its white petals vertical, before they turn down to the horizontal position. Then the yellow ray florets commence to open on the outer edge of the flower. After some days, the whole of the disc florets are open and the stamens and styles die leaving the flower in the " overblown " condition. The time from bud-burst to overblown varies according to the season, but is usually about a fortnight and the periods between harvesting will vary accordingly. The best system of harvesting is to pick often enough to avoid the overblown flowers. The period will vary around two weeks. Buds and immature flowers with vertical petals are not to be picked but all maturing flowers at all the other stages are harvested. The removal of young flowers with petals horizontal stimulates the plant to produce more flowers. However, if flowers are permitted to become overblown, this will place too great a strain on the plant and subsequent flowering is reduced.

The flowers are broken off just under the disc, ensuring that no stem is taken with the flower. Flowers should not be picked while wet with dew because they may ferment and overheat before the first drying. The flowers should not be crushed when put into the pickers' baskets. An average day's harvest for one picker when the flush of flowers is on the plants is 40 lb. of fresh flowers. Four pounds of fresh flowers yield about one pound of dried flowers.

Drying

Sun-drying is satisfactory for small areas and where sunny days can be expected. However, prolonged dull humid weather may cause the half-dry flowers to ferment and to lose some of their pyrethrum content. Where a crop is yielding at the rate of 800 lb. of dry flowers an acre, a peak day pick over one acre may be expected to yield 280 lb. of fresh flowers. Drying trays should not be loaded with more than one pound of fresh flowers for each square foot of tray. At a spacing period of two weeks between harvests and in sunny weather the day's harvest should be dry before the next harvest comes in, hence one would require not less than 280 sq. ft. of trays for each acre. A well-protected shed is necessary for storing the trays at night or in wet weather.

In hot-air drying, the usual practice is to have two or three trays in a cabinet, through which a draught of hot air is blown. A drier can be built on the farm if a heat-exchanger and a fan and a small motor are obtained. Slow draught driers use temperatures no greater than 140 degrees but newer forced draught driers can employ temperatures as high as 190 degrees. In the former a charge of fresh flowers will be dried in about ten hours, but in the latter one or two hours will suffice to complete the drying.

Faults in drying are fermenting, steaming or scorching the flowers. Fermentation is caused by leaving the fresh flowers in wet piles awaiting a place in the drier, by drying too slowly, or by heaping too deeply. Steaming is brought about by high temperatures accompanied by poor air circulation. Scorching is caused by high temperatures or contact with very hot plates.

Packing

After drying, the flowers are allowed to cool before packing. If the extraction centre is close at hand, ordinary jute bags could be used, but if the flowers are to be sent a long way they may be subject to deterioration due to contact with air and moisture changes and packing in polythene bags may be desirable. The flowers must be lightly packed to prevent breaking them up with subsequent loss through open mesh bags. If it is necessary to store flowers they must be placed in a cool dry place.

Economics of Production

Life of the Plantation, Rotation

Only under the very best of conditions will a plantation remain profitable for more than four years from first flowering and three years is a

more general expectation. Weeds slowly enter the field and more and more frequent weedings become necessary. Plants tend to die from obscure causes which are expensive to combat. The numbers of destructive pests such as nematodes increase with time. As the pyrethrum crop diminishes the operator must seek a renumerative rotation.

In Kenya, where there is local production of grains and pastoral products, very favourable rotations have been found. Pyrethrum is planted for four years, wheat for one season, then the fields are planted to grass and grazed for three to four years. Nematodes disappear and the soil structure improves immensely after the compaction it has suffered under the pyrethrum crop. Suitable rotations for New Guinea cannot yet be anticipated but the best results will probably be obtained from some of the grain or grass crops.

Extraction

Extraction is a complex chemical process and will be one of the largest problems confronting the establishment of a pyrethrum industry in New Guinea. Some interest has been shown by chemical firms in Australia, however, and it may prove economical to erect an extraction plant in New Guinea to deal with fresh flowers if the farm production of pyrethrum becomes a part of Territory agriculture.

Production Costs

Farm production does not demand a high capital cost. Small areas can be worked by hand labour alone. Agricultural machinery can be used for most cultivation and weeding operations if the fields are laid out so that the implements can work between the rows. However, the farm work is essentially for hand labour and machinery would replace little more than one-quarter of the labour force.

The approximate expenditure in units of labour can be determined from Kenya figures and from New Guinea experience with labour (see Table III).

Summary

For suitably well-drained soils at elevations above 5,000 feet in the Territory of Papua and New Guinea, strains of pyrethrum are available which will produce satisfactorily. It is confidently expected that further improved strains will be selected and developed.

As a farm crop it could be developed as a subsidiary to other types of farming, but there is little to indicate at the present that pyrethrum could become a main crop or sole crop for a plantation.

Pyrethrum offers great possibilities as a native farm crop, being especially suited to small plots, hand labour and requiring little capital.

Extraction and marketing are the main difficulties and much has yet to be done in discovering an outlet for the Territory's potential production.

TABLE III.—Estimated Labour Expense in Units On One Acre for Three Years of Pyrethrum Production.

Item	Labour units	Labour units if assisted by agricultural implements
Nursery preparation and care for five months	90	90
Transplanting	40	40
Preparation of land. Cutting Grass. Two diggings, one channel, ridging	100	30
Weeding for three years	240	100
Harvesting for three years	300	275
Baling, drying	60	60
TOTAL	830	595