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INFLUENCE OF SMOKE AND ETHYLENE ON THE FRUITING OF THE PINEAPPLE (ANANAS SATIVUS SHULT)*

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The pineapple is one of the principal export crops of Puerto Rico. The large crop months are May, June and July. These unfortunately, are the peak months for the Cuban crop. As might be expected, therefore, there are times when the American market receives more pineapples than can be profitably sold. If the season of production of pineapples could be extended so that a larger proportion of the fruit could be ready for the American market in advance of the usual time, the economic situation would be improved. It was with these ideas in mind that this investigation was undertaken.

An immediate stimulus to the direction of this investigation was the fact that one of the important growers in Puerto Rico was shipping his pineapples to the American market some months in advance of the other growers. From observations and from discussions with this grower and others, it appeared, that the only departure in cultural methods made by this grower was the use of smoke to hasten the flowering of the pineapple. In practice this grower covers a small part of the pineapple field with a tent of loose cloth. Within this tent smudge fires are provided and smoke production allowed to continue for twelve hours. Flower and fruit production follow in a shorter period of time than usual.

Assuming these as facts, consideration was given to the possible stimulating agent in the smoke responsible for this rapid forcing of the plants. From the fact that ethylene is produced in destructive distillation of wood and that ethylene has been found to be effective as a forcing agent, it seemed logical to test not only the smoke but to modify the practice so as to include treatment with ethylene gas. An added incentive to determine the possible influence of smoke and ethylene gas was the recognized practice of the use of smoke in certain areas in the Philippine Islands to force the Mango tree into flower.

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This practice of smoking the Mango tree (*Mangifera indica* Linn.) has been described by González (**5**). Smudges are built on the ground, under the trees, a few meters from the trunk. These smudges consist of conical piles of light combustible material, with a cover of moist or green grass on the top. When ignited, these smudges produce a dense smoke, under which condition the trees are kept until flowering is attained.

Recently, in the island of Puerto Rico the smoking of pineapple plants to hasten the flowering has become a practice among certain growers. A portion of the field is covered with a tent as earlier described, and within this tent between the rows of pineapples, smudge fires are made; the plants being exposed to the influence of the smoke for a period of not less than twelve hours. Flower production was claimed to have been attained shortly afterwards. The origin of this practice is not yet known.

Molisch (**10**), (**11**), (**12**), Knight and Crocker (**7**), (**8**), and Bokerny (**1**) have studied the influence of smoke on plants.

Contrary to the results obtained in the Philippines and in Puerto Rico, these investigators have reported that smoke derived from the burning of tobacco, paper, straw and wood, is toxic to many plants. This suggests that the quantity of smoke per unit volume of air and the physiological state of the plant are factors of importance.

In order to make clearer the character of this investigation it seems desirable to inscribe briefly the cultural methods used in Puerto Rico. The variety Red Spanish is the most extensively grown pineapple. The popularity of the Red Spanish is due to the fact that it produces abundantly and the fruit has excellent shipping qualities. The propagation of the pineapple plant is accomplished by means of slips, suckers and crowns. Slips are shoots that originate from the buds produced at the base of the fruit. Suckers develop from the axils of the leaves, while crown slips originate at the upper end of the fruit.

Among growers in Puerto Rico slips are more popular as propagating material than suckers. It is commonly believed that suckers will produce only two crops while slips will give three crops. From suckers, a crop is obtained at the end of fourteen to sixteen months, while from slips eighteen months are required. To growers this advantage of early production is not sufficient to offset the disadvantage of the sucker producing only two crops.

The propagating material may be planted at any time of the year, but spring and summer planting is preferred by growers. Root development may begin shortly after planting but generally speak-

ing new leaf development is not apparent until five to six weeks after planting. Under favorable conditions, particularly with an adequate water supply, leaf development may occur sooner.

Normally, suckers will flower at the end of ten to thirteen months. Slips require fourteen to sixteen months to flower. With both there are irregularities, some plant flowering ahead of the usual period. Whether such unusual behavior is due to the stage of maturity of the slip when planted or to the soil and weather condition, is not yet known.

Experimental

The use of smoke to force pineapple plants into fruit production is a practical development. No controlled experimental work has been reported of this practice. For this reason it seemed desirable to determine the influence of smoke under controlled conditions.

In considering the cause of flowering of the pineapple plant following the treatment of smoke, the primary hypothesis raised was that smoke forces the pineapple plant out of a dormant condition. However it was recognized that some constituents of smoke probably ethylene might effect metabolic changes even though the plants were not in a dormant condition, which changes might conduce to floral development.

Both slips and suckers are completely developed plants. The roots at the time of planting are very short. The fact that new leaf development is retarded four to six weeks after planting suggests that slips and suckers are in a state of dormancy. It seemed probable that the use of ethylene on these might bring about an immediate resumption of growth with a consequent shortening of the time for flower production. There also remained the possibility as was realized, of a more pronounced effect of ethylene on fruit production. Accordingly an experiment was devised in which both slips and suckers were exposed to ethylene previous to planting. Such a method, if it proved successful, would obviously be a cheaper and more practical method than the use of smoke under field conditions.

I. USE OF SMOKE UNDER FIELD CONDITIONS

In these particular experiments, consideration was given to the influence of different quantities of smoke and to the effect produced as influenced by the age of the plants.

The plots for experimental purposes were selected in a field at Isla Verde, Santurce, Puerto Rico. The plants were normal in appearance and growing in a soil which consists of a fine sand under-

laid by a stratum of heavy clay impervious to water. The top five inches contained an abundance of organic matter. The soil is low in calcium, phosphorus and potassium. Natural drainage is poor and consequently artificial drainage is essential. This was provided. In general it may be stated that the soil is not well suited for crop production. To obviate variations in the plots due to soil conditions, sections were selected in the field for uniformity of soil and plants.

Each plot was one-fifth acre in area and had approximately 2,000 plants. Each plot comprised twelve rows of plants. A tentlike structure about four feet in height was constructed over each plot. The cloth used was of a loosely woven cotton, a low grade muslin. The material used to produce the smoke was placed in cans of five gallons capacity and placed within the tent. The smoke was produced by a slow combustion of the dry husk of the cocoanut fruit together with the green bud scales of the cocoanut palm. The dry husks were slightly moistened. The fuel was renewed several times during the treatment. Combustion was slow with a low flame and producing a large amount of smoke. The smoke diffused through the meshes of the cloth. The duration of the treatment was twelve hours, usually from 6 P. M. to 6 A. M.

Experiment I

In this experiment the plants to be treated had been planted seven months previously. On December 1, 1930, twelve cans were placed within the tent and the plants exposed to the smoke for a period of twelve hours.

By the latter part of December 1930 the favorable effect of smoke was apparent by the development of red pigment in the lower part of the leaves near to the growing point. This change is recognized as an indication of the flowering period. By January 3, 1931, the flower stalk had appeared and by the end of January the fruit was well formed. The fruits produced by treated plants were mature and harvested in March 1931. The fruits obtained from the controls were harvested two months later. Practically every plant in the treated plots responded to the smoke treatment. The fruits were of marketable size and of quality equal to the fruit produced by untreated plants. The even bearing of the treated plants is shown in figure 1.

Plants adjacent to treated plots and which were under the influence of the smoke diffusing out of the tent also flowered.

One of the treated plots in this experiment did not flower. It was found, however, that the laborers had not given proper attention to the fires and the plants received only an eight-hour treatment.

Experiment II

An entire section of pineapple field, which had not flowered after twenty months of growth, was selected to test the influence of smoke in forcing plants to flower. Sections of two thousand plants each was covered with a tent and smoked for a period of twelve hours. The concentration of the smoke within the tent was increased by using twenty cans of the burning material.

Flowering was noted six weeks after the smoke was applied. Through a misunderstanding, the entire field was treated and no controls left. It was noted, however, that the plants showed no signs of approaching flowering at the time of treatment. As stated previously, when the pineapple plant is near to the flowering period, the lower part of the inner leaves near to the growing point becomes red. This coloration usually appears approximately eight weeks before flowering. Such signs were not observed in this section prior to the treatment, and from the fact that all plants flowered and fruited at the end of six weeks, after treatment, it is probable that the smoke was effective.

Experiment III

In the third experiment, plants which had already given one crop of fruit and which were about twenty-four months old were treated with smoke for twelve hours in the usual way. The experiment was varied so as to include different concentrations of smoke. Such concentrations were adjusted by using different numbers of cans producing the smoke. Sections were provided in which 8, 12, 16 and 20 cans of the burning material were used respectively. The plants were treated on November 24, 1930. Normally these plants would not have flowered until late in February. By treating them with smoke regardless of the number of cans used to produce the desired concentration, all flowered early in January, six weeks after the treatment. Sections left as checks had not flowered up to April 1931. The experiment is still in progress.

II. TREATMENT OF SLIPS AND SUCKERS BEFORE PLANTING WITH ETHYLENE AND SMOKE

Since ethylene is a product obtained during destructive distillation of wood, and since it has been used as a forcing agent in the

fields of Floriculture, Pomology and Vegetable Crops it was also tried as a forcing agent for pineapple cuttings with a view to developing a better method than the smoke treatment.

Mature slips and suckers were placed in a closed room and ethylene gas applied in two different concentrations, one part of gas to eighty parts of air (1:80) and one part of gas to two hundred parts of air (1:200). Gas was supplied every day at eight o'clock in the morning and at six in the afternoon. The room was ventilated for about half an hour before a new application of gas. These treatments lasted one week, at the end of which time slips and suckers were planted and observations of growth and development of roots were made. Checks were held as close to the same conditions of temperature humidity and light as could be obtained. A larger number of slips were used because they are preferred by planters as propagating plants.

The treated slips and suckers were planted August 16, 1930 in the experimental plots of the Insular Experiment Station of Puerto Rico. The number of plots and treatments are as follows:

6 plots of slips—1:80 treatment
6 plots of slips—1:200 treatment
4 plots of suckers—1:80 treatment
3 plots of suckers—1:200 treatment
3 plots of slips untreated—controls
3 plots of suckers untreated—controls

Each of these plots contains twelve plants. The control plots were scattered among the treated plots as can be seen from Table I.

Smoke was also used on slips before planting. They were placed in a closed room and treated with smoke for a period of ten hours. The smoke was obtained from smudge fire built in the same room. Wood was used as the combustible material to produce the smoke. This material was covered with green grass and sand to insure slow combustion.

For plants treated with ethylene and smoke before planting, no fertilizers were used. The plants were left entirely to develop with the natural fertility of the soil.

I. RESULTS

The slips and suckers treated with ethylene were planted August 16, 1930. The treated slips were turning yellow and appeared more dry than the controls at the time of planting, especially the ones to which the high concentration of the gas had been given. The young plants were favored by rain during the first and second weeks after

planting. Controls and treated plots showed no difference in root development or growth during the first weeks. In general the control plants appeared more vigorous.

No data on growth were taken until five months later when all treated plants had fruited. These plants had flowered at the end of three months after planting. The results presented here were taken during the last week of January 1931, when many treated plants had well matured fruits. When the fruits were harvested the plants were six months old. Up to this time none of the plants in the control plots had bloomed. The experiment is still in process. By May 1, 1931, nine months after planting only two of the control plants derived from suckers had flowered.

None of the plants which had been exposed to smoke previous to planting showed any appreciable response to the treatment. The smoke-treated plants were in appearance similar to the plants in the control plots. The experiment is still in progress and it remains to be determined if this treatment will prove of value.

The results obtained from the treatment of the slips and suckers with ethylene are of unusual interest. Generally plants from suckers will not flower until nine months after planting while plants produced by slips flower only after thirteen months. With these ethylene treated plants, flowering was noticed three months after planting. Not all of the treated plants had produced fruits by February 1931. These results are presented in Table I. It is not yet possible to state definitely the flowering dates of the untreated plants, but it may be stated that the treated plants flowered at least six months before the control plants.

These results are significant in one other respect. Generally plants derived from suckers flower before those produced from slips. In this particular experiment the ethylene-treated slips and suckers flowered at the same time. This fact is of special significance as will be developed subsequently. While the plants derived from slips flowered as soon as the suckers the latter produced larger fruits. These differences are brought out clearly in Table II and representative fruits are shown in Plate II.

The fruits produced by these treated plants were in general undersize and of no commercial value. It should be remembered that no attempt was made to provide favorable conditions for plant growth by the addition of fertilizers.

TABLE I

NUMBER OF PLANTS THAT PRODUCED FRUIT BY FEBRUARY 1931

Plot No.	Treatment	Number of Plants that Fruited	Number of Plants that did not fruit
1	Ethylene—1:80...Slips	4	8
2	Control—.....Suckers	0	12
3	Ethylene—1:200...Slips	9	3
4	Ethylene—1:80...Suckers	4	8
5	Ethylene—1:80...Slips	4	8
6	Control—.....Slips	0	12
7	Ethylene—1:200...Suckers	6	6
8	Ethylene—1:80...Suckers	5	7
9	Control—.....Suckers	0	12
10	Ethylene—1:200...Slips	7	5
11	Ethylene—1:200...Slips	6	6
12	Ethylene—1:80...Slips	5	7
13	Control—.....Slips	0	12
14	Ethylene—1:200...Slips	4	8
15	Ethylene—1:200...Suckers	5	7
16	Ethylene—1:80...Suckers	3	9
17	Control—.....Suckers	0	12
18	Ethylene—1:200...Suckers	7	5
19	Ethylene—1:80...Suckers	4	8
20	Ethylene—1:80...Slips	4	8
21	Control—.....Slips	0	12
22	Ethylene—1:200...Slips	5	7
23	Ethylene—1:80...Slips	1	11
24	Ethylene—1:200...Slips	6	6

TABLE II

AVERAGE WIDTH AND HEIGHT OF FRUITS PRODUCED BY SLIPS AND SUCKERS

	Slips			Suckers	
	Average Width of Fruit in inches	Average Height of Fruit in inches		Average width of Fruit in inches	Average Height of Fruit in inches
1	1.43	2.31	4	2.93	3.75
3	1.44	2.41	7	3.04	3.91
5	1.42	2.19	8	3.15	3.80
10	1.57	3.43	15	2.45	3.20
11	1.53	2.32	16	3.25	3.66
12	1.75	2.75	18	2.67	3.50
14	1.87	2.62	19	3.17	3.93
20	2.06	2.81	.....	.....	.....
22	2.20	2.85	.....	.....	.....
23	1.00	2.00	.....	.....	.....
24	1.62	2.50	.....	.....	.....
Average	1.62	2.47		2.95	3.67

II. INFLUENCE OF CONCENTRATION OF ETHYLENE ON FRUITING

Slips and suckers as previously stated were given two different treatments with ethylene. One lot was exposed to ethylene at a concentration of one part of gas to eighty parts of air, the second lot was exposed to one part of gas to two hundred of air. The data in Table III suggests at least, that the earlier fruiting was obtained

with the concentration of one to two hundred. This was true for both slips and suckers. The experiments should be repeated before definite conclusions are warranted.

III. INFLUENCE OF CONCENTRATION OF ETHYLENE ON THE SIZE OF THE FRUIT

A comparison was made of the influence of the concentration of ethylene on the size of the fruit. The data show that the size of the fruit was not significantly influenced by the concentration of ethylene. The summarized data are given in Table IV.

TABLE III

INFLUENCE OF CONCENTRATION OF ETHYLENE ON THE NUMBER OF PLANTS THAT FRUITED BY FEBRUARY 1931

Plot No.	Concentration 1:80	Concentration 1:200	Plot No.	Concentration 1:80	Concentration 1:200
1	4		4	4	
3		9	7		6
5	4		8	5	
10		7	15		5
11		6	16	3	
12	5		18		7
14		4	19	4	
20	4				
22		5			
23	1				
24		6			
Average	3.6	6.2		4.0	6.6

TABLE IV

CONCENTRATION OF ETHYLENE ON SIZE OF THE FRUIT
ALL PLOTS CONSIDERED

Concentration Ethylene	Slips		Suckers	
	Average width in inches	Average Height inches	Average width in inches	Average Height inches
1:80	1.53	2.41	3.10	3.78
1:200	1.70	2.52	2.72	3.53

OTHER EXPERIMENTS

In addition to the various experiments described in the preceding pages, slips and suckers were shipped to Ithaca in October 1930. These were treated with ethylene, ethylenechlohydrin, dichlorethylene and trichlorethylene at a concentration of 1 : 1000, and planted singly in nine-inch pots in an Ontario Silt Loam. These plants were kept in a greenhouse at a temperature close to 80°F. Unfortunately these

plants have made but little growth under these conditions. A similar lot was brought back from Puerto Rico in February 1931 and treated in a similar manner. Sufficient time has not yet elapsed to permit any conclusions. In Puerto Rico during the month of February new experiments were started with various treatments, both with slips and suckers before planted and with plants under field conditions. These results will be reported at a later date.

Discussion

The use of smoke on plants in the field resulted in a very general flowering of all plants and subsequent early fruit production. The experiments confirm the results obtained in practice by certain growers in Puerto Rico. However, additional experiments are necessary to determine more precisely the essential conditions. The fact that in certain experiments no relation was found between the quantity of smoke used and the response obtained makes it appear probable that there is a wide latitude in this respect. A similar latitude has been noted in the use of ethylene on slips and suckers.

The experiments using ethylene gas on slips and suckers while not yielding uniform results, nevertheless forced plants into flower in about three months instead of after a year or longer. Fruit production was exceptionally early and although the size of the fruit was small it seems possible to increase this by the proper use of fertilizers.

The fact that the ethylene treatment of slips and suckers did not result in a simultaneous flowering of all plants indicates that the physiological condition of these plants must be given consideration in further investigations. From the practical standpoint this failure of uniformity in the time of flowering may be desirable since it enables a longer season for selling fruits.

As yet no analysis have been made to determine the chemical changes occurring in field plants following the smoke treatment, nor for those plants which had been treated with ethylene before planting. González (5) maintained that the effect of smudge fires on the Mango tree (*Mangifera indica,* Linn.) was a temperature effect. Since the fires are maintained for long periods of time temperature may possibly be a factor but at the same time there is a possibility that this forcing effect may be due to the hydrocarbon gases evolved during the combustion. In a slow combustion of wood, straw, or any other organic material there is a destructuve distillation process, in which process various hydrocarbon gases are formed such as acetylene, ethylene, propylene, etc. It is obvious, therefore, that attention must be given to these gases as possible forcing agents.

In the experiments in which the pineapple plants were exposed to smoke under a tent for a period of twelve hours, the combustion was slow and the heat produced was little and could have elevated the temperature but slightly. The temperature increase would be no greater than that commonly experienced during normal conditions. The fact that plants outside the tent, but exposed to the diffusing smoke, also flowered suggests that the constituents of the smoke and not the temperature produced during combustion were responsible for the hastening of the plants into bloom. This view that a gas or gases are the forcing agents is supported by the results obtained from the use of ethylene on slips and suckers before planting.

One other distinct aspect of the problem should be emphasized. Does smoke shorten a resting period in the pineapple? It has been demonstrated that most biennial and perennial plants exhibit a definite resting condition. Thus the question arises: does the pineapple plant enter a period of rest previous to flower production? There is, however, no apparent cessation of vegetative growth before flowering occurs. This suggests that the plant is not in a resting condition. The effect of smoke must, therefore, be to influence metabolism in such a way as to force the meristem into reproductive growth. Harvey (6), Denny (4) and other have demonstrated that ethylene treatments are followed by a conversion of stored food to available food. It is possible that in this experiment with smoke such changes occur in the pineapple with a resulting change in the soluble carbon nitrogen, ratio, which changes might induce flower production.

In support of this view are the results obtained from the treatments of slips and suckers with ethylene. These normally do not produce new leaves until six weeks after planting at the maximum; therefore, the resting condition could not prevail for more than six weeks. On the basis of overcoming the resting condition with ethylene, the time for flower production in the pineapple should have been shortened about six weeks. As a matter of fact the saving in time was more than six months in the more favorable cases. These results point to the conclusion that the ethylene treatment has modified metabolism in such a way as to induce also flower production. This principle, if correct, should prove to be one of paramount importance both for purely scientific as well as from the practical stand-point.

In previous work, except for that of González (5), attention has been given largely to the toxic action of smoke on seedlings. Molisch (**10**), (**11**), (**12**), has shown that tobacco smoke is very toxic to many plants and that smoke produced from paper, straw and wood has the

same effect. On the basis of his data he concludes that carbon monoxide is probably the constituent determining the toxicity of tobacco smoke. Nejubow (**13**), Crocker (**2**), (**3**), Lehman (**9**), and Knight and Crocker (**7**), (**8**), have reported that ethylene is toxic to epicotyls of certain seedlings and to other plant organs. According to Crocker (**2**), (**3**), ethylene seems to be the predominant toxic agent evolved during destructive distillation. Bokorny (**1**) attributes the toxicity of tobacco smoke to the ammonia produced during burning. It is possible that under certain conditions smoke may be injurious to pineapples. In these experiments and in practice the plants are exposed to smoke during the hours of darkness when the stomates are practically closed. Under this condition only a small amount of gases may enter. Perhaps if the smoke treatment were given during the day time, especially in the morning, a much shorter treatment would give the same results.

In future treatments of slips and suckers with ethylene, consideration should be given to humidity and temperature relations. Histological studies to determine the time of flower production should also be made.

In conclusion it should be stated that both smoke and ethylene treatment of slips and suckers hold great promise for controlling the time of fruit production of pineapples. It is probable that under tropical and semi-tropical conditions that these methods may find application for other fruits and flower crops.

SUMMARY

1. The experiments using smoke on pineapple plants in the field confirm the results obtained in practice by certain growers in Puerto Rico. The use of this process in the field resulted in a general flowering of all plants and early fruit production.
2. There was no relation between the quantity of smoke used and the response of plants. This indicates a wide latitude as regards concentration of smoke.
3. The age of the plants was not a factor hindering the effect of smoke treatment.
4. From the results obtained in the smoke treatments and ethylene treatments it seems that one or more constituents in smoke and not the temperature produced are responsible for the hastening of bloom.
5. Under the conditions in which smoke treatments were given to field plants, smoke was not toxic.
6. Large-size fruits were obtained following the smoke treatments.
7. The treatment with smoke previous to planting gave no appreciable response.

8. Slips and suckers treated with ethylene previous to planting flowered six months before the control plants.
9. Fruits obtained from ethylene treatments were undersize. Suckers yielded larger fruits than slips.
10. No significant difference was noted with the several concentrations of gas when used on slips and suckers.
11. The results obtained indicate that the ethylene treatment has modified metabolism and induced flower production.

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ILLUSTRATIONS

Plate I.—Left: Pineapple plants treated with smoke seven months after planting. Right: Control plots.

Plate I.—Representative fruits obtained from slips and suckers treated with ethylene.

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PLATE I.

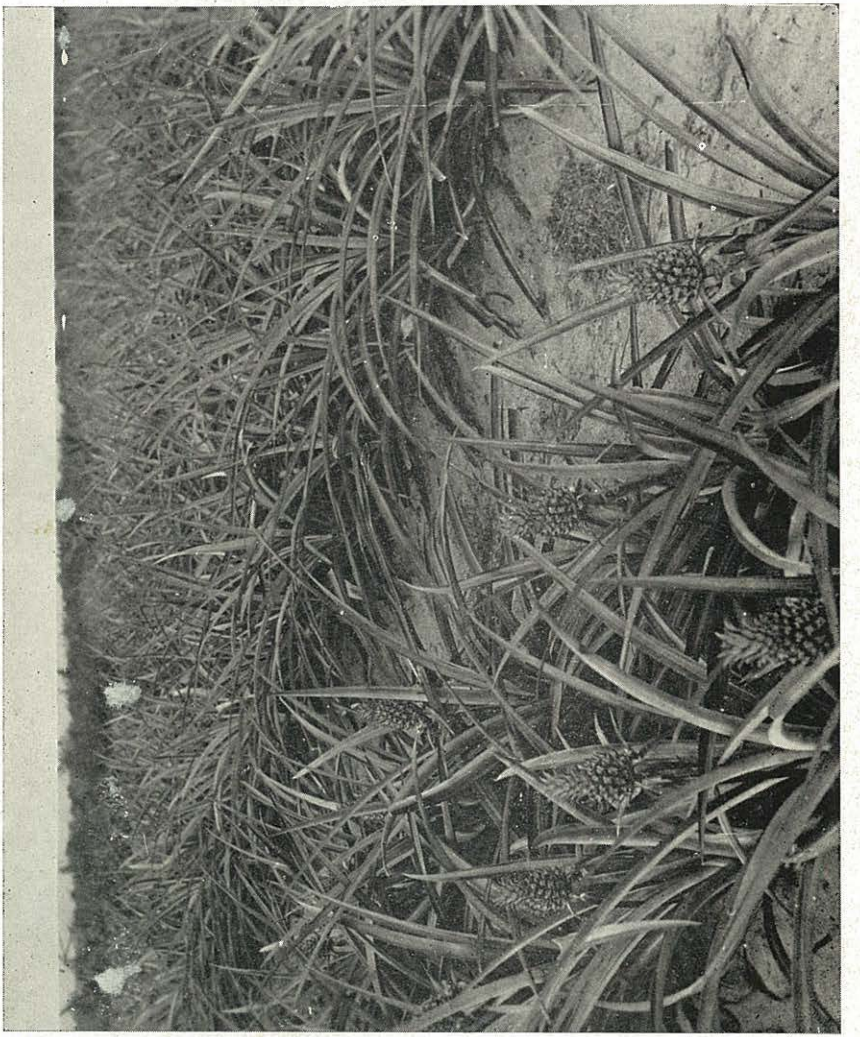

PLATE II.