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PYRETHRUM PLANT INVESTIGATIONS IN COLORADO

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FORT COLLINS, COLORADO

PYRETHRUM PLANT INVESTIGATIONS IN COLORADO

II. A Review of the Progress Since 1932

By C. B. Gnadinger, L. E. Evans, and C. S. Corl*

The first planting of pyrethrum *(Chrysanthemum cinerariaefolium)* at the Colorado Experiment Station was made in 1929. A preliminary report has been published on the work completed at the end of the 1932 season (5). The present paper is a brief review and summary of a part of the investigations conducted during 1933, 1934, and 1935.** Other phases of the

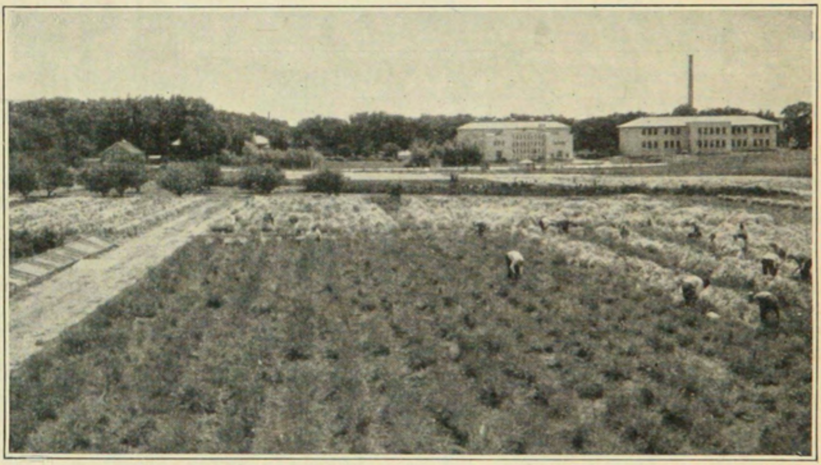

Figure 1.—Commercial planting of pyrethrum at Fort Collins during the picking period in 1934

investigations are in progress, but sufficient data have not been collected to warrant a summary or review in this report.

Plant Improvement Project

Variations in yield of flowers and pyrethrins for 39 individual 3-year-old plants were reported in 1933 (5). Similar data on some of these individual plants were obtained in 1933 and 1934, together with data from 11 additional plants which were set out in 1932. No data were secured in 1935 since many of the plants were divided for increase or were discarded. The analyses, presented in table 1, show a considerable variation in

*Colorado State College and Colorado Experiment Station, Fort Collins, Colo., and The McLaughlin Gormley King Company, Minneapolis, Minn., cooperating.

**Certain phases of the investigations during this period were reported at the annual meeting of the American Society for Horticultural Science, at St. Louis, Mo., December 29, 1935-January 2, 1936.

the yield of pyrethrins of these individual plants from year to year.

The A9 plants were from seed planted in 1929; the A2 series was planted in 1932. The 1932 analyses of the A2 series are not comparable because the samples for analysis were collected in the late fall which is not the normal blooming period for this plant. It has since been found that flowers harvested in the late fall are somewhat richer in pyrethrins than flowers harvested in June and July from the same plants.

TABLE 1.—*Variation in yield of pyrethrins of individual plants from year to year.*

Plant no.	Pyrethrins (air-dried basis) 1932 %	1933 %	1934 %
A9-77	1.77	......	......
A9-86	1.00	......	0.89
A9-90	1.29	1.11	1.57
A9-150	1.10	1.10	1.05
A9-151	1.13	......	1.07
A9-153	0.94	......	0.89
A9-187	1.13	......	1.05
A9-206	0.90	0.95	1.03
A9-237	1.96	......	1.39
A2-117	......	1.21	0.99
A2-118	1.26	1.07	......
A2-125	......	1.08	0.90
A2-138	......	1.25	0.97
A2-282	......	1.11	1.01
A2-355	1.29	1.22	0.99
A2-361	......	0.94	0.89
A2-369	......	1.04	1.13
A2-706	1.03	1.03	......
A2-927	0.94	0.79	0.80
A2-1052	1.12	0.86	0.81

Analyses were not calculated to the moisture-free basis because it has been shown that the moisture content of the air-dried flowers is sufficiently uniform (5).

These results (table 1) are at variance with those of Martin and Tattersfield (6), who state that a given plant yielded flowers containing approximately the same percentage of pyrethrin I for 3 successive years, while the yield of total pyrethrins of flowers from eight individual plants was the same for each plant for successive harvests.

There was also a wide variation in the number and weight of flowers produced by the plants included in table 1. This is shown in table 2.

TABLE 2.—*Variation in yield of flowers from individual plants from year to year.*

Plant no.	1932 No. of flowers	1932 Dry weight g.	1933 No. of flowers	1933 Dry weight g.	1934 No. of flowers	1934 Dry weight g.
A9-86	96	13.70	......	....	106	14.30
A9-90	77	10.42	80	9.50	178	22.90
A9-150	543	66.15	354	43.30	346	46.07
A9-151	283	28.51	......	....	200	26.94
A9-153	82	9.86	......	....	190	20.90
A9-187	84	11.63	......	....	123	16.91
A9-206	325	39.89	184	19.48	131	16.20
A9-237	85	10.81	......	....	221	26.07
A2-117	......	....	217	26.30	113	11.73
A2-118	108	10.61	115	10.80	......	....
A2-125	......	....	169	20.81	468	52.99
A2-138	......	....	259	28.56	399	53.22
A2-282	......	....	286	38.76	300	31.19
A2-355	57	9.15	195	20.23	439	46.92
A2-361	......	....	153	22.51	342	51.36
A2-369	......	....	232	25.26	357	47.79
A2-706	49	8.33	195	22.92	......	....
A2-927	85	10.76	259	24.53	454	47.98
A2-1052	65	8.57	170	22.70	388	57.29

These data show no correlation between the yield of pyrethrins from a given plant and the number and weight of flowers produced by the plant from year to year. Earlier studies (1) have shown no significant correlation between yield of pyrethrins and number and weight of flowers of an individual plant.

Comparison of Yield of Pyrethrins of Mother Plants and Progeny Lines

At the beginning of the investigations in 1932 little was known about the amount of cross-pollination that occurs in pyrethrum under field conditions. To eliminate cross-pollination and facilitate inbreeding, a portion of the flowers from selected plants was covered with a 40-mesh cloth bag. A very small amount of seed was obtained from the bagged heads, and as a result it was necessary to plant open-pollinated seed the following season for the first-generation progeny lines. The failure to obtain a high percentage of viable seed from the bagged heads led to the study of self-fertilization in pyrethrum as influenced by the type of isolator used. The results of these studies to date show wide differences in the yield of inbred seed from various types of isolators. A small population of inbreds was studied in 1935 and is reported herein.

The open-pollinated seed from a number of individual plants of the A9 series was sown early in 1933 in hotbeds, and the plants were transplanted to the field in May. The progeny lines contained a small number of plants, due to the loss that occurred from "damping-off" *(Pythium debaryanum)* in the seed bed. A well-drained soil together with proper aeration and watering of the hotbeds have reduced the plant losses due to "damping-off"; hence larger populations have been obtained within the open-pollinated and self-pollinated progeny lines.

In table 3 the yield of pyrethrins of some of the mother plants is compared with that of progeny lines at Fort Collins in 1934 and 1935, and at Avon in 1935.

TABLE 3.—*Comparison in yield of pyrethrins of mother plants and progeny lines.*

Mother plant Number	Mother plant Pyrethrins (%)	Year	Place	Progeny line Number	Progeny line Pyrethrins (%)	Year	Place
					Open-pollinated line		
A9-77	1.77	1932	FC	P_1 A-4-1	0.97	1934	FC
				" A-4-3	1.28	"	"
				" A-4-4	1.03	"	"
				" A-4-7	1.05	"	"
				" A-4-8	1.08	"	"
				" A-4-11	1.11	"	"
				" A-4-12	0.94	"	"
				" A-4-13	0.90	"	"
				" A-4-15	1.01	"	"
				" A-4-26	1.58	"	"
				" A-4-31	1.55	"	"
				" A-4-32	1.48	"	"
				" Average	1.17	"	"
				P_2 A-4-11-13	1.02	1935	FC
				" A-4-11-14	1.17	"	"
				" A-4-11-16	1.00	"	"
				" Average	1.06	"	"
				P_2 A-4-11-1	1.28	1935	Avon
				" A-4-11-3	1.24	"	"
				" A-4-11-4	1.79	"	"
				" Average	1.44	"	"
					Self-pollinated line		
				P_1 A-4-55	1.30	1935	FC
					Open-pollinated line		
A9-86	1.00	1932	FC	P_1 A-32-2	1.08	1934	FC
	0.89	1934	FC	" A-32-9	0.88	"	"
				" A-32-11	0.91	"	"
				" Average	0.96	"	"
					Open-pollinated line		
A9-90	1.29	1932	FC	P_1 A-1-3	1.08	1934	FC
	1.11	1933	FC	" A-1-15	0.89	"	"
	1.57	1934	FC	" A-1-22	1.13	"	"
				" A-1-26	1.15	"	"
				" A-1-38	1.05	"	"
				" Average	1.06	"	"

Note: FC=Fort Collins.

Number	Mother plant Pyrethrins (%)	Year	Place	Number	Progeny line Pyrethrins (%)	Year	Place
					Open-pollinated line		
A9-140	1.51	1932	FC	P_1 A-2-15	0.83	1934	FC
				" A-2-24	0.89	"	"
				" A-2-32	0.87	"	"
				" A-2-40	0.89	"	"
				" A-2-42	0.55	"	"
				" A-2-58	0.87	"	"
				" A-2-60	0.73	"	"
				" A-2-78	1.08	"	"
				" A-2-79	1.22	"	"
				" Average	0.88	"	"
					Open-pollinated line		
A9-151	1.13	1932	FC	P_1 A-19-2	0.89	1934	FC
	1.07	1934	FC	" A-19-3	1.15	"	"
				" A-19-5	1.05	"	"
				" Average	1.03	"	"
					Open-pollinated line		
A9-153	0.94	1932	FC	P_1 A-30-4	1.04	1934	FC
	0.89	1934	FC	" A-30-8	0.99	"	"
				" A-30-10	0.86	"	"
				" Average	0.96	"	"
					Open-pollinated line		
A9-237	1.95	1932	FC	P_1 A-5-1	1.54	1934	FC
	1.39	1934	FC	" A-5-3	1.12	"	"
				" A-5-5	1.39	"	"
				" A-5-6	0.96	"	"
				" A-5-8	1.13	"	"
				" A-5-9	1.18	"	"
				" A-5-11	1.13	"	"
				" A-5-12	1.05	"	"
				" A-5-13	1.18	"	"
				" A-5-16	1.18	"	"
				" A-5-20	1.15	"	"
				" A-5-30	0.89	"	"
				" A-5-34	1.13	"	"
				" A-5-36	1.15	"	"
				" A-5-41	1.10	"	"
				" A-5-45	0.94	"	"
				" A-5-47	1.02	"	"
				" A-5-48	1.07	"	"
				" Average	1.13	"	"
				P_2 A-5-1-4	1.11	1935	Avon
				" A-5-1-7	1.08	"	"
				" Average	1.10	"	"
				P_2 A-5-45-1	1.24	1935	FC
				" A-5-45-2	1.42	"	"
				" A-5-45-3	1.40	"	"
				" A-5-45-6	1.14	"	"
				" Average	1.30	"	"

Note: FC=Fort Collins.

Mother plant Number	Mother plant Pyrethrins (%)	Year	Place	Progeny line Number	Progeny line Pyrethrins (%)	Year	Place
					Self-pollinated line		
				P_1 A-5-50	1.06	1935	FC
				" A-5-53	1.28	"	"
				" A-5-54	1.27	"	"
				" A-5-55	1.08	"	"
				" A-5-56	1.21	"	"
				" A-5-58	1.21	"	"
				" A-5-61	1.01	"	"
				" A-5-62	1.19	"	"
				" Average	1.16	"	"

Note: FC=Fort Collins.

As shown in table 3, there is considerable variation and a reduction in the yield of pyrethrins within the progeny lines. Comparison of the mean yield of pyrethrins of the mother plants and progeny lines shows a partial relationship, although it is not considered significant. Further analysis of the table shows that the mean yield of pyrethrins of the self-pollinated line, number A-5 in 1935, compares favorably with the mean yield of the open-pollinated line, number A-5 in 1934. Apparently one generation of inbreeding has little effect on the yield of pyrethrins. The mean yield of pyrethrins of individual plants at Avon has been slightly higher than the mean yield of similar plant material at Fort Collins. The difference is shown by comparing the yield of pyrethrins of progeny lines, numbers A-4 and A-5 at Fort Collins and Avon for the season of 1935.

Considering the variation that occurred in the yield of pyrethrins, it is noted that the progeny lines from high pyrethrin-yielding mother plants (A9-77 and A9-237) are slightly higher in yield of pyrethrins than the parent stock, progenies, common seed stock, or foreign and domestic strains. The differences in the yield of pyrethrins between the various plant materials and the selected progeny lines are shown in table 4. In every instance, except one, the selected progeny lines yielded a higher mean percentage of pyrethrins in 1934 and 1935 than did the parent stock, common seed stock, progenies, or foreign and domestic strains during the same period.

The evidence, although based on small populations, indicates an improvement in the yield of pyrethrins over common seed stock through selection of the open-pollinated seed from mother plants.

The plant improvement project includes a further study of the variability of morphological and physiological characters of the open-pollinated and self-pollinated progeny lines as compared with the parent stock or clonal lines. Other phases of the plant-improvement project include a study of the effect of self-

TABLE 4.—*Mean yield of pyrethrins of parent stock, common seed stock, progenies, and foreign and domestic strains as compared with the mean yield of progeny lines number A-4 and A-5.*

Plant Material	Mean yield of pyrethrins 1932 %	1933 %	1934 %	1935 %
Parent stock (A9 series)	1.18	......	1.12	......
Parent stock (A2 series)	......	1.01	0.94	......
All progeny lines:				
Fort Collins	......	......	1.06	1.07
Avon	......	......	......	1.36
Common seed stock:				
Fort Collins	1.18	1.01	0.93	0.94
Avon	......	......	1.26	1.23
Foreign and domestic strains:				
Fort Collins	......	......	0.95	0.97
Open-pollinated progeny line, A-4:				
Fort Collins	......	......	1.17	1.06
Avon	......	......	......	1.44
Open-pollinated progeny line, A-5:				
Fort Collins	......	......	1.13	1.10
Avon	......	......	......	1.30
Self-pollinated progeny line, A-5:				
Fort Collins	......	......	......	1.16

fertilization on morphological and physiological characters and amount of cross-pollination that occurs in pyrethrum.

Since 1932 there has been a gradual decline in the mean yield of pyrethrins of the plant material at Fort Collins, Colo. The variation in the precipitation, irrigation water supply, and mean temperatures that occurred during this period offers a partial explanation of the wide differences and reduction in the mean yield of pyrethrins of the plant material. In table 5 the total monthly precipitation for the 4 years, 1932 to 1935, is compared with the normal at the end of 1932.

TABLE 5.—*Total monthly precipitation for 1932, 1933, 1934, and 1935 compared with normal.**

Month	Normal	1932	1933	1934	1935
January	0.42	0.08	0.16	0.00	0.07
February	0.62	0.48	0.13	1.11	0.89
March	1.02	1.09	0.60	0.71	0.21
April	2.05	0.88	1.91	1.41	1.24
May	2.83	2.14	4.56	1.92	6.71
June	1.60	1.11	0.05	1.25	0.62
July	1.73	2.15	0.71	1.33	1.11
August	1.28	3.68	4.34	0.28	0.50
September	1.24	0.01	2.10	0.79	3.29
October	1.15	0.34	0.00	0.00	0.62
November	0.50	0.34	0.06	0.06	0.66
December	0.46	0.49	1.03	T	0.00

*Weather records furnished by R. E. Trimble, Colorado Experiment Station Meteorologist, Colorado State College.

The precipitation for the 4 years was generally lower than the normal. The area around Fort Collins had a rather adequate and uniform supply of spring moisture from 1932 to 1935. During the 4-year period, 1932 to 1935, the precipitation during the winter months was below normal, and as a result there was a depletion of moisture reserves in the subsoil. The total precipitation for May, 1933 and 1934 was well above the normal.

In addition to the low rainfall there was a gradual decline in the amount of reservoir water available for summer irrigation purposes from 1933 to 1935. With a shortage of reservoir water, it was necessary to limit the number of summer irrigations and shorten the duration of each irrigation during the seasons of 1933 and 1934. The number of irrigations during the growing period decreased from five in 1932 to four in 1933 and to three in 1934. The three irrigations in 1934 were of shorter duration, amounting to 1 to 1½ hours each as compared with 2 and 3 hours for each irrigation in 1932 and 1933. In 1935 the water supply was about normal; however, the runs were short, amounting to 2 hours each. The lengths of rows were comparable for the four seasons.

The mean monthly temperatures during the growing period for each of the four seasons, 1932 to 1935, were as abnormal as the precipitation for the same period. These temperatures are given in table 6.

TABLE 6.—*Mean monthly temperatures, April to October, for 1932, 1933, 1934, and 1935, compared with normal.*

Month	Normal	1932	1933	1934	1935
April	45.50	47.75	43.51	48.14	45.12
May	54.00	56.69	53.28	61.04	48.88
June	63.40	63.50	68.86	66.07	63.31
July	67.40	71.86	72.06	73.68	71.89
August	67.30	69.51	67.29	70.16	69.57
September	59.10	59.70	62.86	55.68	59.08
October	47.60	45.65	52.39	53.30	47.18

The season of 1932 was nearly normal in mean monthly temperatures and total precipitation. In 1933 the mean temperatures were below normal during the months of April and May. The total precipitation for May in 1933 and 1935 was 4.56 and 6.71 inches, respectively, which accounts for the cooler temperatures that prevailed during that month. In 1934 the mean temperatures for April, May, and June were higher than the normal mean temperatures for these months. In 1935 mean temperatures for these months were nearly normal.

The climatic conditions during the growing seasons for the past four seasons, 1932 to 1935, had a direct effect upon the date on which the pyrethrum began flowering. In 1932 the first flowers opened on June 14, and the peak of flowering was reached on June 29. In 1933 the season was late, due to the lower temperatures during April and May. The plants in 1933 did not commence flowering until June 29, and the peak of flowering was reached on July 8. In 1934 the season was greatly advanced because of the warm temperatures during April, May, and June, and as a result the first flowers opened on June 6, and the peak of flowering was reached on June 16. In 1935 flowering commenced on June 29, and the peak was reached on July 7.

In table 7 the mean monthly temperatures for June and July are compared with the mean yield of pyrethrins of the plant material at Fort Collins for the four seasons, 1932 to 1935, and at Rocky Ford, Fort Lupton, Avon, and Vanadium for the two seasons, 1934 and 1935. It is noted that the mean yield of pyrethrins at Fort Collins for the four seasons is quite variable, and is to a certain degree associated with the mean monthly temperatures for June and July. The months of June and July in 1932 were characterized by low mean daily temperatures during the blooming period, together with an adequate supply of moisture. The plant material under study in 1932 was partially shaded by trees in the afternoon. In 1933 and 1934 the

TABLE 7.—*Comparison of the mean monthly temperatures for June and July and mean yield of pyrethrins of the plant material for the seasons 1932 to 1935.*

Plant Material	Mean monthly temperatures, Degrees F.: June	Normal	July	Normal	Pyrethrins %	Elevation Feet
Fort Collins:						5,000
1932	63.5	63.4	71.8	68.4	1.18	
1933	68.9	63.4	72.0	68.4	1.01	
1934	66.0	63.4	73.6	68.4	0.93	
1935	63.3	63.4	71.8	68.4	0.94	
Rocky Ford:						4,250
1934	73.5	70.4	80.6	74.9	0.83	
1935	70.2	70.4	78.3	74.9	0.87	
Fort Lupton:						4,906
1935	65.7	66.4	74.4	71.2	0.96	
Avon:						7,600
1934	58.2	55.6	66.1	61.1	1.26	
1935	56.8	55.6	63.6	61.1	1.23	
Vanadium:						9,200
1934	51.4	53.8	59.0	58.6	1.20	
1935	51.8	53.8	57.1	58.6	1.34	

Note: Mean monthly temperatures at Avon and Fort Lupton approximate.

mean monthly temperatures during June and July, especially during the blooming period, were high. The mean daily temperatures in 1933 and 1934, during the 10 days previous to the peak of blooming, were 69.4° F. and 63.5° F., respectively. It is possible that the subnormal precipitation and lack of water for irrigation in 1934 may have counteracted the favorable effect that low temperatures apparently have on the production of pyrethrins during the blooming period.

Figure 2.—Commercial planting of pyrethrum in full bloom at Avon, Colo.

In 1935 the mean daily temperature for the 10 days previous to the peak of blooming was 69.3° F. The number of irrigations during the blooming period was slightly below that of 1932.

The possible relationship that exists between yield of pyrethrins and the temperature during the blooming period is still further shown by comparing the mean monthly temperatures during June and July with yield of pyrethrins at Rocky Ford, Fort Lupton, Avon, and Vanadium. At Rocky Ford, Fort Lupton, and Fort Collins, where the mean monthly temperatures were high during June and July, the mean yield of pyrethrins was low; at Avon and Vanadium, where the mean temperatures were low during June and July, yield of pyrethrins was high.

The evidence presented shows a rather close relationship between the mean temperature during the growing period and the mean yield of pyrethrins, and accounts to a certain extent for the low mean yield of pyrethrins obtained at the lower elevations where warmer conditions existed previous to and during the blooming period.

Martin and Tattersfield (7) stated that pyrethrum flowers grown in the high-altitude regions of Kenya Colony, Africa, were high in insecticidal activity. These workers found the yield of pyrethrins to be high in plants grown at a summer temperature of 2° to 15° C. (35.6° to 59° F.), and low in plants grown at a summer temperature of 15° to 25° C. (59° to 77° F.).

Effect of Fertilizers on Yield of Flowers and Pyrethrins

In order to determine the effect of nitrogen, phosphorus, and potash on yield of flowers and pyrethrins, an experiment was started in 1932 and continued through the first-production year in 1933. Data on second-year production in 1934 were not available because of the loss of plants.

The fertilizer plots were located on a soil known as the Fort Collins loam. A soil analysis previous to application of fertilizer treatments showed no marked deficiency in nitrates, phosphates, or potassium.

The field planting was made in the early part of May with plants grown in hotbeds. The plots were three rows wide and 15 feet in length. The plants were spaced 18 inches apart, and the rows were spaced 30 inches apart. A space of 2 feet was allowed between plots.

The treatments were repeated seven times, using a Latin square random distribution.

The fertilizers used were: Ammonium sulphate (25 percent available nitrogen); superphosphate (45 percent available phosphorus pentoxide); and muriate of potash (50 percent available potassium oxide). These were combined in the following ratios to make up the seven treatments:

Treatment	N %	P_2O_5 %	K_2O %
A	4	12	4
B	0	12	0
C	4	12	0
D	0	12	4
E	0	0	4
F	4	0	0
G	0	0	0

Each treatment was made up separately according to percent availability and filler required in 1,000 pounds of mixed fertilizer. The six fertilizer treatments were applied at the rate of 39 grams per plant or at the rate of 1,000 pounds per acre. The 39 grams of mixed fertilizer were placed in a 2-inch furrow around the plant and then covered with soil. The plots were irrigated frequently enough to maintain a normal growth.

Data of Autumn-Harvested Flowers, 1932

The following autumn, after transplanting in May of 1932, there was a uniform production of flowers, and it seemed worth while to determine whether there was any difference in the number of flowers produced, weight of flowers, mean weight of flower head, and yield of pyrethrins between the variously-treated plots. The number of flowers per plant was not great enough the first year after setting to permit sampling of each of the 49 plots; hence, flowers of each of the four pickings from the seven plots of each treatment were pooled and the weight and percentage of total pyrethrins were determined. Four pickings were made: August 27, September 7, September 17, and October 1.

A summary of the data collected from the fertilizer plots in the autumn of 1932 is given in table 8.

There was no significant difference between the various treatments and the mean yield of flowers, mean weight per flower head, or yield of pyrethrins. The results of the 1932 fertilizer experiment were taken from flowers produced the same year the plants were set in the field. Normal yields are usually taken from plants the second year after field setting in the spring of the year. It was noted, however, that the yield of flowers, mean weight per head, and yield of pyrethrins increased from the August 27 picking to the October 1 picking. These data show a relationship in the yield of pyrethrins and temperatures during the blooming period similar to the relationship that was shown in table 7. The mean daily temperature, 10 days prior to August 27, was 69.8° F.; 10 days prior to September 7, 62.8° F.; 10 days prior to September 17, 61.8° F.; and 55.5° F. during the 10 days prior to October 1. In practically every instance the mean weight per flower head and the yield of pyrethrins of flowers picked during the cooler periods showed an increase over the flowers picked during the warmer periods.

TABLE 8.—*Results of fertilizer studies at Fort Collins in 1932.*

Treatment	Date of picking	No. plants picked	Flowers picked	Dry weight of flowers g.	Mean weight per head g.	Pyrethrins %
A	8/27/32	48	313	40.01	0.1278	1.08
	9/ 7/32	45	363	53.50	0.1473	1.11
	9/17/32	39	277	40.94	0.1477	1.08
	10/ 1/32	61	476	74.01	0.1554	1.34
Total			1429	208.46		Mean 1.15
B	8/27/32	56	302	42.37	0.1402	1.13
	9/ 7/32	55	303	46.70	0.1541	1.09
	9/17/32	43	233	36.29	0.1557	1.05
	10/ 1/32	69	512	96.48	0.1493	1.27
Total			1350	201.84		Mean 1.14
C	8/27/32	39	285	38.02	0.1334	1.22
	9/ 7/32	47	384	56.50	0.1510	1.18
	9/17/32	32	255	39.00	0.1529	1.21
	10/ 1/32	54	497	75.30	0.1515	1.30
Total			1421	208.82		Mean 1.23
D	8/27/32	41	307	41.28	0.1344	1.17
	9/ 7/32	48	329	48.20	0.1465	1.04
	9/17/32	34	231	34.19	0.1480	1.08
	10/ 1/32	70	455	69.73	0.1532	1.27
Total			1322	193.40		Mean 1.14
E	8/27/32	32	266	35.17	0.1322	
	9/ 7/32	45	328	47.30	0.1442	1.07*
	9/17/32	34	249	36.76	0.1476	
	10/ 1/32	61	436	66.61	0.1527	1.12**
Total			1279	185.84		Mean 1.10
F	8/27/32	47	351	47.53	0.1354	
	9/ 7/32	52	399	62.20	0.1558	1.15*
	9/17/32	40	285	44.20	0.1550	
	10/ 1/32	64	548	87.16	0.1590	1.25**
Total			1583	241.09		Mean 1.20
G	8/27/32	55	336	46.26	0.1376	
	9/ 7/32	60	337	51.90	0.1540	1.10*
	9/17/32	37	246	38.32	0.1553	
	10/ 1/32	68	456	71.86	0.1575	1.23**
Total			1375	208.34		Mean 1.17

*Flowers collected on 8/27 and 9/7 pooled for analysis.
**Flowers collected on 9/17 and 10/1 pooled for analysis.

Data of 1933

In 1933 the yields of flowers and pyrethrins were obtained for each of the 49 plots. The total yield of flowers per plot was obtained on the basis of nine competitive plants in the three rows of the plot. Competitive plants are those with competition on either side and spaced according to the standard spacing widths of the plots. The yield in pounds of flowers and pyrethrins per acre was calculated on the basis of the total plot yields. The percentage of total pyrethrins was determined from the thoroughly mixed sample of flowers from each of the nine competitive plants within each plot. The total weight of pyrethrins per acre was determined from pounds of flowers times percentage of pyrethrins. The mean number of flowers and weight of flower head were computed from total plot yields.

The significance of differences was obtained by the analysis of variance (2), the 5-percent point being taken as the level of significance.

The results of the fertilizer studies in 1933 are summarized in table 9 together with the "z" value, standard error in percentage of the mean, and the difference required for significance between treatments.

TABLE 9.—*Results of fertilizer studies at Fort Collins, Colo., in 1933.*

Treatment	Pounds of dry flowers per acre	Total pyrethrins %	Pounds of pyrethrins per acre	Mean yield flowers per plant	Mean weight of dry flower head g.
A	410.29	0.934	3.82	157	0.101
B	372.14	0.951	3.54	151	0.096
C	371.29	0.957	3.53	138	0.105
D	440.57	0.984	4.37	172	0.103
E	440.71	1.006	4.48	166	0.104
F	389.57	0.975	3.84	137	0.100
G	432.52	0.962	4.26	160	0.102
z	-0.0828	-0.0433	0.0110	0.1630	-0.2563
5%	0.4420	0.4420	0.4420	0.4420	0.4420
SE in %	8.112	2.369	9.577	7.411	3.828
Diff. for sig.	93.624	0.064	1.077	32.000	0.011

The summary in table 9 shows no significant differences between the treated and untreated (treatment G) plots, or between treated plots. It is noted that in treament E (0-0-4), where muriate of potash was used alone, there is a slight increase in quantitative and qualitative characters over the other treatments.

The results of these studies are similar to those reported by Ripert (8). Martin and Tattersfield (7) found no significant differences in pyrethrin I content or yield of flowers of potted clones subjected to the following treatments:

No manure.
Farmyard manure.
Complete dressing of nitrogen, phosphorus, potassium, calcium artificial fertilizers.

Complete artificial, excluding nitrogen.
Complete artificial, excluding phosphorus.
Complete artificial, excluding calcium.

The plants were grown in a heavy soil and the experiment extended over a period of 3 years. Plants grown in sand with deficiencies of nitrogen, phosphorus, and potash had substantially the same pyrethrin content as fully manured plots.

Winter Hardiness of Pyrethrum

No serious loss of plants from desiccation or low temperatures occurred in the 1929 planting at Fort Collins during the period from 1929 to 1932. The location of these plants and the conditions during this period were such that the information secured may not be applicable to more adverse conditions that may occur under open-field conditions. It was particularly important to know the effect of covering and exposure of the plant during the dormant period on desiccation and yield of flowers the subsequent production year, since it would be necessary to cover inbred and clonal lines during severe winter conditions.

In 1933 a preliminary study was made of the effect of covering and exposure on desiccation and yield of flowers and pyrethrins of the individual plant the subsequent season. Three treatments were included as follows:

Treatment 1. Control plot, foliage acting as a natural covering.
Treatment 2. Covering of wheat straw to a depth of 12 inches.
Treatment 3. Removal of natural-foliage covering.

The leaves of the plants in treatment 3 were removed on December 15, 1932, and the straw covering in treatment 2 was applied on January 5, 1933, and removed April 25, 1933. Each treatment was duplicated and included three-row plots of 35 feet in length with 3 feet between plots.

The minimum temperature recorded during these trials at Fort Collins was —22° F. During these trials it was noted that the moisture in the soil and straw covering in treatment 2 was sufficient to prevent drying out of the plants. The amount of snowfall was not sufficient to affect the data collected from the treatments that received no covering.

The results of this preliminary experiment are summarized in table 10, giving the yield in number and weight of flowers and pyrethrins in comparison of each treatment on the basis of five uniform and competitive plants in the center row of each plot.

TABLE 10.—*Effect of covering and exposure on yield of flowers and pyrethrins (1932-33).*

Plot no. and treatment	Number flowers harvested	Dry weight g.	Mean dry weight of individual flower g.	Pyrethrins %
1A—Natural covering	814	105.77	.1299	0.94
1B—Natural covering	887	111.22	.1253	1.09
2A—12" covering of straw	1165	130.18	.1117	1.18
2B—12" covering of straw	927	144.52	.1559	1.08
3A—Leaves cut back to crown	707	93.47	.1322	1.19
3B—Leaves cut back to crown	563	80.04	.1421	0.81

The yield in number and dry weight of flowers increases with the amount of covering. There was little change in the mean dry weight of the flower head. There are considerable differences in the yield of pyrethrins of each treatment and replication. The highest yield of pyrethrins was recorded from plots 1B, 2A, and 3A. The results of this experiment indicate a partial injury to the flower buds of the previous season's crown growth during the previous year when covering was insufficient. The results show the possible error that may result in comparing differences between individual plants of inbred lines, open-pollinated lines, and clonal lines that have been covered for winter protection at Fort Collins. The plant material at Avon is covered with snow during the winter months, which gives protection against desiccation and low temperatures.

Foreign and Domestic Strains of Pyrethrum

A continual search is being made for individual plants or groups of plants that possess high pyrethrin content, high yield of flowers, and other desirable plant characteristics necessary for breeding purposes. To date 25 strains of pyrethrum from foreign countries and the United States have been planted in the nursery at Fort Collins. In 1934 a total of 22 strains of pyrethrum had been planted in the nursery. In 1935, the first production year, the percentage of winter-killing, relative flower-yielding ability, and yield of pyrethrins were determined from the nursery-row planting of each strain.

Considerable variation existed between the various strains as to the percentage of winter-killing; likewise there was a wide difference in flower- and pyrethrin-yielding ability. These differences are shown in table 11. The percentage of winter-killing that occurred in each strain during 1934-35 varied from 20 percent to as high as 96 percent in comparison with an average of 52 percent. The loss of plants was due to desiccation. An average loss of 10 percent of the plant material in progeny lines occurred during the winter of 1934-35.

TABLE 11.—*Summary of the nursery row test of foreign and domestic strains of pyrethrum in 1934 and 1935 at Fort Collins, Colo.*

Strain no.	Source	Percent loss of Plants (1935 planting)	Flower pro-duction	Pyrethrins 1934 %	Pyrethrins 1935 %
E-4	U. S. Department of Agriculture	32	Fair	0.96	0.97
E-5	Germain Seed and Plant Company	36	Fair	......	1.05
E-10	Rothamsted Experimental Station	63	Poor	0.89	0.94
E-11	Danish Seed Company	30	Fair	0.93	0.92
E-12	Rose, Yugoslavia	33	Poor	1.09	1.06
E-13	Brac, Yugoslavia	96	Poor	0.92	0.87
E-14	Okayama, Japan	81	Poor	0.90	0.97
E-15	Hiroshima, Japan	70	Poor	0.87	0.92
E-16	Hokkaido, Japan	39	Poor	0.94	0.80
E-17	Yugoslavia (locality unknown)	45	Fair	......	0.97
E-18	Switzerland, lot 1, (locality unknown)	38	Fair	......	0.96
E-19	Switzerland, lot 2, (locality unknown)	50	Fair	......	1.10
E-20	Stafford Allen and Sons, England	67	Poor	......	1.10
E-22	Aggeler-Musser Seed Co.	54	Poor	......	0.86
E-23	Tokyo Plant & Implement Co., Tokyo, Japan	24	Fair	......	0.82
E-24	Dairen, South Manchuria	25	Fair	......	0.82
E-25	Southeastern Agricultural College, England	20	Fair	......	1.02
E-26	Dubrovnik, Yugoslavia	75	Poor	......	0.92
E-27	Hvar, Yugoslavia	65	Poor	......	1.09
E-28	Mljet, Yugoslavia	81	Poor	......	0.99
E-29	Supetar, Yugoslavia	58	Poor	......	0.99
E-30	M. Herb, Naples, Italy	69	Poor	......	1.01
	Mean	52.3		0.94	0.96

The actual yield in number of flowers was not determined, but the strains were graded on the basis of good, fair, and poor flower production. Approximately 100 flowers per plant were taken as a standard of comparison for an average yield. The flower production of 13 of the strains was considered poor, or under 100 flowers per plant, and nine strains averaged around 100 flowers per plant.

Eight of the strains yielded a mean of 0.94 percent pyrethrins in 1934; and 22 strains in 1935 yielded a mean of 0.96 percent pyrethrins.

No outstanding individual plants were selected in any of the 22 strains for plant-breeding work.

Variation in Yield of Pyrethrins During the Blooming Period of a Plant

It is customary to collect 100 flowers at the same stage of maturity from an individual plant for the sample that is to be assayed for total yield of pyrethrins. The individual flower is picked when two to four rows of the outer-disk florets are open. The purpose of the following studies was to determine the variation in the number of flowers of the proper stage of maturity, and particularly the variation in yield of pyrethrins that may occur during the blooming period. In 1932 a study was made of the variations in the number of flowers of the same stage of maturity and yield of pyrethrins that occurred during the blooming period. The results were reported in 1933 (5). In these tests there was no significant difference in the number of flowers picked and the yield of pyrethrins at three different picking dates during the blooming period.

A similar study was made in 1933 on one of the individuals studied in 1932. The results are given in table 12 together with those obtained from that individual in 1932. It is noted that very little difference occurred in the number and weight of flowers for the sample or yield of pyrethrins at three different picking dates during the blooming period. It has been shown from the results that the sample of 100 flowers for the determination of the weight and assay of pyrethrins from an individual plant can be collected at any time during the blooming period.

TABLE 12.—*Variation in yield of flowers and pyrethrins during blooming period.*

Picking period	Number flowers picked	Fresh weight g.	Dry weight g.	Mean dry weight per head g.	Pyrethrins %
6/16/32 to 6/20/32	139	86.09	17.60	.126	1.10
6/21/32 to 6/23/32	205	96.32	25.93	.126	1.15
6/24/32 to 6/25/32	162	83.28	18.74	.116	1.06
6/26/33 to 6/28/33	115	75.30	15.06	.130	1.07
6/29/33 to 6/30/33	96	47.51	11.54	.120	1.07
7/ 1/33 to 7/ 6/33	148	70.58	16.70	.112	1.14

Relation Between Maturity of Flowers and Decomposition in Storage

It is well known that the pyrethrin content increases as the flowers mature (3). This increase continues from the small-bud stage up to the time of maturity; that is, when a majority of disk florets are open. After pollination, however, there is a rapid increase in the weight of the flower head without a corresponding increase in pyrethrin content, resulting in a lower percentage of pyrethrins in overblown flowers (9).

Gnadinger and Corl (4) have shown that there is a marked decomposition of pyrethrins during storage of pyrethrum flowers. This has been confirmed by Tattersfield and others. It has been observed that some lots of flowers lose pyrethrins more rapidly than others; in some samples the loss was only 3 percent in 6 months; in others, 20 percent of the pyrethrins decomposed in 60 days. The loss of pyrethrins during storage is of considerable economic importance; hence it seemed advisable to determine, if possible, the reason for the difference in keeping-quality of various lots. As one phase of this problem, the relation between the maturity of the flowers and their decomposition in storage was investigated.

The flowers used in this experiment were grown at Fort Collins and were selected from plants of uniform growth and flower yield. The samples, which represented three stages of maturity, were all picked on the same day and dried at the same time and in the same way. The samples of flowers, representing each stage of maturity, were collected from the same lot of plants. The stages of maturity and the number of samples collected at each stage were:

Stage 1. Bud stage. Corollas of marginal florets erect; first row of disk florets open; 20 samples of 100 flowers each; mean dry weights 8.90 ± 0.7570.*

Stage 2. Nearly mature stage. Two-thirds of disk florets fully open; 20 samples of 100 flowers each; mean dry weight 15.97 ± 0.8112.*

Stage 3. Overblown stage. Collected 5 days after all disk florets fully open; 20 samples of 100 flowers each; mean dry weight 22.16 ± 2.234.*

*Standard error.

The 20 samples of a given stage were composited and subdivided into three groups of three, five, and five samples, respectively. Each subsample was thoroughly mixed and divided into two equal parts. One part was ground and assayed by the copper-reduction method, 10 days after picking; the moisture content was also determined. The other part was placed in a cheesecloth bag and suspended from a hook in the ceiling of a large room. The bags were woven closely enough to prevent sifting. The temperature of the room varied from 72° to 90° F. All samples were stored under the same conditions. After approximately 60 days in storage they were ground and assayed. The analyses, before and after storage, are compared in table 13.

The immature flowers (stage 1) showed no loss of pyrethrins during 60 days' storage. The nearly mature flowers (stage 2) showed an average loss of 1.1 percent, which is within the limits of error of the assay method. The over-mature flowers (stage 3) showed a definite average loss of 13.0 percent pyrethrins. The moisture content of the different samples was rather uniform after storage.

It would seem from this experiment that the selection of the proper time for harvesting pyrethrum is even more important than hitherto supposed; if the flowers are picked when immature, they will not have attained their maximum yield of pyrethrins; if picked when too mature, they will lose pyrethrins rapidly during storage.

Occurrence of Pyrethrins in Fresh Flowers

Fairly mature flowers were picked and immediately dropped into acetone, where they were allowed to macerate for 7 days. The carefully filtered acetone extract was diluted with water and applied to flies, roaches, and ants. All these insects showed characteristic pyrethrum poisoning. Control solutions containing acetone and water, in the proportions present in the diluted pyrethrum extract, were not toxic.

TABLE 13.—*Maturity and keeping quality of flowers.*

					Pyrethrins, moisture-free basis		
Stage	Sample	Av. weight per flower g.	Days in storage	Moisture %	Before storage %	After storage %	Pyrethrins lost during storage %
1	A	0.101	0	6.5	0.96	......	......
1	A	0.101	60	9.1	......	0.98	none
1	B	0.101	0	9.3	0.97	......	......
1	B	0.101	63	9.1	......	0.98	none
1	C	0.115	0	11.5	0.99	......	......
1	C	0.115	63	8.5	......	0.97	2.0
1	Avg.	....	....	......	0.97	0.98	none
2	A	0.166	0	9.6	1.12	......	......
2	A	0.166	60	8.4	......	1.09	2.7
2	B	0.184	0	8.2	1.09	......	......
2	B	0.184	60	9.0	......	1.12	none
2	C	0.180	0	6.9	1.05	......	......
2	C	0.180	63	8.7	......	1.01	3.8
2	D	0.158	0	7.3	1.08	......	......
2	D	0.158	63	8.4	......	1.09	none
2	E	0.160	0	7.2	1.10	......	......
2	E	0.160	64	9.2	......	1.07	2.7
2	Avg.	....	....	......	1.09	1.08	1.1
3	A	0.242	0	6.6	0.95	......	......
3	A	0.242	60	8.5	......	0.83	12.6
3	B	0.224	0	6.2	1.00	......	......
3	B	0.224	60	9.5	......	0.86	14.0
3	C	0.221	0	5.8	1.02	......	......
3	C	0.221	63	9.5	......	0.86	15.7
3	D	0.240	0	7.4	0.99	......	......
3	D	0.240	63	7.8	......	0.87	12.1
3	E	0.230	0	5.8	0.95	......	......
3	E	0.230	64	9.0	......	0.85	10.6
3	Avg.	....	....	......	0.98	0.85	13.0

Effect of Baling on Loss of Pyrethrins During Storage

The practice of compressing Japanese pyrethrum in bales originated before the pyrethrins were identified and long before it was known that pyrethrum flowers deteriorate in storage. Baling was probably resorted to in order to reduce ocean freight charges rather than to preserve the flowers.

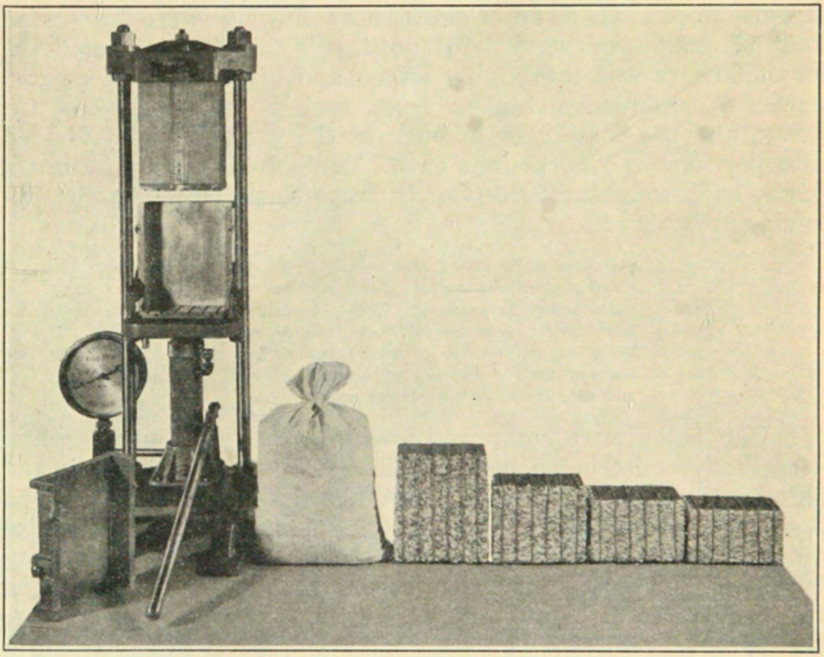

Figure 3.—Hydraulic press used in baling 2.20-pound samples shown at right.

If baling inhibits loss of pyrethrins during storage, the flowers should be compressed immediately after drying. At present the flowers are stored in uncompressed bags until the time for shipment arrives; they are then compressed into bales and loaded on the vessel. Under these conditions flowers may not be compressed until 8 months after harvesting. If flowers were baled at harvest time, the difficulty of sampling, at the time of shipping, would be greatly increased; moreover, it would be necessary to dry the flowers very thoroughly after harvesting, to prevent "heating" of the bales, with consequent loss of pyrethrins.

Japanese flowers are compressed at a gauge pressure of about 6,000 pounds per square inch. In Yugoslavia a pressure of about 2,000 pounds is used. Kenya flowers are somewhat less compressed than Japanese.

Several investigators have surmised that the baling of flowers prevents decomposition of pyrethrins during storage; but, heretofore, no experimental evidence on the effects of baling has been presented.

The authors have investigated the effect of baling on flowers grown at Avon, Colo. These flowers were harvested July 17, 1935, and were dried until July 26. On August 3 the lot of flowers was thoroughly mixed and divided into six equal parts. A sample was taken from each of the six parts for assay, and the remainder of each of the six parts was divided into portions of 2.20 pounds each. The sub-divisions of the six parts, each weighing 2.20 pounds, were then treated in the following manner:

Part 1. Stored in white cotton seed bags.
Part 2. Baled under pressure of 1,000 pounds per square inch.
Part 3. Baled under pressure of 5,000 pounds per square inch.
Part 4. Baled under pressure of 10,000 pounds per square inch.
Part 5. Baled under pressure of 16,000 pounds per square inch.
Part 6. Sprayed with a solution of antioxidant and baled under pressure of 10,000 pounds per square inch.

The bales were compressed with a hydraulic press, using a specially constructed box to hold the flowers. The press and bales made from parts 1 to 5 are shown in figure 3; the bag and each of the bales weighed 2.20 pounds net. The plates which formed the tops and bottoms of the bales were of stainless steel. The bags and bales were suspended from the ceiling to permit free circulation of air during storage at room temperature.

The analyses of the samples at the time of baling, after 93 days in storage and after 263 days in storage, are given in table 14.

The change in pyrethrin content at the end of 93 days in storage was not greater than the error of the copper-reduction method, except in the case of part 2.

After storage for 263 days the loss of pyrethrins was greatest in the bales which had been made under 1,000 pounds gauge pressure. This was probably because the pressure was sufficient to break up the flowers but not great enough to exclude air. The pyrethrin loss in the uncompressed flowers was only slightly greater than in highly compressed flowers. The antioxidant did not prevent decomposition of the pyrethrins, probably because it was applied only to the surface of the flowers.

TABLE 14.—*Effect of compression on loss of pyrethrins in storage.*

Part	Gauge pressure lbs. sq. in.	Pressure on flowers lbs.-sq. in.	Vol. of 2.2 lb. bale cu. in.	Weight per cu. in.-oz.	Days in storage	Moisture in grd. flowers %	Pyrethrins (dry basis) %	Pyrethrins lost %
1	0	0	485	.072	0	4.6	1.41	......
1	0	0	485	.072	93	7.5	1.38	2.1
1	0	0	485	.072	263	6.0	1.17	17.0
2	1,000	55	126	.279	0	6.2	1.45	......
2	1,000	55	126	.279	93	6.9	1.33	8.2
2	1,000	55	126	.279	263	6.5	1.12	22.8
3	5,000	278	90	.391	0	5.8	1.44	......
3	5,000	278	90	.391	93	7.5	1.38	7.6
3	5,000	278	90	.391	263	5.1	1.21	16.0
4	10,000	555	72	.488	0	5.5	1.44	......
4	10,000	555	72	.488	93	7.1	1.42	1.3
4	10,000	555	72	.488	263	6.4	1.22	15.3
5	16,000	889	61	.577	0	5.8	1.47	......
5	16,000	889	61	.577	93	6.9	1.52	none
5	16,000	889	61	.577	263	5.1	1.27	13.6
6	10,000	555	72	.488	0	5.0	1.48	......
6	10,000	555	72	.488	93	8.2	1.43	3.3
6	10,000	555	72	.488	263	7.0	1.29	12.8

Commercial Production of Pyrethrum Flowers in Colorado

The study of the commercial possibilities of pyrethrum flower production in Colorado was first started in 1933. These studies were planned to furnish information on the adaptability of the crop in the various agricultural districts, methods of handling the plantation, methods of harvesting and handling flowers, and cost of producing and handling a pound of dry flowers.

In May of 1933 a 4-acre field of pyrethrum was set out at Fort Collins and a 1-acre field at the Rocky Ford Substation. In May of 1934 a 2-acre field was set out at Rocky Ford, a 1-acre field at Fort Lupton, and a 1-acre field at the Avon Substation. The plants for these commercial plantings were grown in the hotbeds and greenhouses at Fort Collins. The planting distances were 18 to 21 inches between plants and 36 inches between rows.

In 1936 the number of plantings is to be increased by releasing seed to several growers in 14 of the high-altitude counties of the state. These acreages will vary from ½ to 1 acre in size.

The plantings at Rocky Ford were discontinued in 1935 because of the loss of plants during the dormant period and the extremely low yield of flowers per plant.

The commercial plantings at Fort Collins proved to be successful the first year of production; however, the loss of plants during the winter of 1934-35 indicated that the culture of the plants in this area should not be recommended. Loss of plants was due in most cases to one of the following reasons: (1) excessive desiccation of dormant plants; (2) crown-rot disease; (3) lack of information on timeliness of irrigations.

The plantings at Fort Collins in 1934 yielded an average of 525 pounds of dried flowers per acre. A sample of these flowers collected from the drying trays yielded an average of 1.03 percent pyrethrins. However, the lot of flowers on arrival at Minneapolis 3 weeks later yielded 0.82 percent pyrethrins.

Figure 1 shows the commercial planting at Fort Collins during the picking period. The large, wooden drying trays with wire-screen bottoms are also shown.

The Fort Lupton planting suffered a loss of approximately 59 percent of the plants during the dormant period of 1934-35. With a 41 percent stand of plants, the yield was approximately 300 pounds of dried flowers per acre.

The plantings made at Avon in 1934 came into production in 1935. The loss of plants during the period after transplanting and up until harvest was less than 1 percent. The loss was not due to drying out of the plant nor to crown-rot disease. In this area there is a good covering of snow during the winter months, which prevents desiccation and gives protection to the plant against possible injury due to low temperature.

The 1-acre planting at Avon yielded 925 pounds of dry flowers. The yield of pyrethrins of this lot after arrival at Minneapolis was 1.26 percent. A 100-pound sample collected at an earlier stage of maturity yielded a mean of 1.34 percent pyrethrins.

Figure 2 is a view of the Avon field in full bloom. The methods of drying the flowers are shown in figure 4. A portion of the flowers was dried in large, wooden trays similar to those used at Fort Collins in 1934. The other method of drying, illustrated in figure 4, consisted of placing about 15 to 20 pounds of fresh flowers in a 100-pound burlap bag and hanging the bag over a wooden frame. The frame consisted of several long poles placed parallel and at a distance of 12

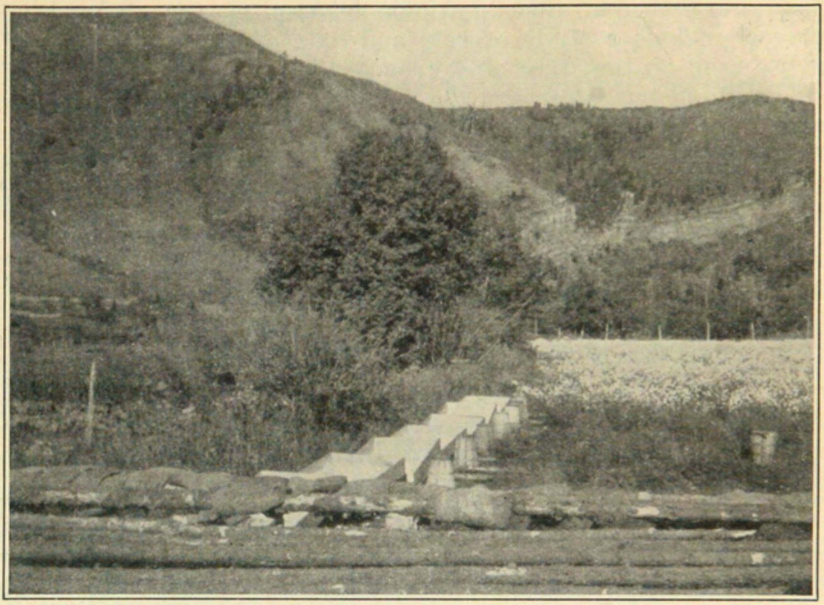

Figure 4.—Methods of drying pyrethrum flowers at Avon, Colo., in 1935. Wooden trays shown in the background are tilted at one end to allow for greater aeration and sun exposure. Burlap bags in the foreground contain approximately 15 to 20 pounds of fresh flowers.

inches apart on cross poles. The cross poles were placed 48 inches above the ground level.

The increased yield of flowers and pyrethrins at Avon in 1935 has led to the abandonment of plantings and further testing of the crop in the lower altitudes and plains regions east of the mountains. There are several high-altitude regions in Colorado in which the climatic conditions are similar to those at Avon.

Previous to 1935 the commercial plantings were made with transplants produced in hotbeds or the greenhouse. This method of handling pyrethrum, which is common in Pennsylvania and foreign countries, appeared to be the only method adaptable to the crop. This was particularly true where seed was used that was low in germination and slow in germinating. In 1933 and 1934 seed produced at Fort Collins was sown directly in the field under irrigated conditions with the idea of starting a nursery and later transplanting to the main field. The success of these plantings led to the study of methods of sowing pyrethrum seed under field conditions rather than in hotbeds and later transplanting. The plantings in 1936 are to be field-seeded.

The principal investigational phases of the commercial project include a study of rate and date of planting; effect of nurse crop on the stand and growth of pyrethrum; a study of cultural and irrigation practices during germination and initial growth of the seedlings; and a study of the effect of pre-treatment of the seed on percent germination and rate of germination.

In addition to investigating methods of field sowing pyrethrum, a study is being made of methods of harvesting and handling the flowers.

SUMMARY

There is considerable variation in the number and weight of flowers, and there is also a wide variation in the pyrethrin content of flowers produced by individual plants during the same year and from year to year.

Progeny lines from high-test mother plants yielded slightly higher pyrethrin contents than those grown from common seed stock.

Evidence of a close relationship between pyrethrin content and temperature during the growing season is presented. Where mean monthly temperatures were high, the pyrethrin content was low; in the cool mountain valleys the pyrethrin content was high.

The application of commercial fertilizers had little effect on the yield of flowers or pyrethrins based on the conditions of the experiment.

A comparison of the yield of flowers and pyrethrins of 25 foreign and domestic strains of pyrethrum was made, and the results did not show any outstanding strains or plants.

Immature or nearly mature flowers retain their pyrethrin content during storage better than overmature flowers.

Pyrethrins occur in fresh flowers as well as in dried flowers.

Compressing the flowers into bales does not prevent loss of pyrethrins during storage. There was only a little more decomposition of pyrethrins in uncompressed flowers than in flowers compressed under 16,000 pounds pressure.

The increased yield of flowers and pyrethrins in the high-altitude regions of Colorado has led to the abandonment of plantings in the plains regions and lower elevations. Encouraging results have been obtained in the mountain districts.

This investigation is being continued.

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