STUDIES ON THE EFFECTS OF CERTAIN VOLATILE CHEMICALS ON THE PRODUCTION OF FORCED RHUBARB

THESIS FOR THE DEGREE OF M. S.

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Studies on the Effects of Certain Volatile Chemicals on the Production of Forced Rhubarb

Thesis

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By

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Introduction

The winter forcing of rhubarb is one of the important forcing industries in Michigan. Since that portion of the crop that is placed on the market relatively early in the season is more profitable than that which matures later, the growers often attempt to start forcing by the latter part of November. Experience has shown that plants forced this early produce a much smaller crop than is secured when forcing is started twenty to forty days later. Occasionally the roots started as early as November do not yield until the following March. It is obvious that the breaking of the rest period is an important factor in the forcing of this crop. It was thought that a study of the factors affecting the production of early rhubarb might give results that would have not only practical application, but might throw some light upon the problem of "rest period" in this herbaceous perennial.

Literature Review

The use of volatile chemicals as an aid in the forcing of shrubs, tuberous and bulbous plants, and herbaceous perennials, has been studied by a number of investigators. Among the first workers was Johannsen (1), who studied the effects of ether on lilacs and other hardwooded plants. His results showed that plants subjected to ether vapors in the early part of the "rest period" bloomed from two to three weeks earlier than untreated plants. Stuart (9) found that anesthetics imparted a decided growth impulse when applied to plants in a state of complete rest. Howard (4) studied the rest period of bulbs and herbaceous perennials and found that freezing was the most effective treatment for causing early growth, especially in the case of herbaceous perennials. Coville (12) found that the freezing of dormant hardwooded plants is a prerequisite to their resumption of normal growth in spring. Bramble (17) found that ethylene chlorhydrin has proven to be very successful in breaking the rest period of both sugar maple and chestnut seedlings. Denny (16) found that ethylene chlorhydrin was remarkably effective for breaking the rest period of potatoes.

Lazenly (5), Sayre (10), and Morse (11) reported that freezing of rhubarb roots is essential before they can be forced profitably. Sayre (10) also found that light freezing (20°F.) gave the best growth, and severe freezing (-10°F.) proved detrimental and reduced the yield. Card (13) found that frozen rhubarb roots gave greater yields than unfrozen ones. Unfrozen roots were far behind in activity, which showed clearly the necessity of freezing the roots before attempting to force them. Stuart (2) (3), studying the effect of ether on forcing,

found that ether treatment gave a decided impulse to dormant rhubarb roots by hastening the "vital processes" in the plant, and resulted in more vigorous growth and increase in weight of product, but stated that it did not seem to replace freezing, and that freezing rhubarb roots early in the season was necessary. Hepler (6) found that ether accelerated growth very pronouncedly in the first two pickings, but on the third picking its effect disappeared. He stated that ether hastened maturity seven times more than the treatment of the check plots at the first picking. He also found that the higher yield of treated roots was due to ether, in each separate picking, up to the fifth, and that the final total yield was 49 per cent more than that of the untreated check. Hammersly (7) secured the following increase in yield of rhubarb by etherization (in per cent increase over untreated):

Four year old roots, 67; three year old, 126; two year old, 21; and one year old roots, none. Roots treated with chloroform showed very little increase in growth, and etherized unfrozen roots did not make any growth until late March.

Vorhees (8) found that etherization did not increase the total yield but did increase the percentage of marketable petioles, as compared to untreated plants. He also stated that ether-treated roots gave an increase in yield over the untreated check for the first picking.

Materials and Methods

Two year old roots of the Victoria Variety were secured from a commercial forcer in Macomb county. The roots were dug in late November, 1932, and had been subjected to light freezing. From November 16 to 22 the temperature was low enough to freeze at least the surface buds to a limited extent. During this period the maximum air temperature was 24° F. and the daily minima ranged from 13° to 15° F. However, the average amount of snow on the ground during this period was four inches, which undoubtedly protected the roots from the effect of low temperature. It has been shown by Bouyoucos (18) that with 13° F. air temperature soil temperature soil temperature of uncovered ground three inches below the surface was 20.2° F. and as high as 30.6° F. when the soil was covered with uncompacted snow. This shows that during the above mentioned period the minimum temperature two inches below the ground could not have been lower than 26° F. and was probably slightly higher. This temperature was sufficient, however, to freeze the top buds of the rhubarb roots.

The roots were washed thoroughly with tap water in order that all parts could obtain the full effect of the chemicals. To determine the influence of size of root on yield, the weights of individual roots were taken, and the yield obtained from each root was recorded separately.

Sixty four roots fairly uniform in size were selected; half of them were frozen at 2° below zero (F.), and half of them were not given any additional freezing. On the fourth of December the severely frozen roots were divided into four lots, each consisting of eight uniform clumps. The chemical reagents were used at the following concentrations:-

(1) 40 per cent commercial sulpheric ether
20 c.c. per cubic foot or 70.6 c.c. per 100 litres of air space, regardless of the space occupied by the clumps.

(2) Ethylene chlorohydrine 2.8317 c.c. per cubic foot or or 10 c.c. per 100 litres of air space.

(3) Ethylene dichloride 2.8317 c.c. per cubic foot, or 10 c.c. per 100 litres of air space.

Two lots, severely frozen and slightly frozen roots, were exposed twenty four hours to the vapors of the chemicals in an air tight wooden box of 3.83X2.83 X 2.41 feet. After twenty four hours of exposure the roots were stored and covered in bushel baskets at room temperature. Two similar lots were kept untreated for the check plots.

On December 8 the roots were set in beds under a green house bench used for carnations. The bench in the middle of the house was selected to minimize variations in temperature and moisture. Eight each of the frozen and slightly frozen roots which had received the same treatment were placed in adjacent beds. Burlap and heavy black building paper was nailed around the bench to exclude all light. Good ventilation was provided for by an electric fan at one end of the room and an especially constructed ventilator at the other end. The temperature and humidity during the growing period were fairly constant, around 54° F. and 82 per cent respectively. Just enough water was given at intervals to keep the soil surrounding the roots moist at all times.

The first picking was made on December 30, twenty two days after the roots had been set in the beds, and subsequent pickings were made weekly. (Until February 22, 1933.) The yields were recorded in grams according to the following grades:-

(1) Fancy. Petioles over 3/4 inches in diameter, 15 to 18 inches long and highly colored.

(2) Choice. Petioles from 3/4 to 3/8 inches in diameter, 12 to 18 inches long and fairly well colored.

(3) Culls. Petioles less than 3/8 inches in diameter, and less than 12 inches in length.

Presentation of Data

A. The effect of volatile chemicals on roots slightly frozen (26°-29° F.) in the field.

Only the yields of the first six pickings are included in the following tables. The last three pickings were discarded, because the roots yielded few fancy stalks and the remainder was practically all culls. Roots were set in the adjacent beds and each lot consisted of eight clumps. The first picking was made on December 30, twenty two days after the roots had been planted in the beds.

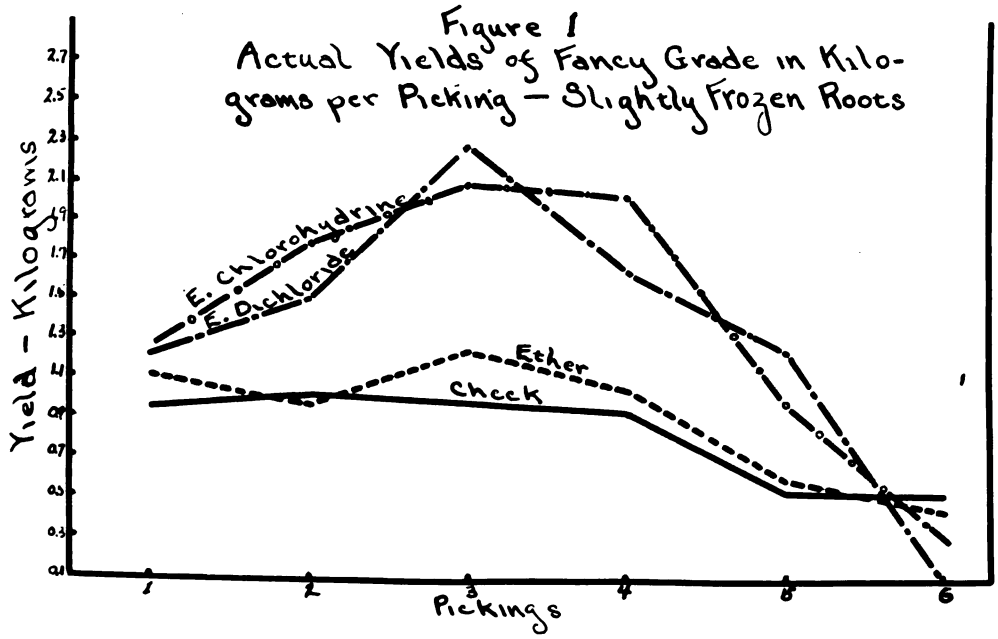
Table 1: The effects of treatments of slightly frozen roots upon the yield of petioles (by grades) for the first six pickings.

	Date of Harvest							
CHECK	Dec.30	Jan.5	Jan.11	Jan.18	Jan.25	Feb.1	Grand Total	Mean & P. E.
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	kgms.
Fancy	944	995	953	929	510	497	4828	
Choice	613	451	640	1224	1216	627	4771	
Total	1557	1441	1593	2153	1726	1124	9599	1.20±.34
E.CHLOHYDRIN								
Fancy	1222	1779	2076	2000	962	294	8333	
Choice	490	474	1714	1280	1285	1042	6285	
Total	1712	2253	3780	3280	2247	1336	14618	2.44±.57
E.DICHLORIDE								
Fancy	1217	1495	2260	1637	1216	86	7911	
Choice	310	1032	655	1352	1479	1262	6090	
Total	1527	2527	2915	2989	2695	1348	14001	2.33±.44
ETHER								
Fancy	1105	967	1219	1006	540	435	5272	
Choice	641	797	1176	1123	1353	869	5959	
Total	1746	1764	2395	2129	2893	1304	11231	1.87±.31

Table 1 and graphic representation in Fig. 1 show that ethylene chlorohydrine treated roots gave the highest yield of fancy product and the highest total yield. Roots treated with ethylene dichloride rank second in production of fancy petioles and total yield per picking. This treatment also gave greater yield of fancy stalks than the ethylene chlorohydrine treated roots for the third and fifth picking. Etherized roots produced higher total yields and more fancy stalks than the check plot, but the

Figure 1

Actual Yields of Fancy Grade in Kilograms per Picking — Slightly Frozen Roots



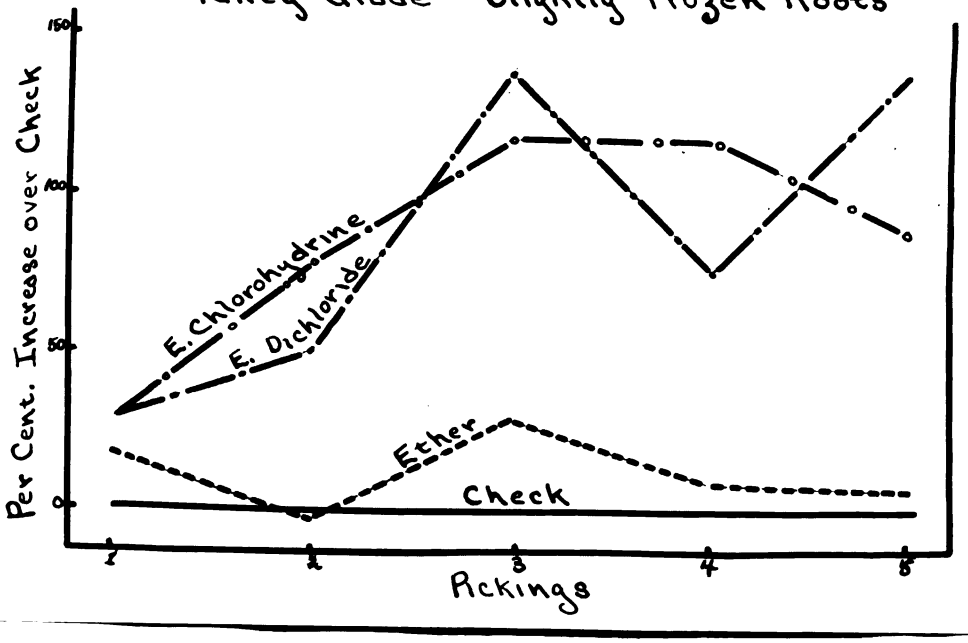
difference in yield was not very significant. It should be noted, however, that the production of fancy petioles and the total yield were much less than those obtained from either the ethylene chlorohydrine or ethylene dichloride plots. Petioles from roots treated with ethylene chlorohydrine were a deep red color, whereas the petioles obtained from other treatments were pink. It is apparent from Table 1 that the highest yield of fancy petioles as well as the total yield for the six pickings was obtained from the plots treated with ethylene chlorohydrine, the next highest obtained from the plots treated with ethylene dichloride treatment. Etherized roots produced less than the above mentioned treatments. but slightly more than the check; however, the amount of culls was higher than the other treatments or that of check.

Table 2. The percentage increase of fancy petioles for each picking obtained from three different treatments over check:

	ETHER		ETH. CHLOROHYDRINE		ETH. DICHLORIDE	
Date of Harvest	This Picking	To Date	This Picking	To Date	This Picking	To Date
December 30	+17.1	17.1	+29.4	29.4	+ 28.9	28.9
January 5	-2.9	6.8	+78.8	54.7	+ 52.2	39.9
January 11	+27.9	13.8	+117.8	75.5	+137.1	71.9
January 18	+ 8.2	12.5	+115.3	85.2	+ 76.2	73.0
January 25	+ 5.9	11.7	+88.6	85.6	+138.4	80.7
February 1	-14.2	9.2	-89.0	72.6	-477.9	63.9

Data presented in this table and graphic representation in Fig. 2 show that at the first picking all the treatments gave a considerable percentage increase over the check plots. There was no significant difference in increase between the ethylene chlore-

Figure 2.
Increase as Per Cent. of Check by Pickings
Fancy Grade — Slightly Frozen Roots

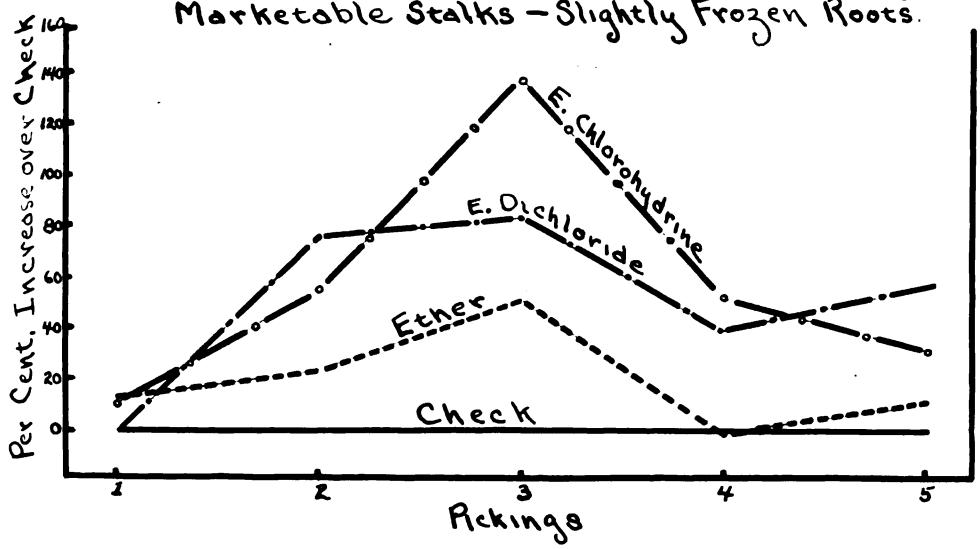


hydrine and ethylene dichloride treatments; however, both gave nearly twice as much increase as that obtained from etherized roots. In the later pickings ethylene chlorohydrine treated roots gave the greatest increase of all the treatments, and the next highest was obtained from ethylene dichloride treatment. Etherized roots gave a slight increase over the check plots, but the differences shown in Table 2 were not of any consequence. This same treatment gave no increase for the second picking. It is apparant from Table 2 that the percentage increase in yield of fancy petioles obtained from the ethylene chlorohydrine treatment for the six pickings was very significantly higher than was obtained by other treatments. The next highest percentage increase was secured from ethylene dichloride treatment. Etherized roots gave a much smaller percentage increase than the above treatments, and the increase obtained was not of any consequence.

Table 3. Per cent increase of *marketable petioles for each picking obtained from the different treatments over check.

	Ether		Ethyl. Chlorohyd.		Ethyl. Dichloride	
Date of Harvest	This Picking	To Date	This Picking	To Date	This Picking	To Date
December 30	+12.1	12.1	+ 9.9	-9.9	-1.9	-1.9
January 5	+21.9	16.9	+ 55.8	32.0	+ 74.7	35.0
January 11	+50.35	28.5	+137.9	68.7	+ 82.9	51.6
January 18	-1.1	19.0	+ 52.3	63.5	+ 38.8	47.3
January 25	+ 9.6	17.1	+ 30.2	56.7	+ 56.1	49.3
February 1	+16.0	17.0	+18.8	52.3	+19.9	45.9

Figure 3.
Increase as Per Cent of Check by Pickings
Marketable Stalks – Slightly Frozen Roots.



* The term marketable was applied to all the salable stalks; under this classification, Fancy and Choice grades were combined and the percentage of increase expressed on this basis.

Data presented in Table 3 and Fig. 3 show that at the first picking ether and ethylene chlorhydrine treatments gave an increase in percentage of marketable stalks, but the difference in increase between the above treatments was very low. Ethylene dichloride treated roots gave an increase in yield over check plots. In the subsequent pickings the increase in yield obtained from the ethylene chlorohydrine treated roots was remarkably higher than that obtained by other treatments. Etherized roots gave less increase as compared to ethylene dichloride treatment, and no percentage increase for the fourth picking. On the whole, Table 3 shows very clearly that the increase in percentage for the six pickings obtained from the ethylene chlorohydrine treatment was very considerable. Etherized roots gave the lowest percentage increase of all the treatments.

Table 4. Total yields for each grade of rhubarb expressed in grams and in percentage of the total yield for the four plots.

	Fancy	Per cent Fancy	Choice	Per cent Choice	Culls	Per cent Culls	Total
CHECK	4829	39.4	5920	40.9	2402	19.6	12241
ETHYLENE CHLOROH.	8800	46.3	7338	38.6	2869	15.1	19007
ETHYLENE DICHLOR.	8025	42.7	7956	42.3	2787	14.8	18768
ETHER	5362	34.7	6774	43.9	3286	21.3	15422

This table points out that the differences in percentage of the total yield by grades obtained from the different treatments

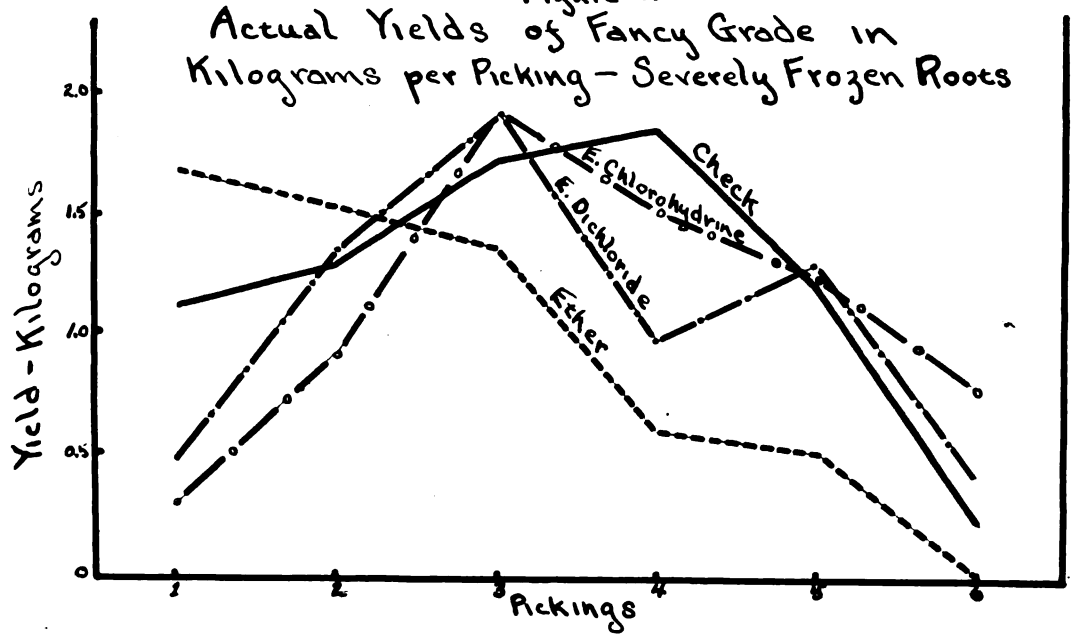
were very small. As compared to the actual yields, ethylene chlorohydrine treatment gave 82.2 per cent increase of fancy, and 63.8 per cent of marketable stalks over check, and ethylene dichloride gave 66.1 and 62.2 per cent for the same grades. The percentage increase obtained from the etherized plot was very small in comparison to the above treatments, for it was only 11.0 per cent of fancy, and 27.2 per cent of marketable petioles. It is apparent that ethylene chlorohydrine treatment has proven 7.5 times, and ethylene dichloride 6 times more effective for the production of the fancy petioles than the ether treatment.

B. The effects of volatile chemicals on severely frozen (-2°F) rhubarb roots.

Table 5. Yield of petioles by grades expressed in grams from the different treatments on severely frozen and check plots.

	Date of Harvest							
CHECK	Dec. 30	Jan. 5	Jan.11	Jan.18	Jan.25	Feb. 1	Grand Total	Means & P. E.
	gms.	gms.	gms.	gms.	gms.	gms.	gms.	kgms.
Fancy	1185	1291	1745	1856	1218	210	7505	
Choice	638	771	702	1158	1663	1260	6192	
Total	1823	2062	2447	3014	2881	1470	13697	2.28±4382
E.CHLOR.								
Fancy	290	905	1924	1508	1251	779	6657	
Choice	58	284	786	822	1520	787	4257	
Total	348	1189	2710	2330	2771	1566	10914	1.82±4382
E.DICHL.								
Fancy	491	1339	1951	977	1297	410	6465	
Choice	364	832	1099	590	1102	656	4643	
Total	855	2171	3050	1567	2399	1066	11108	1.85±5186
Ether								
Fancy	1676	1524	1369	608	512	0	5689	
Choice	1443	771	998	1325	1277	606	6420	
Totals	3119	2295	2367	1933	1789	606	12109	2.02±6299

Figure 4.
Actual Yields of Fancy Grade in Kilograms per Picking – Severely Frozen Roots



Data presented in Table 5 and Fig. 4 show that the etherized frozen roots gave a larger yield of fancy petioles, as well as total yield in the first two pickings, than was obtained from either check or the other treatments. It should be noted, however, that after the third picking the effect of ether disappeared. Ethylene chlorohydrine and ethylene dichloride treatments had an inhibiting effect, as the yields obtained from both of the treatments were much less, and even less than the check plot. Table 5 also shows that ethylene chlorohydrine and ethylene dichloride treatments lengthen the forcing period, as the yields obtained in the last two pickings were considerably higher than the ether and check plots. It is apparent that ether accelerated the growth in the first two pickings, but did not increase the total yield. The highest yield of fancy petioles as well as total yield was obtained from the check plot, and none of the treatments increased the total yield from these severely frozen roots.

Table 6. Per cent increase of fancy petioles over the check obtained from different chemical treatments, at each picking. (On the severely frozen roots.)

Date	Ether		E. Chlorohydrine		E. Dichloride	
of Harvest	This Picking	To Date	This Picking	To Date	This Picking	To Date
Dec. 30	+ 41.4	+ 41.4	-308.6	-308.6	-141.3	-141.3
Jan. 5	+ 18.1	+ 29.2	-42.6	-107.2	+ 3.7	+ 35.3
Jan. 11	-27.4	+ 8.2	+ 10.2	+ 35.3	+ 11.8	-11.6
Jan. 18	-205.2	-19.3	-16.4	-31.3	-89.9	-27.7
Jan. 25	-137.8	-28.2	+ 2.7	-24.2	+ 6.5	-20.5
Feb. 1	- ∞	-319,2	+ 270.9	-12.8	+ 95.2	-16.1

Table 6 and the graphic representation in Fig. 5 indicate that ether was the only treatment that increased the percentage of fancy petioles over that produced by the check plot, and only in the case of the first two pickings. The total yield of the fancy grade, at the end of the picking season, was highest for the check plot.

Table 7. The per cent increase or decrease in yield of marketable stalks over that of the check plot for the different treatments.

Date of Harvest	Ether		E. Chlorohydrine		E. Dichloride	
	This Picking	To Date	This Picking	To Date	This Picking	To Date
Dec.30	+ 71.1	+ 71.1	-423.8	-423.8	-113.2	-113.2
Jan. 8	+ 11.3	+ 39.3	-73.4	-152.7	+ 5.3	-28.4
Jan.11	-3.3	+ 22.9	+ 10.7	-49.1	+ 24.6	-4.2
Jan.18	-55.9	+ 3.9	+ 29.3	-42.1	-92.3	-22.2
Jan.25	-61.0	-6.3	-3.9	-30.8	-20.1	-21.7
Feb.1	-142.5	-13.1	+ 6.5	-25.5	-37.9	-23.3

It is evident from the data presented in Table 7 that the production of marketable petioles was similar to that of the fancy grade. The only increase in production over the check plot was the case with the fancy grade. The ethylene chlorohydrine and ethylene dichloride treatments actually reduced the yield of the severely frozen roots.

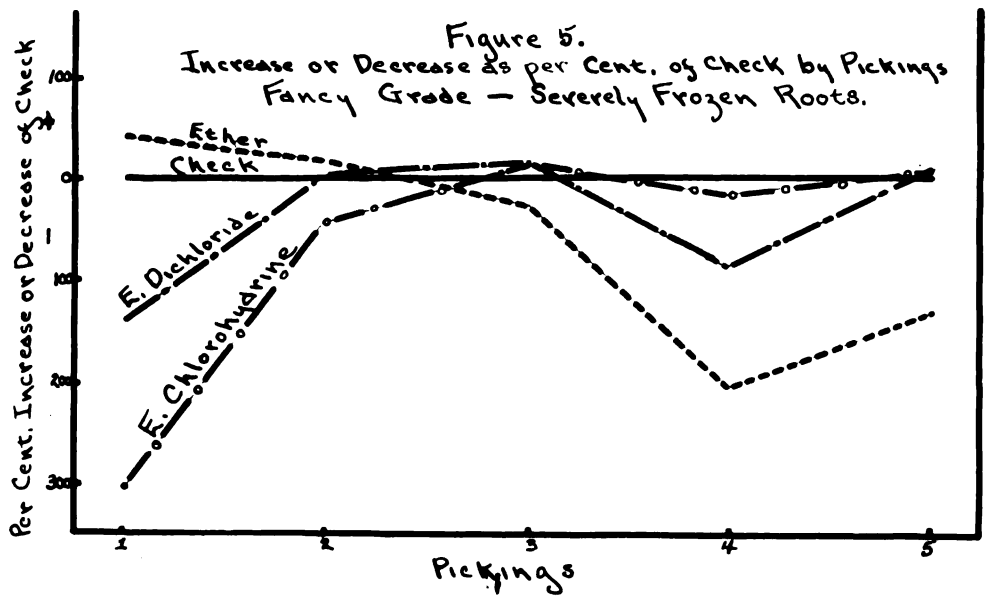


Figure 5.
Increase or Decrease as per Cent. of Check by Pickings
Fancy Grade — Severely Frozen Roots.

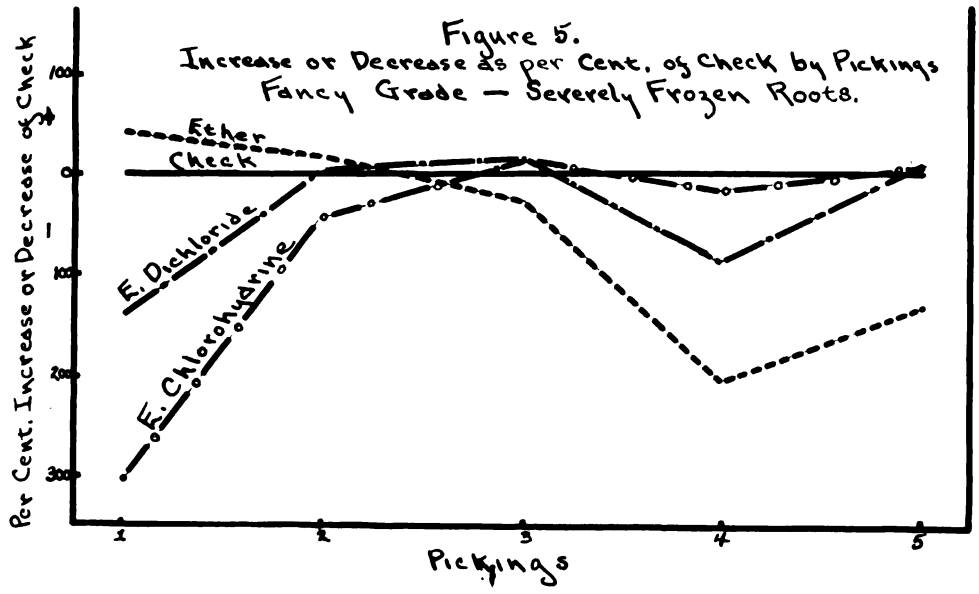


Figure 5.
Increase or Decrease as per Cent. of Check by Pickings
Fancy Grade — Severely Frozen Roots.

Table 8. The total yields for each grade of rhubarb expressed in grams and in percentage of the total yield for the four plots.

	CHECK		E.CHLOROHYDR.		E. DICHLORIDE		ETHER	
Grades	Yield gms.	Per cnt. Total	Yield gms.	Per ct. Total	Yield gms.	Per cnt. Total	Yield gms.	Per cnt. Total
Fancy	7505	45.3	7197	46.0	6839	43.6	5889	36.1
Choice	7039	42.5	5868	37.5	5877	37.4	6852	43.5
Culls	2026	12.2	2580	16.5	2978	18.9	3201	20.3
Totals	16570		15645		15694		15742	

Data presented in Table 8 show that the differences in percentage of the total yields obtained from the different treatments and check plot were not significantly high. However, the comparison of the actual yields showed that all the treatments produced no increase of fancy or marketable petioles over that produced by the check plot. The ether treatment gave 32 per cent decrease in production for fancy grade, whereas, 4 and 9 per cent decreases for the same grade were given by the ethylene chlorohydrine and ethylene dichloride treatments, respectively. It is evident from the results shown in Table 8 that none of the treatments produced a higher yield than the check plot.

Discussion and Conclusion

The results obtained with ether in this investigation are comparable to those obtained by Stuart (2) (3), and Hepler (6). They have shown that frozen roots treated with ether produced larger yields than the untreated plots. Data presented in Tables 1, 2, 3, and 4 show somewhat the same results, though the increases in yield were not as high as those secured by Hepler. He did not give the temperature at which the roots in his studies were frozen, but since they were dug and left on the top of the ground, they were in all probability frozen solid before treatment. The differences between his results and those presented in this paper may be accounted for by this difference in the severity of the freezing.

The experimental evidence presented shows that ethylene chlorohydrine and ethylene dichloride are much more effective than ether in influencing the production of forced rhubarb from slightly frozen roots. Although all the chemical reagents produced larger yields during the season than the check plots, yet data presented in Tables 1, 2, 3, and 4 show that the increases obtained from ethylene chlorohydrine and ethylene dichloride are significantly higher than obtained from the ether treatment. This was true especially for the "fancy" grade rhubarb of the first four pickings. The "fancy" grade petioles of the first four pickings were considered important as it is the "fancy" grade rhubarb that brings the highest returns to the forcer, due to early demand and high market prices.

The severely frozen roots (-2°F.) when subjected to the same

treatments gave different results from those secured from slightly frozen roots. Ethylene chlorohydrine and ethylene dichloride reduced the yield, especially in the first one or two pickings. Both treatments showed a tendency to delay maturity, since larger yields were obtained in the later pickings. The results secured with ether were in full accord with those obtained by Vorhees (8). He has shown that etherized frozen roots produced greater yields, especially in the first two pickings, than the unetherized plots, and that the effect of ether disappeared on the third picking. He also stated that etherization did not increase the yield.

The comparison of the results of severely frozen and the slightly frozen lots shows that the check of the severely frozen lot gave significantly higher total yield than the check of the slightly frozen lot. Therefore it is apparent that [illegible] temperature was not sufficient for entirely breaking the "rest period". The yields obtained from the slightly frozen ethylene chlorohydrine and ethylene dichloride treated roots, especially the former, were significantly higher than those secured from the same treatments on severely frozen plots, and also significantly higher than the check of the severely frozen lot. Hence ethylene chlorohydrine apparently increases the effect of slight freezing, and since no increase in yield was obtained from these treatments on severely frozen roots, it would appear that ethylene chlorohydrine shortens or helps to break the "rest period", although no unfrozen roots were tested with these chemicals.

The question of whether or not these chemicals(ethylene chlorohydrine) break the "rest period" due to the increase in enzymes or sucrose, which was found by Denny (16) and his co-workers, has not

been investigated. They found a quantitative increase in peroxidase and catalase as well as sucrose where ethylene chlorohydrine was used on potatoes, although there was not a high correlation between these increases and sprouting.

Summary

(1) Slightly frozen (26° to 29°F. in the ground) roots when treated with ethylene chlorohydrine, ethylene dichloride, and ether gave larger total yields and higher percentages fancy and marketable petioles than the untreated roots.

(2) Ethylene chlorohydrine gave the higher percentage of fancy and marketable stalks for the first four pickings and 82.23 per cent increase of total fancy and 63.85 per cent of marketable stalks over the check plots.

(3) Roots treated with ethylene dichloride produced 66.18 per cent of total increase of marketable petioles than was obtained from the untreated roots. It also produced the next highest per cent increase of fancy and marketable petioles for the first four pickings.

(4) Ether treated roots gave a slight per cent increase over the check plot, but the increases obtained were insignificant as compared to those obtained from ethylene chlorhydrin and ethylene dichloride treatments.

(5) Severely frozen (-2°F.) etherized roots produced a larger percentage of fancy and marketable petioles than the other treatments, including the check for the first two pickings. Ether accelerated the growth in the first two pickings, but did not increase the total yield.

(6) Ethylene chlorohydrin and ethylene dichloride had a retarding effect on yield, especially in the first one or two pickings, and no increases in total yield were obtained over check.

(7) The severely frozen untreated roots produced the highest total yield over the other treatments, higher also than the untreated

Acknowledgments

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Literature Cited

(1) Johannsen, W. (The forcing of plants by ether) The American Gardener, 20:25, 1899, and The American Gardener 21: 358-360, 372-373, 1900.

(2) William Stuart (etherization as an aid in rhubarb forcing) Seventeenth Annual Report of Vt. Agr. Exp. Sta. 1906.

(3) William Stuart (The use of anesthetics in the forcing of plants) Nineteenth Annual Report of Vt. Agr. Sta. 1905-1906.

(4) W. L. Howard (Summer rest of bulbs and herbaceous perennials) Mo. Res. Bull. 15

(5) W. R. Lazenly(forcing rhubarbs in dark) Proceedings of Society for Horticultural Science, 1905.

(6) J. R. Hepler (The effects of ether and various temperatures in forcing rhubarb) Proceedings of the American Society for Hort. Science.

(7) Hammersly, R. W. (Experiment in forcing rhubarb) Unpublished thesis, University of Wisconsin, 1913.

(8) J. A. Vorhees (The use of ether in forcing asparagus, rhubarb, and strawberries. N. J. Ag. Exp. Sta. Report. 1906.

(9) William Stuart (The role of anesthetics and other agents in plant forcing) Vt. Agr. Exp. Sta. Bull. 150; 1910.

(10) C.B. Sayre (Winter forcing of rhubarb) Ill. Agr. Exp. Sta. Bull. 298. 1927.

(11) J. E.Morse (The new rhubarb culture) Orange Judd Company, N. Y. 1901.

(12) F. V. Coville (The influence of cold in stimulating the growth of plants) Journal of Agr Res. 20: 15, 1910.

(13) Fred W. Card (forcing rhubarb) Rhode Island Agr. Exp. Sta. Bull. 55. 1899.

(14) J. T. Scott (Rhubarb) Gardening; Volume XII, p. 549-550; 1904.

(15) J. E. M. (Pie plant in dark) Rural. New Yorker, Vol. LVII, No. 2544, p. 736, 1898.

(16) Denny (Hastening the sprouting of dormant potato tubers) American Jour. of Botany, Vol. 13, pp. 118 and 386. 1926.

(17) Bramble. (Breaking the dormancy of tree seedlings by chemical treatments) Science 75. No. 1937, p. 193, 1932.

(18) Bouyoucos. Michigan Board of Agriculture, page 805-807, 1916.