A STUDY OF SOME ENVIRONMENTAL FACTORS INFLUENCING THE SHOOTING TO SEED OF WINTERED-OVER CABBAGE.

by

Victor R. Boswell

Thesis submitted to the Faculty of the Graduate
School of the University of Maryland,
in partial fulfillment of the
requirement for the degree
of Doctor of Philosophy

1 9 2 6.

TABLE OF CONTENTS.

A STUDY OF SOME ENVIRONMENTAL FACTORS INFLUENCING THE SHOOTING TO SEED OF WINTERED-OVER CABBAGE.

by

Victor R. Boswell,
College Park, Md.

Statement of the Problem.

In sections of the Middle and South-Atlantic states where the weather is mild enough for cabbage to live through the winter with no artificial protection, frequently seed is sown in the fall and transplanted to the field in the early winter. Of course, no top growth is made during the winter but the advantage is that the plants become established so that with the earliest growing weather in the spring, they resume growth and are ready for market sooner than spring-grown plants. Some losses occur from winter-killing, and also a varying amount of loss is suffered as a result of the plants shooting to seed instead of forming heads. The percentage of "seeders" appearing, varies greatly from year to year in the same location, and varies greatly on different farms in a given season.

The widely different views as to the cause of this formation of flower stalks, and the variation in certain details in the production of the crop are evidence of the lack of information concerning the factors which control the phenomenon. It is known that genetic factors play a part in "bolting" of cabbage, as it is sometimes called. But hereditary factors do not account for the behavior entirely. Some hold that it is determined only by cultural conditions, altho it is more probable that both genetic and environmental factors play a part. We shall be concerned chiefly with the environmental factors.

Some of the environmental conditions variously supposed to be responsible for the formation of flower stalks instead of heads are: Warm, open winters; very severe winters; extreme changes in winter temperature; checking of growth in the plant bed, soil conditions, fertilizer treatment and even the mode of transplanting. Growers have learned that the time of planting the seed is an important factor, and many always plant on a certain date if it is at all possible. The soil conditions can be controlled to some extent; and the plants during their early development may be subjected to varying climatic conditions by sowing the seed at different dates. These latter two factors are the ones which most growers attempt to control, and by the very nature of the case, they are about the only ones which they can control. Accordingly, the major portion of this work was devoted to a study of the influence of: (1) Time of sowing the seed, (2) fertilizer treatment in the plant bed, and (3) fertilizer treatment in the field. Other points which were studied are: (1) Influence of varying the temperature after transplanting, (2) influence of the chemical composition of the plant upon its subsequent behavior, and (3) strain differences.

The primary object of the work herein reported was to study the environmental factors controlling the shooting to seed of cabbage. In attempting to control the production of seeders, other results may be brought about which may occasion as great or greater losses in yield than does flower stalk formation. Before any practice designed to control shooting to seed can be recommended, it is essential to know how it is going to influence the crop in other ways that will also affect the yield. Therefore, because of the practical importance of the problem, much attention has been directed to the matters of winter-killing, percentage harvested, and ultimate yield, as well as to the production of seeders.

REVIEW OF LITERATURE.

Numerous investigators have studied various factors which influence the vegetative and reproductive tendencies in a wide range of plant forms. Fungi and the higher plants, including annuals, biennials and perennials, have all been the objects of considerable investigation, with respect to their vegetative and reproductive development as influenced by such factors as: Nature of the substrate; duration, quality and intensity of light; temperature, pruning, ringing and wounding. Since the literature dealing with the influences of the above-mentioned factors upon reproduction in general, is so extensive, it is impracticable to attempt a citation to more than a very few works dealing with matters closely related to the problem under consideration. First we shall consider some experimental results and opinions relative to premature reproductive development in the cabbage, since this plant is of primary interest in this work.

Results reported by McCue (24)(25) show that commercial stocks of cabbage seed may be very heterozygous, and that many types of plants can be isolated by inbreeding. Later reports on the same project by Detjen (6)(7), state that from a single sample of seed, every gradation of plant form has been observed from a solid head to an annual blossoming type which never forms a head. A few lines have been developed which are free from the non-heading tendency, and from annual blossoming plants. On the other hand, an early blossoming type has been isolated which shows 62% of flower stalks the first year of growth, even when the seed are started in the spring. Despite the clear evidence that the genetic make-up of the plant plays such a large part in determining its type of development, Detjen*believes that environmental factors do have an influence upon the percentage of seed stalks which may appear.

Sutton (28) stated that certain varieties which are consistent headers when planted in the spring and developed under favorable conditions, are unsuitable for sowing the previous fall on account of "bolting" to seed in the spring. And that there is a tendency for some plants to bolt, even in the most carefully selected seed stocks, if the seeds are sown so early as to allow too much development before winter. Crosses of a red, bolting variety and a green, heading variety gave all light-red, heading plants in the first generation. In the second generation there was a breaking up which resulted in:

27 red heads
10 red bolters
8 green heads
3 green bolters

This result suggested that the tendency to shoot to seed is a recessive Mendelian character. Other investigators have found the heading character to be dominant over the non-heading in various crosses of <u>Brassica oleracea</u>.

*Personal interview with the writer. October 1925.

Paice (26) noted that bolting, or freedom from bolting, is a varietal characteristic. However, he believed that environmental conditions are also a factor, for he stated that the time of sowing seed in the late summer or fall is important. "If there is no check to the seedlings when quite small, there will be a complete freedom from bolting." This last statement is not borne out in the work reported in the present paper, but it indicates a view which is prevalent among many who have worked with the cabbage.

Erwin (8) concluded from observations upon plants carried over winter in the greenhouse, that cultural rather than hereditary factors are responsible for premature flower stalk formation.

Zimmerly (35) has reported a rather marked variation in the tendency of different strains to shoot to seed when all were grown under the same conditions. White (34) has observed the same.

Blount (3) suggested the use of immature seed as a cause of the premature flowering of cabbage.

Exposure to various temperatures at certain critical periods in the development of many plants, is known to effect widely different types of development. The effects of a given treatment vary upon different species, and it may vary in the case of one species when it is applied at dissimilar stages of development. No general statement can be made regarding the influence of temperature upon plant development as a whole. Low temperature inhibits or delays reproduction in some cases, promotes it others, or may be without apparent influence.

Aderhold (1) found that the exposure of young kohlrabi plants to a temperature of 2-8° C. for 8-10 hours caused them to shoot to seed instead of forming "balls". Gutzeit (13) noted a similar behavior of the flower stalk in the case of the beet when the seeds were germinated at a temperature of 3° C. He concluded from his work that low temperature during germination and early development was conducive to seed stalk formation, while high temperature inhibited it. Knott, (18) however, was unable to confirm Gutzeit's report in regard to the beet. Knott germinated beet and cabbage at 5° and at 25° C. and noted the subsequent development. There was no difference in the type of development made, nor even in the amount of vegetative growth. Only vegetative growth resulted.

There appears to be a rather marked and consistent formative effect of low temperature upon many of the cereals. Appel and Gassner(2) noted that barley plants germinated at 5-7° C. were much slower in starting than those germinated at 20-25°, but that the former soon outstripped the latter in growth, when the two lots were placed under the same conditions. Those germinated at the higher temperature were strongly vegetative, developing poor stems. Gassner (12) stated that the decreased yields of grains are often due to the lack of cold requirement in the early stages of growth. Walster (32) germinated barley at high and at low temperatuers, and secured results similar to those of Appel and Gassner(2). He pointed out that the excessive leaf development results from the intake of large quantities of nitrogen at the higher temperature, which cannot be counter-acted by the application of phosphorus or potassium. Hutcheson and Quantz (16) grew small grains in the greenhouse at temperatures ranging from 14.4°

to 23.9° C. With increasing temperature, excessive leaf development and decreased culm formation occurred.

A checking in growth of some plants at critical stages in their development throws them into flowering or seed stalk formation upon the resumption of growth. Cserchàti (5) found that the longer the weather interfered with the growth of the beet, the greater was the percentage of premature seeders. Early planting resulted in increased seed stalk formation. Also, he observed varietal differences in the tendency to shoot to seed. Thompson (30) showed that celery plants which were started too early in the season and transplanted to unfavorable conditions in the field, exhibited a greater tendency to flower prematurely than those started later. If plants which had been started early were severely checked in growth by crowding, drying or other means, a higher percentage of seeders resulted than if plants of the same age were not checked prior to setting in the field. Plants from late-sown seed (relatively small) formed seed stalks to a lesser degree than the plants from early-sown seed which were relatively large; and the plants started later showed less response to the various treatments for checking growth. The size of the plant was mentioned as being a factor involved in shooting to seed. Paice (26) called attention to the same factor in the case of wintered-over cabbage.

A considerable amount of evidence has been accumulated which indicates that the carbohydrate-nitrogen relation at certain periods of growth of a plant bears an important relation to the type of subsequent development. By controlling environmental factors, Klebs was able to cause certain of the lower plants to remain vegetative, produce zoospores, or to reproduce sexually. He was able to bring about similar responses in higher plants (17). The balance between the formation of elaborated foods as influenced by light, and the supply of salt nutrients was found to be the controlling factor. Low temperature reduced respiration and led to the accumulation of sugars by hydrolysis of insoluble carbohydrates.

Fischer (9) attributed an overproduction of flowers to an excess of carbohydrates resulting from conditions favorable for photosynthesis but unfavorable for vegetative development, namely: abundant light and low moisture supply with low absorption of salts. Later (10), he was the first to point out the importance of high C/N ratio in reproduction, and emphasized the nitrogen supply as one of the chief formative factors. But Crocker (4) has pointed out that he failed to show that a very high C/N ratio reduced both vegetative and reproductive development.

Freund (11) showed in studies with algae that the effect of any reagent or set of external conditions upon reproduction depended very largely upon the previous culture conditions. This fundamental fact has been amply borne out in the work of other investigators upon higher plants as well as the lower forms.

Kraus and Kraybill (19) established that fruitfulness in the tomato is correlated with a balance between nitrogenous and carbohydrate materials in the plant. And that nitrogenous fertilizers may increase or decrease fruitfulness, depending upon the amount of available carbohydrates in the plant. Either a great preponderance of carbohydrates or of nitrogenous substances results i n unfruitfulness.

Kraybill and Smith (20), have more recently observed that tomato plants grown in a medium quite deficient in phosphorus exhibited a higher total nitrogen, soluble nitrogen, and carbohydrate content than plants well supplied with phosphorus. These plants were small and unfruitful. Data are unavailable at this writing, whereby the differences in carbohydrate-nitrogen balance in these two types of plants can be noted; but from the information at hand it appears that the C/N ratios may not be materially different. Phosphorus is the determining factor. Hepler and Kraybill (15) noted that heavy fertilization of tomatoes with available phosphorus, increased both the number of flower clusters and the number of flowers per cluster.

Pieters (27), working with a fungus of the Saprolegniaceae, found that a mycelium, while growing vegetatively, may develop tendencies that may influence the number and character of reproductive organs developed later, under different conditions. Phosphates in the medium tended to increase reproduction.

CULTURAL EXPERIMENTS AND METHODS.

Location, soil and climate.

These experiments were conducted on the experiment station grounds at College Park, Md. The field soil is a Sassafras loam of medium to low fertility, which had been devoted to the culture of general farm crops, and which had received no heavy applications of commercial fertilizers or manure. The plant beds are of a similar soil classification, but are rather more fertile than the field in question. The plant bed areas had been devoted to the culture of vegetable crops for several years, had received moderate applications of manure and fertilizer, but were not in a very high state of fertility.

The climate at College Park is somewhat more rigorous than in the sections where early spring cabbage is more commonly wintered-over. This however, from the experimental standpoint, is an advantage rather than a disadvantage, for somewhat greater range of temperatures prevails.

Daily and weekly temperatures for the duration of the experiment are given in Graphs I and II.

Materials.

Henderson's Early Jersey Wakefield cabbage was used in the greater part of the work of 1923 and 1924. In the first season's work some Copenhagen Market was started, but it was all winter-killed. In the latter year the Warren Wakefield was studied in a more limited way.

Plant bed management.

In 1923 no fertilizer plots were planned for the plant bed. A small uniform area of but medium fertility was seeded in rows a foot apart, and three sowings were made: Aug. 25, Sept. 5 and Sept. 15. The usual date of sowing the seed in this locality is about Sept. 5-6. The plant bed was maintained in a state of good culture. The 1923 results suggested the use of fertilizer treatments in the plant bed, so in 1924 one-half of the bed was given an application of a readily available 7-6-5 fertilizer at the rate of 1000 lbs. per acre, before planting. The seed was sown in rows running across both the fertilized and non-fertilized areas on: Sept. 2,

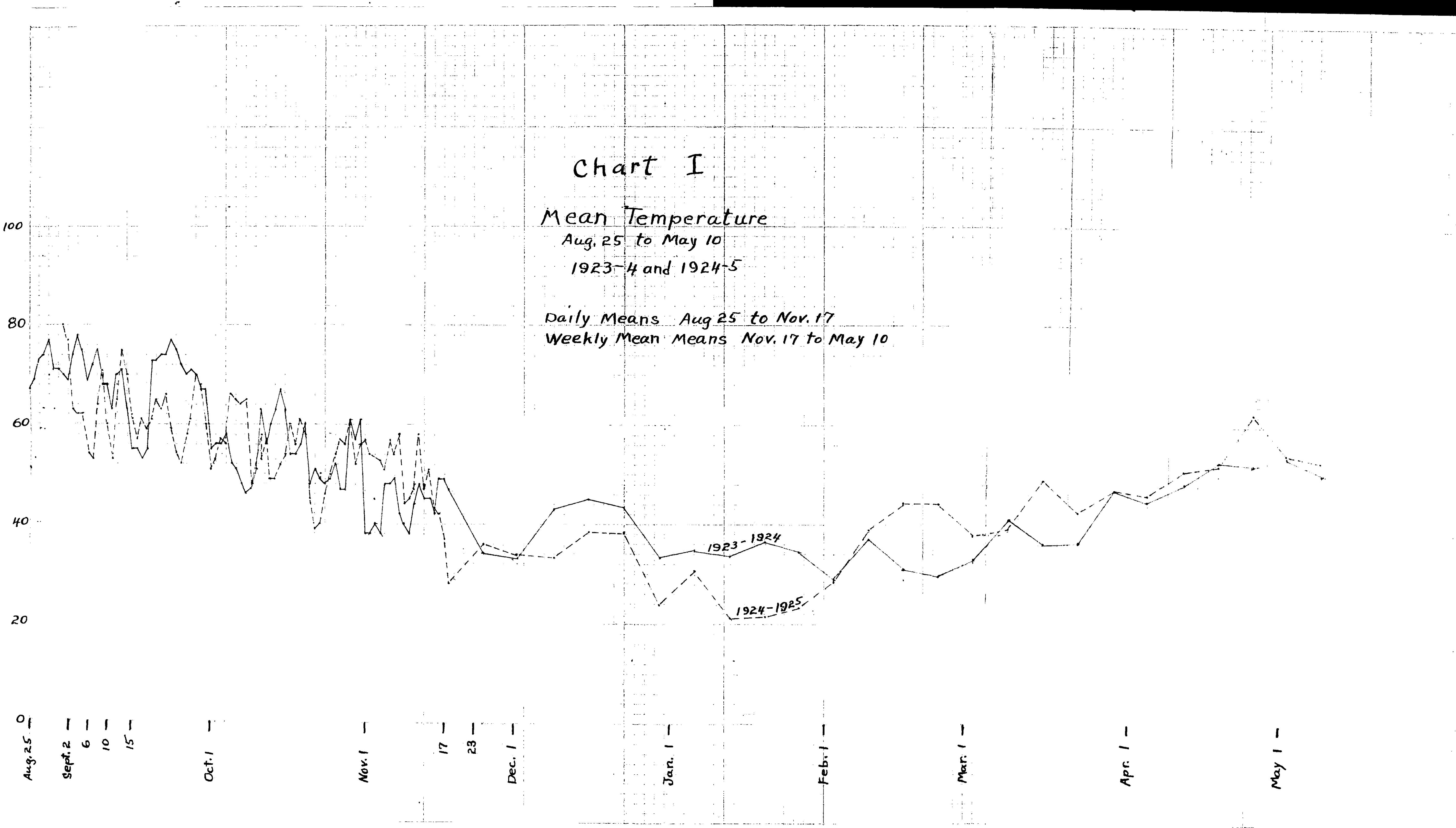
Chart I
Mean Temperature
Aug. 25 to May 10
1923-4 and 1924-5
Daily Means Aug 25 to Nov. 17
Weekly Mean Means Nov. 17 to May 10
100
80
60
40
20
0
1923-1924
1924-1925
Aug. 25
Sept. 2
6
10
15
Oct. 1
Nov. 1
17
23
Dec. 1
Jan. 1
Feb. 1
Mar. 1
Apr. 1
May 1

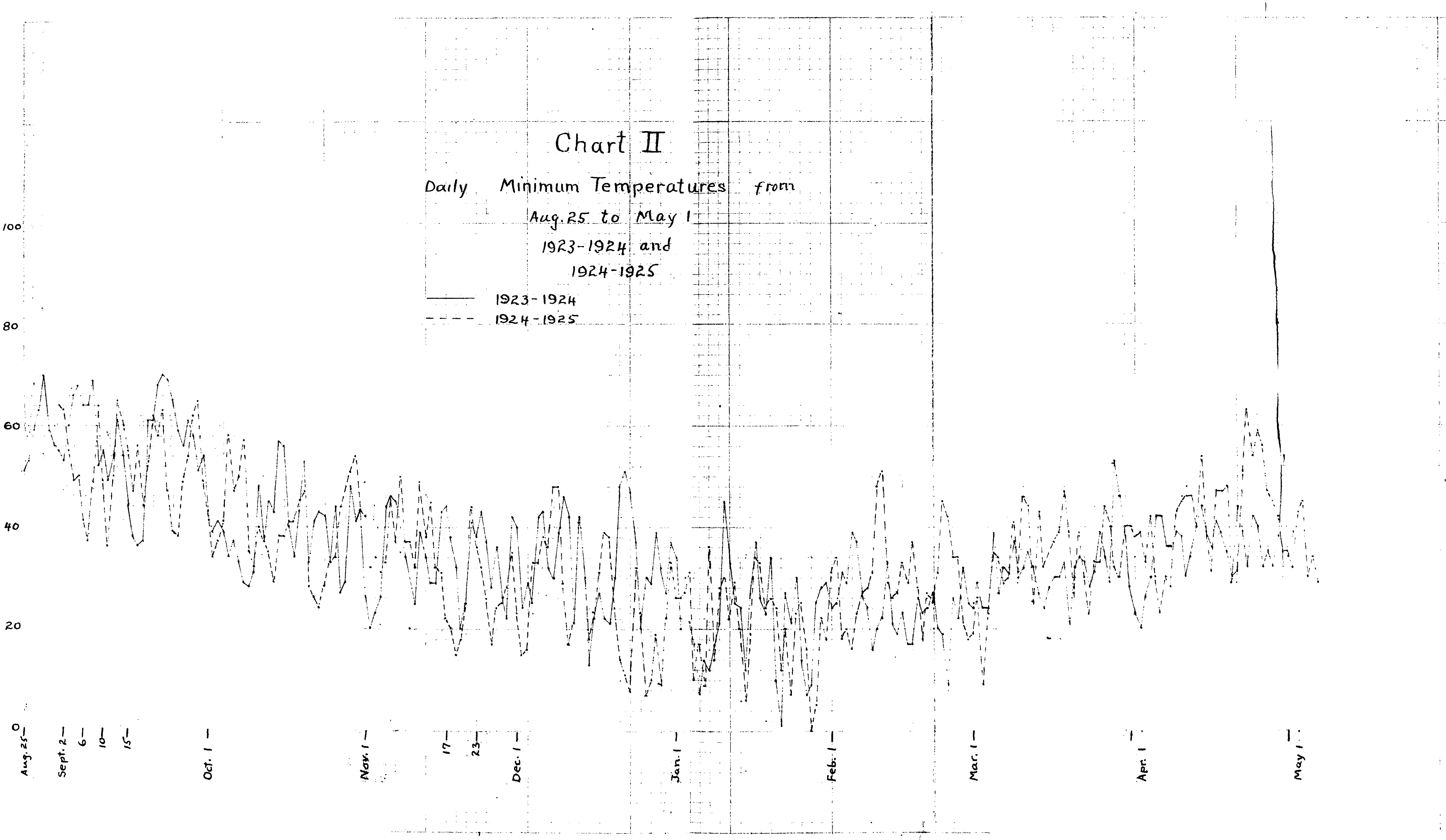
Chart II
Daily Minimum Temperatures from
Aug. 25 to May 1
1923-1924 and
1924-1925
1923-1924
1924-1925
100
80
60
40
20
0
Aug. 25
Sept. 2
6
10
15
Oct. 1
Nov. 1
17
23
Dec. 1
Jan. 1
Feb. 1
Mar. 1
Apr. 1
May 1

Sept. 6, Sept. 10 and Sept. 15. After the plants were well established, the fertilized areas were given a top dressing of nitrate of soda at the rate of 200 lbs. per acre. A second application was given on Oct. 6 after a period of heavy rains.

Field management.

Ridges about eighteen inches high were listed up three feet apart, in an east and west direction. A readily available 7-6-5 fertilizer was applied in the ridge, but near the surface, as the ridges were listed up. In 1923, every second block of three rows was unfertilized. A guard row was left between the fertilized and non-fertilized blocks in every case. All plots were in triplicate.

The plants were transplanted to the field Nov. 26 and 27, 1923; and Nov. 17 and 18, 1924. They were set about half way up the south side of the ridge. Two applications of nitrate of soda at the rate of 200 lbs. per acre were given to all fertilized rows. The first was applied early in April and the second, the middle of May. In 1924-1925 the field treatment was uniform throughout. The methods used were the same as for 1923-1924 except that there were no unfertilized areas.

Data recorded.

In 1923 a system was devised whereby notes could be taken at intervals on the size, vigor and type of development of each plant in the experiment. The date of harvest and the weight of each head was also recorded. Thus, a complete history of the condition and behavior of nearly 5,000 individual plants was secured. The same scheme was started in the fall of 1924, but very unfortunately the plants were covered with a heavy, compact mass of snow and ice for several weeks during the winter; and so very many plants were obliterated, that the positions of the surviving plants could not always be located accurately on the record sheets, in the spring. In 1924-1925 records upon winter-killing, percentage of seeders, percentage cut, and yield could be taken only upon a row basis, instead of upon a plant basis.

The counts of seeders were made the first week in May. A very few late flower stalks appeared after this date in some of the early plantings, but not enough to change the percentages reported, appreciably.

PRESENTATION OF DATA.

General considerations

The results of the field observations are summarized in TABLE I. Several points of interest are apparent from a study of this table, as follows: (1) Successively later sowing of the seed results in the production of plants which are increasingly susceptible to winter-killing, with the exception of the extremely early planting (Aug. 25) which also winter-killed badly. (2) Plants heavily fertilized, in the plant bed winter-kill worse than those not fertilized, while the fertilizer treatment in the field produces no consistent effect. (3) In general, each successively later planting reduces the percentage of plants which go to seed, in any plant bed treatment. (4) Heavy fertilizing in the plant bed increases the percentage of seeders from plants of a given planting date, but the fertilizer treatment given in the field has no evident effect. (5) The highest percentages of plants harvested, based upon the number transplanted, are

TABLE I.

SUMMARY OF FIELD DATA ON CABBAGE INVESTIGATIONS.

	Date Sown	Treatment *	Row No.	Number Transplanted	Number Living	Percent Killed.	Percent Seeders (TP)*	Percent Seeders (L) *	Percent Harvest (TP)*	Percent Harvest (L)*	Pounds Harvest per 100 (TP) *	Pounds Harvest per 100 (L) *	Average Wt. per head.
1923-1924	8-25	Fert.	2	145	94	35.2	21.4	33.0	28.8	45.8	61.9	95.5	2.09
	9-5	Fert.	3	145	99	31.7	15.2	22.2	47.6	69.7	100.0	146.6	2.27
	9-15	Fert.	4	160	72	55.0	0.0	0.0	31.9	70.8	63.8	142.0	2.00
	8-25	None	6	145	94	35.2	24.8	38.3	23.4	36.2	22.1	34.0	0.94
	9- 5	None	7	148	108	27.0	10.8	14.8	45.9	63.0	47.4	64.9	1.03
	9-15	None	8	154	43	72.1	0.0	0.0	9.1	32.6	8.5	32.3	0.93
1923-1924	8-25	Fert.	18	143	57	60.1	11.9	29.8	22.8	57.9	48.2	121.0	2.03
	9- 5	Fert.	19	145	113	22.1	22.0	28.3	52.4	67.3	133.0	171.0	2.58
	9-15	Fert.	20	145	77	46.9	1.4	2.6	42.1	79.1	79.1	149.0	1.88
	8-25	None	22	116	73	37.1	22.4	35.6	28.4	45.1	35.6	56.6	1.25
	9- 5	None	23	113	83	26.6	14.1	19.3	42.5	57.9	50.6	68.9	1.19
	9-15	None	24	116	84	27.5	1.7	2.4	38.8	53.5	38.2	54.4	1.01
1923-1924	8-25	Fert.	34	132	79	40.2	25.8	43.0	28.0	46.8	63.5	106.0	2.29
	9- 5	Fert.	35	143	107	25.2	14.0	18.7	53.8	71.9	142.5	194.0	2.55
	9-15	Fert.	36	145	69	52.4	0.7	1.4	39.3	82.6	77.0	161.5	1.99
	8-25	None	38	134	56	58.2	19.4	46.4	15.7	37.5	19.6	47.0	1.25
	9- 5	None	39	33	24	27.3	6.1	8.3	51.5	70.8	44.2	60.9	0.86
	9-15	None	40	135	62	54.1	0.7	1.6	31.1	67.8	28.6	62.4	
1924-1925	9- 2	Fert.	1	285	198	30.5	30.2	43.4	25.2	36.4	37.0	44.1	1.21
	9- 2	None	2	289	243	16.0	13.5	16.0	53.3	63.4	59.9	71.2	1.12
	9- 6	Fert.	3	315	214	31.9	31.8	47.0	33.0	48.6	43.5	64.0	1.32
	9- 6	None	4	280	233	16.8	21.4	25.7	52.5	63.1	66.6	80.0	1.27
	9-10	Fert.	5	294	132	55.1	10.5	23.5	26.8	59.9	33.2	71.6	1.20
	9-10	None	6	324	195	39.8	6.2	10.2	39.2	65.1	46.9	77.9	1.20
	9-15	Fert.	7	317	134	57.8	4.1	9.7	32.2	76.1	36.8	87.0	1.14
	9-15	None	8	306	132	57.0	3.6	8.3	33.0	76.5	41.8	97.0	1.27
1924-1925	9- 2	Fert.	17	355	197	44.5	34.4	62.0	18.3	33.0	18.3	44.4	1.35
	9- 2	None	18	326	208	36.2	19.0	29.8	34.1	53.4	43.2	67.8	1.27
	9- 6	Fert.	19	294	156	49.7	23.5	46.6	24.8	46.8	42.5	80.1	1.71
	9- 6	None	20	353	216	38.8	14.7	24.1	41.9	68.5	52.4	85.6	1.25
	9-10	Fert.	21	276	127	54.0	6.5	14.2	32.6	70.8	44.6	96.8	1.37
	9-10	None	22	348	174	50.0	3.4	6.9	37.9	75.9	48.3	96.8	1.28
	9-15	Fert.	23	301	125	57.5	3.3	7.8	31.9	76.7	39.4	94.7	1.24
	9-15	None	24	334	169	49.4	2.7	5.3	43.0	85.2	49.5	97.9	1.15

*-Fertilizer treatment was made in the field in 1923-1924 and in the plant bed in 1924-1925.

TP-On basis of number transplanted.

L -On basis of number living.

found in the plots from the sowings of intermediate dates (Sept. 5 and 6). (6) Heavy fertilizing in the plant bed lowers the percentage cut, while fertilizing in the field raises it. (7) The yield, calculated to a uniform number of plants transplanted, behaves in essentially the same way as the percentage cut.

The table referred to shows only the final results of the various treatments, and does not show what factors are responsible for, or associated with them. An analysis of some of the detailed data will reveal some of these factors, will show what intermediate plant responses are correlated with the ultimate results.

Methods of statistical analysis.

Since the plants transplanted to the various plots consisted of the "field run" of the plant bed, since no effort was made to select plants of any uniformity, there is considerable variation in the distribution of sizes of plants in the duplicate and triplicate plots.* The first lots of plants pulled ran a little larger than those pulled later, because the men pulling the plants unconsciously selected the larger ones as they worked. Plants for one whole series were drawn and transplanted, then for another complete series of plots. The result is obvious. It results in a high probable error for the mean of replicate plots. If comparisons between treatments are made on a basis of means of replicates

* The "field run" of the bed was used purposely, to determine what the effect of the various treatments would be on the population as a whole. The system of detailed note-taking was designed in order to study the behavior of individuals or of certain groups.

together with their probable errors, as calculated by Bessel's formula $E_m = \pm .6745\sqrt{\frac{\Sigma d^2}{n(n-1)}}$ the true conditions are obscured in many cases. For example, consider the percentage of plants killed in the fertilized vs. non-fertilized plots in the plant bed for various plantings. (Table II). A glance shows that the probable errors of the means for any given planting date are so high as to render the differences between the means insignificant. And yet, Table I shows plainly that in both series (duplicates) the fertilized plants were killed much more severely than the adjacent rows of non-fertilized plants. With very few exceptions, the relative differences between various treatments in a given replication, hold throughout the replications. Under such conditions, the effect of any given treatment can be determined much better by the use of Student's method than by Bessel's formula. Student's method (29), has been used in determining the significance of the differences between means throughout this work, with the exception of the figures in Table II.

In comparing any treatment with its corresponding check or with another treatment, pairs of rows were used which were adjacent or were not more than 12 feet apart. In determining the difference in amount of winter-killing between the plantings of Aug. 25 and Sept. 5, 1923, the rows paired for comparison were (See Table I):

2	3
6	7
18	19
22	23
34	35
38	39

TABLE II.

SUMMARY OF TABLE I.

Year	Date Sown	Treatment.*	No. Transplant.	Percent Killed.	Percent Seeders (TP)	Percent Seeders (L)	Percent Seeders (TP)	Percent Harvest (L)	Pounds Harvest per 100 plants (TP)	Pounds Harvest per 100 plants (L)
1923 - 1924	8 - 25	Fert.	420	44.9 ± 5.1	19.7 ± 2.7	35.3 ± 2.7	26.5 ± 1.9	48.2 ± 3.7	57.9 ± 4.6	107.8 ± 7.1
	9 - 5	Fert.	433	26.3 ± 1.9	17.1 ± 1.7	23.1 ± 1.9	51.2 ± 1.3	69.6 ± 0.9	125.2 ± 12.3	170.5 ± 13.0
	9 - 15	Fert.	450	51.4 ± 1.6	0.7 ± 0.3	1.3 ± 0.5	37.8 ± 2.1	77.5 ± 2.4	73.3 ± 4.6	150.8 ± 5.4
	8 - 25	None	385	43.5 ± 5.0	22.2 ± 1.1	40.1 ± 2.2	22.5 ± 2.5	39.6 ± 1.9	25.8 ± 4.7	45.9 ± 6.5
	9 - 5	None	294	27.0 ± 0.1	10.3 ± 1.4	14.1 ± 2.2	46.6 ± 1.8	63.9 ± 2.5	47.4 ± 1.8	64.9 ± 2.2
	9 - 15	None	405	51.2 ± 8.7	0.8 ± 0.3	1.0 ± 0.5	26.6 ± 5.8	51.3 ± 6.9	25.1 ± 8.3	49.7 ± 8.6
1924 - 1925	9 - 2	Fert.	640	37.5 ± 7.0	32.3 ± 2.1	52.7 ± 9.3	21.7 ± 3.4	34.7 ± 1.7	27.6 ± 9.4	44.2 ± 0.1
	9 - 2	None	615	26.1 ± 10.1	16.2 ± 2.8	22.9 ± 6.9	43.7 ± 9.6	58.4 ± 5.0	51.5 ± 8.4	69.5 ± 1.7
	9 - 6	Fert.	609	40.8 ± 8.9	27.6 ± 4.1	46.8 ± 0.2	28.9 ± 4.1	47.7 ± 0.9	43.0 ± 0.5	72.1 ± 8.0
	9 - 6	None	633	27.8 ± 11.0	18.0 ± 3.4	24.9 ± 0.8	47.2 ± 5.3	65.8 ± 2.7	59.5 ± 7.1	82.8 ± 2.8
	9 - 10	Fert.	570	54.5 ± 0.5	8.5 ± 2.0	18.8 ± 4.6	29.7 ± 2.9	65.3 ± 5.5	38.9 ± 5.7	84.2 ± 12.6
	9 - 10	None	672	44.9 ± 5.1	4.8 ± 1.4	8.5 ± 1.7	38.5 ± 0.6	70.5 ± 5.4	47.6 ± 0.7	87.3 ± 9.5
	9 - 15	Fert.	618	57.6 ± 0.1	3.7 ± 0.4	8.7 ± 0.9	32.1 ± 1.1	76.4 ± 0.3	38.1 ± 1.3	90.8 ± 3.9
	9 - 15	None	640	53.2 ± 3.8	3.1 ± 0.4	6.5 ± 1.5	38.0 ± 5.0	80.8 ± 4.4	45.6 ± 3.9	97.4 ± 0.4

* Fertilizer treatment was made in the field in 1923-1924, and in the plant bed in 1924-1925.

The pairs used in determining the effect of fertilizer on winter-killing were rows:

For 1923-1924*		For 1924-1925*	
2	6	1	2
3	7	3	4
4	8	5	6
18	22	7	8
19	23	17	18
20	24	19	20
34	38	21	22
35	39	23	24
36	40		

Thus, the effect of varying one treatment was determined for all plots, regardless of the other variables. With the great variation that will occur in such groups of pairs as those above, the odds that differences are significant will tend to be low unless there is a very potent factor involved. If the differences are all expressed as percentage increase (or decrease) over the check, or treatment with which it is compared, the variation referred to will be compensated for and the odds will be much higher. This method of calculation was tried out, but since it does not materially alter the results, it is not presented here.

Tables IV and V were worked out from Table I in the manner described. Tables VI and VII and VIII were derived from Table A in the appendix, and Table IX was calculated from Table B. In calculating the results found in Tables VI, VII, VIII and IX the pairs considered consisted of no less than ten plants. The use of classes containing less than ten plants was found to frequently introduce extremes which are not representative of conditions.

---

* Fertilizer in the field in 1923-1924, and in the plant bed 1924-1925.

Influence of various treatments upon the type of plants produced in the plant bed.

Table III shows the distribution of plant sizes of different degrees of vigor for each plant bed treatment and planting date in the two years' work. The classification into "small", "medium" and "large" plants, as well as the description of vigor as "poor" "medium" and "good", is purely arbitrary. The grouping was made by observation. "Small" plants were about 3½ inches in height, or smaller; the "medium" plants 3½ to 5 inches; and the "large" plants were above 5 inches in height. Such a method of grouping is subject to error, but when the same person takes all the data on a large number of plants it should give a fair index to the relative sizes of the plants in the various plots.

The table shows that: (1) The earlier the seed is sown under any given plant bed treatment, the greater is the percentage of large plants which is available for transplanting. The converse is also true. (2) For a given planting date, the heavily fertilized area in the plant bed produces a considerably higher percentage of large plants than does the unfertilized area, and (3) the fertilized area produced a higher percentage of plants of poor vigor in every case. None of these results are surprising, but they are emphasized here because of the bearing they have upon the data which are to be discussed later. It may be quite possible to obtain the desired size of plant by heavy fertilizing, but there appears to be a greater loss of hardiness by forming succulent growth than can be gained by merely increasing the size of the plant.

TABLE III.

Influence of date of sowing and fertilizer treatment upon the size and condition of plant produced.

	I Early Sown			II Medium- Early Sown			III Medium - Late		IV Late Sown		
	Fertilized seed bed	No Fertilizer in seed bed		Fertilized seed bed	No Fertilizer in seed bed.		Fertilized seed bed	No Fertilizer in seed bed	Fertilized seed bed	No Fertilizer in seed bed	
Description of plants	Sept. 2 1924	Aug. 25 1923	Sept. 2 1924	Sept. 6 1924	Sept. 5 1923	Sept. 6 1924	Sept. 10 1924	Sept. 10 1924	Sept. 15 1924	Sept 15 1923	Sept 15 1923
Small Poor	0.7	7.1	.7	2.2	3.5	1.1	6.8	6.5	8.2	11.8	5.6
Small Medium	1.05	9.9	7.6	2.2	6.4	8.2	2.0	13.5	40.0	35.4	63.4
Small Good	0.7	2.2	22.2	0	3.0	15.0	2.0	12.0	8.5	12.5	2.0
Medium Poor	11.6	16.2	2.8	7.9	6.4	3.9	20.4	6.5	0.3	5.9	0
Medium Medium	6.7	20.4	15.9	16.8	28.0	15.8	23.5	22.5	31.0	28.6	28.8
Medium Good	18.0	12.8	38.8	18.4	35.0	49.5	25.2	38.3	11.3	20.3	3.0
Large Poor	6.0	3.0	0.3	2.5	0.5	0	3.4	0.3	0	0	0
Large Medium	9.5	11.5	4.5	13.0	4.5	1.4	7.1	0	0.6	0	0
Large Good	45.8	18.8	6.9	36.8	12.1	5.0	9.5	0.6	0	0	0
Total Large	61.3	23.3	11.7	52.3	17.1	6.4	20.0	0.9	0.6	0	0
Percent Killed	30.5	41.8	16.0	31.9	22.2	16.8	55.1	39.8	57.8	49.9	.7
Percent Seeders[1]	52.7	28.2	22.4	46.8	26.1	25.0	18.9	8.7	8.8	0.5	6.6
Percent Seeders[2]	32.5	15.26	16.4	28.0	14.6	17.7	8.6	4.8	3.7	0.2	3.1

1. Based on number of plants living.
2. Based on number of plants transplanted.

TABLE IV. (See Chart III)

Influence of time of sowing upon various plant responses.

Year	Date Sown.	Based upon the number of plants transplanted			Based upon the number of plants living.		
		Percent Killed	Difference between pairs.	Odds (Student's)			
1923 - 1924	Aug. 25	44.3					
	Sept. 5	26.6	17.7	94:1			
	Sept.15	51.3	24.7	255:1			
1924 - 1925	Sept. 2:	31.8					
	Sept. 6	34.3	2.5	24:1			
	Sept.10	49.7	15.4	43:1			
	Sept.15	55.4	5.8	8:1			
		Percent Seeders			Percent Seeders	Difference between pairs.	Odds (Student's)
1923 - 1924	Aug. 25	20.9			37.7		
	Sept. 5	13.7	7.2	16:1	18.6	19.1	138:1
	Sept.15	0.7	13.0	1428:1	1.3	17.3	1428:1
1924 - 1925	Sept. 2	24.3			37.8		
	Sept. 6	22.8	1.4	2:1	35.8	1.9	2:1
	Sept.10	6.6	16.2	434:1	13.7	22.1	191:1
	Sept.15	3.4	3.2	26:1	7.8	5.9	14:1
		Percent Harvest			Percent Harvest		
1923 - 1924	Aug.25	24.5			44.9		
	Sept.5	48.9	24.4	3332:1	66.8	21.9	999:1
	Sept.15	32.3	16.6	163:1	64.5	2.3	2:1
1924 - 1925	Sept. 2	32.8			46.5		
	Sept. 6	38.0	5.2	24:1	56.7	10.2	30:1
	Sept.10	34.1	3.9	3:1	67.8	11.1	18:1
	Sept.15	35.0	0.9	2:1	78.6	10.8	131:1
		Pounds Harvest per 100 plants			Pounds Harvest per 100 plants		
1923 - 1924	Aug.25	41.8			76.7		
	Sept.5	86.3	44.5	131:1	117.7	41.0	110:1
	Sept.15	49.2	37.1	270:1	100.2	17.5	66:1
1924 - 1925	Sept. 2	39.6			56.9		
	Sept. 6	51.2	11.6	113:1	77.5	20.6	55:1
	Sept.10	43.1	8.1	10:1	85.8	8.3	14:1
	Sept.15	41.9	1.2	2:1	94.1	8.3	8:1

CHART III.

Influence of Time of Sowing Seed upon Winter Killing and Shooting to Seed.

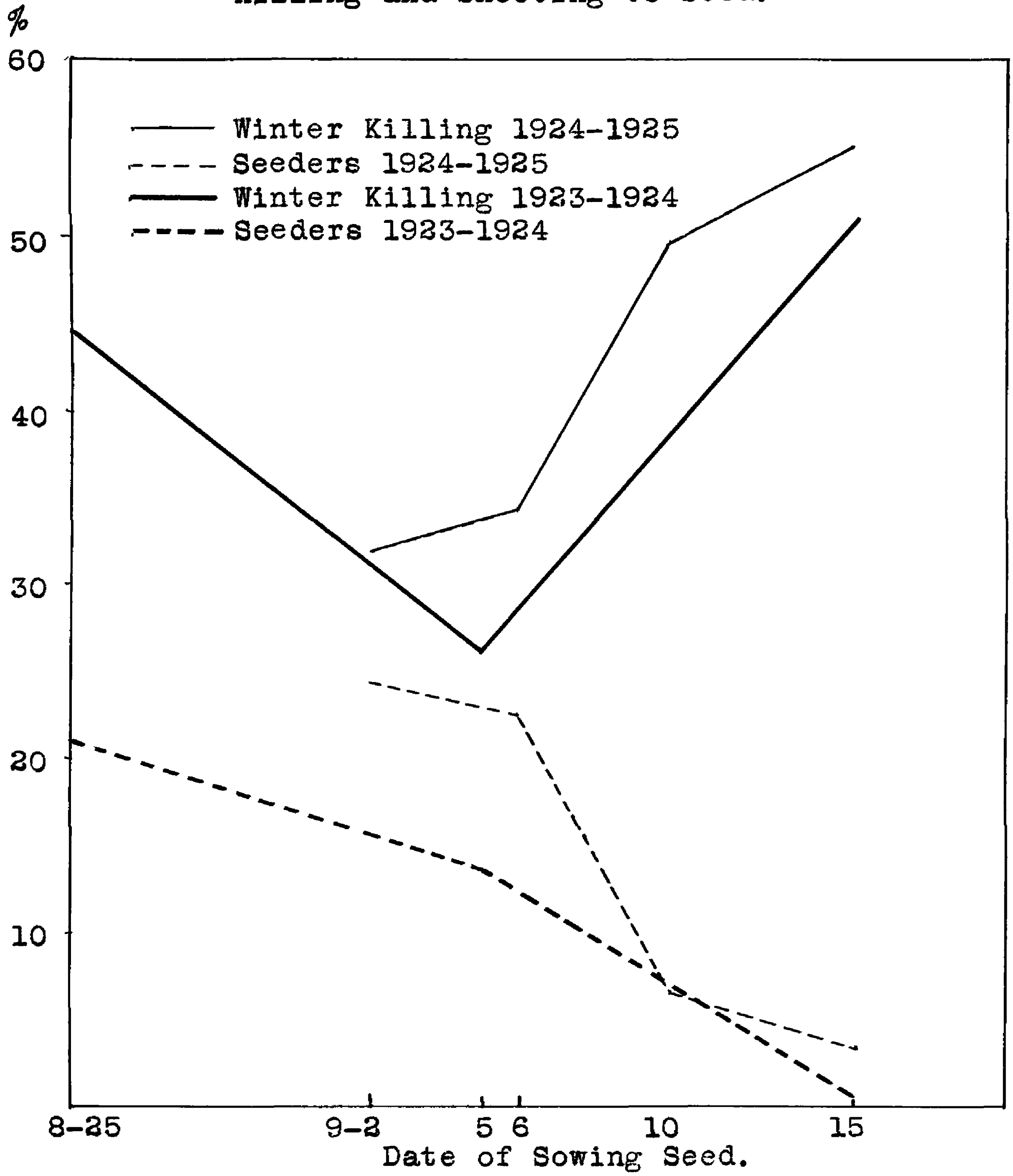

TABLE V.

Influence of Fertilizer upon various plant responses.

Treatment in plant bed.	Treatment in field.	Based upon the number of plants transplanted.			Based upon the number of plants living May 1.		
		Percent killed	Difference between pairs	Odds (Student'S)			
Uniform	Fert.	41.0		Less than			
	None	40.6	0.4	2:1			
Fert.	Uniform	47.6					
None		38.0	9.6	1249:1			
		Percent Seeders			Percent Seeders	Difference between pairs	Odds (Students)
Uniform	Fert.	12.5			17.7		Less than
	None	11.1	1.4	2.4:1	16.3	1.4	2:1
Fert.	Uniform	18.0			32.0		
None		10.5	7.5	138:1	17.2	14.8	434:1
		Percent Harvest			Percent Harvest		
Uniform	Fert.	38.5			65.8		
	None	31.8	6.7	9:1	49.7	16.1	89:1
Fert.	Uniform	27.9			68.9		
None		41.8	13.9	833:1	56.0	12.9	302:1
		Weight Harvest per 100 plants.			Weight Harvest per 100 plants.		
Uniform	Fert.	85.5			142.3		Greater than
	None	32.9	52.6	3332:1	53.3	89.0	10,000:1
Fert.	Uniform	35.7			72.9		
None		51.1	15.4	1427:1	84.3	11.4	151:1

Winter-Killing.

Influence of time of sowing.

Consider first the data for 1923. Table IV shows that there is a significant difference in the percentage of plants killed, which were produced from seed sown on different dates. There were 44.3% of the Aug. 25 planting, killed: and but 26.6% of the Sept. 5 planting. The odds are significant. What factor or condition can be correlated with this fact? Table III shows that there were many more large plants in the Aug. 25 plot than in that for Sept. 5., and that a considerable percentage was killed in the first case, while practically none were killed in the latter. (See also Table IV). The percentages of plants killed, according to size, were:

Table VI.

Influence of size of plants upon Winter-Killing (1923-1924)

	Aug. 25	Sept. 5.	Difference	Odds
Small	75.6	78.7	3.1	4:1
Medium	44.9	41.6	3.3	2:1
Large	13.4	1.7	11.7	1000:1

Many of the large plants of the Aug. 25 lot were noticeably larger and much more succulent than the large plants of Sept. 5. It was these plants which were killed. The increased percentage kill, and the greater number of very large, poor plants in the Aug. 25 lot, combine to make the difference between the two plantings quite significant. There was no significant difference between the percentages of small and of medium plants killed in the two plantings in question.

It will also be observed in Table IV that the Sept. 15 plantings was injured more than either of the previous ones. Table III shows that it consists of a high proportion of small plants, and no large ones at all. Very large plants are tender, but the majority classed as "large" are hardy, and are chiefly responsible for the relatively low kill in the Sept. 5 planting. More of the small plants of the latest planting were killed than the same size in either of the previous plantings, probably because a larger proportion of them were very small and of poorer vigor.

A critical study of the effect of size of plant on hardiness was made by comparing the percentage kill in all classes of large plants, paired with the corresponding classes of medium-sized plants, regardless of other factors. Also the medium and small plants were compared. A similar comparison was worked out with respect to varying degrees of vigor. The results are presented in Table VII. Size of plant in itself is not considered the determing factor in amount of killing, but rather the degree of vigor and hardiness that seems to be very closely associated with the size which the plant has attained.

Table VII.

Influence of size and vigor of plants upon winter-killing, 1923-1924.

Size	Vigor	% Killed	Difference between pairs.	Odds (Student's)
Small		74.8	25.5	10,000:1
Medium		49.3		
Medium		44.9	15.2	62:1
Large		29.6		
	Poor	87,7	34.8	10,000:1
	Medium	52.9		
	Medium	46.8	29.6	10,000:1
	Good	17.2		

The percentages given for the "medium" groups are seen to differ somewhat, depending upon the extreme with which they are compared. This results from necessarily using different pairs in calculating the averages and odds.

In the second year's work, the first planting was made Sept. 2, late enough to avoid the production of extremely large, tender, plants. (See Tables III and IV.) Since this type of plant was eliminated, the percentage of winter-killing is seen to steadily increase from the earliest to the latest planting. The greatest difference occurs between the lots planted on Sept. 6 and Sept. 10. In the previous year's work, the greatest difference occurred between Sept. 5 and Sept. 15. Thus, from the standpoint of resistance to winter-killing, it appears that plants from seed sown Sept. 5 and Sept. 6 are the best.

Influence of fertilizer treatment.

Table VIII shows the percentage pf plants killed, for each planting date and fertilizer treatment in the field calculated from the percentage of each class killed as shown in Table A in the appendix. At first glance, it appears that there is a difference between the percentage of killing on the fertilized and non-fertilized plots. But when the odds are calculated, the apparent difference is found to be insignificant. The results of the comparisons based on percentage killed in each class, follow:

Table VIII.

Influence of field fertilizer treatment upon winter-killing. 1923-1924.

Date sown	Fertilized	Not Fertilized	Difference	Odds (Student's)
Aug. 25	48.0	50.0	2.0	2:1
Sept. 5	42.6	46.8	4.2	5:1
Sept. 15	54.1	63.4	9.3	10:1
Total (row basis)	41.0	40.6	0.4	2:1

Soil conditions were such as to respond greatly to fertilizer treatment, as is evidenced by the differences in yield of cabbage on the fertilized and non-fertilized rows. But there was no noticeable effect upon winter-killing. Heavy applications of fertilizer in the seed bed, however, had a quite marked effect upon susceptibility to winter injury, as is shown in Table V. The odds indicate that the difference between 47.6% killing of the fertilized plants and 38.0% of the non-fertilized plants, is significant. This was due not only to the extreme size of some fertilized plants, (See Table III) but also to the lesser degree of hardiness of the fertilized plants of a given size, resulting from very rapid growth late into the fall.

Seed Stalk Formation.

Time of Planting.

Table IV shows that as the date of sowing the seed of cabbage is delayed in the fall, the percentage of seeders which form in the following spring, is successively decreased. This relation holds whether the percentage is based upon the number of plants transplanted, or upon the number living. In both season's work it will be noted that even though the percentage of seeders is higher for plantings made before Sept. 5 or 6 than it is for plantings made on those dates, the differences are not significant when based upon the number of plants transplanted. In the case of Aug. 25 planting, so many more plants were killed than in Sept. 5 planting, that the difference in tendency to go to seed is not shown, when percentages are calculated upon the number of plants transplanted. When the percentage of seeders for these two dates is based upon the number of plants living, a quite significant difference appears. In the field in late spring, this difference was plainly evident at a glance. There is no significant difference in percentage of seeders in the plantings of Sept. 2 and 6. If a larger number of replications could have been used, it is believed that the observed differences would prove significant.

Plantings made even a few days after Sept. 5 or 6 go to seed much less than those made on those dates, or earlier. The 13% difference between Sept. 5 and 15 is significant by odds of 1428 to 1. Between Sept. 6 and 10 (1924) the difference of 16.2% is significant by odds of 434 to 1. Still later planting lowers the percentage of seeders further, with odds which are significant when compared with Sept. 6 but not when compared with Sept. 10.

Reference to Table III will show that the plantings which exhibited the highest percentages of seeders in the spring contained the highest percentages of large plants at transplanting time. Table B which represents the detailed data secured upon 1350 individual plants, shows that it is the large plants in the early plantings which are chiefly responsible for the high percentage of seeders. The later the sowing, the smaller are the plants produced, and the lower is the percentage of seeders the following spring. The figures from Table B are summarized in Table IX so as to show the influence of size and vigor of plants upon shooting to seed.

Table IX.

Influence of size and vigor of plants upon shooting to seed.

Size	Vigor	Percent. Seeders	Difference Between pairs	Odds (Student's)
Small		2.1	6.1	14.6:1
Medium		8.2		
Medium		16.6	19.0	10,000:1
Large		35.6		
	Poor	16.0	2.9	3.3:1
	Medium	18.9		
	Medium	12.9	4.4	26.7:1
	Good	17.3		

Table IX shows no significant difference between small and medium -sized plants, in the tendency to go to seed. But the odds are greater than 10,000 to 1 that the 19.0% difference in seed stalk formation between medium and large plants, is significant. The degree of vigor seems to be of little, if any, influence upon shooting to seed. It will be recalled, however, that this latter is a very important point with respect to hardiness.

In discussing the above results with Mr. H. H. Zimmerly of the Virginia Truck Experiment Station, he mentioned some similar results which had been secured at Norfolk. They are presented in Table X. Very good agreement exists between the findings of the Virginia Station and of this station.

Table X.

Comparison of Seed Shoot Production from Small, Medium and Large Cabbage Plants at the Virginia Truck Experiment Station.*

Size of Plants	No. Set	No. Wintered Safely	No. Seeders	PerCent Seeders
1921 — Early Jersey Wakefield Variety, Seed Sown September 22, 1920				
Small 3-4 inches	264	246	8	3.3
Medium 5-6 "	264	230	27	11.7
Large 8-9 "	264	234	95	40.6
1922 — Early Jersey Wakefield Variety, Seed sown Spetember 24, 1921				
Small 3-4 inches	600	383	1	.3
Medium 5-6 "	600	514	15	2.9
Large 8-9 "	600	535	132	24.7
1923				
Small 3-4 inches	400	373	1	.3
Medium 5-6 "	400	393	15	3.8
Large 8-9 "	400	380	70	18.4

* Data furnished through the courtesy of the Virginia Truck Experiment Station, Norfolk, Virginia.

Fertilizer treatment

Table V shows that fertilizer treatment in the field is without effect upon the percentage of seeders formed. There is but 1.4% more seeders in the fertilized plots, with odds but 2 to 1 that the difference is significant. When the comparison was made on the basis of the detailed data in Table B the difference was .4% with odds less than 2 to 1.

Fertilizer treatment in the plant bed, however, has a remarkable influence upon the tendency to go to seed. It is unfortunate that the detailed data could not be secured in 1924-1925 as for 1923-1924, so that the influence of the fertilizer could have been followed with the plant as a unit, rather than the row. But since there is such excellent agreement between the two years' results as a whole, the writer feels justified in interpreting the 1924-1925 results in the light of what data has been secured. The mean percentage of seeders for all plots of fertilized plants is 18.% and for the non-fertilized, 10.5%. The odds indicate that this difference is significant. If the percentage increase of the seeders in the fertilized plot over that in the non-fertilized plot is considered as mentioned under "Methods of Statistical Analysis", the odds are greater than 10,000 to 1 that a significant difference exists. An examination of Table I shows that for each planting date in both duplicate series, the fertilized plot produced a higher percentage of seeders in every case. In many cases this difference was very large, but in the latest plantings the difference is small, in terms of absolute percentages. The relative differences are large in all cases. This occurrence can be correlated with the size of the plants considered: The higher the percentage of large plants in a plot, the higher the percentage of seeders. The difference in behavior of fertilized and non-fertilized plants is the same as that between those from early- and late-sown seed, respectively.

Since the chemical analysis of plants from early- and late-sown seed in 1923-1924 showed a rather well-defined difference in the C/N ratio, it was originally believed that in the fall the high C/N ratio of early-sown plants, could be correlated with the shooting to seed in the spring. The seeders showed a higher C/N ratio than the non-seeders. But the 1924-1925 studies disproved this idea, leaving but one factor, which we have observed, invariably correlated with the tendency to shoot to seed --- the size of the plant at the time it is checked by low temperature in the fall. Thus, the action of the fertilizer seems to be identical with that of early sowing, insofar as shooting to seed is concerned, namely: it produces large plants. This point will be discussed in more detail later.

Percentage "Cut" and Yield.

Time of planting

Tables I and IV show that on the basis of the number of plants transplanted, the highest percentage cut is obtained from the sowings of Sept. 5 and 6. It will be recalled that the earlier sowings lost heavily from going to seed and also from winter-killing; and that although later sowings went to seed but slightly, if any, they were winter-killed very badly. The percentage cut is largely determined by the combined effects of shooting to seed and of winter-killing, but not entirely. There is a variable percentage of the plants which live through the winter, that form neither heads nor seed stalks. This class of non-heading, non-seeding plants is not altered appreciably by changing the planting date.

When the percentage cut is based upon the number of plants living, it increases consistently with the delay in planting date. The reason is obvious for the factor of killing is eliminated; the percentages non-heading, non-seeding plants vary in no consistent direction, and the percentage of seeders greatly diminishes.

The yield per 100 plants (<u>not</u> yield per 100 heads harvested) fluctuates in the various plots in essentially the same way as the percentage cut. Again the planting dates of Sept. 5 and 6 are outstanding. The Aug. 25 plots yielded less than half as much as those of Sept. 5; and the Sept. 2 planting yielded 39.6 pounds against 51.2 pounds for Sept. 5. The odds are significant in both cases.

<u>Fertilizer treatment</u>

Table V shows that fertilizer treatment in the field had no significant effect upon the percentage cut, when based upon the number of plants transplanted, but there is a significant difference in favor of the fertilized plots when based upon the number of plants living. The fertilized plots gave a percentage cut of 65.8 against 49.7 for the unfertilized, with odds of 89 to 1. It was stated above that the percentage cut was largely determined by the combined effects of winter-killing and going to seed. Furthermore, it was shown that fertilizer treatment in the field was without effect upon killing and seeding. Then how does fertilizer treatment influence percentage cut? The soil of the unfertilized areas was so extremely unproductive that from the commercial standpoint, the crop was an utter failure. The plants made such poor growth that a large proportion of them were quite worthless, even though they were observed to be of the "heading" type. The yield of all fertilized plots averaged 85.5 pounds, and the unfertilized 32.9 pounds when based upon 100 plants transplanted. The odds are 3332 to 1 that the difference is significant. When calculated upon the basis of 100 plants living, the difference in yield is much greater, with odds of more than 10,000 to 1.

Fertilizer treatment in the plant bed was again a great factor. Through its harmful influence in increasing shooting to seed and killing, a much higher percentage cut was secured from the plants from the unfertilized area, regardless of the basis upon which the percentage was calculated. Reference to Table V shows that heavy fertilizing in the seed bed was distinctly harmful from the standpoint of both percentage cut and yield. On the basis of 100 plants transplanted, the fertilized plants yielded 35.7 pounds and the unfertilized 51.1 pounds, with odds of 1427:1. Based on 100 plants living the yields were 72.9 and 84.3 pounds respectively with odds of 151 to 1. It is emphasized that the diametrically opposite results from the use of fertilizer in the plant bed and in the field are due to quite different causes. In

1923-1924 it was simply a matter of the influence of field soil fertility upon the yield of two different lots of plants of similar potentialities insofar as hardiness and tendency to seedstalk formation is concerned; while in 1924-1925 field soil conditions were uniform and the result was brought about through the production of plants for transplanting which had very different potentialities at the time they were set in the field.

Practical Aspects of the Field Experiments.

Interest in the scientific and theoretical aspects of this problem must not cause us to lose sight of the great practical importance of it. The final yield, the ultimate return per plant transplanted is the point in which the grower is interested. Of what profit is it to the grower, to prevent flower stalk formation, if by so doing, he increases the losses through winter killing? Does it make any difference as to which loss the grower chooses to stand? Moderate losses due to winter killing can be compensated for to a large extent by replanting with hot-bed, spring-grown plants, or spring-grown plants from other sources. But losses from the formation of seed stalks appear so late in the spring that replants could not be ready for harvest in time to be of great value.

The "net efficiency" of the various methods of plant production and field management which have been discussed, has been calculated by dividing the total yield of cabbage per plot by the number of plants transplanted per plot. This takes into consideration, the combined losses from winter-killing and from seeding. As mentioned above, losses from winter-killing can be corrected to some extent, so the figures in Table XII may be

1923-1924 it was simply a matter of the influence of field soil fertility upon the yield of two different lots of plants of similar potentialities insofar as hardiness and tendency to seed-stalk formation is concerned; while in 1924-1925 field soil conditions were uniform and the result was brought about through the production of plants for transplanting which had very different potentialities at the time they were set in the field.

Practical Aspects of the Field Experiments.

Interest in the scientific and theoretical aspects of this problem must not cause us to lose sight of the great practical importance of it. The final yield, the ultimate return per plant transplanted is the point in which the grower is interested. Of what profit is it to the grower, to prevent flower stalk formation, if by so doing, he increases the losses through winter killing? Does it make any difference as to which loss the grower chooses to stand? Moderate losses due to winter killing can be compensated for to a large extent by replanting with hot-bed, spring-grown plants, or spring-grown plants from other sources. But losses from the formation of seed stalks appear so late in the spring that replants could not be ready for harvest in time to be of great value.

The "net efficiency" of the various methods of plant production and field management which have been discussed, has been calculated by dividing the total yield of cabbage per plot by the number of plants transplanted per plot. This takes into consideration, the combined losses from winter-killing and from seeding. As mentioned above, losses from winter-killing can be corrected to some extent, so the figures in Table XII may be lower than if replanting had been done. It will be noted that in both 1923 and 1924, seasons of very different weather conditions, the greatest return was obtained from seed sown Sept. 5 and 6 respectively, in seed beds of but medium fertility. The very low yields of 1924 are due to an unusually severe winter and a drought the latter part of May and first part of June.

Table XI.

(See Page 30.)

TABLE XI

ULTIMATE YIELDS RESULTING FROM VARIOUS TREATMENTS AND DATES OF SOWING SEED.

Date of sowing.	Treatment in seed bed	Treatment in field.	Avg. wt. return per plant transplanted *(lbs.)
8-25-23	None	Fertilized None	0.59 0.37
9- 5-23	None	Fertilized None	1.32 0.36
9-15-23	None	Fertilized None	0.79 0.27
9- 2-24	Fertilized None	Fertilized "	0.27 0.51
9- 6-24	Fertilized None	Fertilized "	0.43 0.59
9-10-24	Fertilized None	Fertilized "	0.38 0.48
9-15-24	Fertilized None	Fertilized "	0.38 0.46

* Determined by dividing total plot yield by the number of plants transplanted.

GREENHOUSE AND COLDFRAME EXPERIMENTS.

Influence of winter temperature upon shooting to seed.

As mentioned in the statement of the problem, there is an opinion among many that the severity of the winter season has much influence upon the percentage of seeders formed. An effort was made to determine whether the winter temperature has any such effect, by growing plants from the same plant bed lots, both indoors (or under coldframes) and outdoors simultaneously, and noting the response. The objection may be offered that such a treatment may be an unfair test because of the different light conditions to which the plants would be subjected under glass. It is believed, however, that such differences in intensity and quality of light would not be a disturbing factor, for Detjen (6)(7) found greenhouse conditions favorable for bringing cabbage into normal flowering. Others have also noted the same. Harvey (14) found that even continuous artificial light did not prevent the heading of plants grown directly from seed. These two observations lend support to the belief that the cabbage is not sensitive to even considerable variations in light conditions.

Methods.

Coldframe experiment.

Seventy-two uniform plants, below medium size but of good vigor, were transplanted into a cold frame on Dec. 20, 1923, and covered with ordinary glass sash. They were grown from seed sown Sept. 6. An identical lot of plants was placed adjacent to the frame in the same kind of soil. The latter were treated the same in every way except that they were given no protection. The frames were removed with the advent of warm spring weather. Notes upon the condition and percentage of seeders were taken the first week in May, 1924.

Greenhouse experiment.

On Nov. 22, 1924, just after planting the large field plots, 90 plants from each plant bed plot (see section on "Plant Bed Management") were transplanted one foot apart each way in a greenhouse. The plots corresponded exactly to those in the field. Growth began very soon after transplanting and was uninterrupted until late in March when the experiment was terminated. Unfortunately, the temperature of the house was allowed to run too high on several sunny days, so that the plants did not make the best type of development. There was also some crowding near the end of the experiment.

Presentation of Data

Coldframe experiment

Although the plants in the frame had made considerably more growth than those in the open, there was no appreciable difference in the percentage of seeders. Growth differences gave evidence that quite different temperatures prevailed in the two treatments. Seven percent of the plants in the frame went to seed, and 8 percent, in the open. The more favorable growing conditions in the frame evidently did not alter the flower-stalk-forming tendencies which the plants possessed at the time they were transplanted.

Greenhouse experiment

It became necessary to remove the plants from the green-

[redacted]

TABLE XII.

BEHAVIOR OF FALL-GROWN PLANTS IN THE GREENHOUSE.

Date of sowing	Treatment in seed bed	Percent. Forming flowers	Percent. forming flower stalks (?)	Percent. forming heads	Percent. Reproductive	Percent. reproductive in field
9- 2-24	Fertilized	8.1	47.7	10.5	55.8	52.5
	None	0.0	19.5	46.5	19.5	22.4
9- 6-24	Fertilized	9.9	16.0	35.8	24.9	46.8
	None	0.0	21.0	44.8	21.0	25.0
9-10-24	Fertilized	0.0	16.5	49.4	16.5	18.9
	None	0.0	12.5	40.9	12.5	8.7
9-15-24	Fertilized	0.0	12.5	40.9	12.5	8.8

[redacted]

house before they had attained their ultimate first season's growth. But they had developed far enough to enable one to distinguish between seeders and non-seeders in most cases. At the time the data were taken (Mar. 27) some plants were in full flower, some exhibited only flower stalks, while others had formed good firm heads. Table XII shows that the percentage of plants which tended to go to seed in the various plots, bore essentially the same relation to each other as they did in the field. These results were compared with those of the field based on the number living, because the plants used in the greenhouse were carefully selected for uniform good size and vigor, the type of plant which would have resisted winter-killing, and which were more nearly comparable to the plants which lived through the winter. Reference to the table shows a fair agreement between the results in the house and in the field. If larger numbers of plants could have been used, they probably would have checked even closer.

Here again, as in the cold frame experiment of the season before, widely different winter temperatures seemed to exert no appreciable influence upon an apparently predetermined tendency toward a certain type of development.

CHEMICAL STUDIES.

The literature abounds in evidence which shows that the physiological conditions within the plant which are responsible for, or associated with various growth responses or types of development, may in many cases be identified by chemical methods.

In the past ten years the application of chemistry to the problems of the horticulturist has increased remarkably. Especial interest has been aroused in horticultural circles in this country, in the carbohydrate-nitrogen relation, with respect to its influence upon vegetative and reproductive development. Without going into a discussion of the literature, let it suffice to say that it has been established that plants exhibiting a very vigorous vegetative developemtn possess a lower C/N ratio at certain critical periods than do those which tend toward floral development. This relation has been found to be rather widespread in its occurrence, and a number of means are known for controlling it within limits, in various plants. It is common knowledge that a generous supply of available nitrogen affects flowering and maturity in many horticultural plants. A high intake of nitrogen has been found to lower the C/N ratio, while withholding nitrogen or otherwise retarding the growth of the plant may tend to bring about a high C/N ratio, and conditions which are conducive to the formation of reproductive organs. But as stated in the "Review of Literature", when phosphorus is deficient, this relation does not hold.

The aim of the chemical studies herein reported, was to determine whehher any correlation exists between the phosphorus content, various carbohydrates, nitrogenous constituents of the cabbage plant, at various stages of development; and the tendency to shoot to seed.

Samples for analysis

In taking samples for analysis, it was impracticable to attempt taking a sample which would be truly representative of the entire population of a plot because of the rather wide range in the size and condition of the plants in some plots. Such a sample would have been much too large and unwieldy. Therefore, such plants were sampled as to be as representative as possible of the plants which composed the greater portion of the plot. The extremes were omitted. In the 1923-1924 work, 8 to 10 plants or representative portions of them, composed a sample. This number did not give as close agreement between duplicates as was desired, so the following season samples were drawn from a ground and mixed composite of no less than 15 plants. Even such small numbers as mentioned, from large and variable groups composing the plots, revealed significant differences in the composition of the plants in different plots and at different stages of growth. All samples were taken in duplicate.

Preservation of samples

In the first year's work, the few plants chosen for analysis were weighed whole, halved or quartered, depending upon the size. The composite sample of 50 grams was then quickly cut into about $\frac{1}{4}$-inch pieces or strips, and transferred to a wide-mouthed Erlenmeyer flask containing .25 grams of calcium carbonate. Sufficient hot 95% alcohol was added to bring the final concentration of alcohol to 70-75%. Slight variations in the moisture content of the tissue were disregarded in calculating the amount of alcohol to be added. The flask was placed in a boiling water-bath under a reflux condenser, brought to a boil as quickly as possible and boiled for 1 to 2 minutes to inactivate all enzymes, cooled, tightly stoppered and stored. On account of the large bulk of the samples taken in 1924-1925 the plants (or halves or quarters) were coarsely ground through a food chopper into a large porcelain vessel. The sample was thoroughly mixed, 75 gms, withdrawn for preserving in alcohol as described above, and a collateral sample of 20 gms, was taken for moisture determination. The duplicate was treated in the same manner. The samples to be preserved in alcohol were handled with all possible speed, so that not more than ten to twelve minutes were consumed in grinding, weighing, and killing in alcohol. The material was ground rather coarsely so that very little sap was expressed, and where this occurred it was thoroughly mixed with the ground tissue before weighing. No sap was expressed from the samples taken after the plants had become hardened by exposure to very cold weather.

Grinding and extracting

The samples taken the first year were ground and extracted as follows: The alcohol was decanted from the stored sample into a 250 cc. volumetric flask, the insoluble matter in the storage flask was rinsed once with 70% alcohol, and the rinsings poured into the volumetric flask. The residue was transferred to a small evaporating dish, dried for 24-30 hours at 80° C., cooled in a desiccator, weighed, ground in a mortar to pass a 100-mesh sieve, and stored in a stoppered vial. The evaporating dish was rinsed with 70% alcohol and the rinsings added to the extract in the volumetric flask. This extract was then made up to volume.

Suitable aliquots of the residue were weighed into paper extraction shells and extracted for three hours in a Soxhlet apparatus. The extraction flask contained 100 cc. of 70% alcohol. The extract obtained with the Soxhlet apparatus was then combined with an aliquot of the original extract corresponding to the aliquot of the residue taken for further extraction, and used in the determination of sugars or of soluble nitrogenous substances as the case happened to be. Let this total extract be called extract T.

The following year it was believed that it would be advantageous to extract the material as thoroughly as possible before it was dried, since it has been shown that drying changes some of the soluble nitrogen compounds into insoluble compounds. It was also desirable to obtain as high a concentration of soluble materials in the extract as possible, so as to secure quantities which could be measured with greater accuracy. The following method was adopted: The alcohol was decanted from the storage flask onto a filter in a Buchner funnel and the residue rinsed once. The residue was transferred quantitatively to a large mortar, 5-10 gm. of clean quartz sand and about 50 cc. 70% alcohol were added. The residue was macerated to a uniformly fine, creamy consistency, which required 20-30 minutes, depending upon the nature of the sample. The macerated tissue was transferred to a 500 cc. wide-mouthed Erlenmeyer flask with the aid of about 100 cc. of 70% alcohol. The flask was placed in a water-bath under a reflux condenser, brought to a boil as quickly as possible, then boiled gently for 15 minutes. The contents of the flask were thoroughly agitated every few minutes by gentle shaking. The mixture was filtered hot on the Buchner with the aid of suction, the residue was returned to the flask with 150 cc. of 70% alcohol and the process twice repeated. After the third extraction, the residue on the Buchner was washed with about 25 cc. of alcohol, transferred quantitatively to a small evaporating dish and placed in an oven at 55° C. until it could be ground in a mortar. After grinding to pass a 100-mesh sieve it was extracted for 8 hours with alcohol in a Soxhlet apparatus. The large size of the sample necessitated a longer period of extraction than did the small aliquots referred to above. All extracts were combined, made up to 1000 cc., and aliquots withdrawn for the estimation of the various constituents described below. This extract may also be designated as T.

Carbohydrates

All determinations of sugars were made by Bertrand's modification of the Munson and Walker method. (21). The methods of handling the alcoholic extract T in the estimation of sugars, and the residue in the estimation of hydrolyzable polysaccharides are the same as those described in Maryland Agricultural Experiment Station Bulletin No. 258.

The method of starch determination was adapted, with modifications, from that described by Walton and Coe (33). The method as used in the first year's work was as follows: A suitable aliquot of the extracted residue was weighed into a 250 cc. beaker and thoroughly moistened with a few cc. of water. Fifty cc. of boiling water were then added quickly, and the beaker was suspended in a boiling water bath for 45 minutes to gelatinize the starch. After gelatinization, the sample was cooled to 50°, and 10 cc. of an extract of malt diastase were added. The beaker was returned to the water bath at 50° and the temperature gradually raised through a period of 30 minutes to 70° where it was maintained for 30 minutes; then raised to 80°, maintained for 10 minutes, and finally raised to the boiling point to inactivate enzymes. After cooling to 50°, another portion of 10 cc. of diastase extract was added, and the material held at 55° for 1 hour, after which the enzymes were inactivated as before.

The digested sample was examined under the microscope with iodine-potassium iodide solution for traces of starch, to make certain that digestion was complete. The contents of the beaker were then transferred to a 250 cc. volumetric flask, and 160 cc. of 95% alcohol added with shaking, to precipitate mucilaginous, gummy, and pectin-like materials. After making up to the mark and shaking thoroughly, the contents of the flask were filtered, 200 cc. of the filtrate were withdrawn, freed from alcohol on the water bath, and transferred to a Florence flask with water to a volume of 150 cc. Fifteen cc. of hydrochloric acid (sp. gr. 1.125) were added and the solution boiled gently under a reflux condenser for 2½ hours. From this point the hydrolyzed products of the starch digestion were treated as described for polysaccharides.

Because of the greater simplicity and equal, if not greater, efficiency of starch digestion by saliva, the samples for 1924-1925 were digested by this method. All other steps in the procedure were as described in the two preceding paragraphs. The saliva digestion was carried out as follows: After gelatinization and cooling to 50°, 5 cc. of saliva (1 part saliva: 1 part water) were added. The sample was then covered and set in an incubator at 50° for 1 hour, after which the enzymes were inactivated in the manner referred to previously. The material was cooled to 50° and procedure repeated. The contents of the beaker were then transferred to a volumetric flask and alcohol added.

The extract of malt diastase was prepared by adding 1 gm. of malt diastase (Merck's) per 100 cc. of water, and stirring from time to time at room temperature. After 2 to 2½ hours the extract was filtered and ready for use.

Nitrogenous substances

1. Alcohol-insoluble nitrogen.

In the first year's work, an aliquot of the extracted residue was analyzed by the Gunning-Kjeldahl method for determination of total nitrogen modified to include nitrates. (31). The following year it was found more convenient to determine total nitrogen in a .5 gm. sample of the dried material which had been taken for moisture determination, and calculate the insoluble fraction by subtracting the figure obtained for total soluble nitrogen.

2. Total alcohol-soluble nitrogen.

An aliquot of extract "T" was transferred to a Kjeldahl flask, placed in the water bath, evaporated practically to dryness, and the total nitrogen determined by the Gunning-Kjeldahl method.

The remainder of extract T, after aliquots had been withdrawn for the estimation of sugars was evaporated down to about 50-60 cc., transferred to a 100 cc. volumetric flask and made up to volume with water. Ten cc. aliquots (Representing 5 to 6 gms. fresh weight of sample) were withdrawn for the determination of amino, amide and nitrate nitrogen.

3. Amino nitrogen.

Ten cc. of the concentrated aqueous solution of alcohol-extract were used for determination of amino-acid nitrogen by the Van Slyke method. (22). Replicate determinations were made until gas volumes (corrected) checked to 0.1 cc. or closer. It was rarely necessary to run more than three.

The methods used in the determination of amide and nitrate nitrogen had not been published at the time the writer made use of them, but were secured through the courtesy of Dr. T. G. Phillips, Professor of Agricultural Chemistry, of the University of New Hampshire. They are here copied from correspondence with Dr. Phillips.

4. Amide and ammonia nitrogen.

Aliquots of the above are transferred to large Pyrex test tubes, of a size to be used in the Van Slyke-Cullen apparatus. Two or three small pieces* of pumice stone and 0.6 cc. of conc. sulphuric acid are added, and the liquid boiled gently under a reflux for 2½ hours. This is cooled and nearly neutralized with 20% sodium hydroxide and prepared for aeration in the Van Slyke-Cullen apparatus, using a few drops of capryl alcohol to prevent foaming. Add 20 cc. of 52% potassium carbonate to liberate the ammonia. Aeration is continued into a measured volume of .02N sulphuric acid for 1 hour at a rate of about 120L. of air per hour.

---

* A little ground pumice was found to be more effective.

5. Nitrate nitrogen

Since amide nitrogen has been removed, DeVarda's method may be applied to the determination of nitrates in the aerated residue from the amide determination, using the potassium carbonate as the alkali instead of sodium hydroxide. The residue from the amide determination is washed into a 500 cc. Kjeldahl flask to a volume of about 150 cc., boiled nearly to dryness, cooled and made up to 300 cc. One gm. of DeVarda's alloy and a few drops of paraffine oil are added, and the liquid distilled through a Davisson scrubber bulb, on a Kjeldahl apparatus into a measured quantity of .02N sulphuric acid for 1 hour.

It is necessary to use great care in starting this distillation as the mixture foams very badly at first, and it may be necessary to remove the flame or turn it very low for a short time; later it boils quietly. It is necessary also to boil the distillate to remove carbon dioxide, and cool before titrating.

Methyl red is used in all the titrations.

Phosphorus

The Pemberton-Neumann (23) method for determining total phosphorus was used upon 1 gm. samples of the dried material taken for moisture determination.

Presentation of Data

General considerations

Tables XIII and XIV present the results of chemical analyses of plants from the plant bed and from the field, which were sown on different dates.

1. Dry matter.

Considering first the data for all three planting dates as a whole, it will be noted that as the season progresses, the percentage of dry matter steadily increases until midwinter. This is to be expected as a result of a condition of extreme hardiness, freezing of the tissues, exposure to desiccating winds, and of the plants being rooted in a frozen soil so that water intake is inhibited. With the advent of warm weather and the resumption of

TABLE XIII.

NITROGEN AND CARBOHYDRATE ANALYSIS OF CABBAGE.* 1923-1924.

Date Sampled	Date Planted	Source	Dry Matter %	Reducing Substances %	Sucrose %	Total Sugars. %	Polysac-charides %	Starch %	Total Carbohy-drates %	Total Insoluble N. %	Total Soluble N. %	Total Nitrogen %	C/N Ratio.
Oct. 2	Aug.25	Plant bed	12.15	4.60	1.69	6.29	14.21	6.18	20.50	3.06	1.111	4.171	4.91
Oct.20	Aug.25	Plant bed	11.40	5.35	4.09	9.44	12.66	3.72	22.10	3.02	1.010	4.030	5.48
	Sept. 5		11.72	2.68	4.27	6.95	12.45	4.14	19.40	3.27	1.415	4.685	4.13
	Sept.15		15.06	1.53	3.17	4.70	13.94	5.61	18.64	3.58	0.848	4.428	4.20
Nov.28	Aug.25	Plant bed	15.60	16.19	13.08	29.27	11.79	1.06	41.06	2.34	0.844	3.184	12.91
	Sept. 5		15.78	14.85	11.77	26.62	11.62	1.31	38.24	2.52	0.827	3.347	11.43
	Sept.15		15.65	10.48	9,58	20.06	11.00	1.18	31.06	2.89	0.806	3.696	8.39
Dec.21	Aug.25	Field	17.64	16.76	9.93	26.29	13.37	1.87	40.06	2.32	0.798	3.118	12.59
	Sept. 5	Field	17.89	15.91	10.16	26.06	13.31	2.56	39.38	2.32	0.918	2.238	12.16
	Sept.15	Field	18.22	15.43	8.57	23.50	13.90	3.03	37.40	2.74	0.728	3.468	10.82
Jan.17	Aug.25	Field	17.98	9.19	17.15	26.34	11.89	0.62	32.23	2.23	0.842	3.072	12.44
	Sept. 5	Field	17.78	7.87	19.31	27.18	12.93	0.57	40.01				
	Sept.15	Field	16.95	7.81	22.95	30.76	14.39	0.81	45.15	2.47	0.792	3.262	13.84
April 19	Aug.25	Field-Seedy	14.46	16.86	4.70	21.56	16.50	4.68	38.06	2.56	0.548	3.108	11.86
		Field-Seedy	14.55	12.52	3.28	15.77	14.42	3.80	30.19	3.05	0.672	3.722	8.11
	Sept. 6	Coldframe Seedy	14.48	18.24	6.23	24.47	11.27	2.56	35.74	2.49	0.758	3.248	11.00
		Coldframe Not Seedy	15.06	17.44	6.41	23.85	11.65	2.57	35.50	2.34	0.777	3.117	11.32
		Open Not Seedy	15.13	17.03	8.58	25.61	14.03	2.89	39.64	2.33	0.664	2.994	13.28
	Sept.15	Field Not Seedy	15.57	11.87	3.72	5.59	14.82	3.98	30.41	3.17	0.493	3.663	8.28

* On dry weight basis.

TABLE XIV.

CHEMICAL COMPOSITION OF CABBAGE PLANTS. (1924-1925).

Date Sampled	Date Sown	Fertilizer*	Dry Matter	Reducing Substances	Sucrose	Total Sugars	Total Polysac.	Starch	Total Carbohydrates	Total Soluble Nitrogen	Amino Nitrogen	Amide Nitrogen	Nitrates and Nitrites	Total Phosphorus	Total Nitrogen	C/N Ratio
10- 4-24	9- 2	+	14.52	8.79	1.72	10.51	16.36	9.67	26.87	.446	.1590	.088	.136	.445	3.315	8.11
		—	12.55	11.20	2.03	13.23	20.37	13.02	33.60	.491	.2060	.125	.119	.	3.133	10.72
10-18-24	9- 2	+	11.47	11.13	2.71	13.84	12.12	4.11	25.96	.785	.2825	.122	.418	.486	4.395	5.91
		—	12.89	11.18	2.94	14.13	14.13	5.84	28.26	.594	.2330	.097	.131	.491	3.890	7.26
	9-15	—	11.98	5.68	1.13	6.81	12.66	5.60	19.47	.918	.3110	.129	.431	.501	4.884	3.99
11- 8-24	9- 2	+	11.49	15.55	4.86	20.42	12.47	2.64	32.89	.868	.2655	.119	.410	.444	3.963	8.30
		—	12.80	17.88	5.56	23.44	16.40	5.36	39.84	.531	.2160	.077	.097	.390	3.017	13.21
	9-15	—	11.81	13.77	4.06	17.83	12.72	3.51	29.55	.733	.2565	.099	.368	.466	4.093	7.46
12-11-24	9- 2	+	16.49	10.66	11.30	21.96	10.99	0.35	32.96	1.020				.477	3.537	9.31
		—	18.33	9,43	17.44	26.88	12.79	0.65	39.67	.582				.398	2.450	16.19
	9-15	—	17.20	10.20	9.73	19.93	10.76	0.43	30.69	1.126				.476	3.917	7.83
3- 7-25	9- 2	+	15.45	15.92	10.04	25.96	12.03	1.69	37.99	.884				.452	3.627	10.47
		—	16.67	14.68	9.62	24.30	12.56	1.49	36.86	.715				.438	3.048	11.91
	9-15	—	16.12	14.87	10.06	24.94	12.84	1.69	37.78	.755				.	3.464	10.90
4- 9-25	9- 2	+	14.05	16.71	8.17	24.89	12.81	2.34	37.70	.645	.2375	.102	.074	.384	3.220	11.71
		—	14.90	15.01	7.15	22.16	13.42	2.54	35.58	.713	.2250	.110	.085	.355	3.521	10.10
	9-15	+	15.30	16.75	8.41	25.16	14.03	2.36	39.19	.552	.1995	.095	.020	.351	3.066	12.78
		—	15.14	14.42	6.66	21.07	12.29	2.27	33.36	.760	.2290	.117	.095	.376	3.640	9.16
5- 1-25	9-10	—	n 10.45	10.51	3.26	13.77	12.36	2.42	26.13	1.049	.2825	.155	.510	.502	4.802	5.44
			s 10.64	11.38	3.09	14.47	13.87	2.59	28.34	.927	.2675	.129	.318	.528	4.480	6.35

* In the plant bed.

growth, the tissue becomes more succulent.

During growth the percentage of reducing substances is low, and it increases greatly with exposure to low temperature and cessation of growth. Reducing substances reach the highest point in November and December; there is apparently a condensation of a portion of them to sucrose in January. The sucrose content increases from a minimum in October to a maximum in January, during a period of severe cold. Upon the resumption of growth in the spring, the sucrose decreases to approximately the value observed in October. The total sugar content undergoes the same type of change as described for sucrose, but it fluctuates less.

3. Total polysaccharides and starch.

There are no such marked changes in the percentage of polysaccharides as in the case of the sugars. The polysaccharides, with the exception of starch, are a fairly stable group of substances, and most of the changes which appear, can be traced largely to fluctuations in starch content. Starch is highest during growth and reaches a minimum in January during the coldest weather. It rises considerably in the spring, but in the samples taken it did not increase to the percentage found in the fall.

4. Nitrogen.

There is a distinct decrease in total nitrogen content between the October and November samplings. The relative difference in age and stage of development of the plants between these two dates is large; the young, vigorously growing plants in October exhibit a higher percentage of nitrogen than they do after they have become thoroughly hardened. After the cessation of growth, there is but little change until growth is resumed in the spring, however there is a slight downward trend during the fall and winter.

There is some disagreement between the figures for total soluble nitrogen in the two years' work, which cannot be explained from the data at hand. In 1923-1924 there was a decrease of soluble nitrogen from the first, followed by a slight rise in midwinter. In 1924-1925 the soluble nitrogen content was lowest in the fall and increased to a maximum in midwinter, after which it decreased until spring. There was a second high point in May after a period of rapid nitrogen intake. There is no very well-defined trend to the changes in percentages of soluble nitrogen.

5. Carbohydrate-Nitrogen relation

Since the fluctuations in total nitrogen content are rather small and those of the carbohydrates large, the changes in the C/N ratio roughly parallel those of the total carbohydrates. It increases through the fall and winter, and decreases after vigorous growth starts in the spring.

6. Phosphorus

No very definite trend is noted in the changes in percentage of total phosphorus.

Influence of the time of sowing upon chemical composition 1923-1924.

Some rather clear-cut differences in the chemical nature of the plants of different sowings, are evident in the first years' work. (see Table XIII) During October, November and December there is a successively lower percentage of reducing sugars, total sugars and total carbohydrates in the later sowings. In January, this relation is apparently reversed for some unexplained reason. Starch content varies in a direction opposite to that of sugar, but since the starch content is so small it has little effect in changing the relative amounts of total carbohydrates in the three plantings. The total nitrogen content of the three groups of plants increases with the delay in planting date. As a result of the lowered carbohydrate and increased nitrogen content in the later sowings, they of course exhibit distinctly different C/N ratios. The later the seed is sown, the lower is the C/N ratio.

When the analysis of "seeders" is compared with that of "non-seeders", the relation found is the same as that which exists between plants from early-sown and late-sown seed, namely: Seeders exhibit a higher C/N ratio than non-seeders. It will be recalled that the earliest sowing goes to seed the most, while that of Sept. 15 produces practically no seeders. This apparent correlation between the C/N ratio during the fall and winter, of early- and late-sown plants; the C/N ratio of seeders and non-seeders, in the spring; and the percentage of seeders in the respective sowings, at once suggests a causal relationship. It will be pointed out later, however, that this correlation is only apparent rather than real.

In view of the apparent correlation between planting date, C/N ratio, and seed-stalk formation in the first years work, it was believed possible and perhaps practicable to lower the C/N ratio of plants from early-sown seed and bring about the chemical conditions found to obtain in the later sowings. Thus it was hoped that large vigorous plants which would survive the winter could be produced by early sowing, and at the same time effect a low C/N ratio by the generous use of readily available nitrogenous fertilizer, thereby preventing the formation of a high percentage of seeders. Accordingly, such an effort was made during 1924-1925 in the manner outlined under "Plant bed management".

1924-1925.

Before considering the influence of the fertilizer treatment, compare the percentages of sugars, total carbohydrates and nitrogen in the early and late sowings. (See Table XIV). The table shows that the composition of the plants of the early sowing (no fertilizer) bears the same relation to that of the late sowing, as was observed in Table XIII for the previous year. The differences are even more consistent through the season than those for 1923-1924. The early sowings, in this case also, went to seed much more than the late. Thus, the time of planting shows a consistent and marked influence upon the chemical composition as well as upon the tendency to shoot to seed. But a true correlation does not exist during the fall and winter.

Influence of fertilizer treatment upon chemical composition.

A consideration of the effect of heavy nitrogenous fertilizer application shows that the apparent correlation between chemical composition through the fall and winter, and shooting to seed in the spring, is but a chance parallelism. In the case of the fertilized vs. non-fertilized plants, no such correlation exists. The relation is diametrically opposite. As mentioned above, the object in applying large quanities of nitrate of soda to the plant bed, was to impart to the plants from early-sown seed a chemical composition similar to that of the plants from later sowings which do not go to seed in the spring. This aim was achieved with a degree of success which quite surpassed expectations. A glance at the figures in Table XIV for the early-sown, fertilized plants shows that they have been altered greatly in their chemical composition, in the direction of late-sown plants which go to seed but little. And still these fertilized plants go to seed much more than the non-fertilized plants which exhibit the higher C/N ratio through the fall and winter.

It has been suggested that a study of the various nitrogen fractions, as amides, amino acids and nitrates might give some index to the conditions within the plant which are more immediately responsible for, or at least correlated with flower-stalk formation. When the percentages of amide, amino and nitrate nitrogen are plotted graphically, the curves are found to rather closely parallel the curve for soluble nitrogen. There is no evident change in the ratios of the respective fractions to the total soluble nitrogen, which can be correlated with the behavior of the plants. Table XV shows the percentage of soluble nitrogen based on total nitrogen as 100; and the percentage of amide, amino and nitrate nitrogen in terms of soluble nitrogen.

With respect then, to the series of samples from October to March, inclusive, no correlation is demonstrated between chemical composition and the tendency to shoot to seed. But between March 7 and April 9 a radical change occurs with the result that on the latter date there _is_ a correlation between composition and seed-stalk formation. Reference to Table XIV will show that the early-sown, fertilized and non-fertilized plants have reversed their relation to each other, insofar as chemical composition is concerned. The C/N ratio

TABLE XV.

Distribution of Nitrogenous Constituents of Cabbage.
Percentage based on soluble Nitrogen as 100.

Date Sampled	Date Sown	Treatment in plant bed	Soluble Nitrogen* 1923-4	Soluble Nitrogen* 1924-5	Amide Nitrogen	Amino Nitrogen	Nitrate Nitrogen	Remarks: Tendency to shoot to seed
10-2-23	8-25-23		26.6					
10-4-24	9-2 -24	Fertilized		17.7	19.7	35.6	30.5	Highest
		None		20.8	25.4	42.0	24.2	Medium
	9-15-24	None						
10-18-24	9- 2-24	Fertilized		21.9	15.5	36.0	53.2	Highest
		None		18.9	16.3	39.3	22.0	Medium
	9-15-24	None		21.2	14.1	33.9	47.0	Lowest
10-20-23	8-25-23		30.2					High
	9-15-23		19.1					Low
11-8-24	9-2 -24	Fertilized		26.9	13.7	30.6	47.2	Highest
		None		20.5	14.5	40.6	18.3	Medium
	9-15-24	None		20.8	13.5	35.0	50.2	Lowest
11-28-23	8-25-23		24.7					High
	9-15-23		21.8					Low
12-11-24	9- 2-24	Fertilized		28.9				Highest
		None		23.8				Medium
	9-15-24	None		28.8				Lowest
12-21-23	8-25-23		28.3					High
	9-15-23		21.0					Low
1-17-24	8-25-23		27.4					High
	9-15-23		24.2					Low
3- 7-25	9- 2-24	Fertilized		24.3				Highest
		None		23.4				Medium
	9-15-24	None		21.8				
4-9-24	From Field		17.6					Seeders
			18.1					Non-seeders
	FROM Coldframe		23.3					Seeders
			25.0					Non-seeders
4-9-25	9- 2-24	Fertilized		20.0	15.8	36.8	11.5	Highest
		None		20.2	15.4	31.6	11.9	Medium
	9-15-24	Fertilized		18.0	17.2	36.1	3.6	Low
		None		20.9	15.4	30.1	12.5	Lowest
5-1 -25	9-10-24	None		20.7	13.9	28.8	34.3	Seeders
				21.8	14.8	27.0	48.6	Non-seeders

* Based on total nitrogen as 100.

of the fertilized plants has increased, and that of the non-fertilized plants has decreased, so that just prior to the appearance of seed stalks the plants of the plots showing the higher percentage of seed-ers do exhibit the higher C/N ratio. This correlation between the C/N ratio in the spring, and the formation of reproductive organs agrees with current conceptions regarding the carbohydrate-nitrogen relation.

At what time the C/N ratio comes into play, and what causes the marked change in the C/N ratio of certain plants, is yet to be determined. Is it the greater leaf area and consequent greater capacity for carbohydrate synthesis of the large plants during the early spring when nitrogen intake is very low that brings about the high C/N ratio and resultant seed-stalk formation? (See Tables XIV and XV).

In view of the findings of Kraybill and Smith and of Hepler and Kraybill in regard to the phosphorus relation it was thought that the phosphoric acid in the fertilizer applied to the plant bed, might have been the factor responsible for the fertilized plants going to seed so much more than the non-fertilized, in spite of their carbohydrate-nitrogen relations, during the fall and winter. Kraybill and Smith found that when phosphorus is a limiting factor, the total nitrogen of the plant is high, soluble nitrogen high, insoluble nitrogen low, carbohydrates high, and the plants are unfruitful. When phosphorus is available, the total nitrogen content is lower, soluble nitrogen lower, the nitrate nitrogen lower as well as carbohydrates; and the plants are fruitful. A study of the phosphorus and nitrogen relations as presented in Tables XV and XVI shows no relation which suggests that phosphorus has been a determing factor in the manner described by Kraybill and Smith. When the phosphorus content is low, nitrogen likewise is low. When phosphorus is high, nitrogen is high, and there is no apparent correlation between the P/N ratio and reproduction. Thus, it can hardly be considered that phosphorus *per se* has been a determining factor.

STRAIN DIFFERENCES.

A few hundred plants of Henderson's Warren Wakefield were produced along with the Jersey Wakefield used in the major portion of the 1924-1925 work. The two strains were handled exactly the same. Table XVII shows that the particular strain of Warren Wakefield studied produces a consistently lower percentage of seeders than does the strain of Jersey Wakefield with which it is compared.

TABLE XVI .

Strain Differences in the Tendency to Shoot to Seed.

Date of Sowing	Treatment in seed bed	Strain.	Percent. Seeders	Plants Living
9-10-24	Fertilized	Warren Wakefield	13.7	518
		Jersey Wakefield	18.9	259
	None	Warren Wakefield	5.9	247
		Jersey Wakefield	6.7	369
9-15-24	Fertilized	Warren Wakefield	3.9	405
		Jersey Wakefield	8.8	262

SUMMARY.

1. Wintered-over cabbage exhibits a tendency to shoot to seed in the spring instead of forming heads. The extent to which this occurs, varies widely.
2. A review of the literature shows that hereditary factors are partially responsible for premature flower formation in cabbage. Numerous observations have indicated that soil and climatic conditions also play a part.
3. The influence of the following factors was studied: Time of sowing seed, fertilizers in the plant bed and in the field, and temperature to which the plants were subjected after transplanting.
4. The plant responses observed in relation to the above factors were: Size and vigor of plants produced in the plant bed, resistance to winter-killing, seed-stalk formation, percentage cut, yield, and chemical composition at various stages of development.
5. The earlier the seed is sown, the larger are the plants available for transplanting. Or, stated in another way, the earlier the seed is sown, the higher is the percentage of large plants, and the lower the percentage of small plants which are available for transplanting.
6. Large (not extremely large), vigorous, stocky plants are the most hardy to cold: small, weak plants are least hardy.
7. Heavy fertilizing with nitrogen in the plant bed produces large, succulent plants which are relatively tender to cold.

8. The larger the plants at the time growth is stopped in the plant bed in the fall, by cold weather, the greater is the tendency to shoot to seed.
9. If other factors are held constant, the earlier the seed is sown (with the exception of Aug. 25) the more hardy are the resultant plants.
10. If other factors are held constant, the earlier the seed is sown, the greater is the percentage of seeders formed in the spring.
11. For any given planting date, plants heavily fertilized with nitrogen in the plant bed are less hardy than those not fertilized.
12. For any given planting date, plants heavily fertilized with nitrogen in the plant bed exhibit a greater tendency to shoot to seed in the spring than those not fertilized.
13. Fertilizer treatment in the field is without appreciable influence upon winter killing or shooting to seed, but greatly increases yield.
14. Mild winter temperatures secured by artificial means do not materially influence the tendency to form seed stalks which the plants possess at the time they are removed from the plant bed.
15. Seeders exhibit a higher C/N ratio than non-seeders.
16. For a given plant bed treatment, plants from early-sown seed exhibit a higher C/N ratio through their entire development than do those from late-sown seed.
17. For a given planting date, plants heavily fertilized with nitro-

gen exhibit a lower C/N ratio through their fall and winter development than do the unfertilized plants. But in March the relation is reversed.

18. Analyses reveal no consistent correlation between chemical composition during the fall and winter, and the tendency to shoot to seed.

19. Just prior to the appearance of flower stalks, and thereafter, a consistent correlation is found between the C/N ratio and the tendency to flower prematurely.

20. The percentages of, and changes in the various nitrogen fractions and total phosphorus, bear essentially the same relation to the tendency to flower prematurely as stated for the C/N ratio. No correlation appears until a few weeks before the appearance of flower stalks.

21. Different strains handled in the same manner show different tendencies to produce seed stalks prematurely.

22. In this work, the factor found to be most closely and consistently associated with premature seed stalk formation, is the size attained by the plant at the time growth is stopped in the fall by low temperature. This correlation holds regardless of the treatment used.

23. The least losses in stand, and the highest yields are secured by sowing the seed Sept. 5 or 6 in a seed bed of but medium fertility. The dates of sowing will vary in different localities.

CONCLUSIONS.

1. Carefully selected seed stocks should be used.
2. Seed should be sown at a time such as to secure plants of no more than medium size (3 to 4 inch), but which have been grown slowly to develop a high degree of resistance to winter temperatures.
3. Early sowing promotes early seeding apparently because it permits the plants to attain a large size before they are checked in growth by low temperature in the fall. If the size of the plant is kept down, time of sowing *per se* is apparently of little influence.
4. Heavy applications of fertilizers which produce large or succulent growth are not to be recommended.
5. The critical period of development during which the C/N ratio seems to be of influence in determining vegetative or reproductive tendencies of the plant, appears to be between Mar. 1 and Apr. 1 under the field conditions concerned, In general, it is probably at the time of resumption of growth after a period of severe checking or enforced dormancy, and for a few weeks thereafter.
6. Winter temperatures appear to be important only insofar as they affect winter killing and "heaving" of the plants.
7. The early fall temperatures which check the growth of the plants in the plant bed are probably the most important. (See conclusion No. 3.)
8. Attempts to influence the tendency to shoot to seed by field treatment after transplanting are at present of questionable value.

LITERATURE CITED.

1. Aderhold, R. Uber das Scheiszen des Kohlrabus. Mitt. Kais. Biol. anstatt fur hand und Forstwertschaft 2:16-17. 1906.

2. Appel, O and Gassner, C. Der schadliche Einfluze zu hoher Heeimungstemperaturen auf die spatere Entwickelung von Getreidepflanzen. Mitt. Kais. Biol. anstatt fur hand und Forstwertschaft 4:5 ff. 1907.

3. Blount, A. E. N. Mex. Agr. Expt. Sta. Bul. 4. 1891.

4. Crocker, Wm. Factors affecting flower development. Bot. Gog 67:445-446, 1919.

5. Cserchati, A. Experiments on premature seed production in beets. Abstract in Expt. Sta. Rec. 11:232. 1899.

6. Detjen, L. R. Report of the horticulturist. Ann. Rpt. Del. Agr. Expt. Sta. Del. Agr. Expt. Sta. Bul. 129, 1921.

7. Report of the horticulturist. Ann. Rpt. Del. Agr. Expt. Sta. Del. Agr. Expt. Sta. Bul. 135, 1923.

8. Erwin, A. T. Bolting in cabbage. Mar. Grow. Jour. 37: No. 6 pp. 24.25. 1925.

9. Fischer, H. Ueber die Blutenbildung in ihrer Abhangigkeit von Licht und uber die blutenbildungen Substanzen. Flora 94:478-490. 1905.

10. Zur Frage der Kohlensaure-Einahrung der Pflanzen. Gartneflora 65:232-237. 1916.

11. Freund, H. Neue Versuche uber die Wirkung der Aussenwelt auf die ungeschlechtliche Fortpflanzen der Algen. Flora 99:41-100. 1908.

12. Gassner, C. Beobachtungen und Versuche uber den Anbau und die Entwickelung von Getriedepflanzen in subtrapishen Klima. Juhresb. Vereinigung fur Angewandte Botanik 8:95-163. 1910.

13. Gutzeit, E. Versuche uber das Schossen der Ruben und Anderer Pflanzen. Mitt. Kais. Biol. anstatt fur hand und Forstwertschaft 6:20 ff. 1908.

14. Harvey, R. B. Growth of plants in artificial light. Bot. Gaz. 74:447-451. 1922.

15. Hepler, J. R. and Kraybill, H. R. Effect of phosphorus upon the yield and time of maturity of the tomato. N. H. Agr. Expt. Sta. Tech. Bul. 28. 1925.

16. Hutcheson, T.B. and Quantz, T. E. The effect of greenhouse temperature upon the growth of small grains. Jour. Amer. Soc. Agron. 9:17-21. 1917.

17. Klebs. G. Uber Problems der Entwickelung. Biol. Centralb. 24:257-267; 289-305; 449-465; 545-559; 601-614. 1904.

18. Knott. J. E. Effect of cold temperature upon growth of vegetables. Jour. Amer. Soc. Agron. 17:54-57. 1925.

19. Kraus, E. J. and Kraybill, H. R. Vegetation and reproduction with special reference to the tomato. Ore. Agr. Expt. Sta. Bul. 149. 1918.

20. Kraybill, H. R. and Smith, T. O. Plant metabolism studies. N.H. Agr. Expt. Sta. Ann. Rpt. 1923. N. H. Agr. Expt. Sta. Bul. 212. 1924.

21. Mathews, A.P. Physiological Chemistry. pp. 891-894. Wm. Wood and Co., New York. 1920.

22. Ibid. pp. 934-941.

23. Ibid. pp. 933-934.

24. McCue, C.A. Report of the horticulturist. Ann. Rpt. Del. Agr. Expt. Sta. Del. Agr. Expt. Sta. Bul. 125. 1919.

25. Report of the horticulturist. Ann. Rpt. Del. Agr. Expt. Sta. Del. Agr. Expt. Sta. Bul. 126. 1920.

26. Paice, J.A. Spring cabbage. Gard. Chron. 72, III: No. 1858 p. 85. 1922.

27. Pieters, A.J. The relation between vegetative vigor and reproduction in some Saprolegniaceae. Amer. Jour. Bot. 2:529-576. 1915.

28. Sutton, E.P.F. Inheritance of bolting in cabbage. Jour. Hered. 15:257-260. 1924.

29. "Student". The probable error of a mean. Biometrika 6: 1-25. 1908.

30. Thompson, H. C. Factors influencing early development of seed stalk of celery. Proc. Amer. Soc. Hort. Sci. 219-224. 1923.

31. U. S. Dept. of Agr. Bul. 107 p. 8. 1912.

32. Walster, H. L. Formative effect of high and low temperature upon growth of barley: A Chemical correlation. Bot. Gaz. 69:97-125. 1920.

33. Walton, G. P. and Coe. M. R. Determination of starch content in the presence of interfering polysaccharides. Jour. Agr. Res. 23:995-1006. 1923.

34. White, Thos. H. Unpublished data. Maryland Agricultural Expt. Sta. College Park, Md. 1918.

35. Zimmerly, H. H. Cabbage strain tests. Va. Truck. Expt. Sta. Bul. 37 and 38. 1922.

[redacted]

TABLE A.

PERCENTAGE OF PLANTS WINTER-KILLED (1923-1924).

	Planted August 25th, Fertilized.		Planted August 25th, Check.		Planted September 5th Fertilized.		Planted September 5th Check.		Planted September 15th Fertilized.		Planted September 15th Check.		Average All Plots.	
	No. Trans-planted	Per-cent Killed	No. Trans-planted	Per-cent Killed	No. Trans-planted	Per-cent Killed	No. Trans-planted	Per-cent Killed	No. Trans-planted	Per-cent Killed	No. Trans-planted	Per-cent Killed	No. Trans-planted	Per-cent Killed
Small Poor	29	96.5	20	100.0	14	100.0	21	100.0	50	86.0	50	100.0	184	97.09
Small Medium	32	71.9	16	87.5	26	84.6	14	92.8	105	71.4	108	78.4	301	81.16
Small Good	9	22.2	1	100.0	12	16.7	2	0.0	53	34.0	44	54.5	121	37.89
Medium Poor	66	83.3	60	90.0	26	92.3	22	86.3	25	64.0	11	90.9	210	84.5
Medium Medium	83	44.6	76	31.6	113	18.6	61	42.6	104	48.1	111	39.6	548	37.5
Medium Good	52	17.3	39	2.6	142	2.8	50	6.0	86	20.9	90	15.5	459	10.9
Large Poor	12	58.3	10	80.0	2	50.0	3	100.0	---	---	----	---	27	72.8
Large Medium	47	12.8	69	17.4	18	0.0	32	0.0	---	---	---	---	166	7.5
Large Good	76	3.9	88	5.6	49	0.0	67	0.0	---	---	---	---	280	2.4
Average	406	41.8	373	35.7	404	22.3	272	31.3	424	52.2	414	549	2193	42.2

[redacted]

TABLE B.

PERCENTAGE OF PLANTS SHOWING SEED STALKS ON MAY 22nd.

	Planted August 25 Fertilized		Planted August 25th, Check		Planted September 5th, Fertilized		Planted September 5th, Check		Planted September 15. Fertilized		Planted September 15 Check		Average all Plots	
	No. Alive	Percent of "Seeders"	No. Alive	Percent of "Seeders"	No. Alive	Percent of "Seeders"	No. Alive	Percent of "Seeders"	No. Alive	Percent of "Seeders"	No. Alive	Percent of "Seeders"	No. Alive	Percent of "Seeders"
Small Poor	1	00.00	00	00.0	4	00.0	1	00.0	7	00.0	00	00.0	13	00.0
Small Medium	12	8.3	00	00.0	9	11.0	2	00.0	37	00.0	25	00.0	85	2.3
Small Good	7	0.0	2	00.0	9	00.0	2	00.0	35	00.0	21	00.0	76	00.0
Medium Poor	10	30.0	5	20.0	4	00.0	3	00.00	8	00.0	1	00.0	31	13.0
Medium Medium	43	16.2	48	16.6	87	5.7	46	10.9	54	00.0	63	00.0	341	7.3
Medium Good	42	26.2	36	16.6	135	20.0	44	20.4	64	1.5	73	4.1	394	14.4
Large Poor	4	25.0	2	50.0	1	60.0	2	00.0					9	22.2
Large Medium	40	32.5	50	34.0	19	26.3	31	29.0					140	31.4
Large Good	61	42.6	87	34.5	48	43.0	65	43.0					261	40.2
Average	220	28.2	230	27.4	316	26.1	196	26.0	205	00.5	183	1.6	1350	17.7