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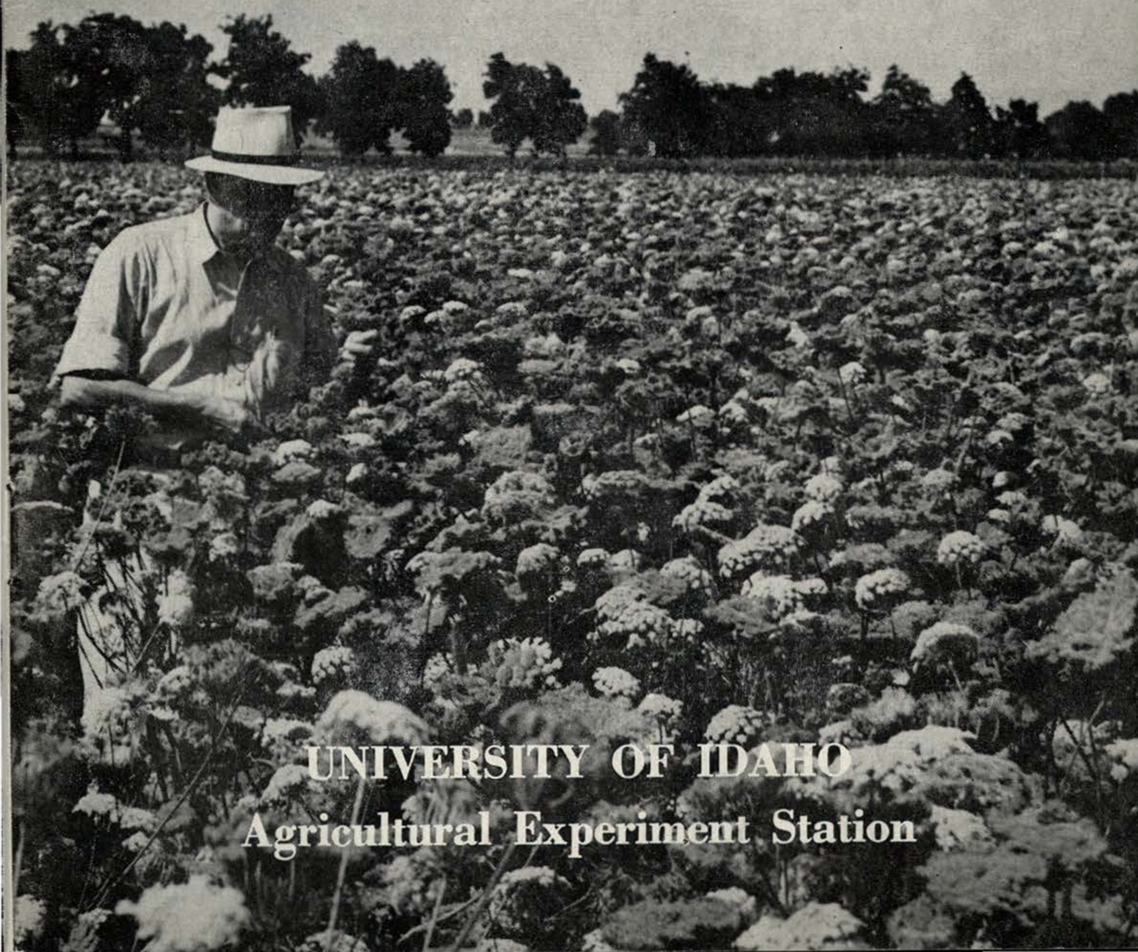

UNIVERSITY OF IDAHO
Agricultural Experiment Station

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Introduction

During the past decade Idaho has become known as "the cradle of the nation's vegetable industry." The state has become so recognized because it produces annually, in the form of seeds, an amount of potential vegetables larger than that of any area of similar size in the United States.

Importance of the Idaho Carrot Seed Industry

Among the vegetable seed crops grown here, carrot seed is an example worthy of discussion. Despite the fact that the land devoted to this crop in Idaho in the past 10 years ranges from a mere 500 to 1,000 acres annually, such acreages account for 25 to 50 per cent of the total U. S. production. In 1943, for example, Idaho produced 630,000 pounds on approximately 900 acres — enough seed at the usual planting rate to plant more than 200,000 acres of carrots. Since then, Idaho's production has fluctuated between 300,000 and 700,000 pounds annually. It is thus evident that to Idaho growers is entrusted a very significant role in the meticulous business of providing embryonic plants for a substantial portion of the nation's carrot-shipping industry as well as to its market and home gardeners. Considering the exacting requirements of the carrot growers, it is a tribute to Idaho seed growers that they have achieved such a volume of production.

Idaho's Growing Areas

Carrot seed production in Idaho is concentrated within two fairly restricted districts:

(1) **The Southwestern district,** which lies in the lower Boise river basin in Canyon and Ada counties. The production here typically constitutes about 85 per cent of the state's total. Here the better farmers around Melba, Caldwell, Nampa and Parma frequently include carrot seed as a row crop in their crop rotations.

(2) **The Middle Snake river district.** Here carrot seed production may be frequently observed around Twin Falls, Filer, Hazelton and Kimberly.

Reasons for Idaho's Adaptability

That these districts have taken the lead in carrot seed production is not the result of chance. The industry is located here because in these districts are to be found in most ideal combination the en-

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vironal and other circumstances necessary for the growing and processing of this commodity. Fertile mineral soils of desirable texture, abundant water for irrigation, high summer temperatures accompanied by relatively low humidity, and absence of precipitated moisture are conducive to high yields and a minimum of diseases. Dry weather at harvest time, which is typical of that season in these districts, greatly enhances the finishing-off of the crop and the achievement of seed having high germination and high vigor. Just as important are the knowledge and resourcefulness of the growers who are skilled row-croppers, well equipped with the tools and machinery of production and who can, if the situation is urgent, improvise new equipment and new methods.

Again, the development here of the industry has been hastened by the fact that nearly every major vegetable seed company in the United States had already established either trial grounds, breeding stations, seed-processing plants, and seed laboratories—or all of these facilities—for use in their enormous pea, bean and sweet corn seed production. For them, then, the addition of specialized facilities for testing and processing carrot and other small vegetable seeds was a natural development.

Another factor in the growth of the industry was the University's early recognition of the adaptability of these crops in certain areas of Idaho and the early realization that in vegetable seed production there existed an opportunity to add staple cash crops to the state's agricultural economy. The subsequent research program, by undertaking production problems which could not be readily undertaken by the industry itself, has helped to point the way to greater efficiency.

Evaluation of Carrot Seed as a Cash Crop

There are several reasons why carrot seed production is attractive to growers. Among these is the fact that the crop is contracted in advance at a stated price per pound for all seed which meets specified germination and purity. Under such circumstances the grower has only to produce a satisfactory crop to qualify for adequate returns on his investment. In other words, the question of profits or losses depends upon the grower's ability to produce satisfactory yields of good seed.

Again, carrot seed is a commodity in which a relatively small bulk carries a relatively high value. This high value per pound is of considerable economic importance in regions such as Idaho where geography has created wide distances between producer and consumer. Although shipments of carrot seed require a higher freight rate per pound than such commodities as potatoes or onions, the total cost of transporting $1,000 worth of carrot seed to market is much less than that of an equally valued shipment of either of these. Because the grower shares this saving with the contracting company, carrot seed can be considered as having a further regional adaptability.

Carrot seed production is a highly specialized operation, and as such should not be undertaken unless the grower is armed with an up-to-date knowledge of the factors involved and is convinced of the necessity of meticulously conforming to even the seemingly small requirements.

Carrot seed production is not especially profitable unless the yields and germination reasonably approach the potential which is possible in our region of natural adaptability. This natural adaptability, however, cannot be expected always to overcome all production hazards and to achieve maximum production of high quality seed. The science and skill of the grower must be the basic ingredients of success.

Plant Characteristics

All carrot varieties grown for seed purposes in Idaho are biennials. During the first year, a large, fleshy root surmounted by a rosette of leaves is formed. The second year, a much-branched flower stalk and seeds are produced.

Root System. In cross-section, from outside to center, the fleshy root exhibits the following tissues or regions (Fig. 1): (1) **Periderm,** or exterior layer of cells forming the "skin"; (2) **Cortex,** which consists mainly of phloem cells, and which, from the standpoint of edibility, is the most desirable portion; and (3) **Core,** which is composed of xylem cells and constitutes the least desirable portion. Best quality carrots are those which have a thick cortex and small core.

Viewed externally the carrot presents the following parts: (1) **Petiole,** or leaf stalk; (2) **Neck,** which is comprised of the collective petiole bases; (3) **Collar,** or plate from which the petioles arise; (4) **Shoulder** or **crown,** which functions as a stem; (5) **Tip** or **base;** and (6) **Tap-root.** Four vertical rows of lateral or secondary roots arise from the fleshy root. Some of these penetrate the soil to a depth of 25 to 30 inches, while their lateral growth may sometimes be even greater. The lateral roots are much divided and subdivided so that they form a large network of organs for absorption of water and nutrients.

Stem and Inflorescence. During the first year the stem is a plate-like organ from which the rosette of leaves arises. During the second year it elongates to a height of 2 to 4 feet, forming rough, hairy branches with large nodes and hollow internodes (Fig. 2). The main stem terminates in a compound umbel (first umbel order). From the main stem arise several side branches each ending in a compound umbel (second umbel order). Each side branch may have 2 to 6 secondary side branches, and there may be up to 5 or 6 umbel orders. The first three orders of umbels, however, account for approximately 90 per cent of the seed.

Flowers. Carrot flowers are typically perfect, with both male and female organs in the same individual flower or floret. These florets are small, whitish and numerous, and possess five stamens and five separate petals, under which are green bracts. The flowers possess two-compartment ovaries in each of which there is a single ovule or egg-cell. In the fertilization of these egg-cells, pollen shed when the anthers burst attaches to the sticky stigma, germinates, and grows down the style into the egg-cell where male and female germ cells are united. Pollen from an individual flower or floret is shed before the stigma is receptive, so that pollination and fertilization occur only by means of pollen from a younger blossom on the same plant or from another plant. The nectar in the carrot

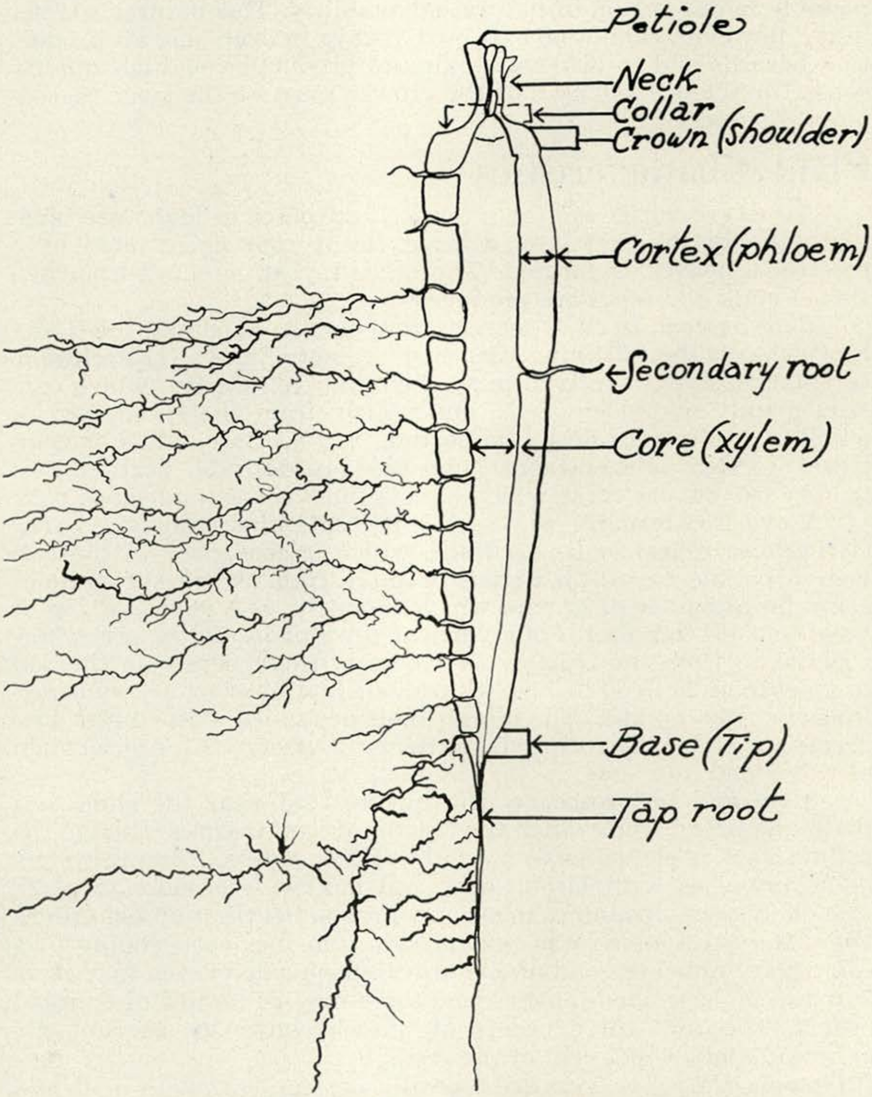

Fig. 1— Diagrammatic longitudinal section of an Imperida carrot illustrating various terms used in describing the anatomy of the root. For simplification, the secondary root system has been almost completely omitted on the right side of the fleshy root. (Drawings by Florence K. Franklin).

flowers is readily accessible and attractive to a large number of insects, so cross-pollination is frequent. There appears to be no pollination from wind or gravity. Opening of the blossoms and the shedding of pollen are not continuous processes but proceed in waves which correspond to the umbel orders. Flowers open first in the first order (king) umbel (Fig. 2), while those in the second order typically open about 9 days after the first order, those in the

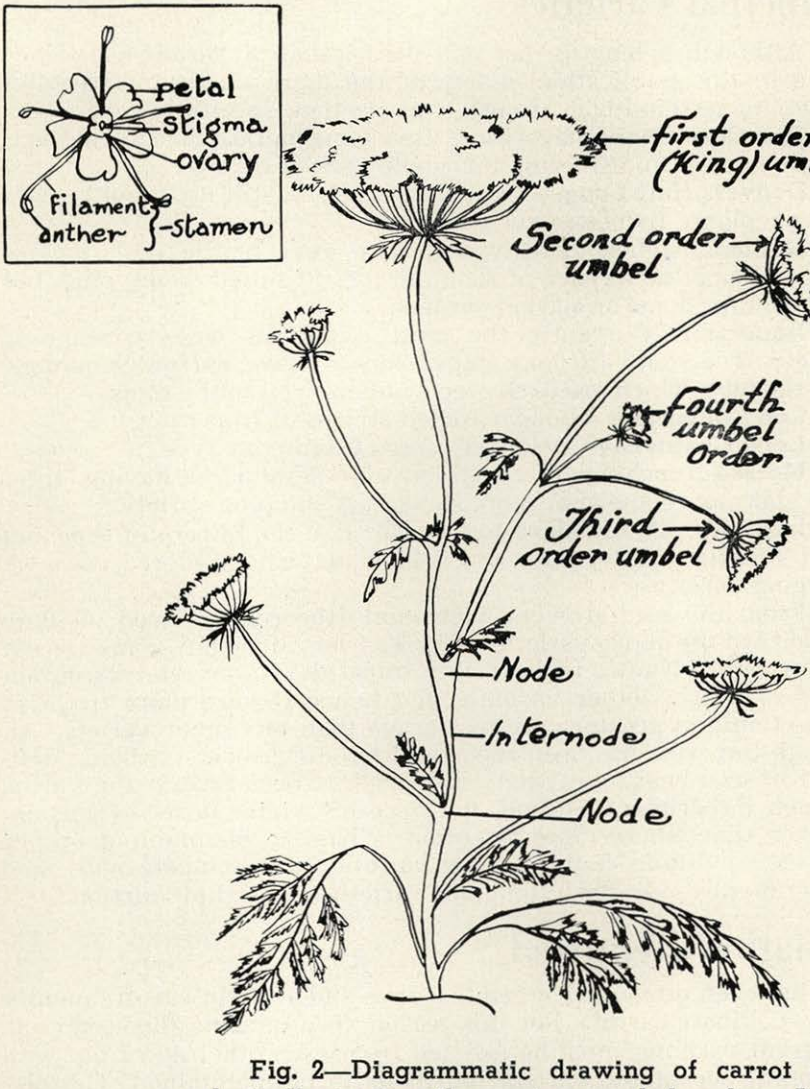

Fig. 2—Diagrammatic drawing of carrot seed plant illustrating the various umbel orders. Inset: Diagrammatic drawing (greatly enlarged) showing an individual floret or carrot flower and its principal anatomical structures. (Drawings by Florence K. Franklin).

third order 11 days after the second, and the fourth order 13 days after the third. There may be, of course, a difference respecting the blooming time of a given order with different plants in the field.

Seed. Seeds develop in joined pairs on a single pedicel. At maturity these split into separate seeds, each having five longitudinal ribs which bear relatively long hairs or spines.

Principal Varieties

Although a lengthy list and description of varieties have no place in this publication, a few of the more important varieties grown for seed in Idaho are listed, as are their specific uses.

Red Core Chantenay—Most used for general planting, storage, and in canning and freezing for whole pack or dicing.

Danvers Half-Long—A bunching variety, still used, but rapidly being replaced by better varieties.

Nantes—Highest quality, but with very brittle roots, sparse tops, and poor adherence of root and top. Ill-suited to shipping, but excellent for home or market gardeners.

Imperator—Currently the most important western shipping variety. The roots are long, taper slowly, have narrow shoulders, and the tops, which are dark green, adhere well to the roots.

Long Imperator—Longer rooted strains of Imperator.

Long Chantenay—A longer rooted Chantenay type.

Morse's Bunching—Very similar to Imperator, but having larger tops and roots somewhat more slender. A shipping variety.

Imperida—A new short-topped carrot of the Imperator type, but with slightly smaller core and a high percentage of red cores. A shipping variety.

From the seed-growers' viewpoint—the relative seed yielding capacity of the above varieties—there is very little difference except in the case of Nantes and possibly Imperida. Nantes carrots do not store so well as other varieties and hence require more frequent inspection and greater care in storage than any other variety. Although Imperida has been reported by some growers as being deficient in seed-bearing capacity, this has not been true at the Parma Branch Experiment Station, its place of origin. It seems certain, in fact, that where more attention is paid to maintaining proper storage conditions both of these varieties will compete with, and sometimes even exceed, the other varieties in seed production.

Isolation Required

It has been previously noted that bees and other insects frequently cross-pollinate carrots. For this reason, in producing the seed crop, different varieties must be isolated from each other and from wild carrots if acceptable varietal purity is to be maintained. The distances required depend mainly on the use to which the seed crop is to be put and on the degree of difference in their varietal characters. If the crop to be grown is for stock-seed purposes, isolation of at least 1 mile should be considered the minimum. If the crop is to be used for commercial seed and if varieties dissimilar in root or top length or shape are involved, isolation of ½ mile should be the minimum. Where varieties are quite similar in conformation and use and the object is production for commercial use, ¼ mile will often suffice.

Since there are no wild carrots in the immediate carrot-seed districts of Idaho, these do not currently constitute an isolation problem. Growers should, however, recognize the danger of possible invasion of this production hazard and be ready to deal with it at the earliest possible moment.

Growing Carrot Stecklings Or Mother Roots

Since the carrot is a biennial, the first step in seed production is that of growing the stecklings. Although well-grown roots do not necessarily insure good seed production, it is rarely possible to achieve profitable production with stecklings which have been indifferently grown.

Soils, Preparation of Land, and Seeding

Carrot roots develop best in a deep, well drained soil; and sandy-loams are better suited to steckling production than heavier soils. To avoid soil-borne diseases which cause decay in storage and loss of stand in the field, soils which have an immediate prior history of carrots, lettuce, onions, or beans should be avoided. The importance of this precaution can hardly be over-emphasized.

It is also important to remember that such bacterial diseases as bacterial blight and such virus diseases as aster yellows are easily spread by insects from seed fields to steckling fields. For this reaon, carrot seed fields and carrot steckling fields should not be grown in close proximity. Since lettuce and onions may also be infected with aster yellows virus, carrot stecklings and carrot seed crops should not be grown close to these crops (Fig. 3).

Because carrot seeds are small and the seedlings are at first delicate, seeding should be undertaken only in soils which are in a fine physical state and smooth. The seed is usually planted in dry soil at a depth of ¼ to ½ inch and irrigated up. This is usually planted in two rows on beds 36 to 42 inches wide, with 14 to 18 inches between rows, and 22 to 24 inches between beds. The distances used will depend on the type of tractor used and the other cultivated crops being grown on the particular farm. Gang seeders which plant either 4 or 6 rows simultaneously are usually used, in which case planting shoes which will distribute the seed in 4-inch bands are preferred to those which distribute it in a single line. Rate of seeding for the production of stecklings should be increased beyond that ordinarily used for commercial carrots. Six to eight pounds per acre will usually produce a greater tonnage of roots of proper size than will lesser or greater amounts. In growing stecklings, seedings are usually made from June 15 to July 10.

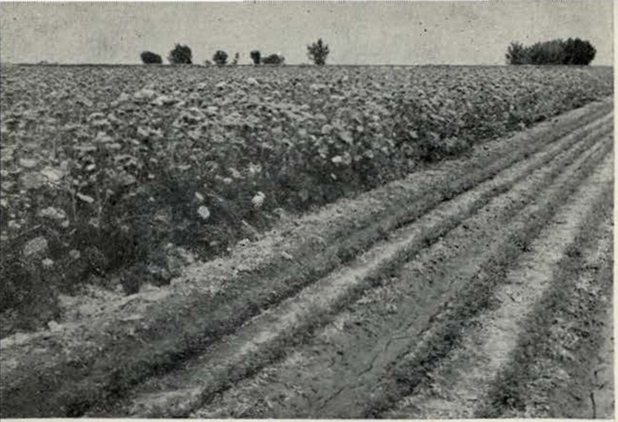

Fig. 3—A too common error in seed production: Growing seed and stecklings too close together, where insects can readily carry bacterial blight (caused by bacteria) and aster yellows (caused by a virus) from one crop to the other. Under these circumstances, if even a small number of seed-bearing plants has become infected during the growing season, these may provide enough infection to inoculate all of the young steckling plants. Since roots so contaminated often look healthy, the grower who uses these stecklings may have cause to wonder why his seed crop does not materialize the following year even though the stand looks promising.

Irrigation and Fertilizers

The first irrigation water is applied immediately after planting. Thereafter, water should be applied every 2 or 3 days until the plants have emerged. Subsequent irrigations should be less frequent, but often enough to insure a continuous supply of moisture, since lack of moisture stimulates the production of rough and misshapen roots which make the determination of off-types difficult when roguing. Prolonged applications of water which result in saturation of the soil surface across the bed should be avoided as they promote infection by storage diseases. For this reason, frequent, light irrigations are to be preferred over less frequent, heavy applications. Although the frequency will depend on the soil type, average intervals between irrigations during the hottest part of the summer would be 7 to 10 days, while 3 weeks or more would probably be sufficient when digging time with its cool weather approaches.

If barnyard manures are used, they are best applied to the crop preceding the carrots. Manures contain growth-regulating substances which may cause root deformities. Applications of nitrogen should, except in the case of quite sandy soils, be kept under 50 pounds of elemental nitrogen per acre (250 pounds ammoniam sulphate or equivalent). The use of phosphate fertilizers at the rate of 60 to 80 pounds of P_2O_5 per acre is usually profitable (300 to 400 pounds of single super phosphate or equivalent). These fertilizers can be applied most easily by broadcast application after plowing by disking them in during seed-bed preparation.

Weed Control

Continuous and early control of weeds must be maintained if the crops is to be well grown and the best yield of roots obtained. This no longer constitutes a great problem, due to the fact that selective sprays of stove-oil or light oils manufactured especially for the purpose have eliminated hand weeding. Several oil companies manufacture and sell special oil mixtures. Their only advantage over stove oil is that their formulation is standardized while that of stove-oil may vary somewhat in content and may occasionally contain ingredients injurious to the crop. Irrespective of the oil used, timely applications are essential to success. The first spray should be applied to all plants in the row when the carrots show from two to three true leaves and while the weeds are yet small. Rate of application will vary from 50 to 80 gallons per acre, depending on the size of the weeds and the amount required to cover them with a light film of oil. A slit opening, rather than a round hole, should be used in the nozzles with low pressure (25 to 50 pounds per square inch), and the height of the nozzles adjusted so that the spray material is confined to such areas as are inaccessible to tractor cultivation. (Fig. 4).

A second spray may be required to suppress weeds until the carrots are large enough to compete successfully. **In applying oil sprays, the grower would do well to remember that the finely-divided oil particles as they come from the jets constitute a highly inflammable and explosive mixture.** It is therefore of utmost importance that every precaution be taken to prevent fires or stop them should they get started. Precautions preclude all smoking around the machine or the sprayed area. A reliable fire extinguisher at a convenient place on the tractor is essential.

Where tractor cultivation is used to supplement weed control by sprays, shallow cultivation should be the rule. Considering the wide lateral extent of the fibrous secondary root system noted previously, it is obvious that deep tillage will discourage growth by severing much of the absorptive system.

Harvesting Stecklings

Carrot roots are usually dug during late October or early November—early enough to avoid freezing damage to the roots in the field and late enough that temperatures in the storage cellar can be lowered sufficiently to make proper storage possible.

Roots are topped prior to digging so that, ideally, about 1 inch of neck remains attached to the roots. Topping may be done by hand with Japanese lettuce knives or shears, or mechanically by mowing with a sickle-bar equipped with clover lifters, or by roto-beaters. It has been recently observed that topping by roto-beaters, which leaves rather too much of the leaf petioles attached, is in some cases followed by the use of a specially designed power scythe. In using beaters, it is important that the height of the flails be carefully regulated so as to avoid bruising of the carrot shoulders or excessive injury to the necks. Bruising, from whatever cause, naturally increases storage difficulties, and excessive removal of the neck

Fig. 4—Applying selective herbicidal oil sprays for control of weeds in young carrots.

and terminal growing point causes failure to produce seed stalks when roots are transplanted. Although hand topping is generally productive of roots of the best condition for storage, mechanical methods are now most frequently used because of the reduced cost. If mechanical methods are properly executed, however, there should be little difference between the two methods. Irrespective of the method used, no more roots should be topped in any one day than can be harvested in that day. The tops attached to the roots act as a good insulator in preventing freezing damage in the field.

After topping, the roots are loosened from the ground or dug either with a plow, an old-fashioned one-horse beet lifter converted to tractor use, or by several different types of tools which attach to the cultivator bar. The use of potato diggers has been tried and generally rejected as causing excessive damage to the stecklings, unless digger chains are reversed and the speed reduced. Stecklings should be picked from the ground into baskets, burlap bags, or crates (Fig. 5) immediately following digging and promptly hauled into storage. It is important in preparing roots for storage that they be free of caked soil, leaves, or other trash since these seem to increase storage difficulties. Although experiments are currently being conducted on the use of fungicidal dusts, sprays, and dips prior to storage, this work has not progressed far enough to warrant making specific recommendations concerning them.

Storage of Stecklings

Probably the greatest hazard of carrot seed production in Idaho occurs in storage; so, until new research projects now in progress point the way, it is necessary that every currently known means of promoting the storage life of the carrots be scrupulously followed. Of particular importance is the necessity of rigid sanitation in preparation for storage. This involves the removal in the spring of all rotten carrots, broken carrots, and other refuse, and of burying these under at least a foot of soil so that fungus spores are not disseminated either in the storage or in the fields. Before the new crop is stored, it is highly desirable that the entire cellar interior, including racks, bins, floors, and all crates to be used in storage, be thoroughly sprayed with a spray consisting of one pint of formaldehyde in 50 gallons of water. This should be applied in the summer

Fig. 5—Picking carrot stecklings after digging.

when temperatures in the storage are relatively high. The storage should, of course, be closed up tightly for several days following the spray for a prolonged fumigating effect.

Stecklings stored in cellars are either placed in slatted onion crates (Fig. 6) or bulked in bins (Fig. 7) equipped with removable decks, placed at intervals of about 4 feet, one over the other, as the roots are stored. When crates are used they should not be filled so full as to cause bruising when the crated carrots are stacked. When decks are used, stecklings should not be piled more than 1½ to 2 feet deep.

Ideal conditions for storage include the maintenance of the storage atmosphere as near 32° F. and 85% relative humidity as possible. Although these conditions rarely can be continuously maintained in an air storage, a close approximation of them can usually be achieved if a twice-daily check is made of the atmosphere in the storage and every advantage of favorable outside temper-

Fig. 6—Constant checking of the storage temperature, followed by intelligent manipulation of ventilators and doors to take every possible advantage of favorable outside temperatures will reduce both storage and field losses. Although the instrument shown here is a recording thermometer, a twice daily check of the storage atmosphere with a plain, but accurate, thermometer will serve notice as to what treatment is desirable.

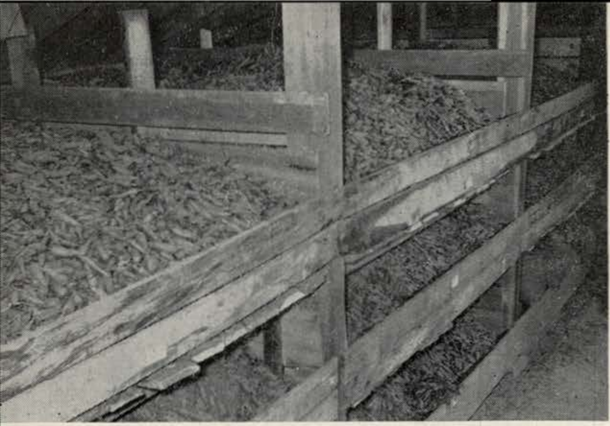

Fig. 7—Carrot stecklings bulked in open bins. Some separation is made here to avoid deep piles.

atures taken. This includes starting night ventilation of the storage and daily closure of vents and doors at least a week in advance of actual use, since the storage life of the stecklings can be materially increased by early reduction of the root temperature to the appropriate level. Maintenance of proper storage atmosphere thereafter is not achieved by accident, but usually can be closely approached if the necessity is fully recognized and if the matter is considered of sufficient importance that a responsible person, equipped with an accurate thermometer, accepts the responsibility. Although this is is of great importance throughout the storage period, it is supremely important at and immediately after the time the roots are stored and during the spring just before they are removed from storage. Since most difficulties in storage arise during these two periods, special vigilance at such times will pay good dividends—not only when the roots are sorted but especially when the seed is harvested.

When cellar storage is not available, stecklings are sometimes stored in long trench pits which are usually about 4 feet wide and 3 feet deep. These are filled with roots, upright ventilator ducts are placed, and the mass of roots generously covered first with straw and then with soil. Such pits are best located in sandy soil in an area higher than the surrounding land in order to afford good drainage. Although such storages have frequently been observed to hold the stecklings in good condition through the storage period, inability to change quickly the temperature is often a hazard. Another objection to pit storages is the discomfiture of sorting and roguing roots out-of-doors in the typically freezing weather preceding spring when they are removed from the pits.

Growing the Seed Crop

Sorting, Roguing, and Removing Stecklings from Storage

Before planting, roots are carefully sorted over belt graders to remove all diseased specimens and off-type roots. This should be done only once and that immediately before the roots are to be transplanted, for repeated sorting of lots which have developed storage diseases serves only to cause further spread of disease organisms. During the sorting process the stock is rogued to remove specimens which do not conform to varietal characteristics. Such specimens include roots of poor color, excessively large collars, enlarged fleshy lateral roots, excessively pinched shoulders, and roots which are grossly larger than the usual run of large roots in the lot. Some roguing for core-size can also be done at this time since roots having wide collars ordinarily have large cores. If roots are being selected for stock seed production, the roguing is usually more severe and is done as the carrots are stored so that the interior of the root can be examined to eliminate large or poorly colored cores. In this case the roots are sliced either longitudinally or transversely and the roots retained are covered with a protectant such as Arasan or Fermate dust.

Effects of Delaying Planting After Removal from Storage

That sorted roots should be planted immediately after removal from storage is indicated by the results (Table 1) of experiments at the Parma Branch Station in 1944, 1945, and 1946. These experiments were undertaken to determine what effects the frequently observed practice of delaying planting after removal from storage might have on the yield, stand, and quality of seed. These delays often occur after the contracting companies have delivered stecklings

Table 1. Effects on stand, seed yield, and germination of delaying planting of Danvers Half Long carrot stecklings after removal from storage, Parma Branch Station.

Treatment	Average Mean Stand Plants/Acre		Average Mean Seed Yield per Acre			Average Germination	
	1944	1945	1944	1945	1946	1944	1945
	No.	No.	Lb.	Lb.	Lb.	Percent	Percent
Roots 10 days out of storage prior to planting	----	2516	----	144.4	----	----	83.13
Roots 7 days out of storage prior to planting	4719	3484	359.8	221.3	630.0	73.75	86.16
Roots 3 days out of storage prior to planting	8712	----	619.4	----	1088.0	72.83	----
Roots planted same days as removed from strg.	8439	8712	712.6	651.2	1132.0	74.00	87.00
Least difference required for							
significance *At 19:1 odds	Not sig.	1389	Not. sig.	122.3	Not sig.	Not sig.	Not sig.
significance **At 99:1 odds	Not sig.	2105	Not. sig.	185.2	Not sig.	Not sig.	Not sig.

*In this table, as in those that follow, any differences less than those here indicated must be regarded as being due mostly to chance rather than to treatment.

**Differences of this size are highly significant.

from storage only to have planting delayed because of interference by the grower's other spring work. In these experiments, uniformly sized roots were removed from storage at various intervals prior to planting, placed in burlap bags after the fashion of the industry and kept in an open shed until planted on a common planting date. For these experiments a randomized plot design was used each year with three to four replications of each treatment depending on the year. Results indicate that in 1945 there was a decrease in stands and that each year (1944, 1945, 1946) there was a progressive decrease in yields with each increase of the delay in planting after removal from storage. Although these differences are not all statistically significant, it appears that they probably failed in this because only three replications were used in 1944 and 1946. Again, since temperatures and amount of wind vary considerably from year to year, it is interesting to speculate as to how much more seriously yields and stands might have been reduced had more adverse drying conditions been encountered in any of the years these studies were made. The results indicate that for the years (1944 and 1945) that seed germination was tested there were no significant differences respecting germination among any of the treatments.

Planting the Stecklings

Seedbed Preparation. It is recommended that as much care be accorded seedbed preparation for the planting of carrot stecklings as for crops in which the planting of small seeds is involved. Fall plowing is highly desirable to avoid large air pockets in the seedbeds and to promote intimate contact of roots and soil. The soil should be worked while still moist but not until it can be fitted without causing a cloddy condition. Although the seedbed should be firm, overworking the soil is also possible and should be avoided. A more uniform planting depth and spacing can usually be achieved if the soil is leveled or floated to a smooth surface.

Method of Planting. In transplanting carrots, different angles are assumed by the roots as the result of slight variations in the planting equipment. In most commercial plantings, transplanting has long been done from low sleds (Fig. 8) drawn behind slow moving tractors. These sleds vary in size, but resemble each other in that all are provided with a receptable or bin for holding several sacks of stecklings, and that each has furrowing tools at the front, behind which are slots in the sled bed through which laborers

Fig. 8—Showing carrot planting sled and its manner of use.

insert roots into the furrow as the sled is towed. The sleds vary in the type of furrowing tools used. In one instance this tool is a long, narrow blade known as a spear-point which makes a narrow slit furrow approximately 1½ inches wide and 6 to 10 inches deep and which leaves the furrow nearly filled with loose, friable soil. In planting in such a furrow, the roots are thrust into this soil in an upright position until the crown of the root is submerged beneath 1 to 2 inches of loose soil. Because this furrow is narrow and full of loose soil, the forcible thrust insures intimate contact of the root with moist soil so that no closing or covering device is necessary.

The other commonly used type of furrowing tool is a V-shaped corrugating shovel which makes a comparatively wide, open trench. When this type of tool is used, a closing device must be provided at the rear end of the sled to close the furrow and cover the stecklings. This device may be in the form of a V-scraper, the wide opening of which points towards the front of the sled; or a disc hiller may be used. With either hiller, the resulting method of placement is the same. Due to the forward motion of the sled and soil, there is a strong tendency for the roots to be planted at various angles other than in an upright position. There is also a tendency to cover the upper part of the root with soil that is dryer than that necessary for immediate initiation of secondary root growth.

To check on the effects of these fundamentally different methods of root placement, studies were made in 1943, 1944, and 1945 in an

Table 2. Effects on stands, seed yields, and germination of different methods of planting of Danvers Half Long stecklings, Parma Branch Station.

Method of Planting	Average stand plants per acre			Average seed yield per acre			Average Germination	
	1943	1944	1945	1943	1944	1945	1944	1945
	No.	No.	No.	Lb.	Lb.	Lb.	Percent	Percent
Roots dropped in horizontal position in V-shaped furrow	7142	7623	7502	490.0	432.1	411.3	75.58	81.31
Roots slanted at 45 angle in V-shaped furrow	7745	10527	8470	552.0	815.7	556.8	72.25	81.56
Roots inserted into narrow slit furrow in upright position	7019	10527	8808	995.0	814.1	690.0	78.33	80.63
Least difference required for significance:								
At 19:1 odds	Not sig.	2414	1036	Not sig.	Not sig.	173.1	Not sig.	Not sig.
At 99:1 odds	Not sig.	4004	1568	Not sig.	Not sig.	261.7	Not sig.	Not sig.

effort to determine whether choice of planting methods was a factor in seed production. In these experiments, a randomized block design was used with three or four replications, the number of replications being varied in different years. Results of these experiments are shown in Table 2.

Stand counts shown in Table 2 indicate that in 1944 there was a significant reduction in stand when roots were planted horizontally as compared with either of the other angles of placement. In 1945 horizontally-placed roots gave significantly lower stands than vertically-placed roots.

Viewing the effects (Table 2) on seed yield of the different methods, it is evident that although significant differences between treatments occurred only in 1945 the trend in all three years was for a substantial reduction in seed yield whenever the upright method was not used. This, coupled with the fact that use of the V-furrowing shovel results in both horizontal and angular placement, would leave the use of such tool of questionable desirability. For such reasons it would seem that the use of the spear-point method may serve as a means of increasing stands and seed yields where other methods are now in use. Although no experiments have been conducted respecting the use or failure to use the planting sled, at least one large company has recently discarded it because of poor spacing resulting from its use. Another objection to the sled is its inability to give uniform planting depths. Although this company has retained the use of the spear point, the procedure now is to drop the roots from baskets at appropriate intervals with field laborers following behind to thrust them into the ground. (Fig. 9). All air spaces between the roots in the row must be carefully eliminated. This is most easily accomplished immediately after planting by driving the tractor back over the field so that at least one wheel comes within 6 inches of each planted row. The weight of the tractor, thus applied, is usually sufficient to make a satisfactory closure. Sometimes a plank (Fig. 9) is dragged during this operation to smooth the soil, but this is probably unnecessary.

Germination data recorded in 1944 and 1945 indicate that there was no effect on germination resulting from the use of different methods of planting.

Planting Date as a Factor of Seed Production. Previous work at the Parma Branch Station by Dietz and Woodbury (1, 2)[2] and Franklin (5) has shown that fall transplanting of stecklings is not as reliable in southern Idaho as is spring planting. The investigations did not attempt to determine the most appropriate season for spring planting. In the hopes of ascertaining the cause of some of the frequently observed variations in stands and seed yields among different growers, a study of spring planting dates was carried on at the Parma Branch Station in 1948, 1949, and 1950. In these experiments, stecklings of similar size were removed from storage and planted at intervals of 2 weeks, beginning on or about March 1 each year and continuing until about April 15. Plots were arranged in a randomized block design with four replications of each planting

2/Numbers in parentheses refer to literature cited.

date each year. Results of these experiments are shown in Table 3.

Analysis of the data respecting plants per acre indicates that in 1949 there was no significant difference in stand between the first two planting dates but that stands were significantly reduced thereafter with each delay in planting. In 1950 there were no significant differences in stand among the first three planting dates; but, when planting was delayed until April 15, the reduction in stand was highly significant.

Further examination of the data in Table 3 reveals that in 1948 and 1950 there was no significant reduction in seed yield unless planting was delayed until after April 1. In 1949 there was a significant reduction in seed yield with each delay in planting after March 15. Since this was the year in which stands were also significantly reduced with each delay in planting after March 15, it would appear that the reduced yields were the result of reduced stands and that the reduced stands were due to progressive deterioration of roots in storage after that date. Although no data are here presented to substantiate this conclusion, such a conclusion agrees with the general observations made and recorded that year at the time of planting—that with each delay in planting date, it was necessary to reject an increasing amount of diseased roots to obtain what was regarded as acceptable planting stock. Even after such vigorous rejection, it would appear from the results that the selected roots carried a substantial amount of infection which was not detected and that such infections developed rapidly after planting. This, indeed, seems logical when it is remembered that usually after

Table 3. Effects of planting date on stand, seed yield, and germination of carrot seed from Red Core Chantenay (1948 and 1950) and Imperator (1949) stecklings, Parma Branch Station.

Steckling Planting Date*	Average stand count plants per acre		Average seed yield per acre			Germination Average		
	1949	1950	1948	1949	1950	1948	1949	1950
	No.	No.	Lb.	Lb.	Lb.	Per-cent	Per-cent	Per-cent
March 1	16,179	14,144	1265	1296	707	96.1	91.6	89.8
March 15	15,090	13,416	1286	1245	736	97.1	89.3	93.0
April 1	11,460	14,040	1307	996	728	97.4	91.6	89.1
April 15	8,556	10,816	1058	622	453	97.4	92.5	91.5
Least difference required for significance:								
At 19:1 odds	2,780	1,040	166	241	183	Not sig.	Not sig.	Not sig.
At 99:1 odds	3,995	1,493	228	346	262	Not sig.	Not sig.	Not sig.

*Planting dates + or — 3 days.

March 15 in southern Idaho it is difficult to maintain storage temperatures at, or even near, optimum (32° F.).

No statistically significant differences were found among the different planting dates as far as germination was concerned.

Viewing the results, the conclusion must be reached that delaying planting after March 15 is often a major source of losses in carrot-seed production in southern Idaho. Furthermore, the data indicate that plantings can be safely made as early as March 1, provided the amount of soil moisture will permit good seedbed preparation.

Depth of Planting. Sunburning and/or dehydration of the crown appears to be one of the frequent causes for failure of carrot roots to grow after planting in the field. Although no data are here presented to substantiate such a claim, throughout the past 10 years the writer has observed what appears to be a high correlation between sun-burned crowns (shoulders), and the failure of the roots to grow and produce seedstalks. It is not known whether this failure is caused by excessive dehydration of the crown and growing point, by the formation of toxic substances in the root, by the inactivation of naturally-elaborated hormones responsible for growth, or the formation of growth-inhibiting hormones. From the growers' standpoint, at least, it is probably enough to point out that sunburning sometimes appears to be an important factor in their failure to obtain even stands. Sunburning and dehydration of the crown and growing point can be prevented by covering the stecklings to a depth of at least 1 inch above the crown—as measured after the soil is settled. Because of the possibility of curtailing the oxygen supply planting much deeper than this does not seem to be wise unless the soil is very sandy.

Root Size and Spacing as Production Factors. Until studies of root sizes and spacings were undertaken (4) at the Parma Branch Station in 1943, 1944, and 1945, there existed no experimental evidence to indicate how these factors might influence seed production.

Fig. 9—Planting carrot stecklings without use of sled. Although not as highly mechanized, this method usually results in better planting, for the speed of laborers is not regulated by tractor speed. Hence, there is less danger of improper planting. The slit-furrow, however, is still recommended.

Because seedsmen had noted a seemingly greater plant vigor and size resulting from planting large roots, there was, in 1943, a trend toward adopting the use of large stecklings. Because seedsmen had noted, too, the seemingly increased spread and vigor of plants growing adjacent to a missing plant, they suspected that increasing the distance between plants in the row might be a means of achieving greater economy.

To determine the facts as nearly as possible, the Parma experiments utilized three different sizes of Danvers Half Long stecklings: Small, ¾ to 1¼ inches in diameter; medium, 1¼ to 1¾ inches; and large, 1¾ to 2¾ inches. Each size was then planted in rows 36 inches apart at intervals of 8, 12, 18, 24, and 36 inches within the rows. In all years a split plot design was used with 3 replications of each size and each spacing. Individual plots consisted of one record row flanked on both sides by guard rows. Plot lengths were 40 feet in 1943 and 1944 and 30 feet in 1945.

The effects on seed yield of the different spacings within the rows are shown in Table 4 in which the combined yields for 1943, 1944, and 1945 were analyzed.

Table 4. Effects on seed yields of spacing carrots of the Danvers Half Long variety at different distances in the row with a constant distance of 36 inches between rows, Parma Branch Station, 1943, 1944, and 1945.

Planting distance within rows	Seed yield per acre Average of 3 years—1943, 1944, 1945
inches	pounds
8	871.24
12	810.20
18	729.14
24	644.66
36	559.92
Least difference required for significance:	
At 19:1 odds	85.54
At 99:1 odds	113.27

Analysis of the data from which the information in Table 4 was taken showed that there was no significant interaction between spacings and sizes; therefore, all sizes responded similarly to a given spacing. This agrees with results obtained by Harrington (8) who made similar studies in California several years after the Parma experiments. Analysis of the data showed, also, that there was no significant difference among years in the way in which spacing affected seed yield; therefore, the results of the 3 years were averaged to simplify the table.

Although the data in Table 4 show a steady increase in seed yield with each decrease in spacing within the row, these differences are not all statistically significant. For example, stecklings spaced at 8-inch intervals did not give significantly higher yields than those spaced at 12 inches. Neither did 12-inch spacings give significantly higher yields than spacings of 18 inches—although the difference in yields between them barely missed statistical significance. Spacings of 8 inches gave very significantly higher yields than spacings of 18 inches. It would therefore appear that, **as far as seed yields alone are concerned,** the optimum spacing must be somewhere between 8 and 12 inches. This is in fairly close agreement with later work by Harrington (8) provided area occupied per plant is considered. **It should also be observed here that spacings of 12 inches or less had a markedly depressing effect on weed growth in excess of that of wider spacings.**

The effects of different spacings on seed viability are shown in Table 5 in which germination results from 1944 and 1945 are exhibited separately.

Although they do not agree either with the results of Harrington (8) or Hawthorn (10), the data shown for 1944 in Table 5 clearly indicate that the 8-inch spacing of stecklings resulted in significantly lower germination than did 18-inch or wider spacings. There was not, however, any significant difference between spacings of 12 and 18 inches. In 1945, although 8-inch spacings resulted in germinations significantly lower than wider spacings, it is obvious that 12-inch spacings were statistically just as good as any wider spacings used.

Table 5. Effects on percent seed germination of spacing carrot stecklings of the Danvers Half Long variety at different distances in the row when distances between rows are constant at 36 inches, Parma Branch Station, 1944 and 1945.

Planting Distance with rows	Average Germination 1944	Average Germination 1945
Inches	Percent	Percent
8	65.75	79.31
12	68.50	82.50
18	69.94	82.38
24	73.36	84.19
36	72.94	83.88
Least difference required for significance:		
At 19:1 odds	3.81	1.87
At 99:1 odds	5.17	2.51

Viewing now the combined effect of spacing on both seed yield and germination, it seems that of the spacings studied the 12-inch spacing most nearly meets the requirements of Idaho's seed indus-

try where high germination and high seed yields are equally important and where the soil fertility level is average or slightly less as was the case in the Parma experiments. Although these experiments were not conducted on soils of widely different fertilities, it would seem reasonable to suppose that where the soil is of high fertility decreasing the spacings in the row might significantly increase yields without reducing germination. By similar reasoning, it seems likely that where soils are definitely low in fertility, spacings within the rows should be increased somewhat beyond 12 inches.

Again, despite the fact that the experiments described here do not show it, reason would seem to suggest that if spacings of less than 36 inches **between the rows** were found to enable the seed plants to compete more successfully with weeds after the crop is laid by, planting distance **within the rows** should probably be increased beyond that recommended in order to provide a similar growing area per plant. Thus, if 12-inch spacings within the row are taken as being desirable where the rows are spaced 36 inches apart, the area per plant is 432 square inches. If such an area per plant were to be maintained, indicated spacings within the row would appear to be about 14 inches where spacings between rows were reduced to 30 inches, and 18 inches if spacings between rows were reduced to 24 inches. Such reasoning is, in fact, partially supported by comparing the results shown in Table 5, where spacings of 36 inches between rows were used throughout, with those of Harrington (8) wherein spacings of only 30 inches between rows were used. In both cases, maximum seed yields were obtained from what was essentially the same area of soil per plant.

Analysis of the data from which the information in Table 6 was taken showed that there were no significant differences among years respecting the manner in which root size affected seed yield. The yields shown are therefore the averages for 3 years. Analysis

Table 6. Effects on seed yield of using different sizes of Davers Half Long stecklings, Parma Branch Station, 1943, 1944, and 1945.

Root Size (Diameter)	Seed Yield (Average of 3 years — 1943, 1944, 1945)
	lb. per acre
Small (¾ to 1¼ inches)	750.18
Medium (1¼ to 1¾ inches)	785.96
Large(1¾ to 2½ inches)	633.02
Least difference required	
for significance:	
At 19:1 odds	107.04
At 99:1 odds	156.33

of the data further showed than in 1944 and 1945 there were no significant differences respecting germination resulting from the use of different root sizes.

Table 6 indicates that small and medium-sized roots can be expected to give significantly higher yields than large roots. Despite the fact that small roots gave higher yields than large roots and were statistically equal in yielding ability to medium roots, the results of the work of Mann and MacGillivray (12) should be used as a further guide in the choice of size within the small size class. The discovery by these investigators that small carrots result more often from late-germinating seeds and from other inherited characters than from crowding should be of considerable importance to every carrot seed producer. The importance of this lies in the fairly obvious fact that where roots are excessively smaller than the field average, such lack of size is probably an heritable characteristic which will be perpetuated by failure to eliminate such specimens. Thus, despite the fact that a considerable number of roots under ¾-inch in diameter were eliminated to make the "small" class as used in these experiments, from the standpoint of achieving a more desirable progeny, it probably would have been desirable to eliminate from use as stecklings any roots under 1-inch in diameter.

The fact remains, however, that if the highest possible seed yields are to be achieved, the grower should aim at the production of medium and small roots rather than large roots, realizing that the excessively small roots can be eliminated before planting. Table 7 gives further evidence of the desirability of growing small and medium roots in preference to large roots because of the greater economy of storage prior to transplanting as well as tonnage required to plant an acre. By referring to Table 5, however, it can be readily ascertained that the entire cost of small and medium-sized roots, when planted at closer intervals, can be readily offset by the additional seed yields. Since storage of carrot stecklings is usually

Table 7. Average number of pounds per acre of stecklings of the Danvers Half Long variety required to plant an acre for carrot seed production when different sizes and spacings were used, Parma Branch Station, 1943.

Spacing within rows	Stecklings Size Classes		
	Small ¾″ to 1 ¼″	Medium 1¼″ to 1 ¾″	Large 1 ¾″ to 2 ¾″
Inches	Lb.	Lb.	Lb.
8	1288	2812	6289
12	907	2309	4294
18	586	1412	2915
24	454	1140	2319
36	312	824	1681

on a per ton basis, the economy of storing small and medium roots is readily apparent.

Again, ease of planting small and medium roots as compared to large roots definitely favors the small and medium roots.

In passing, it is probably worth while to mention that the seed yields obtained from large roots at no time measured up to the performance of these roots immediately after transplanting. Each year this study was conducted, early growth for the large roots was faster and ranker, and blossom time was reached earlier than in the case of small and medium roots. Likewise, medium roots seemed to show a seemingly similar early superiority over small roots. By harvest time, however, it seemed inevitable that the seedplants from the small roots had caught up with those of the medium roots, and that the medium roots had caught up with the large roots as far as maturity was concerned. They had surpassed them as far as seed yield was concerned.

Weed Control

It is regrettable that there is currently no method of total weed control in the seed-producing year as there is in the root-producing year, for weeds in the transplant crop have always been the greater problem. Just as regrettable is the fact that this problem is not always wholly recognized by the grower, because it is infinitely larger than the mere effect of the weeds as competitors with the seed crop for nutrients and water. It is larger, even, than the effect of uncontrolled weeds in contamination of the soil by weed seeds. Indeed, one of the greatest possible sources of loss of carrot seed within the entire production process occurs when weed seeds which have found their way into the seed bag at harvest time have to be removed in the cleaning process. This problem becomes more serious as the amount of weed seed increases. Because so many of the weed seeds involved are so nearly identical in density to that of carrot seed, it is often impossible, even with the best use of the costliest and widest assortment of cleaning equipment, to make a satisfactory separation without taking with the weed seed an excessive amount of carrot seed. There have been, in fact, several known instances in which carrot seed lots have been so contaminated by weed seeds, that it was impossible to obtain any merchantable seed from an entire seed lot. That this does not happen more frequently is a tribute to the skill and ingenuity of the processing seedsmen and manufacturers of cleaning equipment.

In view of the economic importance of the weed problem as noted, and the lack of a reliable system of weed control beyond that of cultivating and hoeing as necessary, the grower is urged to delay the "laying by" of the crop until the latest moment possible without causing injury to the plants. He is urged, furthermore, to take note of what has been said earlier relative to the effect of root spacings on weed population and of what will be said hereafter when the topics of irrigation and harvesting are discussed. Although such recommendations are not the full answer to the weed problem, they seem to offer easily-applied means of reducing weed populations.

Fertilizers and Soil Management

Although experiments conducted by Reger and Franklin (13), have indicated that there is no response as measured in seed yield from commercial fertilizers other than nitrogen, these experiments were interrupted during the war and cannot be regarded as conclusive. Although these experiments definitely showed that applications of 40 to 80 pounds of available nitrogen per acre (200 to 400 pounds of ammonium sulphate or 120 to 180 pounds of ammonium nitrate) were necessary to achievement of the most economic seed yields, more work is needed before the use of phosphate can be eliminated. Lacking such evidence, the question of the usage of phosphate must be answered in generalizations. The question of the usage of phosphate in producing the seed crop is probably determined to a large exent by the amount of phosphate used in the production of the mother roots or stecklings. Indeed, it would seem that if phosphate applications recommended earlier have been followed, there may be little benefit from phosphate applications to the transplant crop, in which case it is possible that the seed-plant may derive some phosphate from that stored in the root. Nevertheless, if phosphate has not been recently applied to the soil in which the transplant crop is to be grown, it would seem desirable to apply 40 to 60 pounds of available P_2O_5 per acre (200 to 300 pounds of single super phosphate or equivalent).

In judging the amount of fertilizers to apply, it is necessary to consider well the previous cropping history and the soil type. For example, the minimum nitrogen applications recommended herein would probably suffice in soils which have had a history of frequent legume crops turned under; if not, the maximum recommendations might apply. Similarly, minimum nitrogen applications might suffice for the heavier carrot soils, whereas maximum applications might be necessary in a sandy situation. The conditions respecting phosphate fertilizers have already been discussed.

From the standpoint of good soil management it is desirable, of course, that the organic matter content of carrot soils be kept at a reasonably high level by turning under green manure crops or the liberal use of barnyard manure. Such treatments should be applied preceding the crop which precedes the carrot transplant crop. The reasons for this are fairly obvious. For example, if carrot roots were to follow plowed-under alfalfa the unrotted alfalfa roots would preclude a good use of the spear-point in the planting operation, and where barnyard manures were used immediately before the transplant crop, weed populations usually would be too high for a good seed crop.

Irrigating the Seed Crop

As previously indicated, carrot stecklings should be planted into moist but not wet soil. When this recommendation is followed, there should seldom be occasion for irrigation until the plants are at least 5 to 6 inches tall. On the heavier soils, the beginning of irrigation should probably be delayed even longer.

Although the determination of frequency of irrigation and amount of water applied have not yet been reduced to an exact science, such experimental work as has been done may shed some light on the subject.

That irrigation, once started, should be applied in moderate amounts thereafter and discontinued fairly early has been suggested by a preliminary experiment at the Parma Station conducted by Reger and Franklin (14) in 1943. In this experiment, uniformly-sized roots were planted in two large blocks, one of which was to receive heavy applications of water every 2 weeks, and the other to receive only light applications every 2 weeks. In the heavy irrigation treatments, water was applied until the beds were saturated completely across, while in the light applications water was allowed to penetrate only halfway across the beds. Within each one of these blocks, additional treatments were set up in which irrigation was discontinued at the following stages: (1) When the king umbels and a very few secondary umbels were generally in full bloom; (2) when umbels down to and including the third order were in full bloom; and (3) 3 days prior to harvest. Individual plots consisted of a single row 250 feet long and 3 feet wide flanked on either side by two guard rows. A randomized block design was used with three replications for each treatment involving time of discontinuation of irrigation.

Results of this experiment indicated that there was no significant difference between seed yields from plots receiving light irrigation when compared to those receiving heavy irrigation. Likewise, there was no significant difference among the treatments insofar as the stage at which irrigation was discontinued since the plots in which irrigation was discontinued earliest gave yields which, statistically, were just as high as those where irrigation was discontinued only 3 days prior to harvest. **It was noted, too, that there was a very noticeable reduction in weeds where light irrigations were used and where water was discontinued early.** Too much credence cannot, of course, be accorded an experiment which, because of the war's impact on personnel, had to be discontinued after 1 year. Certainly we might expect seasonal differences in the necessity for water; and certainly soil types different than the sandy silt loam on the Parma Station should be expected to have different water requirements.

It should be noted, however, that the experiments of Hawthorn (10) who worked on the problem of irrigation of carrot seed for several years in Utah tend to corroborate the results obtained at Parma. He found that low soil moisture generally favored high seed yield in carrots; and that in 4 years of testing there was never a clear-cut advantage in favor of heavy irrigation. Although Hawthorn noted that the percentage of germination of carrot seed was little affected by soil moisture, the work of MacGillivray and Clemente (11) has shown that germination may be slightly lowered as a result of heavy irrigation under Davis, California conditions.

These facts would at least seem to indicate that many Idaho growers may be applying water that does not benefit the seed yield nor germination and which **may be causing increased weed populations and decreased germinations.**

Harvesting the Seed Crop

Proper Maturity. Without the benefit of controlled experiments in harvest maturity, the decisions of different seedsmen as to what constituted the proper stage at which to pull carrot seed plants for curing have been highly varied.

In an effort to provide a basis for standardizing these decisions by determining how different stages of maturity affect seed yields and viability, experiments were run at the Parma Branch Station in 1948 and 1949 in which seed plants were pulled for curing at the following maturities: (1) When the seed in the second order umbels was generally brown and those of later orders generally green; (2) When seed in the third order umbels was turning from green to brown; and (3) When seed in the third order umbels was generally brown and some fourth order umbels turning. Plots for these studies were arranged in a randomized block design with four replications of each harvest date. Individual plots consisted of a single row 50 feet long and 3 feet wide. Seed from each harvest was threshed after curing 5 days in the windrows.

From the results shown in Table 8, it appears that insofar as yields are concerned there is a fairly wide latitude respecting the stage of maturity at which carrot seed may be harvested—since the differences in seed yield resulting from different harvest dates were in no case significant in either year.

Examinations of germination data in Table 8, however, discloses that in 1948 there was a significant reduction in seed viability as

Table 8. Effects of harvest date on carrot seed yield and germination in the Imperator variety, Parma Branch Station, 1948 and 1949.

General Maturity Stage and Harvest Date	Seed Yield Lb./Acre 1948	Seed Yield Lb./Acre 1949	Percent Germination 1948	Percent Germination 1949
Plants pulled when seed in 2nd order umbels was generally brown (Aug. 11 in 1948 and Aug. 8, in 1949)	1431	788	91.25	93.25
Plants pulled when seed in 3rd order umbels turning brown (Aug. 18 in 1948 and Aug. 15 in 1949)	1410	892	96.13	91.88
Plants pulled when seed in 3rd order umbels generally brown with some 4th order umbels turning (Aug. 25 in 1948 and Aug. 22 in 1949)	1390	996	96.88	93.88
Least difference required for significance at 19:1 odds	Not sig.	Not sig.	4.04	Not sig.
99:1	Not sig.	Not sig.	6.11	Not sig.

Fig. 10—Threshing carrot seed. Note at right how windrows of roots have been laid out on ground which has been freed of weeds by disking. This not only reduces the amount of weed seeds which find their way into the seed bags, but also reduces loss of carrot seed because the pulled plants lay flat, and hence are not so easily picked up by the wind prior to threshing.

a result of pulling the plants at the earliest maturity. Although similar results did not recur in 1949, the evidence of 1948 is probably reason enough to recommend that harvesting be delayed at least until the seed in the 3rd order umbels is turning brown, especially when this can be done without reduction in seed yield.

In applying the foregoing recommendation, the grower should be cautioned to use the stage of maturity herein described rather than the harvest dates as the criterion for deciding harvest time. The reasons for this, although fairly obvious, may be listed as follows: (1) Different soil types and different fertilizer programs, (2) different seasons, (3) different sites, (4) different root sizes, and (5) different irrigation schedules may, alone or in combination, cause considerable variation in the date at which a given stage of maturity is reached, according to general observations made in southern Idaho's seed fields by the author. That the soil moisture level is especially important in determining when a given state of maturity will be reached has, indeed, been proven experimentally by Hawthorn (10) who states that low soil moisture hastened carrot seed maturity as much as 2 weeks or more as compared to date of maturity under high soil moisture. Since the studies at Parma were conducted with relatively low soil moisture levels, the harvest dates given here are probably early when compared to the current practice of the industry.

It should be noted, too, that all seed lots from the earliest harvest at Parma contained a substantial percentage of green seed—enough in fact, to give each early lot a definite greenish appearance. Whether justifiable or not, such a color is frequent cause for complaint by the buyer.

Method of Harvesting. Numerous have been the attempts to make carrot seed harvest a fully mechanical process by combining it standing. It would still appear, however, that the hand-labor of pulling and windrowing cannot yet be economically eliminated because of the inability to control weed seed production, especially as harvest time approaches. This is especially true where carrot seed is allowed to ripen to such a degree as to be suitable for direct combining. The weed seed which is harvested coincidentally with carrot seed under such conditions is in such large amount and usually of such similar density that subsequent milling for removal of the weed seed causes tremendous losses of otherwise saleable carrot seed. Until more effective means of achieving weed control late in the growing season are discovered, hand pulling of the seed plants must be recommended. **It is also recommended that, in pulling, great care be taken to disengage any weeds which are entangled with the seed plant. If this is impossible, as with dodder, the seed plant should be removed from the field before threshing.**

In beginning the pulling of a field, three or four rows of seed plants are first windrowed together to clear a lane wide enough for the free use of a disc. The weeds in this lane are then thoroughly disked under, and the seedplants which have been removed from this lane are then moved back to the disked area. Enough space is left in the disked area, however, to accommodate three or four additional rows of plants. The space occupied by these lately pulled plants is now disked, and more plants pulled to fill the newly disked area. This alternate pulling and disking is continued until the entire field is pulled (Fig. 10).

To avoid excessive losses of carrot seed, it is imperative that the seed be pulled only when there is enough dew or other moisture on the plants to toughen up the attachment of the seeds to their pedicels and thus prevent shattering. This usually requires that harvesting begin near 4:00 or 5:00 a. m. and stop at 10:00 a. m. or earlier.

After the plants have lain in the windrow to cure 4 days or more, depending on the weather, they are threshed. This is done either by use of a rub-bar combine in which the attachment of the sickle has been so altered as to permit the points of the sickle blades to point upward rather than in the usual position or by a spike-cylinder combine. Of the two machines, the rub-bar type is probably most often used because of the simplicity of adjustment. As this combine is towed through the field, (Fig. 10) laborers go ahead of the sickle, pick up an armful of cured seed plants, place them on the sickle in such a way that severance of the seed-bearing portion of the plant from the woody roots is readily made. The plant tops are then elevated by the draper into the machine as the laborers reject the severed roots. Where the spike-cylinder type is used, there is no necessity for severing the the roots from the seedstalk, but a great deal more experience is required for adjusting the machine.

Threshing should be done only when the plants are dry enough that the seed is easily rubbed out. For this reason, under Idaho conditions, most threshing is done in the afternoon.

The Seed-to-Seed Method Of Production

As the name implies, the seed-to-seed method differs from the orthodox method just described in that here seed is planted 1 year, roots are grown and left in place as grown, and seed is harvested in the same place the following year. The method has been little used for the following reasons:

(1) **Seedsmen have always considered that it makes for needless waste of land.** As they point out, roots so produced on one acre, if transplanted after the conventional method, would produce 8 to 12 acres of seed.

(2) **The method renders impossible the roguing out of off-type roots, and thus perpetuates inferiority.**

By growing the crop as a winter annual, that is, by seeding August 15 to September 1 and harvesting seed the following August, the author (6, 7) was able to dispose of the first objection and produce seed yields approaching 1 ton per acre. Following that, he suggested to seedsmen that perhaps such a method could be utilized in southern Idaho provided plantings were made from intensively selected stock seed and provided the method were used 1 year only for increase. **Subsequent observations and reasoning have served to indicate that the method cannot yet be recommended if seed of high quality is to be obtained.** Following are some of the reasons:

(1) As has been previously noted in the spacing studies, seed viability was decreased by excessive crowding. Although the seed produced experimentally by the seed-to-seed method was not subjected to germination tests, the crowding in the row was in all cases more severe than in the closest of the spacing tests. It therefore seems likely that decreased germination could easily have exceeded that reported elsewhere in the closest of the spacing tests.

(2) Despite the fact that good seed yields were produced both years the method was tried, a large percentage of the roots was killed by alternate freezing and thawing. Since many of the winters since that time have had more extended periods of freezing and thawing, it seems likely that the use of the method in such years would have resulted in excessive losses of stand.

(3) Roots having the coarsest and most undesirable characteristics seemed to have had the greatest capacity for survival. This was especially true where rogues resembling the wild carrot were concerned.

For these reasons it seems presently correct to conclude that the seed-to-seed method invites risks which reliable seedsmen cannot afford to accept. The possibility of adapting the method to commercial use is still being investigated.

Insects and Diseases

The only insects which may be of importance in carrot seed production in southern Idaho are two species of legume or lygus bugs **Lygus hesperus** Kngt. and **L. elisus** Van D. These are sucking insects which often feed on carrots. Research is in progress to determine if these two species of lygus bugs will cause a reduction in yield and germination of carrot seed. Flemion and Olson **(3)** report that the closely related tarnished plant bug, **L. oblineatus** (Say), destroys the embryo and also causes a reduction in carrot seed yields in the eastern states. For control of lygus bugs, see Idaho Agricultural Experiment Station Bulletin No. 279, 1950 **Idaho Recommendations for Insect Control**, which may be had by addressing The Mailing Room, Agricultural Science Building, Moscow, Idaho, or by contacting your local county agricultural extension agent.

Several diseases affect carrot-seed production in Idaho. Among the field diseases are: Bacterial blight, dodder, macrosporium blight, watery soft rot, gray mold, and aster yellows. Diseases which affect the roots in storage are bacterial soft rot, watery soft rot, black rot, gray mold, and dry rot. Any one or all of these diseases may, if conditions are favorable, greatly reduce stands and seed yields. These diseases, their symptoms, and their controls are discussed in **Diseases of Carrot Seed Crops** in Idaho, Idaho Agricultural Experiment Station Bulletin No. 262, 1950.

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Literature Cited

1. Dietz, Carl F. and Geo. W. Woodbury, Fall vs. spring planting of carrot stecklings. Ann. Rpt. (unpublished), Univ. of Idaho Hort. Dept. 1940.
2. ————————. Fall vs. spring planting of carrot stecklings. Ann. Rpt. (unpublished), Univ. of Idaho Hort. Dept. 1941.
3. Flemion, Florence and June Olson, Lygus bugs in relation to seed production and occurrence of embryoless seeds in various um-

belliferous species. Contrib. Boyce Thompson Inst. 16(2)39-46. 1950.
4. Franklin, DeLance F. Some problems in carrot seed production. Seed World. 63:8. 1948.
5. Franklin, DeLance F. Fall vs. spring planting of carrot stecklings. Ann. Rpt. (unpublished), Univ. of Idaho Hort. Dept. 1942.
6. Franklin, DeLance F. Seed-to-seed production of carrot seed. Ann. Rpt. (unpublished), Univ. of Idaho Hort. Dept. 1943.
7. ______________. Seed-to-seed production of carrot seed. Ann. Rpt. (unpublished), Univ. of Idaho Hort. Dept. 1944.
8. Harrington, J. F. Effect of spacing and size of root on carrot seed yield and germination. Proc. Amer. Soc. Hort. Sci. 58: 165-168. 1951.
9. Hawthorn, Leslie R. Cultural studies on carrot stecklings in relation to seed production. U.S.D.A. Circ. 877:1-21. 1951.
10. ______________. Studies of soil moisture and spacing for seed crops of carrots and onions. U.S.D.A. Circ. 892:1-26. 1951.
11. MacGillivray, J. H. and L. J. Clemente. Effect of irrigation on the production of carrot seed. Proc. Amer. Soc. Hort. Sci. 54: 299-303. 1949.
12. Mann, Louis K. and J. H. MacGillivray. Investigations on variation of carrot root sizes. Calif. Agri. 3(10):9-13. 1949.
13. Reger, Mason W. and DeLance F. Franklin. Fertilizer studies with onions and carrots for seed production. Ann. Rpt. (unpublished), Univ. of Idaho Hort. Dept. 1943.
14. Reger, Mason W. and DeLance F. Franklin. Irrigation treatments of the onion and carrot seed crops. Ann. Rpt. (unpublished), Univ. of Idaho Hort. Dept. 1943.

Summary

A substantial part of the U. S. carrot seed industry is located in Idaho because Idaho meets all the requirements for the production of high yields of high quality seed. Since successful production of carrot seed is, however, both a science and an art, maximum yields and germinations will result only if all available knowledge is employed by skilled hands. Because even seemingly "small" details are usually found to be of considerable importance when analyzed as to their effects at harvest time, they, and other recommendations, are here summarized:

Steckling Production and Storage

Stecklings should be produced only on well drained, well prepared soils which have not produced lettuce, carrots, onions, or beans for at least 2 years previously. Seeding June 15 to July 10 at 6 to 8 pounds per acre with a wide (4-inch) shoe at a depth of ¼ to ½ inch will usually produce a greater tonnage of desirable-sized stecklings than any other amounts. Seed should be planted into dry soil and irrigated every 2 or 3 days until the plants have emerged. Water should be applied often enough thereafter to keep the soil

continuously moist, but lightly enough to avoid saturating the entire bed.

Nitrogen applications should be kept under 250 pounds of ammonium sulphate or equivalent except on sandy soils, because it may cause storage complications when used too liberally. Three hundred to 400 pounds of single super phosphate or equivalent are generally indicated. These fertilizers are most easily applied as broadcast applications after plowing by disking them in during seed bed preparation.

Weeds can be controlled readily by timely applications of stove-oil type sprays manufactured especially for the purpose. The first spray should be applied when the carrots show from 2 to 3 true leaves. A second spray may be required to control weeds until the carrot plants are large enough to suppress them.

Carrot stecklings are usually dug in late October or early November after topping. Bruising of the roots should be avoided in harvesting, as in all other operations involving them. To help avoid freezing damage in the field, no more roots should be topped in one day than can be harvested that day. Trash and caked soil should be excluded when the roots are picked up because they contribute to decay in storage.

Storages should be thoroughly cleaned immediately after the crop is removed for transplanting, and all carrot refuse removed and buried under a foot of soil, to prevent dissemination of disease spores to the next year's crop. Storages, racks, and crates should be thoroughly sprayed during the summer with a recommended fungicide.

Stecklings are best stored in cellars, either in bins provided with slatted decks or in crates. When bulked on decks, stecklings should not be piled more than 2 feet deep. Although not easily accomplished, maintenance of ideal storage conditions (32° F. and 85% relative humidity) can be reasonably approached if ventilation is practiced whenever outside temperatures are favorable.

Growing the Seed Crop

Before planting, roots should be carefully sorted to remove all diseased specimens and off-type roots. This should be done only once as repeated sortings cause unwarranted spread of disease organisms.

Because delays in planting after removal from storage may cause reduced stands and reduced seed yields, roots removed from storage should be planted the same day. Delayed planting does not, however, significantly affect germination.

A well prepared, moist seedbed is essential. Planting the roots upright in a narrow, slit furrow as made with a spear-point has been shown to be better than planting in a wide furrow in which indifferent placement of roots may result. No significant differences in germination were observed to result, however, from the two different methods of planting.

Transplanting should be done by March 15 if maximum stands and yields are to be achieved. No significant differences in germination were observed from different planting dates.

Crowns should be covered at least 1 inch, as measured after the soil has settled, to avoid sunburning of the crown and resultant stunting.

Spacing roots at 12-inch intervals in rows 36 inches apart was found to be the best for soils of average fertility. Other spacing combinations which afford a similar area per plant would appear satisfactory. When soil is more or less fertile than that used for these experiments, spacings should probably be changed accordingly; but it should be remembered that excessive crowding has been observed to cause decreased germination.

Small (1 to 1½ inches in diameter) and medium (1¼ to 1¾ inches in diameter) roots were found to be more economical than large roots (1¾ to 2¾ inches in diameter) because of the higher seed yields obtained and because of the reduced tonnage which must be handled and stored. Root size did not, however, affect seed germinations.

Failure to control weeds or to eliminate weeds from the carrot seed crop during harvest causes enormous losses when seed is cleaned because of the similar density of carrot seed and many weed seeds.

Applications of from 200 to 400 pounds of ammonium sulphate or equivalent will probably satisfy the nitrogen requirements; the amount indicated depending principally on soil type and previous cropping and fertilizing history. If phosphate has not been recently applied to the field, 200 to 300 pounds of single super phosphate or equivalent will usually guarantee a sufficiency.

If the soil moisture at planting time is at a proper level, no irrigation need be applied until the plants are 6 inches tall. Irrigation experiments indicate that irrigation, once begun, should be applied moderately. Irrigation should be discontinued earlier than is currently the custom, to discourage weeds.

Carrot seed should not be pulled until seeds in the third umbel orders are turning brown, because earlier harvesting may result in reduced germination. Plants should be pulled only when there is sufficient dew to prevent shattering of the seed. To avoid contamination from weeds and losses from wind, the plants should be laid flat on disked soil as they are pulled. Curing 4 days or more in the windrow usually precedes threshing.

The seed-to-seed method of producing carrot seed cannot yet be recommended.

Bulletins on insect and disease control are cited.

This bulletin is the result of more than 10 years of research at the Parma Branch Experiment Station. Although intended to provide seedsmen, growers, and researchers with the latest information respecting carrot seed production in Idaho, it should be regarded as a progress report; for, in Idaho's progressive seed industry, old methods are constantly being abandoned in favor of improved techniques.