# HOT WATER TREATMENT OF ORNAMENTAL NURSERY STOCK FOR NEMATODE CONTROL

# HOT WATER TREATMENT OF ORNAMENTAL NURSERY STOCK FOR NEMATODE CONTROL

By

LOU S. MORRISON

Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1940

Submitted to the Department of Botany and Plant Pathology

Oklahoma Agricultural and Mechanical College

In partial fulfillment of requirements for

the degree of

MASTER OF SCIENCE

1948

OKLAHOMA
AGRICULTURAL & MECHANICAL COLLEGE
LIBRARY
JUN 6 1949



APPROVED BY:

K. Stan Chester

Chairman, Thesis Committee

J. Harvey McLaughlin

Member of the Thesis Committee

K. Stan Chester

Head of the Department

D. C. McIntosh

Dean of the Graduate School

232709

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. K. Starr Chester for suggesting the problem, unrestricted use of the pathology laboratory, greenhouse and necessary equipment and for his many helpful suggestions and advice.

The author is indebted to Mr. Leo Conard of Conard and Son Nursery, Stigler, Oklahoma, Mr. Jack Foote of Durant Nursery, Durant, Oklahoma, and Mr. A. C. Johnson of Johnson Landscape Nursery, Muskogee, Oklahoma, for the nursery stock used in this problem.

Lou S. Morrison

STRATHMORE PARCHMENT
100% RAG U.S.A.

TABLE OF CONTENTS

# INTRODUCTION

The common root knot nematode Heterodera marioni (Cornu) Goodey, (formerly called H. radicicola (Gruff) Müller) is a constant menace and hindrance to the grower of susceptible varieties of ornamental nursery stock in the lighter, sandier soils of the south. The nurseryman must guard against introduction of nematodes in "lining out" nursery stock and in barn yard manure being added to his fields. There is always the probability of nematodes getting into his fields from vehicle wheels and on tools which have been used in known nematode areas and then in nematode-free areas and also by water running from one field to another. Nursery stock that contains nematodes is of no value and quite often the cost of destroying the stock and eradicating the nematodes has been so great that the nurseryman has abandoned the land rather than trying long rotations to free the soil of the nematodes.

Hot water treatments of nursery stock can be used by some growers who have large amounts of stock that is infested. It has been the purpose of this study to extend our knowledge of the species and varieties of nursery stock that can be treated with hot water at a temperature high enough to kill root knot nematodes without injuring the plant tissue.

My interest in the problem of nematode control began while working with the nurserymen and greenhouse growers of Oklahoma as nursery inspector for the Oklahoma State Department of Agriculture. When stock is found that has to be condemned and destroyed it makes one want to find ways and means of salvaging that stock so that growers may not have such great losses.

## LITERATURE REVIEW

The determination of the highest temperature that flowering plants can tolerate for short periods without showing injury or death was first suggested to Sachs (1864) on account of the wide discrepancies between the accounts of travellers and naturalists who had from time to time noted plants growing in very hot soil about hot springs and fumaroles. He used small potted plants of Nicotiana rustica (tobacco), Cucurbita pepo (pumpkin), Zea mays (corn), Mimosa pudica (mimosa), Tropaeolum majus (nasturtium), and Brassica napus (rape), placing them in hand-regulated incubators with glass doors and holding them at predetermined temperatures for various periods of time. All species stood temperatures of 49°-51°C. without harm but none stood a temperature over 51°C. over 10 min. without severe injury or death.

Immersion in water at 49°-51°C. killed the plants, however. Sachs (1864) made no attempt to explain this. A possible explanation might be that transpiration cooled the plants and the poor conductivity of air allowed the stems and leaves in the incubator to remain a little cooler than the indicated air temperature whereas they would quickly come up to the water temperature.

One of the most striking points in all these studies has been the suddenness with which the death point has been reached. Below the critical temperature the plant continues to exist without the faintest suggestion of injury. Raise the temperature a few degrees and almost immediately injury becomes clearly apparent. Illert (1923), Collander (1924), and especially Lepeschkin (1925) working with more refined methods, dealing in some cases with single cells and particularly choosing species in which death is marked by a definite color change, have thrown much light on the reasons for the sudden death at the thermal death point and the nature of the change that takes place.

Primarily it is due to the coagulation of the albuminous substance within the cell, a process that in its chemical aspects is not unlike an explosion, in that it is exothermic - heat is given off - and in that its rate does not conform to the van't Hoff - Arrhenius law that the speed of chemical reaction is doubled for each 10°C. rise in temperature, for the temperature effect instead of doubling becomes twenty-five to eighty times more rapid, as in the case of tissues of the three flowering plants, Tradescantia, cabbage, and beet, tested by Collander (1924). For these three species the time required to kill the cells was 46-252 min. at 50°C., 44 min. for Tradescantia and 3-5 min. for cabbage and beet at 55°C., 4 min. for Tradescantia and a few seconds for cabbage and beet at 60°C.

Other plants worked with to determine injury or death were:

| Species of plants | Maximum temp. °C. | Injury | Observer | Notes |
|---|---|---|---|---|
| Pea (roots) | 45 | Death | Leitch (1916) | |
| Lilac | 50 | Death | Clum (1926) | Thermocouples |
| Privet | 50 | No injury | Clum (1926) | Thermocouples |
| Fuchsia | 48-50 | Death | Clum (1926) | Thermocouples |
| Iris | 50 | Heat canker | Harvey (1923) | Thermocouples |
| Sour cherry | 51 | Burning | Blackman and Matthaei (1905) | Int. thermo-couples |
| Tobacco | 49-51 | No injury | Sachs (1864) | Incubator |
| Pumpkin, corn | 49-51 | No injury | Sachs (1864) | Incubator |
| Mimosa | 49-51 | No injury | Sachs (1864) | Incubator |
| Nasturtium | 49-51 | No injury | Sachs (1864) | Incubator |
| Rape | 49-51 | No injury | Sachs (1864) | Incubator |
| Tobacco | Over 51 | Injury to death | Sachs (1864) | Incubator |
| Pumpkin | Over 51 | Injury to death | Sachs (1864) | Incubator |
| Corn | Over 51 | Injury to death | Sachs (1864) | Incubator |
| Mimosa | Over 51 | Injury to death | Sachs (1864) | Incubator |
| Nasturtium | Over 51 | Injury to death | Sachs (1864) | Incubator |
| Rape | Over 51 | Injury to death | Sachs (1864) | Incubator |

Byars and Gilbert (1919) have shown that immersion of four-inch pots of infested soil in boiling water for five min. killed all root knot nematodes concerned, that the application of three liters of boiling water to eight-inch pots of similarly infested soil gave identical results, and that the application of boiling water at the rate of seven gallons per cubic foot of infested soil practically eliminated the root knot nematode and fungi from shallow benches.

In reviewing the work done on thermal death point of Heterodera marioni in relation to time, Hoshino and Godfrey (1933) determined that the minimal periods of time required for killing the larvae, at the different temperatures in degrees Centigrade, are: 40°, 2 hours, 7.5 min. ± 7.5 min.; 41°, 45 min. ± 5 min.; 42°, 22.5 min. ± 2.5 min.; 43°, 7.5 min. ± 0.5 min.; 44°, 5 min. 52.5 sec. ± 7.5 sec.; 45°, 4 min. 52.5 sec. ± 7.5 sec.; 46°, 3 min., 52.5 sec. ± 7.5 sec.; 47°, 2 min., 52.5 sec. ± 7.5 sec.; 48°, 57.5 sec. ± 2.5 sec.; 49°, the same; 50°, 52.5 sec. ± 2.5 sec.; 51°, 6.5 sec. ± 0.5 sec.; 52°, 1.5 sec. ± 0.5 sec.; 53°, 1 sec.

The minimal periods for killing the eggs of this nematode are: 40°, 4.5 days ± 0.5 days; 41°, 33.5 hours ± 0.5 hours; 42°, 3.25 hours ± 0.25 hours; 43°, 95 min. ± 5 min.; 44°, 47.5 min. ± 2.5 min.; 45°, 14.5 min. ± 0.5 min.; 46°, the same; 47°, 10.5 min. ± 0.5 min.; 48°, 6.5 min. ± 0.5 min.; 49°, 4.25 min. ± 0.5 min.; 50°, 3.5 min. ± 0.5 min.; 51°, 1.5 min. ± 0.5 min.; 52°, 45 sec. ± 15 sec.; 53°, 37.5 sec. ± 7.5 sec.; 54°, 5 sec. ± 2.5 sec.; 55°, the same; 56°, 4.5 sec. ± 0.5 sec.; 57°, 2.5 sec. ± 0.5 sec.; 58°, 1 sec.

These temperatures and time periods are exact for the killing of the two stages of the nematode. It is necessary, of course, that the organisms reach the specified temperatures and that they be maintained for the necessary period before the killing is attained. The lethal temperatures are much lower than those commonly employed in practice when it is desired to destroy nematode infestation in the soil or in dormant plant tissues. It will continue to be necessary to employ higher temperatures than those specified in order to obtain penetration of the necessary temperatures to the points in the soil or other medium in which the nematodes are actually located.

Latta and Yerkes (1939) used roses of four types in their studies; Ulrich Brunner (hybrid perpetual), Mme. Jules Bouchet (hybrid tea), Lady Hillingdon (tea), and Golden Salmon (polyantha). The plants were treated at 46.1°C. and 47.7°C. for 20-25 and 30 min. The results show that all treatments were injurious in some degree. The injury was most evident in the cambium layer of the roots which showed discoloration in varying degrees from slight browning to a very dark color according to the duration and intensity of heat to which they were subjected. Subsequent growth was retarded in direct proportion to the visible cambium injury. From the results it was concluded that under the conditions of their experiments the roses would not tolerate the recommended treatment of 47.7°C. for 30 min. nor even similar treatments of considerable less severity. Nearly all the plants were killed by immersions of 25 and 30 min. duration at 47.7°C. The 20 min. period at 47.7°C. and all those at 46.1°C. caused more or less injury to the cambium layer, with variation in growth response from slight retardation to severe stunting.

Godfrey (1923) found that dasheens can be treated for 40 min. in water at 50°C. without injury to the tubers. This temperature will control root knot nematodes. 52.2°C. will injure the tubers.

Whittle and Drain (1935) have published a list of ornamentals classified according to their degree of susceptibility to root knot nematodes.

Bruhrer, Cooper and Steiner (1933) and Tyler (1941) have compiled a long list of plants resistant or tolerant to root knot nematodes.

According to Chester and Cress (1939), black locust seedlings were treated at temperatures of 46.6°C. to 54.4°C. for periods of 5, 12, and 30 min. duration. Temperatures of 47.7°, 48.8°, and 50° for 30 min., 48.8° and 50° for 12 min., and 50° for 5 min. gave complete control of nematodes without injury to the trees. The 30 min. heating at 48.8° would probably be most satisfactory since it allows wider margins for errors in temperature control during the treatments. The 5 and 12 min. treatments would be less expensive but would require more accurate temperature control.

Tilford (1940), working with peonies, found there is a wide varietal difference in reaction to hot water treatment at 47.7° to 50°C. for 30 to 45 min. Treatments that are noninjurious to the roots do not completely free them of nematodes. Very little difference in growth of healthy and diseased plants could be noted over a period of eight years.

## MATERIALS AND METHODS

The nursery stock used in this experiment was obtained from three Oklahoma nurseries, namely: Johnson's Landscape Nursery, Muskogee; Durant Nursery, Durant; and Conard and Son Nursery, Stigler.

Plants from Johnson and Durant nurseries contained nematodes while plants from Conard and Son Nursery were nematode free. Plants were inspected visually for root knot nematode galls. Random plant galls were checked microscopically for live nematodes. This was done by tearing the gall apart and placing the female nematode on a microscope slide in a drop of distilled water and observing under the medium power lens.

An attempt was made to acquire stock not more than 2 to 3 feet tall. This stock was all pruned to about half its original height, tied in bundles of ten and washed to remove all dirt and foreign material.

The open top water tank used to treat the plants was made of heavy galvanized iron reinforced with 2" x 8" lumber around the top, bottom, and at the corners with a drain at one end at the bottom. It measured 46" x 16" x 20" having a capacity of 63.7 gallons.

The tank was mounted on blocks with a Bunsen burner underneath to supply heat when necessary. Hot water was added to the top of the tank by a rubber hose connected to a hot water tap. Under conditions of this experiment the hot water from the tap had a temperature of 60°C. so cold water had to be mixed to maintain the proper temperature.

Each variety of plants infested with nematodes were divided into three groups. Roots of each bundle were submerged and temperatures maintained at 48°C. and 49°C. for 30 min. The check group was not treated. Plants were removed from the tank and allowed to drain and planted in 6" pots and placed in the greenhouse. All pots in the greenhouse were placed in a large metal pan in order that the greenhouse would not become infested with nematodes. Tomato, pepper and okra seed were sown in each pot as indicator plants.

Due to cool greenhouse temperatures and slow development of nematode galls on indicator plants, plants were allowed to grow fifty-three days before removal from the pots and examination. As each plant was removed from the pot the roots were carefully washed and examined for nematode galls and injury to cambium tissue. All plants containing galls were examined microscopically to determine if nematodes were alive.

All varieties of plants not infested with nematodes were divided into three groups. The group used as check plants were planted directly in the field. The other two groups were treated for 30 min. at 48.5°C. and 49.5°C. and planted in the field.

## EXPERIMENTAL DATA AND DISCUSSION OF RESULTS

The nursery stock used in these tests has not been reported in the literature as having been submitted to hot water treatments. Data are not available as to temperatures these plants will stand and not show damage to the cambium. Temperatures of 48° and 49°C. (118.4° and 120.2°F. respectively) for 30 min. were used for plants listed in Table I because of results obtained by Chester and Cress (1939) in their work with black locust, Robinia pseudoacacia L. All of these plants were infested with nematodes at the time of treatment.

Greenstem forsythia, Forsythia viridissima Lindl., treated at 48°C. did not show any injury from the treatment. All plants made some growth, some made much faster growth than others, but all were growing when the test was discontinued. Indicator plants, tomato, pepper and okra, did not show nematode galls or nematodes within the tissues.

Greenstem forsythia treated at 49°C. showed some injury. Three of the plants died without budding, two plants budded then died, and ten plants withstood the temperature and put out normal buds and foliage. The plants that died showed discoloration of the cambium area and sloughing off of the epidermis of the roots. Injury was confined to areas that were submerged in hot water. The galls were destroyed and had begun to decay when plants were removed from the pots. Indicator plants in the 49°C. treatment did not show nematode galls with the exception of one. This was probably due to soil or water splashing from a check pot.

Morrow honeysuckle, Lonicera morrowi A. Gray, treated at 48°C. showed some injury. One plant did not develop at all while the other two made very good growth. No nematode galls were found on any of the roots of the indicator plants.

Morrow honeysuckle, treated at 49°C. showed some injury but all plants were alive. One plant did not bud but the cambium was green and the other two plants made good growth. The indicator plants did not show any nematode galls.

Shrubalthea, Hibiscus syriacus L., treated at 48°C. showed considerable injury. All plants showed injury to the cambium area in the form of discolored spots; ten of the plants died while the other five made good growth. Secondary roots formed from roots only slightly damaged from the heat. Indicator plants did not show any nematode galls.

Shrubalthea treated at 49°C. showed a high percentage of damage to the cambium area and to the epidermis of the roots. All plants died. Many of the roots were sloughing off badly when the plants were removed from the pots. The indicator plants did not show the presence of nematode galls.

The forsythia, honeysuckle and shrubalthea plants used as checks showed nematode galls on the indicator plants in each pot. Each plant was examined for nematodes microscopically, after being removed from the pot. Nematodes in all stages of development were found in both the plant roots and roots of the indicator plants.

All plants listed in Table II were free from nematodes but treated at 48.5° and 49.5°C. (119.3° and 121.1°F. respectively) for 30. min. to determine if they would survive these temperatures, which are higher than the thermal death point of root knot nematodes.

Amur privet, Ligustrum amurense Carr., did not stand heat treatments at either temperature. Both temperatures cause discoloration of the cambium area.

Apple, Malus sp., did not tolerate heat treatments. The cambium area was badly discolored.

Berry plants, Rubus spp., including boysenberry, youngberry, and raspberry did not survive heat-treatment. The cambium area in each species was badly damaged by heat. All check plants died but examination did not show injury to cambium as in treated plants.

Butterflybush, Buddleia davidi Franch., did not withstand heat treatment. Plants showed serious injury to the cambium area.

Deutzia, Pride of Rochester, Deutzia scabra Thunb., could not be heat-treated successfully. Temperatures that will kill nematodes destroyed the cambium tissue.

Flowering Quince, Chaenomeles lagenaria (Lois) Koidz., was killed by heat treatments. A large area of the cambium tissue was discolored.

Fortune forsythia, Forsythia suspensa fortunei Rehd., was slightly resistant to heat injury but not sufficiently to warrant treatments on a commercial basis.

Grapes, Vitis sp., could be heat treated without injury to the plants. All plants treated made very good growth.

Mockorange, Philadelphus coronarius L., was slightly resistant to heat treatment but cambium injury was too great to warrant treatment.

Peach, Prunus persica (L.) Batsch., could not stand hot water treatments at either temperature used in this experiment. Both temperatures caused plants to start growth then die due to injury to the cambium tissues.

Pussy willow, Salix discolor Muhl., did not tolerate heat treatments. Treatments caused large areas of the cambium tissue to be discolored.

Shrubalthea, Hibiscus syriacus L., was moderately resistant to hot water treatment. There was some injury to the cambium tissue but the percent survival was high enough to warrant treatment. The group of plants gave much better results than those used in Table I. This is due in part to the age of the plants used and in method of growing after treatment.

Tatarian honeysuckle, Lonicera tatarica L., was slightly resistant to heat treatment. Some plants stood treatment at either temperature but not enough to warrant large-scale treatments.

Weigela, Weigela florida Sieb. and Zucc., was injured by heat treatment to such an extent that treatment can not be recommended.

Wistaria, Wistaria floribunda DC, was highly resistant to heat treatment. All plants treated withstood the temperatures and made very good growth.

Table I. Effects of heat treatment on certain nematode-infested ornamental plants.
Temperature of hot water for 30 min. exposure.

| | 48°C. | | | 49°C. | | | Check | | |
|---|---|---|---|---|---|---|---|---|---|
| | Alive | Dead | Nematodes on Indicator | Alive | Dead | Nematodes on Indicator | Alive | Dead | Nematodes on Indicator |
| Forsythia, Greenstem | 15 | 0 | 0 | 12 | 3 | 1 | 13 | 0 | 13 |
| Morrow Honeysuckle | 2 | 1 | 0 | 3 | 0 | 0 | 1 | 1 | 2 |
| Shrubalthea | 5 | 10 | 0 | 0 | 15 | 0 | 9 | 6 | 15 |

Table II. Effects of heat treatment on healthy plants of various types of nursery stock.
Temperature of hot water for 30 min. exposure.

| | 48.5°C. = 119.30°F. | | | 49.5°C. = 121.10°F. | | | Check | | |
|---|---|---|---|---|---|---|---|---|---|
| | Alive | Started then died | Dead | Alive | Started then died | Dead | Alive | Started then died | Dead |
| Amur Privet | 1 | 0 | 9 | 0 | 0 | 10 | 5 | 0 | 5 |
| Apple | 0 | 0 | 10 | 0 | 1 | 9 | 4 | 5 | 1 |
| Boysenberry | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 10 |
| Butterflybush | 0 | 0 | 10 | 0 | 0 | 10 | 6 | 4 | 0 |
| Deutzia, Pride of Rochester | 1 | 0 | 9 | 0 | 0 | 10 | 10 | 0 | 0 |
| Flowering Quince | 1 | 0 | 9 | 0 | 0 | 10 | 5 | 3 | 2 |
| Forsythia, Fortune | 2 | 2 | 6 | 4 | 0 | 6 | 8 | 0 | 2 |
| Grape | 10 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| Mockorange | 3 | 2 | 5 | 0 | 0 | 0 | 4 | 3 | 3 |
| Peach | 0 | 8 | 2 | 3 | 6 | 1 | 6 | 4 | 0 |
| Pussy Willow | 0 | 0 | 10 | 1 | 2 | 7 | 0 | 8 | 2 |
| Raspberry | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 10 |
| Shrubalthea | 7 | 0 | 3 | 7 | 0 | 3 | 10 | 0 | 0 |
| Tatarian Honeysuckle | 3 | 0 | 7 | 2 | 0 | 8 | 10 | 0 | 0 |
| Weigela | 2 | 0 | 8 | 0 | 0 | 10 | 5 | 0 | 5 |
| Wistaria | 10 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 |
| Youngberry | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 10 |

## CONCLUSIONS AND SUMMARY

Ornamental nursery stock containing nematodes was subjected to temperatures of 48° and 49°C. for 30 min. to determine if each variety could withstand enough heat to destroy the nematodes yet remain viable. Greenstem forsythia, Forsythia viridissima, and Morrow honeysuckle, Lonicera morrowi, were resistant to the heat treatment. Shrubalthea, Hibiscus syriacus, proved to be somewhat susceptible to heat injury.

Ornamental nursery stock susceptible to, but free from nematodes was treated at temperatures of 48.5° and 49.5°C. for 30 min. to determine if each variety would remain viable when treated at a temperature above the thermal death point of nematodes. Grape, Vitis sp., and wistaria, Wistaria floribunda, proved to be highly resistant to each temperature. Shrubalthea, Hibiscus syriacus was moderately resistant. The percentage of survival was high enough to warrant treatment. Amur privet, Ligustrum amurense; apple, Malus sp.; boysenberry, Rubus sp.; butterflybush, Buddleia davidi; deutzia, Pride of Rochester, Deutzia scabra; flowering quince, Chaenomeles lagenaria; Fortune forsythia, Forsythia suspensa fortunei; mockorange, Philadelphus coronarius; peach, Prunus persica; pussy willow, Salix discolor; raspberry, Rubus sp.; Tatarian honeysuckle, Lonicera tatarica; weigela, Weigela florida; and youngberry, Rubus sp., proved very susceptible to hot water treatment and cannot be treated successfully.

# BIBLIOGRAPHY

Baker, F. S. 1929. Effect of excessively high temperatures on coniferous reproduction. Jour. For. 27:949-975.

Blackman, F. F., and Matthaei, G. L. C. 1905. Vegetable assimilation and respiration. Proc. Royal Soc. London, 76:Series B, 402-460.

Buhrer, Edna M., Cooper, Corinne, Steiner, G. 1933. A list of plants attacked by the root-knot nematode (Heterodera marioni) U. S. Dept. Agr., Pl. Dis. Reptr. 17:No. 7, 64-96.

Byars, L. P., and Gilbert, W. W. 1919. Soil disinfection by hot water to control the root-knot nematode and parasitic soil fungi. (Abst. in Phytopath. 9:49.)

Chester, K. Starr and Cress, Max. 1939. Heat treatments of black locust for root-knot control. (Abst. in Phytopath. 29:4-5.)

Clum, H. H. 1926. The effect of transpiration and environmental factors on leaf temperatures. Amer. Jour. Bot. 13:194-216; 217-230.

Collander, Runar. 1924. Beobachtungen über die quantitativen Beziehungen zwischen Tötungsgeschwindigkeit und Temperatur beim Wärmetod pflanzlicher Zellen. Soc. Sci. Fennica (Finska vetenskaps societen) Com. Biol. 1:No. 7, 1-12. (Original not seen, Ref. in Jour. For. 27:949-975. 1929.)

Godfrey, G. H. 1923. Root-knot: Its cause and control. U. S. Dept. Agr. Farmer's Bul. 1345:1-26.

Harvey, R. B. 1923. Conditions for heat canker and sunscald in plants. Minn. Hort. 51:331-334.

Hoshino, H. M., and Godfrey, G. H. 1933. Thermal death point of Heterodera radicicola in relation to time. Phytopath. 23:260-270.

Illert, H. 1923. Botanische Untersuchungen über Hitzetod und Stoffwechselgifte. Bot. Archiv. 7:133-141. (Original not seen, Ref. in Jour. For. 27:949-975. 1929.)

Latta, R., and Yerkes, G. E. 1939. The intolerance of dormant rose plants to hot water treatments for root-knot nematode control. Proc. of Amer. Soc. of Hort. Sci. 37:961-962.

Leitch, I. 1916. Some experiments on the influence of temperature on the rate of growth in Pisum sativum. Ann. Bot. 30:25-46.

Lepeschkin, W. 1925. Pflanzenphysiologie. Julius Springer. Berlin. (Original not seen, Ref. in Jour. For. 27:949-975. 1929.)

Sachs, J. 1864. Über die obere Temperaturgrenze der Vegetation. Flora. 22:5-12. (Original not seen, Ref. in Jour. For. 27:949-975. 1929.)

Tilford, P. E. 1940. Root knot of peony. Ohio Exp. Sta. Bimonthly Bul. 25:132-134.

Tyler, Jocelyn, 1941. Plants reported resistant or tolerant to root-knot nematode infestation. U. S. Dept. Agr. Misc. Pub. 406:1-91.

Whittle, W. C., and Drain, B. D. 1935. The root-knot nematode in Tennessee. Univ. of Tenn. Agr. Exp. Sta. Cir. 54.

Typist: Mrs. Datha Morrison