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A Survey of the State of Utah for Areas Infested with the Stem Nematode of Alfalfa

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A SURVEY OF THE STATE OF UTAH FOR AREAS INFESTED WITH THE STEM NEMATODE OF ALFALFA

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INTRODUCTION

Plant nematodes belong to a large group of invertebrates known as round worms. They derive their name from the Greek word "nema," meaning thread. In literature some authors refer to nematodes as nemas. In England and many parts of the United States, plant-parasitic nematodes are called eelworms.

While some damage to plants results from mechanical injury, salivary secretions injected by the nematode into the plant are usually the major cause of damage. Experiments conducted in the first part of the present century have demonstrated large differences in plant growth in soil infested with nematodes and soil freed of nematodes by chemicals. Any plant subjected to nematode attack is reduced in growth.

The most important nematode which attacks and retards the growth of alfalfa in Utah is the stem nematode. This parasite has been reported in most of the major alfalfa-producing counties of the state. In certain areas the nematode is prevalent to such a degree that only resistant varieties can be grown if the crop is to remain for more than two or three years. In other areas stands and yields are reduced in varying degrees. In many additional areas it is not known if the stem nematode is present, since a complete survey of the state has never been made.

The objectives of this investigation were to determine the distribution of the stem nematode of alfalfa through a complete survey of the state. The physical factors of the plant and soil which may be correlated with the presence of the nematode were likewise surveyed.

REVIEW OF LITERATURE

History and present known distribution

The disease produced by the nematode, *Ditylenchus dipsaci* Kuhn, was first described by Schivertz in 1855. He observed the diseased conditions of rye, oats, clover, and other crops but did not describe the parasite. The nema was first described by Kuhn from samples collected from fuller's teasel, *Dipsacus fullonum* L. It was not until 1881 that Kuhn recognized alfalfa as a host (Thorne, 1961).

The eelworm was reported as attacking rye in Kansas in 1907 (Smith, 1923). The nema has also been reported in Canada, South America and Europe. It was first observed in Great Britain in 1948 (Brown, 1957).

The spread of this parasite in the United States has been very rapid. It has been reported as attacking alfalfa in states from coast to coast. Its spread in Utah appears to have been closely correlated with some areas of extensive alfalfa production. Theurer (1957) reported the activity of the nematode in Washington County and McAllister (1959), in addition, reported the eelworm in Salt Lake, Uintah, Utah, Duchesne, Sanpete, Cache, and Box Elder Counties.

Morphology of the stem nematode

Thorne (1961) gave a good description of the eelworm. The nematode is a slender, wormlike animal with a cylindrical form of microscopic size from 1 mm to 1.3 mm in length. The body tapers at both ends, but not nearly as much at the anterior end.

The nematode has a spear which it can protrude through the oral opening and puncture and feed upon the cells of the host plant. Through

the spear, the nema may inject esophageal gland secretions into plant cells or pump the plant cell contents into its digestive tract.

Life cycle of the stem nematode

The life cycle has been studied by several investigators, but apparently the complete life cycle of the race attacking alfalfa is not known. Mating appears to be necessary for reproduction. Yuksel (1960), while working with a race that attacks onions, found that a single male was able to fertilize more than one female. He observed that females produced from 207 to 498 eggs during their lifetime.

Thorne (1961) reported that the young nematode moults once while still inside the egg. After being hatched it rapidly passes through the second and third moults. Yuksel (1960) observed that a lapse of 12 days was required from the time the egg was laid until the nema reached the fourth stage. The sexes could be differentiated by this stage of development.

It is at this fourth stage that the nematode has the ability to become dormant for prolonged periods and to withstand adverse conditions. Thorne (1961) reported that the nemas were not injured when infested alfalfa crowns were exposed throughout the winter in Utah with temperatures as low as 20°F below zero. Fielding (1951) found that the nematode could be revived after being dormant for as long as 23 years. During this dormant period they lie quiescent in fragments of plants or in the soil. With the return of favorable conditions and upon entering a host plant, they undergo the final moult (Thorne, 1961).

Under ideal conditions, the fourth stage may last only four to five days. The female starts deposition of eggs four days after the final moult. There are usually several generations in a single season. The

life span of both males and females is from 45 to 73 days (Yuksel, 1960).

The nematodes over-winter in an inactive state around the crowns of plants and attack the stems in the early spring at the joint of the growing point of the sheath or at the leaf axis. Survival in the field, of most adults, for more than one season may be doubtful because stored food supplies in the intestinal granules would not last through the winter (Thorne, 1961).

Grundbacker (1961) found that the most critical step in completing the life cycle appeared to be the laying of eggs. The development from eggs to larvae appeared to be less critical because at later stages larvae of different sizes usually were present when eggs were found in a plant.

Thorne (1961) reported that larvae attacking the buds must have a film of water in which to travel. Entrance usually occurs through the stomata, although the larvae may enter at the base of the stem or in leaf axials. The cells swell prior to physical contact, which makes entrance through stomatas possible. Palo (1962) suggested that once the nemas are in the plant, they are carried upwards passively as the plant grows. The majority of the nemas are located near the base of the stem.

By the time the nematode has been reported in a new area, it has been widespread, giving the appearance that infested seed was mainly responsible for its introduction. Palo (1962) was of the opinion that the eelworms were not carried within the seed itself, but that the nemas were present in the trash that accompanied the seed. The results of an experiment that he conducted gave support to his claim.

Once the nematodes are introduced to an area they can be spread by several methods. Thorne (1961) analyzed the waste water from an infested Utah field and found that 100 gallons of waste water contained 11,910

D. dipsaci. Most of these were preadults. Machinery working the fields adds an unmeasurable contribution to the problem (Courtney, 1954). Movement of the alfalfa foliage may not contribute as much to the problem of spreading the nematodes as might be expected, although it must be considered a major source of transportation. Palo (1962) reported that heavily infested alfalfa hay kept under normal dry storage conditions was nearly free of living nemas after one year. Thorne (1961) and Courtney (1954) observed that the nemas often migrated from dying plants which may partially account for Palo not observing the eelworm. Thorne also reported that the nemas did not live through heating in a manure pile or through fermentation in silage.

Linford (1937) observed *D. dipsaci* living freely in the soil and recorded that when the nemas were active and moving around, they would occasionally pierce fungal hypae and suck up the cell contents. A close relative of the stem nematode, *D. destructor*, has also been reported feeding on fungus cells (Anderson, 1962).

Biological races

The problem of combating *D. dipsaci* became complicated and confused with the discovery of many different biological races within the species which cannot be distinguished morphologically. These races can only be identified by their preference and ability to reproduce in various hosts. Seinhorst (1957) has shown how some of these races may be identified by using nine test plants, including alfalfa.

Each race is usually host specific. In an experiment in North Carolina, 31 varieties and accessions of alfalfa and two varieties each of red and white clover were tested in the seedling stage for susceptibility to three collections of an alfalfa race of the eelworm. All of

the alfalfas were more susceptible than the clovers (Allison, 1956). Thorne (1961) reported that there may be as many as 400 plant species belonging to more than 40 families that are attacked by one or more of the races of *D. dipsaci*.

Many of these hosts are weeds. In a study conducted on Long Island, New York, 32 plant species, mostly weeds, were collected from an infested field of narcissi and examined for the parasites. Of these plants, 29 were harboring the nematode (Cobb, Stein, and Blanton, 1934).

Barker and Sasser (1959) felt that the various races have not been given the proper taxonomic status in all cases. However, Bovien (1955) pointed out that before *D. dipsaci* is divided into several new species, it will be necessary to ascertain if the characteristics of each race are related to different genotypes, or if they are the results of environmental influence.

Evidence indicates that more than one race can attack and reproduce in alfalfa. Smith and Allen (1943) found that of two races that could reproduce in alfalfa, only one could produce an infection in sweet clover. Barker and Sasser (1959) reported that the Wando variety of garden peas was a very good differential host. Two races that could produce an infection in alfalfa did very well on the garden peas, but a third alfalfa race failed to reproduce on the garden peas. The garden peas reacted in a hypersensitive manner, resulting in necrosis and death of the apical meristem. A lateral bud then assumed apical dominance and the plant developed normally. A similar reaction was observed in Atlantic alfalfa when inoculated with a race of *D. dipsaci* from teasel.

Factors affecting infestation in alfalfa

The nematode invades the alfalfa plant at or above the soil surface

where it is under the greatest influence of soil physical factors. Many of these factors apparently have a great influence on the distribution of the nematode.

One factor which affects nematode populations is the moisture content of the soil. Wallace (1962) found that the vertical distribution in the soil of an infested oat plot showed a marked increase in numbers at the surface after a moderate rain. Sampling at time intervals after the rainfall showed first a decrease in numbers at the surface, followed by a reduction in numbers at all depths. Samples taken a few days following another rainfall indicated a large increase in numbers in the top four cm. of soil. Wallace also studied the power of recovery of nematodes when subjected to an atmosphere of 50 percent relative humidity, which would be about the same as dry soil. He found that after 34 days about 90 percent became active when immersed in water. Wallace expressed the opinion that when the soil surface dries out, it is possible that some of the nematodes migrate downward to the wetter soil, and that those remaining at the surface were subjected to desiccation. Wallace also found evidence that many of the nematodes may have left the plant and entered the soil during a rainstorm. This may have contributed to the increased number of nematodes found in the soil surface after rain. In another experiment conducted by Wallace (1961), the nematodes were found to always move toward a higher moisture content when placed in a moisture gradient.

Evidence was presented by Seinhorst (1956) to indicate that the distribution of nemas in the Netherlands was related to soil type. He found that populations in heavy soil tended to stabilize at about 50 nematodes per 500 grams of soil when a nonsusceptible crop was grown. In light soils the population tended to fall to less than ten nematodes per 500

grams of soil. He felt that populations of 10 to 40 nematodes per 500 grams of soil could cause considerable damage to susceptible crops. An experiment by Wallace (1961) gave support to the findings of Seinhorst. Wallace found that the nematode tended to accumulate in the 55- to 100-micron particle size range when placed in a gradient from 55- to 1300-micron particle size.

Grundbacker and Stanford (1962b) found that temperature could affect resistance in Lahontan alfalfa. Resistance was found to be higher at 52° than at 60 or 70°F in a controlled environment experiment. Wallace (1961) reported that the eelworm appeared to prefer a temperature of 10°C (50°F) when placed in a temperature gradient.

Histological studies of the attack on alfalfa

Krusberg (1961) has reported the results of histological studies of nematode attack on alfalfa over a period of time. The work was performed in the laboratory using very young seedling plants. A water suspension of nematodes spread over the seedlings was used as inoculum. The nematodes were surface-sterilized prior to being placed in the suspension.

Examination six hours after inoculation revealed that the attack could be broken down into three general areas. Some of the parasites had invaded the terminal bud and moved downwards into the parenchyma cells. Other nematodes had moved laterally into the cotyledons and the third group had invaded the embryonic leaves or the shoot apex.

Kruxberg noted that the first observed sign of damage to the plant was the purplish color of affected parenchyma cells that had been stained with safranin and fast green. Normal cells stained green. Nucleoli in unaffected cells stained red, whereas nuclei and nucleoli in affected cells were slightly enlarged and stained purplish. Krusberg also noted

that affected cells tended to be slightly enlarged and occasionally appeared to be separating from one another.

A few cortical cells in discolored areas of the cotyledon base had been punctured by the nematodes and had collapsed. Some cell walls were deformed, while a few appeared normal, but contents of affected cells were always discolored. The cytoplasm of cells adjacent to punctured cells was vacuolated, granular and stained purplish, while the nuclei were enlarged and stained very dark. The nucleoli in these nuclei were stained red. Owens and Novotny (1960) and Bird (1961) reported that the increase in the cell size was a result of turgor pressure and cell wall digestion. The larger nuclei resulted from the pooling of the nuclei of many cells and from division without cytokinesis.

By the twelfth hour a cavity had been formed in one cotyledon. Krusberg noted that the cavity was lined with a thick layer of substance which he presumed to be the remains from the cells that had been destroyed during the formation of the cavity.

After 18 hours, Krusberg recorded seeing the beginning of gall formations, and by 24 hours many of the cortical cells of stems or petioles in the area of a cavity were separated from each other. Barker and Sasser (1959) reported that the separation of cells was more evident in susceptible varieties.

Many of the gall cells were missing chloroplasts by 48 hours. Nematodes were observed moving between the separated cells at the edge of the galled area. It was not until ten days after inoculation that nematode eggs were first observed in the galls.

Examination 20 days after inoculation revealed that the epidermis was expanded and convoluted while most of the cortex was destroyed. Infected plants often displayed inhibited apical growth at this stage.

After 45 days, most of the gall cavities were full of nematodes and eggs. Colonies were found in cavities of the pith. Some vascular strands had been damaged by the eelworms. Mitotic figures were occasionally observed on parenchyma cells in stem galls. Krusberg noted that penetration into the cortex of old plants produced little galling and there was little inhibition of shoot growth.

After 60 days, the epidermis and most of the outer cortex had sloughed off in heavily infected stems.

Krusberg pointed out that the effects on cells often preceded contact by the nematodes, suggesting that salivary secretions diffused in advance of the nematodes.

Biochemical studies of the nematode attack

It is agreed by researchers that a chemical secreted by *D. dipsaci* is responsible for gall formation and separation of cells prior to direct contact with the nematode. Cell separation is a result of the destruction of the middle lamella, which may be regarded as a layer common to adjacent cells. The middle lamella consists mostly of pectic substance, especially in young plants. It is known that pectic enzymes can hydrolyze pectic substance to shorter chain groups and thus destroy the middle lamella (Wood, 1960). Some investigators, including Goodey (1929), felt that pectinase was the chemical responsible for separation of cells and gall formation.

While examining massed nematodes, Krusberg (1960) and Tracy (1958) were unsuccessful in detecting the presence of pectinase. Krusberg (1963) could find no consistent differences in the quantities of pectins between galled and healthy tissues. He concluded that pectinolytic enzymes were not of major importance. Krusberg felt that nematode enzymes must play

a major role in the plant-nematode relationship. He was of the opinion, however, that the galling reaction was most likely a plant growth regulator effect as a result of nematode interference with plant metabolism. Krusberg (1961) suggested that the galling reaction may be a result of tryptophane being converted to indoleacetic acid by nematode enzymes.

While comparing the chemical composition of normal plant tissue and the tissue of galls, Owens and Novotny (1960) found that the activity of all enzymes that were studied was greater in the tissue of galls. They also found that cellulose, free sugars, phosphorylate intermediates, and starch decreased in gall tissue while amino acids, proteins, nucleic acids, phosphorus, and nitrogen all increased in gall tissue.

Krusberg and Blickenstoff (1964) reported that plant growth regulators had an influence on the reproduction rate of *D. dipsaci* attacking alfalfa tissues growing on agar media. The callus tissue grown on media containing 2,4-D maintained the greater number of nematodes. Kinetin was shown to increase the reproduction rate of the nematodes.

Breeding for stem nematode resistance in alfalfa

Some work has been done breeding varieties of alfalfa resistant to the stem nematode. Work has been slow and complicated, because the exact mechanism of resistance and number of genes involved was not known. Bingefors (1960) concluded that the inherited resistance genetics was complicated, with a few major genes mainly responsible. He found that resistant and susceptible varieties were equally invaded, but that the nematode did not reproduce sufficiently to maintain a population in the resistant variety. Histological studies conducted by Bingefors (1962) indicated that the nematodes occurred in tissues with a very disrupted host cellular structure in susceptible varieties, while in resistant plants the nematodes were found in cavities. The cells of surrounding

tissues were not separated. In another investigation, Barker and Sasser (1959) found that safranin would concentrate in areas around the nematodes in resistant plants. They also found that plants with the highest degree of resistance developed necrotic spots which were the result of hypersensitive reaction. The few nematodes that were found in these areas were small in size.

Stanford (1951) found evidence of tetrasomic inheritance in alfalfa for the flower color characteristic. Grundbacker and Stanford (1962) concluded that there was also tetrasomic inheritance demonstrated in the progenies of resistant selections of an Iranian introduction and with the variety "Talent." Both demonstrated one single major factor conferring resistance to the stem nematode. Another type of resistance was demonstrated in an alfalfa introduction from Argentina which was related to one or more factors. Stanford was of the opinion that both of these types of resistance were good sources of resistance, although the latter would require a more laborious breeding procedure.

Grundbacker (1961) discussed a technique for testing alfalfa seedlings for resistance to the stem nematode. The meristematic tissue of the apex served as a critical evaluation of resistance. The nematodes and eggs within the apex were stained and counted to measure the degree of resistance. Susceptible plants showed a distinct swelling in the shoot apex and resistant seedlings usually exhibited very little swelling. Due to intermediate symptoms by some plants, it was not always possible to segregate plants by observations of the swelling alone without splitting the stem and observing the nematodes and eggs.

Resistant varieties

An introduction to the United States, "Turkestan #19304," was the

first known source of resistance. Eighty-five percent of the plants were resistant to the stem nematode. It was later released as the variety "Nemastan." Two recent introductions from Iran were highly resistant with only ten percent of the plants being susceptible (Jones and Smith, 1953).

A few resistant varieties have been developed from the above mentioned, as well as from other sources. Lahontan was developed by the Nevada Experiment Station by synthetically combining five clones of Nemastan. In Nevada it was shown to have a yielding capacity equal to Ranger in areas where the stem nematode was not a problem and was superior to Ranger and other resistant varieties when the nematode was present (Smith, 1955). The variety "Talent," developed in Oregon, showed good resistance (Schoth, 1952). Tome (1952) reported the development of the resistant variety "F. A. V. San Martin" in Argentina.

Because the several races of the nematode that attack alfalfa showed difference among varieties in their host preference, it appears that no variety has universal resistance to all races of *D. dipsaci*. Grundbacker (1962a) reported that the variety developed in Argentina showed only a low degree of resistance to the stem nematodes of California. A selection from Nemastan was susceptible to nematodes collected near Orland, California, but was resistant to those collected in other areas of California, Nevada, Utah, and Virginia (Smith, 1951). Allison (1956) found Lahontan to be only moderately resistant in North Carolina. Nemastan and Lahontan were resistant in Great Britain, while all other varieties tested were susceptible (Brown and Goodey, 1956). Lahontan showed good resistance in southern Sweden, but was not winter-hardy enough to survive the cold winters (Bingefors, 1962). In a field test for resistance in Nevada, Smith (1958) found that Lahontan and Nemastan exhibited good spring growth

with no injury, while Ladak, Vernal, and Ranger produced very little or no spring growth because of injury.

Symptoms of the disease

Jones and Smith (1953) noted that seedlings could be infected very early by penetration of the cotyledonary nodes. Swelling was observed with shortening of the internodes. Unifoliolate and trifoliolate leaves produced by the plant had short petioles which were swollen and distorted. Seedling plants seldom recovered from infection.

Injury to established plants was mostly to crown tissues, especially the young buds and bases of stems. The buds were thickened and seldom formed stems; later they darkened and dropped from the plant. Stems sometimes were infected a foot or so above the ground, with the development of swollen areas at the point of infection (Courtney, 1954).

The most obvious effect of light infection was the production of fewer stems, and in severe infection the obvious symptom was death of many plants. Infected plants could be easily spotted in early spring when nematode infection was severe. Under heavy attack plants made very little early growth. The alfalfa plants were difficult to kill. As some shoots were destroyed by the nematodes, other stems were produced by the plant. The ultimate effect was to thin out stands (Brown, 1957). Thorne (1932) reported that the parasite can destroy one-half to three-fourths of the alfalfa crop. Greatest losses occur after the crop has been growing for over two or three years. The greatest injury is usually to the first crop during the cool, moist months, with seemingly good recovery during dry periods.

The disease complex

Steiner (1954) reported soil-borne plant diseases were complex and

nematodes were quite frequently members of such groups. The nematode provided a port of entry for many plant parasitic microorganisms, both by direct and indirect means. The results of Theurer's investigation (1957) indicated that the stem nematode was one of the main causal agents of the disease complex which depleted alfalfa stands in two or three years' time in Washington County. Jones and Smith (1953) reported that infected buds usually rot off, initiating crown rot. Fusarium wilt and the stem nematode were prevalent together in alfalfa in Georgia (Weimer and Sell, 1948). Smith (1955) reported bacterial wilt was generally present in those areas where the stem nematode occurred. Smith felt that any alfalfa variety developed for resistance to the nematode should also carry resistance to bacterial wilt. The results of studies by Hawn (1963) indicated that the eelworm could be a direct transmitting agent of bacterial wilt. The mode of transmission was not demonstrated, but evidence indicated that the bacterium was carried on the outside of the body of the nematode.

Control

Control of the nematode appears to depend primarily upon the use of good agronomic practices. These include the use of the proper rotation program with the planting of non-host crops for several years and adequate weed control. The use of clean seed of adapted resistant varieties can be very important (Courtney, 1954).

Henderson and Williams (1955) found that aldrin and parathion dusts at rates of two and five pounds per acre, respectively, of active chemical gave good control of the nematode. Bergeson (1955) had good control of the nematode in greenhouse tests using three spray applications of diethyl 1-chlorovinyl phosphate. However, Taylor (1953) pointed out that chemical control usually causes serious injury to the plant and suggested

that resistant varieties give the best means of control.

MATERIALS AND METHODS

Selection of fields to be sampled

A predetermined number of alfalfa fields were selected for sampling in each county; field selection was based upon the total acreage of alfalfa grown and the size of the county. A total of 353 fields were sampled throughout the state. All counties in the state were sampled with the exception of Daggett, where the alfalfa acreage was small.

The fields to be sampled were picked by stopping at random along the main roads leading from communities located within the alfalfa production centers. No attempt was made to sample areas isolated by poor-access roads.

Types of samples collected

Three composited samples were collected from areas within the fields that displayed the most typical plant symptoms. The first sample consisted of stems from several plants. These stems were placed in vials containing the following FAA fixative solution: 50 parts 95 percent ethyl alcohol, 5 parts glacial acetic acid, 10 parts formalin, and 35 parts water.

The second sample consisted of the crown and top growth of a few plants. These plant parts were placed in a plastic bag and transported to the laboratory. The third sample was of soil from the root region of the plants collected in the second sample. The soil was placed in a plastic bag and taken to the laboratory.

Estimations were made of the amount of top growth, percent available

soil moisture, soil type, and whether the alfalfa crop appeared to be in the first year of production.

Extraction of nematodes from alfalfa stems

The nematodes were extracted from the crown and top growth samples by cutting sections from the stems, splitting the sections with a razor blade, and placing the stems in a Baermann separation apparatus. This apparatus consisted of a five-inch funnel with rubber tubing attached to the stem and the tubing closed by a clamp. A piece of window screen, four inches in diameter, was placed within the funnel top. On top of the screen was placed half of a milk filter pad which had been split by pulling the pad apart. The funnel was filled with water so that the level of the water was above the milk filter pad. The split stem sections were placed on the milk filter so that they were under water.

Nematodes would pass through the filter and settle within the clamped tubing. After a period of 24 hours, the nematodes were collected by opening the clamp and drawing off about 25 ml. of water.

To fix the nematodes, 25 ml. of boiling water were added to the nematode suspension. After allowing a half hour for the nematodes to settle to the bottom of the container, most of the water was decanted. The fixative was then poured over the nematodes. It consisted of 100 parts water, 20 parts 95 percent ethyl alcohol, 16 parts formalin, and 2 parts glacial acetic acid.

Extraction of nematodes from soil

The nematodes were collected from the soil samples with the use of soil screens. The soil sample was placed in a large pan, and the pan was filled with water. The water-soaked lumps were broken up by working

them between the fingers. As much soil as possible was worked into solution with the water.

The muddy solution was poured through a ten-mesh screen into another large pan. The coarse organic material remaining on the screen was discarded as was the soil that remained in the first pan. The remaining solution was slowly and carefully poured through a 60-mesh screen into another pan. The material that had settled out of solution was discarded. The collected solution was set aside to allow some of the foreign material to settle. The material collected on the 60-mesh screen was washed into a small steel pan and allowed to settle for one to two minutes.

Both of the collected solutions were poured slowly through a 250-mesh screen. Because the nematode was too large to pass through the 250-mesh screen, the solution that passed through was discarded. The material collected on the screen was washed into a small steel pan. The solution was poured into a beaker and allowed to stand for one-half hour. Most of the water was then decanted, leaving the collected nematodes in several ml. of water.

The nematode suspension was placed in a Baerman separation apparatus and handled as previously described.

Identification of *D. dipsaci*

The plant samples in FAA fixative were examined by placing sections of the stems in small dishes with water and teasing the stems apart with teasing needles while watching for the nematodes with a dissecting scope. Questionable nematodes were mounted on glass slides, examined, and identified with a compound microscope.

Extracts from the soil and plant samples were examined first with a dissecting scope to pick out the questionable nematodes which were then identified with a compound microscope.

RESULTS AND DISCUSSION

Areas of infestation

The result of each sample was recorded as either positive or negative. No attempt was made to estimate the nematode population in any area. It was felt that for a population study to have meaning it would require many more samples in each area and repeated sampling over a period of years. This study was intended to outline the general areas of *D. dipsaci* infestation.

It is probable that many years would be required to locate with detail all areas of infestation. There may only be an extremely small population in alfalfa in years that the weather does not favor the nematode. When the population is at such a low level, it may require the examination of an enormous amount of material to find even one nematode. However, this population could become extremely large in a year of favorable weather.

With these facts in mind, it should be pointed out that negative results do not mean that the nematode was not present in a sampled field. It means instead that the nematode was not found in the samples that were collected from that field. It is conceivable for a field to be suffering extreme damage from the nematode attack and for the sample results to be negative merely because poor samples were chosen.

The results of the survey are listed in Table 1. The data are listed alphabetically, first by county and then by community. Some communities located in one county are listed under an adjacent county. This is because the sample sites were located in the county as listed, and the

Table 1. Results of a state-wide survey for the stem nematode in Utah.

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture	Results	
					Soil	Plant
				%		
Beaver						
*Beaver	May 15, 1965	4	4	75		
Beaver	May 15, 1965	4	4	70		
Beaver	May 15, 1965	4	4	85		
Greenville	May 15, 1965	3	4	60		
Milford	May 15, 1965	3	3	75		
Milford	May 15, 1965	4	3	10		
Milford	May 15, 1965	3	4	75		
Milford	May 15, 1965	5	3	75		
Minersville	May 15, 1965	5	4	10		
Box Elder						
Bear River City	April 26, 1965	4	3	60		
Bear River City	April 26, 1965	6	5	55		
Bothwell	April 26, 1965	6	4	55		
Brigham City	April 26, 1965	5	4	60		
Brigham City	April 26, 1965	6	4	50		
Brigham City	April 26, 1965	7	4	75		
Collinston	April 26, 1965	3	4	65		
Corinne	April 26, 1965	4	4	60		
*Garland	April 26, 1965	5	3	70		
Honeyville	April 26, 1965	7	3	40		
Perry	April 26, 1965	4	6	65		
Riverside	April 26, 1965	3	2	65		
Tremonton	April 26, 1965	5	6	90		
Tremonton	April 26, 1965	6	4	85		
Tremonton	April 26, 1965	6	4	65		
Tremonton	April 26, 1965	3	2	40		
Tremonton	April 26, 1965	6	2	50		
Tremonton	April 26, 1965	6	4	50		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture	Results	
					Soil	Plant
				%		
Box Elder (cont.)						
Willard	April 27, 1965	5	4	70		
Willard	April 27, 1965	7	6	50		
Cache						
Amalga	May 10, 1965	7	6	55		
Benson	May 10, 1965	6	4	55		
Hyde Park	May 10, 1965	7	3	65		
Hyrum	May 10, 1965	4	3	55		
Logan	May 10, 1965	8	3	95		
Logan	May 22, 1965	8	5	15		
Mendon	May 22, 1965	10	3	70		
Newton	May 10, 1965	6	3	55		
Newton	May 10, 1965	4	4	60		
Nibley	May 10, 1965	7	4	60		
North Logan	May 10, 1965	6	3	70		
North Logan	May 10, 1965	6	3	65		
Richmond	May 10, 1965	4	4	55		
Richmond	May 10, 1965	5	4	50		
Richmond	May 10, 1965	4	3	65		
Richmond	May 10, 1965	4	4	65		
Smithfield	May 10, 1965	6	3	65		
Smithfield	May 10, 1965	6	4	60		
Smithfield	May 10, 1965	4	4	55		+
Smithfield	May 10, 1965	6	4	55		
Trenton	May 10, 1965	5	6	65		+
Trenton	May 10, 1965	6	6	60		
Wellsville	May 22, 1965	7	4	15		
Wellsville	May 22, 1965	7	3	90		
*Wellsville	May 22, 1965	10	4	20		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture	Results	
					Soil	Plant
				%		
Carbon						
Helper	May 1, 1965	4	4	45		
Price	May 1, 1965	5	4	15		
Price	May 1, 1965	3	3	25		
Wellington	May 1, 1965	4	4	50		
Wellington	May 1, 1965	4	4	65		
Davis						
Bountiful	May 11, 1965	10	3	100		
Centerville	May 11, 1965	10	6	95		
Clearfield	May 11, 1965	8	6	70		
*Clinton	May 4, 1965	5	4	20		
Farmington	May 11, 1965	12	3	85		
Farmington	May 11, 1965	7	3	85		
Hooper	May 4, 1965	10	4	10		
Kaysville	May 4, 1965	6	4	55		
Kaysville	May 4, 1965	8	3	40		
Kaysville	May 11, 1965	6	3	80		+
Kaysville	May 11, 1965	3	4	85		+
Layton	May 4, 1965	10	4	60		
Layton	May 4, 1965	11	4	40		
Layton	May 11, 1965	8	6	75	+	
Layton	May 11, 1965	7	6	90		+
Uintah	May 4, 1965	5	6	65		
Uintah	May 4, 1965	6	5	15		
West Bountiful	May 11, 1965	8	3	90		
Woods Cross	May 11, 1965	6	3	55		
Duchesne						
Altamont	May 28, 1965	8	6	80		
Altamont	May 28, 1965	5	6	10		+

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results	
					Soil	Plant
Duchesne (cont.)						
Arcadia	May 28, 1965	4	3	75		
*Bridgeland	May 28, 1965	11	4	10		
Bridgeland	May 29, 1965	12	4	20		
Bridgeland	May 29, 1965	12	4	50		
Duchesne	May 29, 1965	12	6	10		
Duchesne	May 29, 1965	6	4	10		
Ioka	May 29, 1965	9	4	40	+	+
Myton	May 29, 1965	8	4	30		
Myton	May 29, 1965	10	3	70	+	
Roosevelt	May 28, 1965	12	4	60		
Roosevelt	May 29, 1965	10	4	5		
Upalco	May 28, 1965	12	4	15		
*Upalco	May 28, 1965	7	4	10		
Emery						
Castle Dale	May 1, 1965	3	4	50		
Castle Dale	May 1, 1965	3	4	40	+	+
Emery	May 1, 1965	2	4	50		
Emery	May 1, 1965	3	4	20		
Ferron	May 1, 1965	3	4	10		+
Ferron	May 1, 1965	6	4	40		
Green River	May 1, 1965	6	4	25	+	+
Huntington	May 1, 1965	4	3	85		+
*Huntington	May 1, 1965	3	5	25	+	+
Garfield						
Cannonville	May 14, 1965	6	3	90	+	+
Escalante	May 14, 1965	16	6	65		
Escalante	May 14, 1965	6	4	70		+
Escalante	May 14, 1965	6	3	75	+	+
Escalante	May 14, 1965	5	4	75		
Henrieville	May 14, 1965	5	4	65		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results Soil	Results Plant
Garfield (cont.)						
Panguitch	May 14, 1965	1	4	85		
Panguitch	May 14, 1965	2	4	80		
Panguitch	May 14, 1965	2	6	75		
Panguitch	May 14, 1965	2	4	70		
Panguitch	May 14, 1965	1	4	60		
Tropic	May 14, 1965	5	4	65	+	+
Tropic	May 14, 1965	4	3	65		+
Grand						
Cisco	May 1, 1965	4	3	95		+
Green River	May 1, 1965	4	5	5		
Moab	May 1, 1965	8	5	10		
Moab	May 1, 1965	8	5	10		
Iron						
Cedar City	May 15, 1965	5	4	15		+
Cedar City	May 15, 1965	5	6	100	+	+
Cedar City	May 15, 1965	5	6	65		
*Beryl Junction	May 15, 1965	6	4	40		
Beryl Junction	May 15, 1965	5	3	75		
Beryl Junction	May 15, 1965	4	3	95		
Enoch	May 15, 1965	4	3	55		
Enoch	May 15, 1965	6	4	10		
Newcastle	May 15, 1965	10	6	60		
Paragonah	May 15, 1965	3	4	90		
Paragonah	May 15, 1965	3	4	90		
Parowan	May 15, 1965	3	4	80		
Parowan	May 15, 1965	4	4	80		
Juab						
Levan	May 13, 1965	4	4	95		
Levan	May 13, 1965	4	3	85		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results Soil	Results Plant
Juab (cont.)						
Levan	May 13, 1965	6	4	85		
Mona	May 13, 1965	6	4	45		
Mona	May 13, 1965	5	4	75		
Nephi	May 13, 1965	4	4	75		
Nephi	May 13, 1965	5	4	90		
Nephi	May 13, 1965	6	4	75		
Kane						
Glendale	May 14, 1965	7	3	100		+
Kanab	May 14, 1965	10	3	100		
Kanab	May 14, 1965	10	3	100		
Mt. Carmel	May 14, 1965	5	3	95		+
*Orderville	May 14, 1965	6	3	95		
Millard						
Delta	May 15, 1965	3	4	20		
Delta	May 15, 1965	10	3	60		
Delta	May 15, 1965	4	4	25		
Fillmore	May 15, 1965	5	3	70		
Fillmore	May 15, 1965	7	4	70		
Flowell	May 15, 1965	9	3	70		
Flowell	May 15, 1965	7	4	40		
Greenwood	May 15, 1965	10	4	70		
Hinckley	May 15, 1965	8	4	25		
Kanosh	May 15, 1965	7	4	65		
Kanosh	May 15, 1965	6	4	50		
Leamington	May 15, 1965	5	6	75		
Leamington	May 15, 1965	6	4	15		
Lynndyl	May 15, 1965	10	4	60		
Lynndyl	May 15, 1965	8	4	50		
Meadow	May 15, 1965	6	3	75		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results Soil	Results Plant
Morgan						
Morgan	May 28, 1965	8	3	70		
Morgan	May 11, 1965	9	4	50		
Peterson	May 11, 1965	7	3	40		
Porterville	May 11, 1965	7	3	60		
*Stoddard	May 11, 1965	9	4	50		
Piute						
Antimony	May 14, 1965	2	4	75		
Circleville	May 14, 1965	3	3	70		
Circleville	May 14, 1965	3	6	100		
Circleville	May 14, 1965	4	3	90		+
Greenwich	May 14, 1965	2	3	85		
Junction	May 14, 1965	3	4	85	+	+
Junction	May 14, 1965	4	6	90		
Kingston	May 14, 1965	3	4	100		+
Koosharem	May 14, 1965	2	4	75		
Marysvale	May 14, 1965	5	4	80		
Marysvale	May 14, 1965	4	4	40		
Marysvale	May 14, 1965	5	6	65		
Rich						
Garden City	June 4, 1965	7	4	10		
Laketown	June 4, 1965	8	4	40		
Laketown	June 4, 1965	4	4	35		
Pickleville	June 4, 1965	6	4	30		
Sage Junction	June 4, 1965	6	4	20		
Randolph	June 4, 1965	4	4	50		
Randolph	June 4, 1965	6	4	55		
Woodruff	June 4, 1965	4	3	85		
Woodruff	June 4, 1965	6	4	15		
Woodruff	June 4, 1965	5	4	65		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results Soil	Results Plant
Salt Lake						
Benion	May 11, 1965	6	3	85		+
Benion	May 11, 1965	7	3	90		+
Benion	May 11, 1965	7	3	80		
Bluffdale	May 11, 1965	7	4	65		
Bluffdale	May 11, 1965	7	4	65		
Draper	May 11, 1965	7	4	70		
Draper	May 11, 1965	8	3	75		+
Draper	May 11, 1965	6	3	70	+	+
Midvale	May 11, 1965	6	6	65		+
Midvale	May 11, 1965	7	6	70	+	+
*Riverton	May 11, 1965	7	3	65		
Riverton	May 11, 1965	8	6	75		+
*Sandy	May 11, 1965	5	6	70		
Sandy	May 11, 1965	9	6	75		
South Jordan	May 11, 1965	7	6	50	+	+
West Jordan	May 11, 1965	7	3	75	+	+
San Juan						
Blanding	May 1, 1965	3	4	90		
Blanding	May 2, 1965	4	4	60		
Blanding	May 11, 1965	4	4	90		+
Bluff	May 11, 1965	10	4	40		
Moab	May 11, 1965	4	4	5		
Sanpete						
Centerfield	April 30, 1965	4	4	40		+
Ephraim	April 30, 1965	3	3	50		+
Ephraim	April 30, 1965	3	3	60		
Ephraim	April 30, 1965	3	4	60		
Ephraim	April 30, 1965	4	4	60		
Fountain Green	April 30, 1965	3	3	65		
Fayette	May 13, 1965	5	3	100		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results Soil	Results Plant
Sanpete (cont.)						
Gunnison	April 30, 1965	3	3	95		+
Gunnison	April 30, 1965	4	3	30		
*Manti	April 30, 1965	3	3	65		
Manti	April 30, 1965	4	4	60		
Mayfield	April 30, 1965	3	3	60		
Mayfield	April 30, 1965	3	4	40		+
Moroni	April 30, 1965	3	3	60		
Moroni	April 30, 1965	2	3	50		+
Moroni	April 30, 1965	2	3	45		+
Mt. Pleasant	April 30, 1965	3	4	40		+
Mt. Pleasant	April 30, 1965	3	4	50		
Mt. Pleasant	April 30, 1965	2	4	50		
Mt. Pleasant	April 30, 1965	2	3	50		
Sterling	April 30, 1965	3	3	65		+
Sevier						
Aurora	May 13, 1965	5	3	75	+	+
Austin	May 13, 1965	4	3	100		
Elsinore	May 13, 1965	2	3	100		+
Elsinore	May 13, 1965	3	6	75		
Koosharem	May 14, 1965	2	3	100		
Monroe	May 13, 1965	4	4	80		
*Richfield	May 13, 1965	4	3	95	+	+
Richfield	May 13, 1965	4	3	90	+	+
Richfield	May 13, 1965	3	3	75	+	+
Salina	May 1, 1965	3	3	75		+
Salina	May 1, 1965	4	3	90		+
Salina	May 1, 1965	3	4	10	+	+
Salina	May 1, 1965	4	4	30		
Sigurd	May 13, 1965	5	3	75		
Sigurd	May 13, 1965	4	4	95		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results Soil	Results Plant
Sevier (cont.)						
Venice	May 13, 1965	4	3	95		
Venice	May 13, 1965	5	4	95	+	+
Summit						
Henefer	May 28, 1965	5	4	15		
Henefer	May 28, 1965	7	4	50		
Hoytsville	May 28, 1965	7	4	40		+
Kamas	May 28, 1965	3	3	70		
Peoa	May 28, 1965	3	3	65		
Wanship	May 28, 1965	7	4	60		
Tooele						
Bauer	May 22, 1965	9	5	10		
Grantsville	May 22, 1965	7	4	40		
Grantsville	May 22, 1965	7	3	80		
Grantsville	May 22, 1965	7	4	20		
Tooele	May 22, 1965	6	4	70		
Tooele	May 22, 1965	10	4	20		
Tooele	May 22, 1965	10	3	10		
Vernon	May 22, 1965	4	4	20	+	
*Vernon	May 22, 1965	4	4	75		
Uintah						
Jensen	May 29, 1965	14	4	10		
Jensen	May 29, 1965	12	4	10		
Jensen	May 29, 1965	10	3	90		
Leeton	May 29, 1965	12	4	15		
Leota	May 29, 1965	10	6	80		
Maeser	May 29, 1965	8	4	20	+	+
Maeser	May 29, 1965	10	6	20		
Naples	May 29, 1965	8	4	50		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results Soil	Results Plant
Uintah (cont.)						
Randlett	May 29, 1965	10	6	15		+
Randlett	May 29, 1965	9	4	15		
Roosevelt	May 29, 1965	10	4	40		
Vernal	May 29, 1965	8	4	15	+	
Vernal	May 29, 1965	10	3	75		+
Utah						
American Fork	May 13, 1965	5	4	40		
Benjamin	May 8, 1965	7	3	50		
Elberta	May 8, 1965	6	4	15		
Genola	May 8, 1965	6	4	90		
Goshen	May 8, 1965	5	5	90	+	+
Goshen	May 8, 1965	4	5	15		
Lake Shore	May 13, 1965	7	4	20		
Lehi	May 13, 1965	6	3	20	+	+
Lehi	May 13, 1965	6	3	15	+	+
*Lehi	May 13, 1965	7	3	15		
Lehi	May 13, 1965	6	4	40		
*Leland	May 8, 1965	7	5	95		
Lindon	May 13, 1965	10	3	50		
Mapleton	May 8, 1965	4	4	70		
Moark Junction	May 8, 1965	4	4	70		+
Orem	May 13, 1965	8	4	50		
Orem	May 13, 1965	10	4	60		
Payson	May 8, 1965	7	4	90		
Payson	May 8, 1965	8	5	90		
Payson	May 8, 1965	7	6	70		
Salem	May 8, 1965	6	4	80		
Santaquin	May 8, 1965	6	6	75		
Spanish Fork	May 8, 1965	10	4	60		
Springville	May 8, 1965	10	4	80		
Springville	May 8, 1965	10	4	85		+

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results Soil	Results Plant
Wasatch						
Heber	May 28, 1965	6	6	40		
Heber	May 28, 1965	5	4	70		
Heber	May 28, 1965	6	4	60		
Midway	May 28, 1965	8	4	20		
Midway	May 28, 1965	6	4	20		
Midway	May 28, 1965	6	4	40		
Washington						
Enterprise	May 15, 1965	3	4	55		
Enterprise	May 15, 1965	5	4	45		
Hurricane	March 29, 1965	5	5	30		
Hurricane	March 29, 1965	4	3	45		
Price Bench	March 29, 1965	3	5	25		+
Rockville	March 29, 1965	4	6	50	+	
Santa Clara	March 29, 1965	3	2	95		
Santa Clara	March 29, 1965	3	5	35		
Springdale	March 29, 1965	4	6	30		
St. George	March 29, 1965	4	3	60		
St. George	March 29, 1965	4	3	75		
Toquerville	March 29, 1965	5	4	70		
Verkin	March 29, 1965	5	4	70		
Washington	March 29, 1965	5	5	25		
Washington	March 29, 1965	5	4	25		
Washington Fields	March 29, 1965	8	5	25		
Washington Fields	March 29, 1965	4	5	80		
Washington Fields	March 29, 1965	4	5	25		
Wayne						
Bicknell	May 14, 1965	3	6	80		
Bicknell	May 14, 1965	2	6	75		
Bicknell	May 14, 1965	2	6	75		

Table 1. Continued

Location	Date of collection	Plant growth in inches	Soil texture**	Soil moisture %	Results Soil	Results Plant
Wayne (cont.)						
Bicknell	May 14, 1965	2	3	85		
Fremont	May 14, 1965	1	3	70		
Loa	May 14, 1965	1	3	70		
Loa	May 14, 1965	2	6	70		
Lyman	May 14, 1965	2	6	75		
Weber						
*Hooper	May 4, 1965	6	5	15		
Hooper	May 4, 1965	10	6	65		
Huntsville	May 4, 1965	4	4	35		
Huntsville	May 4, 1965	4	4	40		
Huntsville	May 4, 1965	5	4	50		
Huntsville	May 4, 1965	5	4	35		
Huntsville	May 4, 1965	5	4	40		
Ogden	May 4, 1965	9	3	40		
Ogden	May 4, 1965	6	3	50		
*Plain City	April 27, 1965	5	4	60		
Plain City	April 27, 1965	5	5	65		
Plain City	April 27, 1965	4	6	80		
Pleasant View	May 4, 1965	10	3	40		
Riverdale	May 4, 1965	7	4	25		
Roy	May 4, 1965	12	4	30		
Roy	May 4, 1965	8	3	50		
South Ogden	May 4, 1965	6	4	45		
South Ogden	May 4, 1965	8	6	60		
Uintah	May 4, 1965	6	6	60		
Warren	April 27, 1965	4	3	65		
Warren	April 27, 1965	7	4	70		

* Samples that appeared to be in first year of production

** Coded as follows: 1 = clay, 2 = clay loam, 3 = silty clay loam, 4 = loam, 5 = silty loam, 6 = sandy loam, and 7 = sand.

communities listed were the nearest communities to the sites. All data were found to be negative unless marked positive with a plus mark. The results of the two plant samples are composited in Table 1, with the results of the soil sample being recorded separately.

Of the 353 fields that were sampled, the nematode was found in 67 of the fields. It was found in 18 of the 28 counties that were sampled, as can be seen in Table 2.

Table 2. Results of survey for the stem nematode listed by county.

Positive counties		
Cache	Iron	Sevier
Davis	Kane	Summit
Duchesne	Piute	Tooele
Emery	Salt Lake	Uintah
Garfield	San Juan	Utah
Grand	Sanpete	Washington
Negative counties		
Beaver	Millard	Weber
Box Elder	Morgan	Wasatch
Carbon	Rich	
Juab	Wayne	
Not sampled		
Daggett		

The distribution of the eelworm appears to be throughout the state, with scattered counties relatively free from attack. The counties in which all samples were negative are all in close proximity to counties in which the nematode was discovered. It appears that no county is located in such a position to be safe from the spread of this parasite.

Although the eelworm was not found in any of the samples collected from Box Elder County, it is known to be present in the Tremonton-Bothwell area. This information was given to the author in a verbal communication with Dr. Gerald Griffin, of the Agriculture Research Service, Logan, Utah.

Relationship between infestation and soil moisture

The percent of available moisture in the soil was estimated at the time the samples were collected. Soil and plant samples were grouped separately into five equal, discrete categories based upon the soil moisture. Figure 1 shows this relationship for both soil and plant samples. The statistical analysis was carried out by the chi square tests for a 2 x t contingency table. Tables 3 and 4 show the results of the tests.

Table 3. Relationship between soil moisture and percent positive soil samples.

	Percent available soil moisture					
	0-20	21-40	41-60	61-80	81-100	Total
Positive	6	4	2	9	7	28
Negative	48	45	77	102	53	325
Total	54	49	79	111	60	353
Proportion positive	0.1111	0.0816	0.0253	0.0811	0.1167	0.0793

χ^2 equals 5.068 with 4 degrees of freedom. Not significant at .05 level.

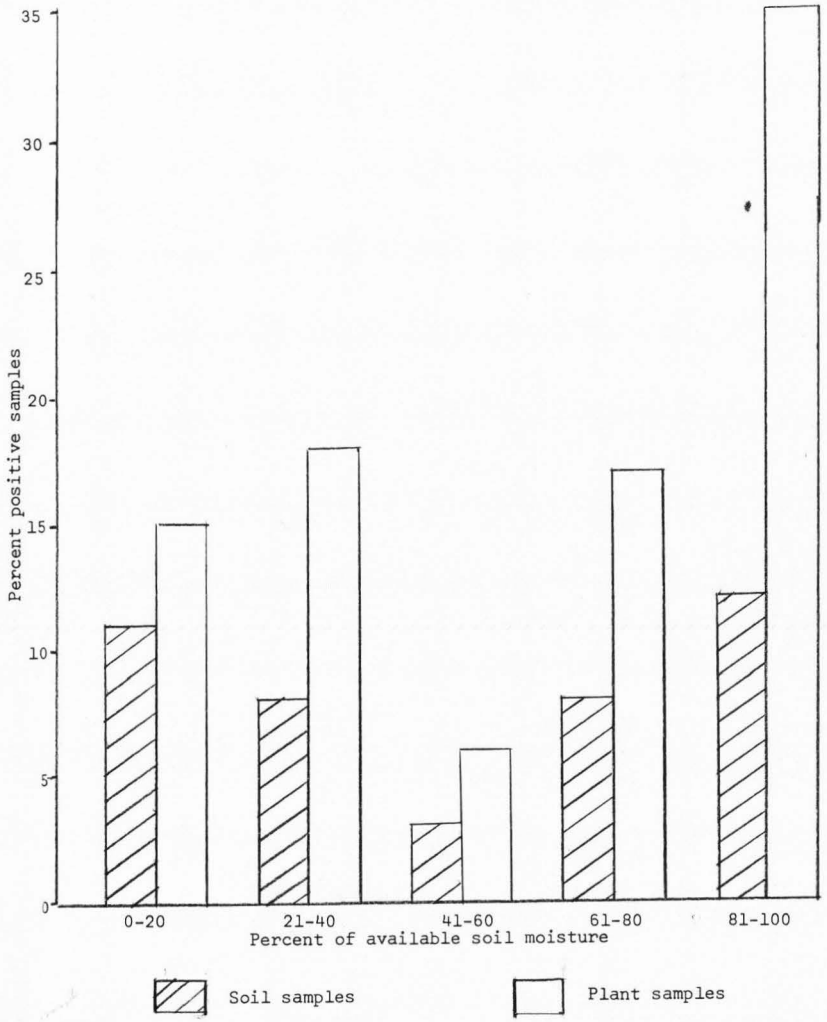

Figure 1. Relationship between soil moisture and percent positive samples.

Table 4a. Relationship between soil moisture and percent positive plant samples.

	Percent available soil moisture					
	0-20	21-40	41-60	61-80	81-100	Total
Positive	8	9	5	19	21	62
Negative	46	40	74	92	39	291
Total	54	49	79	111	60	353
Proportion positive	0.1481	0.1837	0.0633	0.1712	0.3500	0.1756

χ^2 equals 19.827 with 4 degrees of freedom. Significant at .01 level.

Table 4b. Relationship between soil moisture and percent positive plant samples with selected categories.

	Percent available soil moisture		
	0-80	81-100	Total
Positive	41	21	62
Negative	252	39	291
Total	293	60	353
Proportion positive	0.1399	0.3500	0.1756

χ^2 equals 15.189 with 1 degree of freedom. Significant at .01 level.

As can be seen from Table 3, no significant differences were found among the categories of soil moisture in the soil samples. This is contrary to what would be expected, since the literature does indicate that the presence of the nematode is correlated in the soil with higher soil moisture levels. The relatively small number of positive soil samples

probably accounts for this apparent discrepancy. Only 28 of the 353 soil samples tested were found to be positive. Apparently to have gained a more accurate estimate of the true population, many more soil samples would have to be taken.

Table 4 shows that there was a highly significant difference among the categories of soil moisture in the plant samples. As would be expected, the highest category of moisture was highly significant when compared with all remaining samples.

Relationship between infestation and soil texture

The soil texture of the sampled field was estimated at the time the samples were collected. Soil and plant samples were grouped separately into five categories based upon soil texture (Figure 2). Tables 5 and 6 give the statistical analysis.

Table 5. Relationship between soil texture and percent positive soil samples.

	Soil texture					
	Clay loam	Silty clay loam	Loam	Silty loam	Sandy loam	Total
Positive	0	11	10	2	5	28
Negative	4	92	168	19	42	326
Total	4	103	178	21	47	353
Proportion positive	0.0000	0.1068	0.0562	0.0952	0.1064	0.0793

χ^2 equals 3.271 with 4 degrees of freedom. Not significant at .05 level.

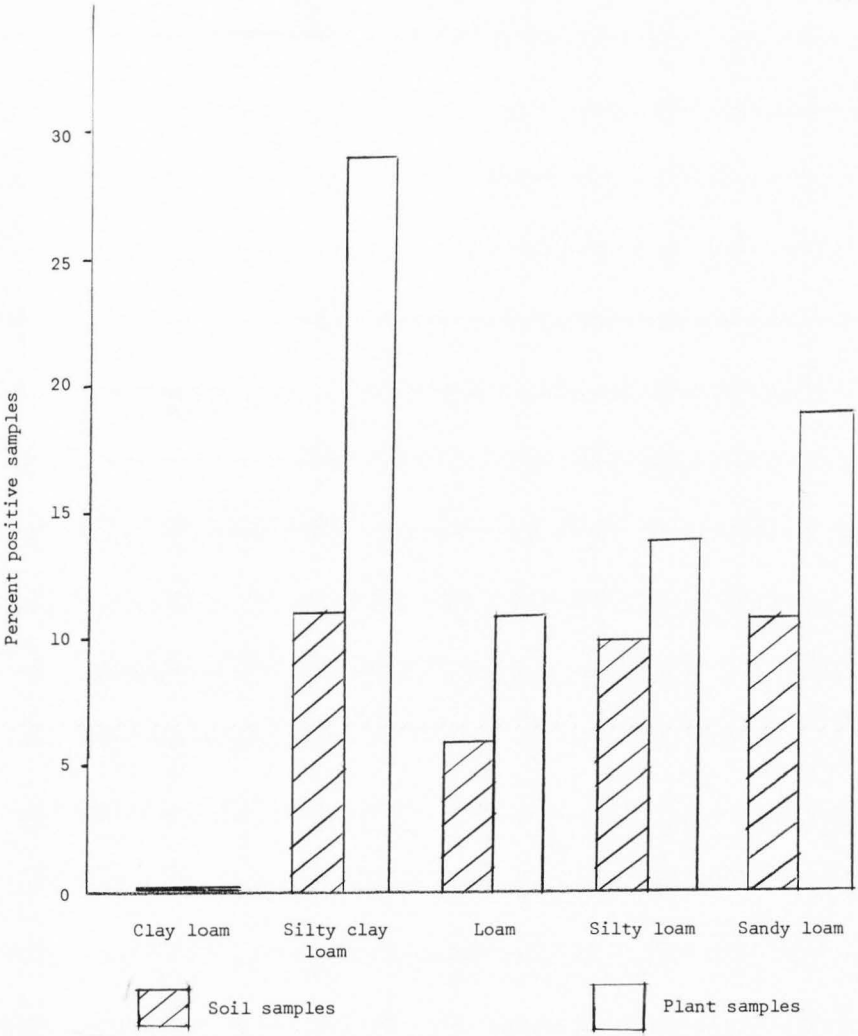

Figure 2. Relationship between soil texture and percent positive samples.

Table 6a. Relationship between soil texture and percent positive plant samples.

	Soil texture					
	Clay loam	Silty clay loam	Loam	Silty loam	Sandy loam	Total
Positive	0	30	20	3	9	62
Negative	4	73	158	18	38	291
Total	4	103	178	21	47	353
Proportion positive	0.0000	0.2913	0.1124	0.1429	0.1915	0.1756

χ^2 equals 15.557 with 4 degrees of freedom. Significant at .01 level.

Table 6b. Relationship between soil texture and percent positive plant samples with selected categories.

	Soil texture		
	Clay loam and silty clay loam	Loam, silty loam, and sandy loam	Total
Positive	30	32	62
Negative	77	214	291
Total	107	246	353
Proportion positive	0.2804	0.1495	0.1756

χ^2 equals 15.949 with 1 degree of freedom. Significant at .01 level.

Again the soil samples failed to show significant results among the soil textures. The plant samples, however, were highly significant. Because of the very small number of clay loam samples, this category was lumped with the silty clay loam category. This combined category was compared with the remaining samples and found to be highly significant.

Relationship between infestation and plant height

The amount of plant growth was estimated at the time the samples were collected. Soil and plant samples were grouped separately into six categories based upon plant height, as is shown in Figure 3. Tables 7 and 8 give the statistical analysis.

Table 7a. Relationship between plant height and percent positive soil samples.

	Plant height in inches						
	0-2	3-4	5-6	7-8	9-10	Over 10	Total
Positive	0	9	11	6	2	0	28
Negative	22	102	92	60	36	13	325
Total	22	111	103	66	38	13	353
Proportion positive	0.0000	0.0811	0.1068	0.0909	0.0526	0.0000	0.0793

χ^2 equals 4.588 with 5 degrees of freedom. Not significant at .05 level.

Table 7b. Relationship between plant height and percent positive soil samples with selected categories.

	Plant height in inches		
	0-2	Over 2	Total
Positive	0	28	28
Negative	22	303	325
Total	22	331	353
Proportion positive	0.0000	0.0846	0.0793

χ^2 equals 2.033 with 1 degree of freedom. Probability of greater χ^2 is between .2 and .1.

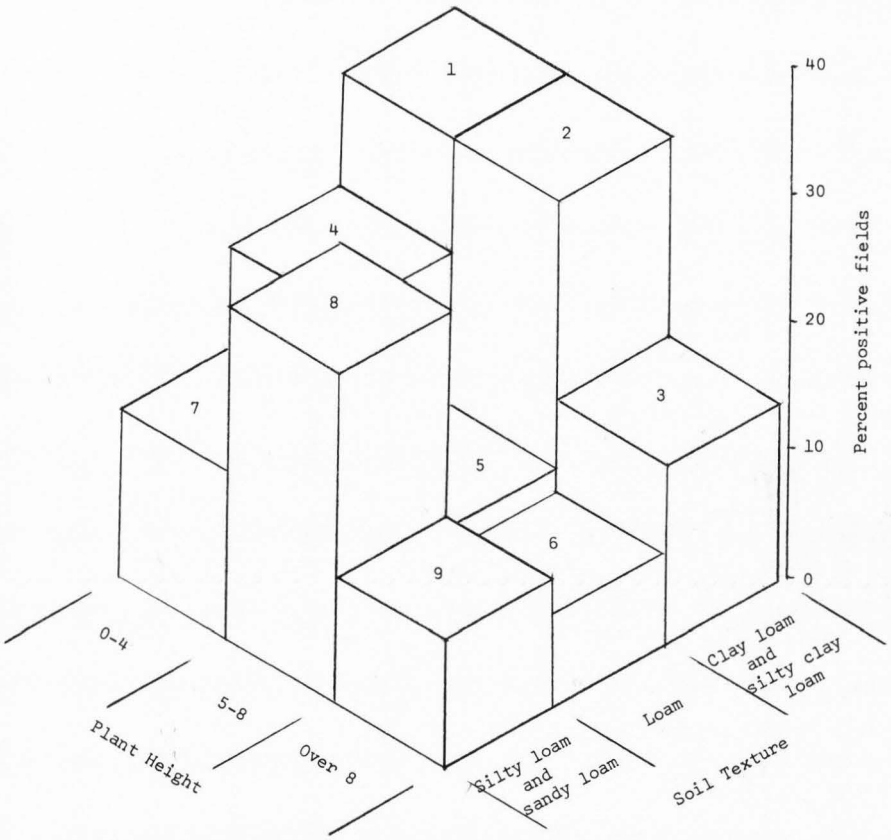

Figure 5. Relationship among plant height, soil texture, and percent positive fields.

This should be figure 3.

Table 8a. Relationship between plant height and percent positive plant samples.

	Plant height in inches						
	0-2	3-4	5-6	7-8	9-10	Over 10	Total
Positive	3	26	19	10	4	0	62
Negative	19	85	84	56	34	13	291
Total	22	111	103	66	38	13	353
Proportion positive	0.1364	0.2342	0.1845	0.1515	0.1053	0.0000	0.1756

χ^2 equals 7.273 with 5 degrees of freedom. Probability of greater χ^2 is between .3 and .2.

Table 8b. Relationship between plant height and percent positive plant samples with selected categories.

	Plant height in inches		
	3-4	All remaining categories	Total
Positive	26	36	62
Negative	85	206	291
Total	111	242	353
Proportion positive	0.2343	0.1488	0.1756

χ^2 equals 3.878 with 1 degree of freedom. Significant at .05 level.

The soil samples failed to show significant results among the plant heights, although indications are present to show that a larger sample size may have shown the zero- to two-inch category to be significantly less than the remaining categories. It would be expected for the soil nematode population to increase as the alfalfa crop grows during the spring months.

The plant samples were not significant; however, the analysis was continued and the three- to four-inch category was tested against the remaining samples and found to be significant at the .05 level. This result is subject to criticism, and conclusions or inference drawn from it should be used with this fact in mind. It does appear, however, that the nematode population reaches a peak per unit of plant material at the time the plants are three to four inches tall and decreases during the remaining active period of the parasite.

Relationship between infestation and plant age

All plant samples of fields in which the alfalfa crop appeared to be in the first year of production were categorized and compared with the remaining plant samples. The statistical analysis is found in Table 9. The results were not significant. The sample size of the one-year-old category is so small the results do not carry much meaning. The nematode population would be expected to increase during the first two or three years of plant growth.

Table 9. Relationship between age of plants and percent positive plant samples.

	Age of plants		
	One year	Over one year	Total
Positive	2	60	62
Negative	17	274	291
Total	19	334	353
Proportion positive	0.1053	0.1796	0.1756

χ^2 equals 0.687 with 1 degree of freedom. Not significant at .05 level.

Interaction among soil texture, soil moisture, plant height, and infestation

Tables 10, 11, and 12 as well as Figures 4, 5, and 6 display the interaction that appears to exist among soil texture, soil moisture, plant height, and presence of the nematode in a field. Apparently any one of these factors will tend to depress the presence of the nema when that factor is limiting. Table 10 and Figure 4 give evidence that the presence of the nematode is maximum when the available soil moisture is over 80 percent and the soil texture is heavier than loam. In Table 11 and Figure 5 indications are seen that maximum eelworm presence is dependent upon the plant being not over eight inches tall and the soil again being heavier than loam. Supporting evidence is presented in Table 12 and Figure 6. A greater percentage of the samples was found to be positive when the available soil moisture was over 80 percent and the plant height was eight inches or less.

Table 10a. Relationship among soil texture, soil moisture, and percent positive fields.

Soil texture	Clay loam and silty clay loam			Loam			Silty loam and sandy loam			
Soil moisture	0-40	41-80	81-100	0-40	41-80	81-100	0-40	41-80	81-100	Total
Positive	2	15	13	13	4	6	4	7	3	67
Negative	11	47	19	56	86	13	17	31	6	286
Total	13	62	32	69	90	19	21	38	9	353
Proportion positive	.154	.242	.406	.188	.044	.316	.191	.184	.333	.190

χ^2 equals 26.495 with 8 degrees of freedom. Significant at .01 level.

Table 10b. Relationship among soil texture, soil moisture, and percent positive fields with selected categories.

Soil texture / Soil moisture	Clay loam and silty clay loam 81-100	All remaining categories	Total
Positive	13	54	67
Negative	19	267	286
Total	32	321	353
Proportion positive	0.4063	0.1682	0.1898

χ^2 equals 10.715 with 1 degree of freedom. Significant at .01 level.

Table 11a. Relationship among plant height, soil texture, and percent positive fields.

Soil texture	Silty loam and sandy loam			Loam			Clay loam and silty clay loam			
Plant height	0-4	5-8	Over 8	0-4	5-8	Over 8	0-4	5-8	Over 8	Total
Positive	3	10	1	13	8	2	15	13	2	67
Negative	17	28	9	50	80	25	35	30	12	286
Total	20	38	10	63	88	27	50	43	14	353
Proportion positive	.150	.263	.100	.206	.091	.074	.300	.302	.143	.190

χ^2 equals 17.805 with 8 degrees of freedom. Significant at .05 level.

Table 11b. Relationship among plant height, soil texture, and percent positive fields with selected categories.

Soil texture / Plant height	Clay loam and silty clay loam 0-8	All remaining categories	Total
Positive	28	39	67
Negative	65	221	286
Total	93	260	353
Proportion positive	0.3011	0.1500	0.1898

χ^2 equals 10.170 with 1 degree of freedom. Significant at .01 level.

Table 12a. Relationship among soil moisture, plant height, and percent positive fields.

Plant height	0-4			5-8			Over 8			
Soil moisture	0-40	41-80	81-100	0-40	41-80	81-100	0-40	41-80	81-100	Total
Positive	9	10	12	8	14	9	2	2	1	67
Negative	19	65	18	45	80	13	20	19	7	286
Total	28	75	30	53	94	22	22	21	8	353
Proportion positive	.321	.133	.400	.151	.149	.409	.091	.095	.125	.190

χ^2 equals 24.577 with 8 degrees of freedom. Significant at .01 level.

Table 12b. Relationship among soil moisture, plant height, and percent positive fields with selected categories.

Plant height	0-8	All remaining	
Soil moisture	81-100	categories	Total
Positive	21	46	67
Negative	31	255	286
Total	52	301	353
Proportion positive	0.4038	0.1528	0.1898

χ^2 equals 18.153 with 1 degree of freedom. Significant at .01 level.

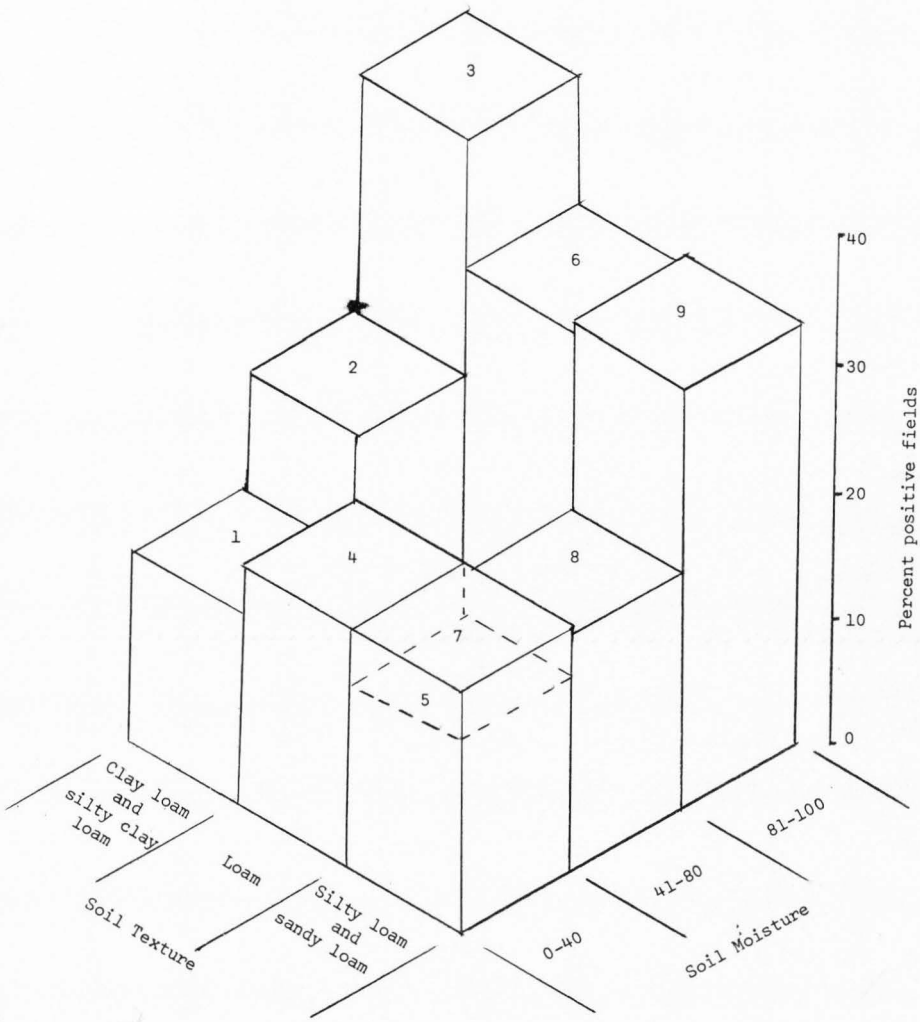

Figure 4. Relationship among soil texture, soil moisture, and percent positive fields.

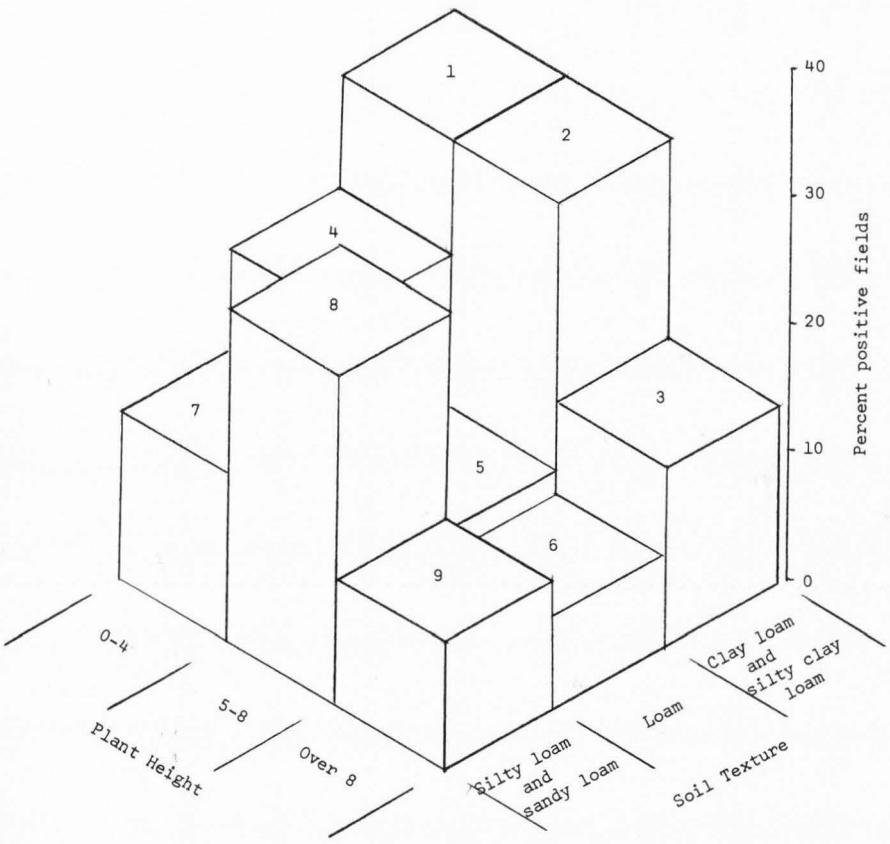

Figure 5. Relationship among plant height, soil texture, and percent positive fields.

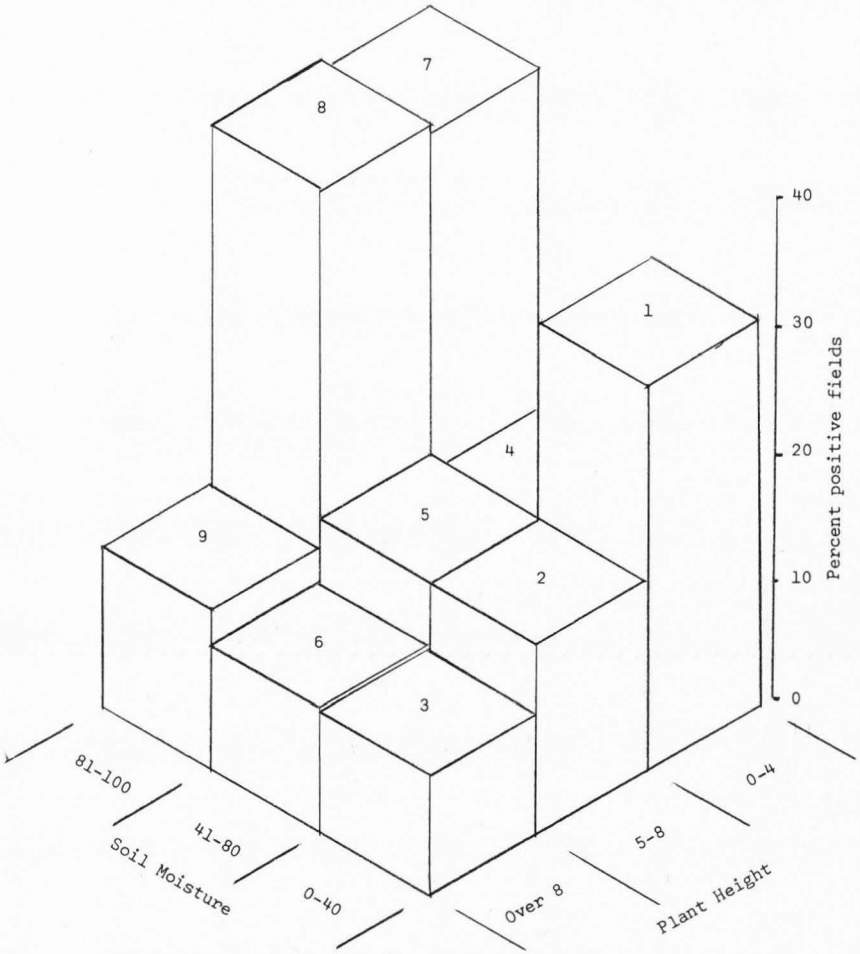

Figure 6. Relationship among soil moisture, plant height, and percent positive fields.

SUMMARY AND CONCLUSIONS

Of the 28 counties in the state surveyed for the stem nematode of alfalfa, 18 were found to be harboring the parasite. All of the negative counties were located in close proximity with one or more of the positive counties. The distribution of the nematode appeared to be throughout the state with only scattered areas relatively free. It would appear that no county is secure from the spread of this parasite.

A highly significant interaction was found to exist among soil texture, soil moisture, plant height, and presence of the nematode in alfalfa fields. The presence of the nematode was found to be at a maximum when the available soil moisture was over 80 percent, the soil texture heavier than loam, and the plant height eight inches or less. These findings would tend to indicate that the conditions for maximum nematode population are very near the conditions required for maximum plant growth, and a vigorous growing crop in the spring months would have to compete on a very competitive basis with the nematode if they were present in the field.

It is probable that the future will see greater stress put on the breeding and use of adapted, resistant varieties. In many of the areas in which the eelworm was found, resistant varieties are not being used at this time. It would be safe to speculate that forage and seed yields could be increased considerably with the use of resistant varieties.

LITERATURE CITED

Allison, J. L. 1956. Stem nematode of perennial forage legumes. (Abs.) Phytopathology 46:6.

Anderson, R. V. and H. M. Darling. 1962. Feeding of *Ditylenchus destructor* on fungi. (Abs.) Phytopathology 52(8):722.

Barker, K. R. and J. N. Sasser. 1959. Biology and control of the stem nematode, *Ditylenchus dipsaci*. Phytopathology 49:664-670.

Bergeson, G. B. 1955. The use of systemic phosphates for control of *Ditylenchus dipsaci* on alfalfa and daffodils. Plant Disease Reptr. 39:705-709.

Bingefors, S. 1960. Stem nematodes (*Ditylenchus dipsaci*) in clovers and lucerne and their control by breeding for resistance. Internatl. Grassland Cong. Proc. 8:78-81.

Bingefors, S. 1962. On resistance to stem nematode in lucerne. (Abs.) Nematologica 7(1):17.

Bird, Alan F. 1961. The ultrastructure and histochemistry of a nematode-induced giant cell. Jour. Biophys. and Biochem. Cytol. 11(3):701-715.

Bovien, P. 1955. Host specificity and resistance in plant nematodes. Ann. Appl. Biol. 42:382-390.

Brown, E. B. 1957. Lucerne stem eelworm (*Ditylenchus dipsaci*) in Great Britain. Nematologica 2:369S-375S.

_____ and J. B. Goodey. 1956. Observations on a race of stem eelworm attacking lucerne. Plant Pathol. 5:28-29.

Cobb, G. S., G. Steiner, and F. S. Blanton. 1934. Observations on the significance of weeds as carriers of the bulb or stem nematode in narcissus plantings. Plant Disease Reptr. 18(10):127-129.

Courtney, W. D. 1954. The bulb and stem nematode, *Ditylenchus dipsaci* (Kuhn, 1957) Filipjev 1936 infecting alfalfa, *Medicago sativa* L., in the Pacific Northwest. Paper presented for Alfalfa Seed Growers at Yakima, Washington, by State College of Washington at Yakima, Washington.

Fielding, M. J. 1951. Observations on the length of dormancy in certain plant-infecting nematodes. Proc. Helminth. Soc. Wash. 18(2):110-112.

Goodey, T. 1929. The stem eelworm, *Tylenchus dipsaci* (Kuhn): Observations on its attack on potatoes and mangolds with a host list of plants parasitized by it. Jour. Helminth. 7:183-200.

Grundbacker, F. J. 1961. Testing alfalfa seedlings for resistance to the stem nematode *Ditylenchus dipsaci* (Kuhn) Filipjev. Helminth. Soc. Wash. Proc. 29(2):152-158.

_____ and E. H. Stanford. 1962a. Genetic factors conditioning resistance in alfalfa to stem nematode (*Ditylenchus dipsaci*). Crop Sci. 2(3):211-217.

Hawn, E. J. 1963. Transmission of bacterial wilt of alfalfa by *Ditylenchus dipsaci* (Kuhn). Nematologica 9(1):65-68.

Henderson, R. G. and A. S. Williams. 1955. Effect of soil insecticide treatments on alfalfa stem nematode. (Abs.) Phytopathology 45:348.

Jones, F. R. and D. F. Smith. 1953. Sources of healthier alfalfa. Plant Diseases, Yearbook of Agr., U. S. Gov. Printing Office, Wash., D. C. p. 236-237.

Krusberg, L. R. 1960. Hydrolytic and respiratory enzymes of species of *Ditylenchus* and *Pratylenchus*. Phytopathology 50:9-22.

_____. 1961. Studies on the culturing and parasitism of plant parasitic nematodes, in particular *Ditylenchus dipsaci* and *Aphelenchoides ritzemabosi* on alfalfa tissues. Nematologica 6:181-200.

_____. 1963. Effect of galling by *Ditylenchus dipsaci* on pectins in alfalfa. Nematologica 9:341-346.

_____ and M. L. Blickenstoff. 1964. Influence of plant growth regulating substances on reproduction of *Ditylenchus dipsaci*, *Pratylenchus penetrans* and *Pratylenchus zeae* on alfalfa tissue cultures. Nematologica 10:145-150.

Linford, M. B. 1937. Notes on the feeding of *Ditylenchus dipsaci*, Nematoda: Tylenchidae. Proc. Helminth. Soc. Wash. 4(1)46-47.

McAllister, D. R. 1959. Alfalfa stem nematodes reduce hay yields. Farm and Home Sci. (Utah Sta.) 20(3):68-69.

Owens, R. G. and Helen M. Novotny. 1960. Physiological and biochemical studies on nematode galls. (Abs.) Phytopathology 50:650.

Palo, A. V. 1962. Translocation and development of stem eelworm, *Ditylenchus dipsaci* (Kuhn) in Lucerne, *Medicago sativa* L. Nematologica 7:122-132.

Schoth, J. A. 1952. Talent alfalfa. Oregon Agr. Exp. Sta. Bul. 511.

Seinhorst, J. W. 1956. Populations studies on stem eelworms (*Ditylenchus dipsaci*). Nematologica 1:159-164.

_____. 1957. Some aspects of the biology and ecology of stem eelworms. Nematologica 2:355S-361S.

Smith, E. H. 1923. The stem nematode of alfalfa in California. Calif. State Dept. of Agr. Monthly Bul. 3-4.

Smith, O. F. 1951. Biological races of *Ditylenchus dipsaci* on alfalfa. Phytopathology 41:189-190.

_____. 1955. Breeding alfalfa for resistance to bacterial wilt and the stem nematode. Nevada Univ. Agr. Exp. Sta. Bul. 188. 15 p.

_____. 1958. Reactions of some alfalfa varieties to the stem nematode. Phytopathology 48:107.

_____ and M. W. Allen. 1943. The bulb or stem nematode on alfalfa, sweet clover, and white clover. Phytopathology 33:525-526.

Standford, E. H. 1951. Tetrasomic inheritance in alfalfa. Agron. Jour. 43:22-225.

Steiner, G. 1954. Changes in basic concept in plant nematology. Agr. Chemistry Review 2:31-32.

Taylor, A. L. 1953. More about the control of nematodes. Plant Diseases Yearbook of Agr., U. S. Gov. Printing Office, Wash., D. C. p. 133-134.

Theurer, J. C. 1957. A study of the root rot-nematode complex and the comparative yield of 17 varieties of alfalfa in Washington County, Utah. Unpublished M.S. thesis. Utah State University Library, Logan.

Thorne, G. 1932. Alfalfa stem nematode causing severe damage in some western areas. Yearbook of Agr., U. S. Gov. Printing Office, Wash., D. C. p. 99-101.

_____. 1961. Principles of nematology. McGraw-Hill Book Company, Inc., New York, New York. p. 66-158.

Tome, G. A. 1952. Alfalfa breeding progress in Argentina. Sixth International Grassland Congress Proc. 1:273-276.

Tracey, M. V. 1958. Cellulase and chitinase in plant nematodes. Nematologica 3:179-183.

Wallace, H. R. 1961. The orientation of *Ditylenchus dipsaci* to physical stimuli. Nematologica 6:222-236.

_____. 1962. Observations on the behavior of *Ditylenchus dipsaci* in soil. Nematologica 7:91-101.

Weimer, J. L. and O. E. Sell. 1948. Stem nematode and *Fusarium* wilt of alfalfa observed for the first time in Georgia. Plant Disease Reptr. 32:350-351.

Wood, R. K. S. 1960. Pectic and cellulolytic enzymes in plant diseases. Ann. Rev. Plant Physiol. II p. 299-322.

Yuksel, Hansan S. 1960. Observations on the life cycle of *Ditylenchus dipsaci* on onion seedlings. Nematologica 5:289-296.