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Effects of cultural practices on early vigor and Fusarium infection in Asparagus officinalis, L. /

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EFFECTS OF CULTURAL PRACTICES ON EARLY VIGOR AND *FUSARIUM* INFECTION IN *ASPARAGUS OFFICINALIS* ,L.

A Thesis Presented

By

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ABSTRACT

The effects of soil fumigation, varieties, planting methods and cultural practices on early vigor and *Fusarium* infection in *Asparagus officinalis*, L. were studied in South Deerfield, Massachusetts in 1978 and 1979. Soil fumigation with Vorlex (1,3-dichloropropene, 1,2-dichloropropane, C-3-hydrocarbons and 20% methylisothiocyanate) at 35 gallons/acre (363 l/ha) improved early vigor of direct-seeded, transplanted and crown-planted asparagus for two years. Direct-seeded asparagus exhibited vigor comparable to beds established from crowns and transplants in fumigated land and greater vigor than all three planting methods in non-fumigated land. *Fusarium* infection on crowns and stalks was not affected by soil fumigation with Vorlex, bed-establishment techniques, cultural practices, fertility and benomyl soil drenches. Asparagus, direct-seeded in W-shaped trenches under light cultivation and standard fertilizer practices exhibited plant vigor equal to or greater than all other cultural practices investigated. Fresh and dry crown weight data was an unsatisfactory parameter for determining plant vigor.

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C H A P T E R I

INTRODUCTION

Asparagus has been an important crop in the Pioneer Valley for 40 to 50 years. Hadley, Massachusetts was once considered the "asparagus capital" of the Eastern United States. The importance of asparagus on the lives of the area's residents is evidenced by the fact that until recently, several towns in the valley postponed the beginning of the school day in the spring until 9:00 A.M. so that children could harvest asparagus in the early morning hours.

Asparagus is one of the first native crops of the season providing early income. Roadside marketing has become a very important aspect of New England farming and asparagus is the first native produce offered on roadside stands. It is also a big attraction for farmer's markets. The asparagus harvest provides employment for the local summer labor force and signals the beginning of the growing season.

Commercial production of asparagus has declined in Massachusetts over the last fifteen years. Aside from economic problems encountered by growers in this region, the primary reason for this decline in production is a fungus disease afflicing asparagus (4,7,28,29). This disease is commonly known as asparagus crown rot or asparagus decline. The causal organisms are *Fusarium oxysporum*, *F. culmorum* and *F. monoliforme*. This fungus has also been identified in New Jersey, Michigan, California, Australia and the Netherlands (4,7,12,19,21, 47,48).

Fusarium spp. is a soil born fungus found in most soils. The first evidence of *Fusarium* infection in asparagus is indicated by yellowing of ferns in mid-season, missing plants in the field and decreased yields. This fungus has been shown to cause the death of small roots, cortical decay in crowns and the eventual death of the plant (47,48).

Asparagus crown rot may be related to poor cultural practices. Von der Brook and Von Ashe (49) reported that field conditions such as high soil moisture, weed competition, low pH and low fertility were limiting factors in early growth of asparagus. These factors combined with *Fusarium* crown rot to produce an asparagus decline syndrome, the slow decline and eventual death of the plant.

Asparagus is a high value crop and very profitable when established beds are maintained for eight to ten years. Good cultural practices are required to maintain high yields. For a perennial crop such as asparagus, neglect for one year will result in poor yields the following year. Most growers in Massachusetts have been using the same cultural practices for years and many tend to neglect their fields after harvest by not performing proper maintenance such as fertilizing, liming and weed control.

This study was undertaken to determine the effect of varieties and cultural practices such as planting methods, fertilizers and fungicides on early vigor and *Fusarium* crown rot incidence in *Asparagus officinalis*, L.. Asparagus plants with improved early vigor may exhibit lower levels of *Fusarium* infection thereby significantly delaying the onset of asparagus decline.

CHAPTER II

LITERATURE REVIEW

The symptoms of *Fusarium* crown rot have been described by Manning as follows; "Plant populations in replanted fields or new fields decline rapidly, often by the end of the first season. Remaining plants either lack vigor or are too few in number to make maintenance of the planting economical. *Fusarium oxysporum* and *F. monoliforme* ... have been shown to cause cortical decay of stem bases and destroy small roots resulting in premature yellowing and death of ferns which results in the decline of the perennial crown" (4,29).

Several species of *Fusarium* fungi have been associated with asparagus crown rot. *Fusarium monoliforme* (W.G. Smith) Sacc.,and *F. culmorum* (W.G. Smith) Sacc. (Weise, 1939) cause brown lesions on stems visible at soil level. These brown lesions later become red-orange and the stem above the lesions turns yellow and dies (45). *Fusarium oxysporum* (Schlecht emend. Snyder and Hansen f. sp. asparagi Cohen by Cohen and Heald (1941)) causes similar oval-shaped brown lesions on stem bases and fleshy roots. A plant with these lesions often shows severe decline (47).

Gehlker and Scholl (20) associated *Fusarium* infection with high soil moisture content, high clay content and poor drainage. They found relatively high amounts of sulfides in the subsoil of *Fusarium* infected soils. Soils with a relatively low percentage of humus, magnesium deficient soils and soils with a pH of 5.4 or below were reported to have high rates of Fusarium infection (20).

Fusarium infection on asparagus has been associated with poor drainage and high water tables by Von der Brook and Von Ashe, (49). They also stated that fields of predominantly male plants showed less Fusarium infection than mixed-sex stands.

Transmission of Fusarium spp. can occur in several ways. Fungal spread through the soil was reported by Von Bakel and Krom-Kerstens (46,47). They also reported evidence of airborn transmission of fungal spores, above ground infection being related to wind direction. Eighty-five percent of Fusarium stem infections were found on those portions of stems facing the prevailing wind. Wind dispersal of fungal spores was also shown by open petri-dish experiments (47).

Transmission of Fusarium by insects was investigated by Von-Bakel and Von Bethe (47). They reported a higher incidence of Fusarium infection in asparagus plants with a relatively high population of asparagus miner fly (Ophiomyzea simplex (Loew) Spencer).

Rhode and Jenkins (36) showed that the root nematode Trichodorus christei (Allen 1957) fed on asparagus. The control of this nematode in tomatoes by Carbofuran soil treatments resulted in a significant reduction of Fusarium wilt (F. oxysporum) in tomatoes (23). Jones et al (24) speculated that nematode control might reduce Fusarium infection in other crops.

Evidence of Fusarium transmission through seeds and crowns was found by Manning (29) and Wiebe (52). Wiebe reported that Spergon treated seeds had a higher survival rate than untreated seeds when planted in *Fusarium* infested soil.

Control of soil born *Fusarium spp.* has been investigated by several researchers. Jones et al (24) showed that D, D-Mencs (Vorlex) (1, 3-dichloropropene, 1, 2-dichloropropane,C-3-hydrocarbons and 20% methylisothiocyanate) a soil fumigant, applied at 30 gallons/ acre in spring before planting controlled *Fusarium spp.* in tomato culture.

Manning and Vardaro (29) report that a combination of soil fumigation with Vorlex and preplant crown soaks with benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate) produced increased shoot and root growth of asparagus planted in soil known to be infested with *Fusarium*. Average fresh weights of ferns and crowns were significantly greater in treated plots, as were the number of ferns per crown.

Benomyl, as a soil drench, was reported by Sonada (39) and Staunton (41) to control *Fusarium* in tomatoes. Morras and Servazzi (32) reported control of *Fusarium* in asparagus with soil drenches using benomyl. An increase in spears per plant from benomyl treatment was reported by Kalchschmid and Krouse (25).

Yang (53) showed that ten to fifty parts per million of benomyl promoted multiple, vigorous shoot development in asparagus seedlings. Yang suggested that benomyl may be beneficial in promoting shoot development, therefore increasing yields.

Treatment of old asparagus soils with Di-Trapex at 77 cc/m^2 resulted in asparagus with less *Fusarium* infection and more vigorous growth than check plots (14).

Recommended cultural practices for asparagus have remained unchanged in Massachusetts for many years. Asparagus fields have been established by planting one-year old crowns in trenches 4 to 5 feet (1.2 -1.5 m) apart. The crowns are set 6-8 inches (10-15 cm) deep at one-foot (30 cm) intervals. These trenches are gradually filled in during the first growing season. Recommended weed control for new plantings is light cultivation. Harvesting begins the second year after bed establishment (2).

The onset of asparagus decline throughout the United States combined with the desire to increase yields and decrease the cost of establishing new asparagus plantings has resulted in the development of new techniques for establishing and growing asparagus. Field establishment of asparagus by direct-seeding and transplanting versus crown-establishment has been investigated in California, New Jersey and Australia (1,3,13,19).

Benson et al (3) in California reported greater spear yields in direct-seeded asparagus than in crown culture. After seven years yields did not differ significantly under both methods of planting. The cost of establishing a direct-seeded field of asparagus is much less than establishing asparagus from crowns (Garrison, 19). Currently (Spring 1980) the cost of one-year old crowns of c.v. Rutgers Beacon is $60/1,000. At a planting density of 8,000 - 10,000 plants per acre the cost of materials alone for planting is $480 - $600/acre. Asparagus seeded at two pounds per acre would cost about $100/acre to seed.

Digging and replanting causes injury to crowns and possible points for Fusarium infection (34). Direct-seeding eliminates the extra labor of digging and replanting crowns and also reduces or eliminates stress and injury to the plants.

Asparagus seed is produced by open-pollination between dioecious plants, resulting in a high degree of variability in the seed of any particular variety (17). Direct seeding offers the advantage of higher plant populations per acre. Through natural selection, weaker plants die out leaving more vigorous plants, possibly more tolerant of Fusarium infection (19).

Garrison (19) has developed a method of direct-seeding and transplanting asparagus using a W-shaped furrow. The shape of these furrows prevents soil from washing down onto seeds which could interfere with germination and provides adequate drainage after heavy rains.

Cultivation in any crop only serves to control weeds and has no beneficial effect on crop growth (5,22,23,30). Cultivation may in fact be detrimental to some crops, especially perennials such as asparagus by injuring crowns and emerging spears. These injuries can serve as points of infection for Fusarium (29,30,35). Zero-tillage cultural systems have been evaluated in several crops in regard to plant growth and soil properties. Jones et al (22) reported beneficial effects of no-till systems in corn. Plots using conventional tillage and no-tillage each with and without surface mulches were studied. It was found that the no-till plots with mulches had the greatest corn yields and soil moisture content. Jones suggested that increased yields were due to increased soil moisture and decreased weed competition. Blevins et al (5) showed that zero-tillage in corn produced higher volumetric moisture content in the soil during the growing season. It was suggested that reduced water evaporation under a no-till system increased soil water, which benefited the crop during short drought periods.

Meggit (30) and his co-workers conducted experiments in no-till asparagus culture using monuron (3-(p-chlorophenyl)-1, 1-di-methylurea) with and without cultivation. They reported increased yields with the use of only monuron to control weeds. There was no advantage in production from cultivation.

A five year study on zero-tillage in asparagus was conducted by Putnam in Michigan (34,35). His results showed that yields of asparagus produced from crowns increased 27% in zero-tillage as compared to conventional tillage (discing). A combination of paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) with either simazine (2-chloro-4, 6-bis(ethylamino)-s-triazine) or monuron produced adequate weed control. Brush was returned to the soil by rotary chopping in the fall. Putnam attributed the increased yields in zero-tillage to a reduction in damage to crowns and emerging spears from discing, reduced weed competition, moderation of soil temperature fluctuations and increased soil moisture.

It is common practice in Massachusetts to disc asparagus fields once in spring before harvest and once after harvest to control weeds and once again after the first hard frost to incorporate dead stalks. Putnam's work (34,35) suggested that these three cultivations may injure crowns and adversely affect future yields. With the use of herbicides this crown damage could be eliminated.

Soil moisture studies in asparagus by Cannell and Takatori (11) showed a relationship between soil moisture levels and spear yields. They reported that under three irrigation levels controlled at 0.4, 0.8 and 2 to 5 bar soil suction, significantly greater yields were obtained in the 0.8 and 2 to 5 bar treatments as compared to the 0.4 bar level. The low yields in the wet treatments were attributed to low soil temperatures during harvest.

Current fertilizer recommendations for asparagus are derived from fertilizer studies on established asparagus plantings. Asparagus responds to increasing levels of nitrogen and potassium with increased yields (9,10,50). However, asparagus does not respond consistently to applications of phosphorus (10,51). No fertilizer requirements have been set for asparagus established by direct-seeding or transplanting. Garrison (19) suggests that a starter fertilizer may be beneficial for transplants.

The fertilizer recommendation for asparagus in Massachusetts is a broadcast application of 1,000 pounds of 10-10-10 analysis (N, P_2O_5, K_2O) fertilizer per acre, once a year (31). Manure is also highly recommended for asparagus (31).

Brown and Carolus (9) have evaluated fertilizer practices in Michigan in relation to actual nutrient requirements of asparagus. Results showed that the asparagus plant was not using all of the fertilizer applied. They suggested that current fertilizer rates could be reduced by 50% and not affect yields.

Several herbicides are labelled for use on established asparagus in Massachusetts, diuron (Karmex), simazine (Princep), dalapon (Dowpon) and 2,4-D. No herbicide is registered for use on newly planted crowns, transplants or direct-seeded asparagus. The only method of weed control presently recommended in newly planted asparagus is cultivation (31).

Metribuzin (Sencor) is a newly registered herbicide for the control of broadleaf and some grassy weeds in asparagus (8,19). The recommended rate of application is 1.12 kg a.i./ha (1 lb. a.i./acre) in established fields. Garrison (19) reported adequate weed control in direct-seeded asparagus with metribuzin at reduced rates (137 g a.i./ha, 1/8 lb. a.i./acre) without injury to young asparagus plants.

Several years growth are required before yield data can be collected and analyzed when conducting research on asparagus culture or breeding. For this reason researchers are limited in the scope of their studies. There is need for finding an appropriate variable which can give a reliable indication of the asparagus plant's early vigor and future yields, thus affording the investigator a means for early evaluation of treatment effects.

Young (54) reported a highly significant correlation between number of stalks (ferns) per plant and number of spears produced in the following season. A high correlation between brush vigor and early spear yields to total yields has been reported by Ellison et al (15). Ellison and Schermerhorn (17) have shown that asparagus plants having early emerging spears produce higher yields than plants whose spears emerge later.

The vigor of asparagus seedlings as an indication of survival of plants in the field has been reported by Scheer and Ellison (38). The survival rate of low vigor seedlings was significantly less than the survival rate of medium and high vigor seedlings. Ellison and Scheer (16) have shown that yields can be directly correlated to brush vigor in the preceeding year.

The ability to correlate brush vigor, measured as fresh and dry weights of stalks (ferns) to future yields provides a useful parameter to compare treatments in asparagus research in plantings not yet producing marketable spears.

CHAPTER III

MATERIALS AND METHODS

Five experiments were designed to investigate the effects of cultural practices on early vigor and Fusarium infection in Asparagus officinalis, L..

Experiment I - Bed Establishment Study

The objective of this study was the comparison of three methods for establishing asparagus plantings in fumigated and non-fumigated land. This experiment was conducted at the University of Massachusetts research farm, South Deerfield, Massachusetts on a Hadley fine sandy loam. Treatments were conducted on fumigated and non-fumigated land. Soil fumigation was performed in October 1977 with Vorlex (chlorinated C-3-hydrocarbons, (1,2-dichloropropane and 1,3 dichloropropene) and methyl isothiocyanate) applied at 363 l/ha (35 gallons/acre) using an injection applicator.

During soil preparation in May 1978, 112.13 kg/ha of N, 49.3 kg/ha, P and 91.9 kg/ha, K (1,000 lbs. 10-10-10 N, P_2O_5, K_2O/A) were applied and disced into fumigated and non-fumigated land. Soil pH was maintained at 6.5 in all treatments by application of limestone at 2242 kg/ha (2,000 lbs./acre). In May 1979 1121.4 kg/ha of 10-10-10 (N, P_2O_5, K_2O) was applied over both locations (fumigated and non-fumigated land) but not disced in. No limestone was applied. The variety of asparagus used was c.v. Rutgers Beacon. Treatments, initiated in June 1978, were randomly assigned in both locations with three replications per treatment. Plots for all treatments were 9 m (30 ft.)long and spaced 1.5 m (5 ft.) apart.

Treatment 1 - Direct-seeding. Asparagus seed was sown 2.5 cm deep at 5 cm intervals in the base of W-shaped trenches (Figure 1). These were formed using a tractor drawn trencher and hand hoeing to form the base. Trenches were 15-20 cm deep, 25-30 cm wide.

Treatment 2 - Transplanting. Ten-week old asparagus transplants were set in W-shaped trenches at 30 cm intervals. Transplants were started in the greenhouse in March 1978 using 2-inch plastic pots with a standard steam sterilized Cornell mix, receiving three applications of soluble 20-20-20 (N, P_2O_5, K_2O) analysis fertilizer at 10 g/l water. All transplants were hardened off in a cold frame one week prior to planting.

Treatment 3 - Crown planting. Uniform one-year old crowns were planted at 30 cm intervals in the base of standard V-shaped trenches, 15-20 cm deep and 25-30 cm wide. This method has been the standard practice for establishing asparagus plantings in Massachusetts.

Weed control throughout 1978 and 1979 was performed by hand hoeing. All trenches were partially filled in early August 1978 and completely filled by September 1978. Insect control was maintained in both years with two applications of Sevin using a hand held sprayer.

Data procurement and analysis. Plant vigor was determined in 1978 and 1979 by the fresh and dry weights of all stalks cut at the soil surface for 7.5 m (25 ft.) in each plot. Fresh and dry crown weight data was taken in 1979 for one crown per replication.

A numerical rating system was designed to rate the degree of

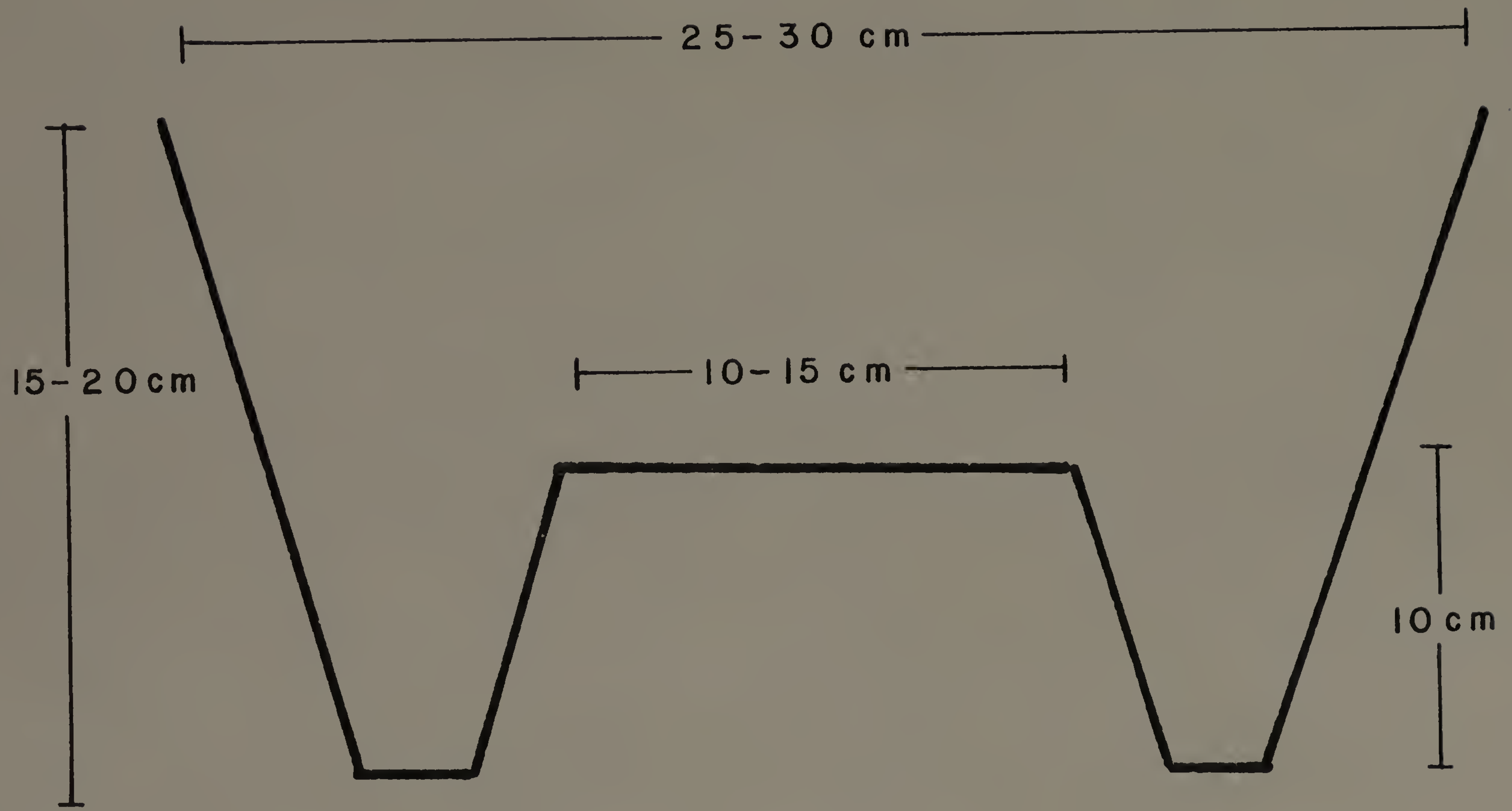

FIGURE I. W-SHAPED TRENCH

Fusarium infection, based on the amount of red-orange lesions on roots and stems caused by *Fusarium* species and the subsequent decay due to infection. One plant from each replications was removed, observed for *Fusarium* infection and a number from 0 to 4 was assigned according to the following criteria:

0 - no infection

1 - small red-orange lesions (2-5 mm) on roots, no decay

2 - red-orange lesions (5-15 mm) on roots and stems, slight decay present

3 - severe discoloration of roots and stems, decay present

4 - severely decayed or dead plant

All data were subjected to analysis of variance and Duncans multiple range tests were performed by methods described in Steel and Torrie (42). All differences were tested at the 5% level of probability, unless otherwise indicated in tables. Data was collected in September 1978 and 1979.

Experiment II - Direct-seeded Cultural Study

The objective of this study was the comparison of several cultural methods in direct-seeded asparagus in fumigated and non-fumigated land and to determine the effect of cultural practices on early vigor and *Fusarium* infection. Design of the following six treatments was based on relationships between early vigor, *Fusarium* infection and field conditions reviewed in the literature. Location of the experiment, soil fumigation,soil fertility, plot size, cultivar, data procurement and data analysis were identical to Experiment I. Treatments, initiated in June 1978, were randomly assigned in fumigated and non-fumigated land with four replications per treatment. Treatments were as follows:

Treatment 1 - Ridge culture. This treatment was designed to provide improved drainage by using raised beds. Seed was planted 2.5 cm deep at 5 cm intervals at soil level. Metribuzin (Sencor 50 WP) was applied pre and post-emergence in 1978 and 1979 at 137 g a.i./ha (1/8 lb. a.i./acre). Plots were ridged in 1978 and 1979 to form raised beds 15-25 cm high and 24 cm wide. No other cultivation was used.

Treatment 2 - Clumping. Three seeds were planted 2.5 cm deep every 30 cm in the base of W-shaped trenches to determine if three plants together could act as one plant with increased vigor.

Treatment 3 - No-till. Seed was planted in the base of W-shaped trenches 2.5 cm deep at 5 cm intervals. Metribuzin was applied as in Treatment 1. This treatment was designed to determine the effect of zero-tillage on direct-seeded asparagus.

Treatment 4 - Fertilizer 1X. Seed was planted in W-shaped trenches as in Treatment 3. In 1978 227 g N, 100 g P and 186 g K were banded per 30 m row 5 cm to the side and 5 cm below the seed (5 lbs. 10-10-10 N, P_2O_5, K_2O/100 ft. row). In 1979 the same amounts of N, P and K were applied as soluble 20-20-20 (N, P_2O_5, K_2O) analysis fertilizer in water over the row.

Treatment 5 - Fertilizer 2X. The fertility level in this treatment was double Treatment 4 (454 g N, 200 g P and 372 g K) per 30 m row (10 lbs. 10-10-10 N, P_2O_5, K_2O, per 100 ft. row).

Treatment 6 - Control. The control consisted of seed planted 2.5 cm deep at 5 cm intervals in the base of W-shaped trenches.

Weeds were controlled in all but Treatments 1 and 3 by hand hoeing. All trenches were partially filled in early August 1978 and completely filled by early September 1978.

Experiment III - Asparagus Variety Study

Recently released *Fusarium* resistant asparagus lines were evaluated as transplants, in fumigated and non-fumigated land for two years. Site preparation was identical to Experiments I and II. The variety study, initiated in June 1978, consisted of four lines currently being investigated for *Fusarium* resistance at Rutgers University in New Jersey and two varieties used by commercial growers in the eastern United States, c.v. Rutgers Beacon and c.v. Mary Washington. Plots were randomly assigned in fumigated and non-fumigated land with three replications per treatment (variety), plots being 9 m (30 ft.) long, spaced 1.5 m (5 ft.) apart. Varieties tested were as follows:

1. Rutgers hybrid 201
2. Rutgers hybrid 202
3. Rutgers hybrid 203 M
4. Rutgers hybrid 204 M
5. c.v. Rutgers Beacon
6. c.v. Mary Washington

Rutgers Beacon and Mary Washington are cultivars currently grown in Massachusetts by asparagus producers.

Transplants were started in the greenhouse and treated as the transplants in Experiment I. Transplants were set out in June 1978 when ten-weeks old in W-shaped trenches at 30 cm intervals. Weed control throughout 1978 and 1979 was performed by hand hoeing. All trenches were filled by the end of the 1978 season. Insect control was maintained as in the previous experiments. Data procurement and statistical analysis methods were identical to those in Experiments I and II.

Experiment IV - Fungicide Soil Drench Study

The objective of this study was to determine the effect of benomyl soil drenches on early vigor and *Fusarium* infection in asparagus established by direct-seeding and transplanting. This study was initiated in June 1979 at the University of Massachusetts research farm, South Deerfield, Massachusetts on a Hadley fine sandy loam. During soil preparation 112.13 kg/ha N,49.3 kg/ha P and 91.9 kg/ha K (1,000 lbs./A 10-10-10 (N, P_2O_5, K_2O)) were applied and disced in. Soil pH was maintained at 6.5 by application of 1121.3 kg/ha limestone (1,000 lbs./acre).

Ten-week old transplants, c.v. Viking 2K, started in the greenhouse in March 1979 as in Experiments I and III, were set out in June 1979 in trenches at 30 cm intervals. Plots were 9 m long spaced 1.5 m apart.

Seed was planted in trenches 2.5 cm deep at 5 cm intervals in plots 6 m (20 ft.) long, spaced 1.5 m apart. The experiment was a randomized block design with four replications per treatment, transplant and direct-seeded blocks being adjacent.

Five rates of benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate) as Benlate 50 WP in water were applied at planting and in August. Treatments were applied over the row as a drench on a per plot basis as follows:

Check - 10 l H_2O - no Benlate

Treatment 1 - 35.7 g (17.85 g a.i.) in 10 l H_2O 1X.

Treatment 2 - 107.0 g (53.50 g a.i.) in 10 l H_2O 3X.

Treatment 3 - 178.0 g (89.0 g a.i.) in 10 l H_2O 5X.

Treatment 4 - 250.0 g (125.0 g a.i.) in 10 l H_2O 7X.

Treatment 5 - 321.0 g (160 g a.i.) in 10 l H_2O 9X.

Weeds were controlled by hand hoeing and gradual filling in of trenches.

Data procurement and analysis. Plant vigor was determined in September 1979 by the fresh and dry weights of stalks (ferns) cut at soil level for 6 m (20 ft.) in each plot for transplants and 4.5 m (15 ft.) in each plot for direct-seeded asparagus. Fresh and dry weights for one crown per replication were also collected. *Fusarium* infection was determined by methods outlined in the previous experiments. All data were subjected to analysis of variance and Duncans multiple range tests were performed as in previous experiments.

Experiment V - Starter Fertilizer Study

The objective of this study was to determine the effect of increased fertility on early vigor and *Fusarium* infection in direct-seeded and transplanted asparagus.

Site preparation, transplanting and seeding, plot size, weed control, data collection and data analysis were identical to

Experiment IV. Four rates of soluble 20-20-20 (N, P_2O_5, K_2O) analysis fertilizer in water were applied at seeding and transplanting in June and August 1979. Treatments were applied over the row as a drench on a per plot basis as follows:

Check - 10 l H_2O - no fertilizer.

Treatment 1 - 156 g/10 l H_2O = 29.1 kg/ha (26 lbs./A) N, P_2O_5, K_2O.

Treatment 2 - 312 g/10 l H_2O = 59.4 kg/ha (53 lbs./A) N, P_2O_5, K_2O.

Treatment 3 - 468 g/10 l H_2O = 89.7 kg/ha (80 lbs./A) N, P_2O_5, K_2O.

Treatment 4 - 624 g/10 l H_2O =116.6 kg/ha (104 lbs./A) N,P_2O_5, K_2O.

CHAPTER IV

RESULTS AND DISCUSSION

Experiment I - Bed Establishment Study

The effect of treatments on fresh fern weight was identical to the effects on dry fern weight, therefore, fresh fern weight was used as the parameter to compare treatments. In 1978 and 1979 fresh fern weights for all treatments were significantly greater in fumigated land (Table 1). Fern yields for crown plantings in 1978 (Table 1) were significantly greater than direct-seeded and transplanted asparagus in both locations (fumigated and non-fumigated land).

No significant differences between treatments within fumigated and non-fumigated land were observed in 1979 (Table 1). Direct-seeded and crown planted asparagus exhibit similar vigor in fumigated land. These data (Table 1) indicate that direct-seeding of asparagus in fumigated land produces vigor equal to crowns in fumigated land, and greater vigor than crowns,transplants and direct-seeded asparagus in non-fumigated land.

Dry crown weights for each treatment in non-fumigated land were not significantly different than those in fumigated land (Table 2). Dry crown weights within both locations are significantly different. In both locations dry crown weights of direct-seeded asparagus are significantly less than that for crown planted asparagus. The data in Table 2 indicate that after two years, crowns of crown planted asparagus are larger than crowns of direct-seeded asparagus. The equal fern vigor of these two treatments (Table 1) is due to the high plant populations in direct-seeded asparagus, 180 plants/plot.

TABLE 1. ASPARAGUS FERN GROWTH ON ONE AND TWO-YEAR OLD PLANTS AS INFLUENCED BY BED-ESTABLISHMENT AND FUMIGATION.

	Fern Fresh Weight (kg)[z]					
	1978			1979		
Treatments	Fum.	Control	Sig.[y]	Fum.	Control	Sig.[y]
Transplants	2.42 a	1.21 a	*	3.45 a	2.60 a	*
Crowns	4.18 b	3.61 b	*	5.23 a	4.16 a	*
Direct-seeded	1.36 a	0.53 a	*	5.24 a	2.97 a	*

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

[y] * Indicates significant difference between locations(fumigated and non-fumigated land).

TABLE 2. ASPARAGUS CROWN GROWTH ON TWO-YEAR OLD ASPARAGUS PLANTS AS INFLUENCED BY BED ESTABLISHMENT AND FUMIGATION - 1979.

	Crown Dry Weight (g)[z]		
Treatments	Fumigated	Control	Sig. .05
Transplants	45.47 a b	35.24 a b	N.S.
Crowns	106.15 b	75.24 b	N.S.
Direct-seeded	17.67 a	21.86 a	N.S.

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

N.S. - No significant difference between locations (fumigated and non-fumigated land).

as compared to 30 plants/plot for crown planted asparagus.

Fumigation had no effect on crown size. It was difficult to remove crowns from the field after two years. The crowns in direct-seeded asparagus were difficult to remove because of their close proximity (seeded at 5 cm intervals). Crown weight data was taken to find another variable in determining plant vigor but was found unsatisfactory due to the difficulty in removal from the field.

All treatments in Experiment I experienced *Fusarium* infection. There were no significant differences in infection ratings between treatments or between locations (Table 3). Fumigation had no effect on the presence of *Fusarium* on asparagus.

The data from Experiment I indicate the following:

a) The presence of *Fusarium* on the plant was not affected by soil fumigation or bed establishment techniques.

b) Soil fumigation improved early vigor of asparagus for two years.

c) Direct-seeded asparagus in fumigated land exhibits the same vigor as crown-planted asparagus in fumigated land and greater vigor than crown planted, transplanted and direct-seeded asparagus in non-fumigated land after two years.

Experiment II - Direct-Seeded Cultural Study

Table 4 shows that ridging, fertilizer X and 2X and control had significantly greater vigor in fumigated land in 1978. In fumigated land, ridging and the two fertilizer treatments had significantly greater vigor than clumping and no-till. Clumping and no-till treatments had

TABLE 3. *FUSARIUM* INFECTION RATING ON TWO-YEAR OLD ASPARAGUS PLANTS AS INFLUENCED BY BED-ESTABLISHMENT AND FUMIGATION - 1979.

	Infection Rating[z]		
Treatments	Fumigated	Control	Sig. .05[y]
Transplants	2.75 a	2.25 a	N.S.
Crowns	2.00 a	1.50 a	N.S.
Direct-Seeded	2.50 a	2.75 a	N.S.

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

[y] N.S. - No significant difference between locations (fumigated and non-fumigated land).

TABLE 4. THE EFFECT OF FUMIGATION AND CULTURAL PRACTICES ON FERN GROWTH IN ONE-YEAR OLD DIRECT-SEEDED ASPARAGUS - 1978.

	Fern Fresh Wt (kg)[z]		
Treatments	Fumigated	Control	Sig. .05[y]
Ridge	2.03 a	0.97 a b	*
Clump	0.98 b	0.53 b	N.S.
No-till	0.95 b	0.49 b	N.S.
Fertilizer X	1.78 a	0.70 a b	*
Fertilizer 2X	1.69 a	1.13 a	*
Control	1.49 a b	0.72 a b	*

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

[y] * Significant difference between locations.

[y] N.S. - No signficant difference between locations(fumigated and non-fumigated land).

significantly less vigor than fertilizer 2X in non-fumigated land. The data in Table 4 indicate more treatment differences in fumigated land than in non-fumigated land.

In 1979 ridging and no-till treatments and the control had significantly greater vigor in fumigated land (Table 5). Treatment differences in fumigated land have almost been eliminated after two years. Only the no-till treatment is significantly different than the control, having less vigor than the control.

In non-fumigated land treatments are still affecting plant vigor (Table 5). Fertilizer 2X has significantly greater fern vigor than ridging, clumping and no-till but vigor equal to Fertilizer X and the control. The data from Table 4 and 5 indicate overall that fumigation has the greatest effect on plant vigor. Increased fertility, no-till or raised bed culture could not improve vigor any more than fumigation alone.

Within the six treatments in Experiment II are three classes of treatment. What is being observed are the effects of these three classes, those being chemical weed control in ridging and no-till treatments, increased fertility in the two fertilizer treatments and zero-tillage in the no-till treatment. These treatments can be combined and compared as orthogonal polynomial single degree of freedom comparisons shown in Table 6. The comparisons are each class of treatments versus all other treatments combined.

In 1978, the herbicide treatments were not significantly different than all cultural treatments for both locations. Fresh fern

TABLE 5. THE EFFECT OF FUMIGATION AND CULTURAL PRACTICES ON FERN GROWTH OF TWO-YEAR OLD DIRECT-SEEDED ASPARAGUS - 1979.

	Fern Fresh Wt (kg)[z]		
Treatments	Fumigated	Control	Sig. 0.05[y]
Ridge	4.41 a b	2.62 a	*
Clump	3.57 a b	2.64 a	N.S.
No-Till	3.43 a	1.24 c	*
Fertilizer X	3.88 a b	3.34 a b	N.S.
Fertilizer 2X	4.87 a b	3.94 b	N.S.
Control	5.08 b	2.97 a b	*

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

[y] * - Significant difference between locations.

[y] N.S. - No significant difference between locations (fumigated and non-fumigated land).

TABLE 6. F-TESTS FOR ORTHOGONAL CONTRASTS OF CULTURAL PRACTICES ON ASPARAGUS FERN GROWTH FOR ONE AND TWO-YEAR OLD DIRECT-SEEDED ASPARAGUS.

	Fern Fresh Wt. (kg)			
	1978		1979	
Comparisons	Fumigated	Control	Fumigated	Control
Herbicide vs. Cultural	n.s.[y]	n.s.	n.s.	12.3**
Fertilizer vs. Cultural	6.02**	4.2*	n.s.	11.9**
No-Till vs. Cultural	11.5**	n.s.	4.04*	15.9**

[y] n.s. - no significant difference.

* - significant difference at 5% probability.

** - significant difference at 1% probability.

yields for the fertilizer treatments were significantly greater than all cultural treatments in both locations. Fern yield from the no-till treatment was significantly less than all cultural treatments in fumigated land but not significantly different in non-fumigated land.

In 1979, the significant differences between all treatments in fumigated land has been reduced. The no-till treatment still has a significantly lower fern yield than all cultural treatments. In non-fumigated land, fern yields in both classes of herbicide treatments are significantly less than all cultural treatments. The fertilizer treatments have significantly greater vigor than all cultural treatments in non-fumigated land.

Treatment effects on plant vigor in fumigated land were reduced after two years, yet in non-fumigated land treatment effects became more pronounced (Table 6). Standard culture (control) and increased fertility improve early vigor in non-fumigated land (Table 5), however fumigation alone increases vigor to a greater extent (Table 5).

Herbicide treatments in both locations caused significant injury to young asparagus plants,reducing vigor after two years. This suggests that metribuzin applied at reduced rates was not suitable for weed control in direct-seeded asparagus (Tables 5 and 6).

Dry crown weights for all treatments were not significantly different within or between locations (Table 7). As in Experiment I, dry crown weight data does not appear to be a satisfactory parameter in determining plant vigor.

TABLE 7. THE EFFECT OF FUMIGATION AND CULTURAL PRACTICES ON CROWN GROWTH OF TWO-YEAR OLD DIRECT-SEEDED ASPARAGUS - 1979.

Treatments	Crown Dry Wt. (g)[z]		
	Fumigated	Control	Sig. .05
Ridge	14.68 a	19.83 a	N.S.
Clump	8.83 a	15.84 a	N.S.
No-Till	11.14 a	11.35 a	N.S.
Fertilizer 1X	11.05 a	8.89 a	N.S.
Fertilizer 2X	9.33 a	16.50 a	N.S.
Control	14.15 a	22.03 a	N.S.

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

N.S. - no significant difference between locations (fumigated and non-fumigated land).

Fusarium infection was present on all plants sampled in all treatments in both locations. There was no significant difference in the severity of infection between treatments or locations. Fumigation and cultural practices had no effect on *Fusarium* infection.

The data from Experiment II indicate the following:

a) Presence of *Fusarium* on direct-seeded asparagus was not influenced by soil fumigation or cultural practices.

b) Early vigor of direct-seeded asparagus is improved by soil fumigation with Vorlex.

c) Soil fumigation had a greater overall effect on early vigor of direct-seeded asparagus than any cultural method.

Experiment III - Asparagus Variety Study

All varieties under investigation except Rutgers hybrid 203 M showed significantly greater vigor in fumigated land in 1978 (Table 8). The vigor of all varieties tested was not significantly different within fumigated and non-fumigated land for 1978 and 1979. The increased vigor of asparagus in fumigated land in 1978 was absent in 1979. All lines tested had equal vigor in fumigated and non-fumigated land. Crown dry weight data also showed no significant differences between varieties or between locations.

Rutgers hybrid 204 M and Rutgers Beacon exhibited significantly greater *Fusarium* infection than all other lines in fumigated soil in 1979, however all lines showed *Fusarium* infection in both locations (Table 9). All lines in non-fumigated soil were infected with *Fusarium* with no differences between lines. Mary Washington

TABLE 8. ASPARAGUS VARIETY STUDY.

	Fern Fresh Wt. (kg)[z]					
	1978			1979		
Variety	Fum.	Control	Sig.[y]	Fum.	Control	Sig.[y]
Rutgers Hybrid 201	2.34 a	1.37 a	*	4.98 a	4.21 a	N.S.
Rutgers Hybrid 202	2.13 a	1.25 a	*	5.72 a	4.51 a	N.S.
Rutgers Hybrid 203 M	1.63 a	1.23 a	N.S.	4.25 a	4.70 a	N.S.
Rutgers Hybrid 204 M	1.96 a	0.97 a	*	5.02 a	4.68 a	N.S.
Rutgers Beacon	2.42 a	1.21 a	*	4.61 a	3.47 a	N.S.
Mary Washington	1.46 a	0.99 a	*	4.38 a	3.59 a	N.S.

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

[y] * - Significant difference between locations.

[y] N.S. - No significant difference between locations (fumigated and non-fumigated land).

TABLE 9. ASPARAGUS VARIETY STUDY - 1979.

	Infection Rating[z]		
Varieties	Fumigated	Control	Sig. .05[y]
Rutgers Hybrid 201	2.00 a	2.33 a	N.S.
Rutgers Hybrid 202	2.00 a	2.33 a	N.S.
Rutgers Hybrid 203 M	2.00 a	2.33 a	N.S.
Rutgers Hybrid 204 M	2.60 b	2.33 a	N.S.
Rutgers Beacon	2.60 b	2.00 a	N.S.
Mary Washington	2.00 a	3.00 a	*

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

[y] * - Significant difference between locations.

[y] N.S. - No significant difference between locations (fumigated and non-fumigated land).

showed significantly less *Fusarium* infection in fumigated land.

The data from Experiment III indicate:

a) All lines tested showed no significant difference in vigor for two years.

b) Soil fumigation improved early vigor after one year but had no effect on vigor after two years.

c) All lines tested showed *Fusarium* infection but Rutgers Beacon and Rugers hybrid 204 M had significantly greater *Fusarium* infection in fumigated soil. The increased *Fusarium* infection had no effect on plant vigor but may affect future yields. The lines showing less *Fusarium* infection may serve as a source of *Fusarium* resistance in further breeding programs.

d) Mary Washington showed significantly less *Fusarium* infection in fumigated soil. This was not consistent with data in Experiments I and II indicating no significant difference in *Fusarium* infection between fumigated and non-fumigated soil. Further data on plant vigor and spear yield must be analyzed to substantiate the exception in *Fusarium* infection data in this experiment.

Experiment IV - Fungicide Soil Drench Study

Fungicide soil drenches had similar effects on direct-seeded and transplanted asparagus (Table 10). Rates 1X and 3X of benomyl significantly restrict early vigor of direct-seeded and transplanted asparagus. The higher rates of benomyl had no effect on plant vigor in transplanted asparagus. In direct-seeded asparagus the 7X rate was significantly more vigorous than 1X and 2X but equal in vigor to the check.

TABLE 10. EFFECT OF BENOMYL SOIL DRENCHES ON FERN GROWTH OF ONE-YEAR OLD DIRECT-SEEDED AND TRANSPLANTED ASPARAGUS - 1979.

	Fern Fresh Wt.	
Treatments	Transplants (kg)[z]	Direct-Seeded (g)[z]
Check	2.64 a	803.50 a
1 (1X) 17.85 g a.i./plot	1.63 b	382.50 b
2 (3X) 53.50 g a.i./plot	1.47 b	348.50 b
3 (5X) 89.0 g a.i./plot	2.15 a b	488.00 a b
4 (7X) 125.0 g a.i./plot	2.38 a b	942.50 a
5 (9X) 160.0 g a.i./plot	2.29 a b	717.60 a b

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

Dry crown weight was not affected by soil drenches of benomyl in direct-seeded or transplanted asparagus. Fusarium infection was present on all plants in all treatments and was not affected as to severity by benomyl soil drenches.

The results of Experiment IV indicate that benomyl applied as a soil drench at lower concentrations (1X, 2X) restricted plant vigor in direct-seeded and transplanted asparagus. Higher concentrations had no effect on plant vigor. All treatments had no effect on Fusarium infection. Applications of benomyl will not harm plants at higher concentrations but are of no benefit in preventing Fusarium infection in one-year old asparagus plantings.

Experiment V - Starter Fertilizer Study

Plant vigor of direct-seeded and transplanted asparagus was not affected by increased fertility at planting or in mid-season. There were no significant differences between treatments and checks for both planting techniques (Table 11).

Crown weights responded to fertilizer treatments (Table 12), however increased fertility did not improve crown weights over the check. Lower fertilizer concentrations restricted crown growth slightly in transplanted and direct-seeded asparagus. Higher concentrations did not affect plant vigor.

Fusarium infection was not affected by increased fertility. All plants sampled in all treatments for both planting techniques showed evidence of Fusarium infection but no differences as to severity of infection.

TABLE 11. EFFECT OF FERTILIZER ON FERN GROWTH OF ONE-YEAR OLD DIRECT-SEEDED AND TRANSPLANTED ASPARAGUS - 1979.

	Fern Fresh Wt.	
Treatments	Transplants (kg)[z]	Direct-Seeded (g)[z]
Check	2.64 a	805.50 a
1 29.1 kg/ha N, P_2O_5, K_2O	2.10 a	758.25 a
2 59.4 kg/ha N, P_2O_5, K_2O	2.55 a	591.00 a
3 89.7 kg/ha N, P_2O_5, K_2O	2.35 a	643.25 a
4 116.6 kg/ha N, P_2O_5, K_2O	1.82 a	483.75 a

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

TABLE 12. EFFECT OF FERTILIZER ON CROWN GROWTH OF ONE-YEAR OLD DIRECT-SEEDED AND TRANSPLANTED ASPARAGUS - 1979.

	Dry Crown Wt. (g)[z]	
Treatments	Transplanted	Direct-Seeded
Check	7.72 a b	1.92 a b
1 29.1 kg/ha N, P_2O_5, K_2O	4.47 a	2.96 b
2 59.4 kg/ha N, P_2O_5, K_2O	7.55 a b	1.60 a
3 89.7 kg/ha N, P_2O_5, K_2O	9.44 b	2.12 a b
4 116.6 kg/ha N, P_2O_5, K_2O	8.99 a b	2.96 b

[z] Mean separation within columns by Duncans Multiple Range Test 5%.

The data from Experiment V indicate that increased fertility does not improve early vigor nor affect *Fusarium* infection. Crown size responded to fertilizer treatments, however, because of the difficulty in removing crowns from the field these data cannot be considered valid as a parameter of early vigor until further yield data is analyzed.

CHAPTER V

CONCLUSIONS

The effects of soil fumigation, bed-establishment techniques, cultural practices and varieties on early vigor and Fusarium infection of *Asparagus officinalis,* L. were studied.

Early vigor of asparagus was significantly improved by soil fumigation with Vorlex. No other treatment had a greater effect on early vigor than fumigation. Improved vigor was not correlated to a reduction in *Fusarium* infection since plants in fumigated and non-fumigated land exhibited equal *Fusarium* infection ratings.

Improved vigor may be due to several factors.

Soil fumigation reduces weed competition since weed seeds are killed by Vorlex. During the two years that these experiments (I,II and III) were conducted less hand hoeing to control weeds was needed in fumigated land. No hand hoeing was necessary until August 1978 in fumigated land. Lack of weeds and subsequent lack of tillage eliminated added stress to plants due to competition and tillage injury therefore improving vigor.

Vorlex may have a growth regulating effect on asparagus similar to that of benomyl reported by Yang (52).

Soil fumigation with Vorlex may inhibit nitrobacteria in soils which are responsible for nitrification. Ammonium nitrogen would not be converted to nitrate nitrogen which can leach, providing more available nitrogen to asparagus plants.

Direct-seeded asparagus exhibited vigor equal to transplants and crown-planted asparagus in fumigated land after two years. The cost of establishing asparagus by direct-seeding in fumigated land is approximately $400/acre ($100 for seed and $300 for fumigation). Crown establishment of asparagus in non-fumigated land costs $480-$600/acre. Ellison and Scheer (15,16,17,38) have correlated early vigor to future yields, therefore the improved vigor of direct-seeded asparagus in fumigated land could represent increased yields at a reduced establishment cost.

Cultural practices such as increased fertility, zero-tillage and raised beds did not improve early vigor of direct-seeded asparagus. Direct-seeding in W-shaped trenches using recommended fertility practices and light cultivation produced vigorous asparagus plants without the increased cost of added fertilizer or herbicides.

Fusarium infection was not affected by soil fumigation, bed-establishment techniques, cultural practices, increased fertility or fungicide soil drenches. The presence of *Fusarium* on asparagus plants in fumigated land may be due to air-born transmission of fungal spores, incomplete elimination of fungi by fumigation or infection by seeds, crowns and transplants.

All lines tested in the variety study (Experiment III) exhibited *Fusarium* infection. Two lines, Rutgers Beacon and Rutgers hybrid 204 M, had significantly greater *Fusarium* infection in fumigated land but increased *Fusarium* infection had no effect on plant vigor. Lines showing less *Fusarium* infection may serve as a source of *Fusarium* resistance in further breeding programs.

The data from these five studies indicate that early vigor of asparagus can be improved by soil fumigation. Direct seeding offered the advantage of lower costs in crop establishment and plant vigor equal to asparagus established from crowns.

Fusarium infection was not reduced by soil fumigation, bed establishment techniques,cultural methods, increased fertility and benomyl soil drenches. The eventual decline of asparagus plants due to *Fusarium* infection would be likely. However, because of improved early vigor derived from soil fumigation, direct-seeding and improved cultural practices the onset of asparagus decline may be delayed.

Benson et al reported increased yields in direct-seeded asparagus (3). Direct-seeding in combination with soil fumigation could be a feasible method for producing asparagus in Massachusetts. Asparagus beds in Massachusetts are currently maintained for 15-20 years. To maintain high yields in direct-seeded asparagus in fumigated land a crop rotation system would be required, renewing asparagus beds every 7-10 years.

Further research is necessary to determine the effects of zero-tillage for established asparagus, cultural practices, insect control and the use of systemic fungicides on *Fusarium* infection and yields.

CHAPTER VI

SUMMARY

Studies were conducted to investigate the effect of several cultural practices on early vigor and *Fusarium* infection on *Asparagus officinalis*, L.. The following results were obtained:

a) Soil fumigation with Vorlex improved early vigor of direct-seeded, transplanted and crown planted asparagus.

b) Direct-seeded asparagus exhibited the same fern vigor as crown-planted and transplanted asparagus in fumigated land and greater fern vigor than all three methods of bed-establishment in non-fumigated land.

c) *Fusarium* infection on asparagus was not affected by soil fumigation with Vorlex, bed-establishment techniques, increased fertility and benomyl soil drenches.

d) Standard cultural practices for direct-seeded asparagus in fumigated land (Experiment II, control) produced fern vigor equal to or greater than all other cultural practices investigated in fumigated and non-fumigated land.

e) Increased fertility at planting and at mid-season did not improve early vigor or affect *Fusarium* infection in direct-seeded or transplanted asparagus.

f) Fungicide soil drenches with benomyl at planting and at mid-season did not improve early vigor or affect *Fusarium* infection in direct-seeded or transplanted asparagus.

g) Crown weight data was not satisfactory for measuring plant vigor due to the difficulty in removing intact crowns from the field.

h) Several hybrid lines tested showed significantly reduced *Fusarium* infection. These lines may be used as a source of *Fusarium* resistant germplasm in future breeding programs.

LITERATURE CITED

1. Asparagus, direct-seeding of. 1971. Agricultural Extension Bulletin 348, University of California.

2. Asparagus, commercial growing of. 1975. Agricultural Research Service, U.S.D.A. Farmers Bulletin No. 2232.

3. Benson, B. L., Hanna, G. C., Takatori, F. H. 1978. Evaluation of crown plantings and direct-seeded asparagus after 15 years. California Agriculture, March. pp. 13-14.

4. Blacklow, W., Manning, W. J. 1977. The etiology of asparagus decline in Western Massachusetts. Proc. Am. Phyto. Soc. 4: (in press).

5. Blevins, R. L., Cook, D., Phillips, S. H., Phillips, R. E. 1971. Influence of no-tillage on soil moisture. Agronomy Journal. 63:593-596.

6. Blumenfield, D., Meinken, K. W., Stuart, B. L. 1960. A field study of asparagus growth. J. Amer. Soc. Hort. Sci. 77:386-392.

7. Boyd, O. C. 1930. Fusarium spp. on asparagus in Massachusetts. Plant Disease Reporter 14:197.

8. Boyer Agrochem Ltd. (Sencorex) (Boyer 94:337). 1973. Selective herbicide with contact and residual action for use in early and main crop potatoes. Tech. Information Bulletin.

9. Brown, L. D., Carolus, R. L. 1960. An evaluation of fertilizer practice in relation to nutrient requirement of asparagus. J. Amer. Soc. Hort. Sci. 86:332-337.

10. Brown, L. D., Lawton, K., Carolus, R. L. 1961. Utilization of applied phosphorous by asparagus spears. Journal article 2799, Michigan Agricultural Exp. Station.

11. Cannell, G. H., Takatori, F. H. 1970. Irrigation-nitrogen studies in asparagus and measurement of soil moisture changes by the neutron method. Soil Science Society of America Proceedings 34:501-506.

12. Conroy, R. J. 1975. Asparagus decline and replant deaths. Agricultural Gazette of New South Wales. 86:(2)23.

13. Crowder, R. A. 1972. Research into direct-seeding of asparagus. New Zealand Journal of Agriculture. Vol.1. No. 10, pg. 43-45.

14. Eckholtz, G. 1969. Preliminary results on soil disinfection in asparagus. Gemuse 5, 124-126. (ABSTR.).

15. Ellison, J. H., Reynard, G. B., Scheer, D. F., Wagner, J. J. 1960. Estimating comparative yields of asparagus strains without full season harvest records. J. Amer. Soc. Hort. Sci. 76:376-381.

16. Ellison, J. H., Scheer, D. F. 1958. Yield related to brush vigor in asparagus. J. Amer. Soc. Hort. Sci. 73:339-344.

17. Ellison, J. H., Schermerhorn, L. G. 1958. Selecting superior asparagus plants on the basis of earliness. J. Amer. Soc. Hort. Sci. 72:353-359.

18. Ellison, J. H., Scheer, D. F., Wagner, J. J. 1959. Asparagus yield as related to plant vigor, earliness and sex. J. Amer. Soc. Hort. Sci. 75:411-415.

19. Garrison, S. A. 1977. New planting method for asparagus. American Vegetable Grower. June 1977, pp 16-17, 50-51.

20. Gehlker, H., Scholl, W. 1974. Ecological factors and cultivation problems in connection with parasitic root rot of asparagus. Zeitschrift Fur Pflanzenknonkleiten und Pflanzenschutz, 81 (6/7):394-406 (ABSTR.).

21. Grogan, Kimble. 1958. The association of _Fusarium_ wilt and asparagus decline and replant problem in California. Phytopathology 49:122-125.

22. Jones, J. N., Jr., Moody, J. E. 1969. Effects of no-tillage, tillage and mulch on soil-water and plant growth. Agronomy Journal 61:719-721.

23. Jones, P. J., Overman, A. J. 1976. Tomato wilts, nematodes and yields as affected by soil reaction and a persistent contact nematicide. Plant Disease Reporter, 60(11):913-17.

24. Jones, P. J., Overman, A. J., Geraldson, C. M. 1972. The effect of mulching on the efficacy of D,D-Mencs for control of _Fusarium_ wilt of tomato. Plant Disease Reporter. 56(11):953-956.

25. Kalchschmid, W., Krouse, C. 1976. Control of asparagus root rot. Pflanzenschutz Umueltschutz, 49(1):14-16 (ABSTR.).

26. Kannaiyan, S., Prasod, M. 1972. Control of _Fusarium_ wilt in muskmelon with Benlate. Current Science 41(15):579-580.

27. Leefe, J. S. 1970. Weed control in asparagus.

28. Manning, W. J. 1978. Asparagus progress report on crown rot control.

29. Manning, W. J., Vardaro, P. M. 1977. Soil fumigation and preplant fungicide crown soaks: effects on plant growth and Fusarium incidence in newly planted asparagus. Plant Disease Reporter, 61(5):355-357.

30. Meggit, W. F., Ellison, J. H., Aldrich, R. J., Willits, N. A. 1959. An evaluation of cultivations and monuron in asparagus. J. Amer. Soc. Hort. Sci. 74:580-582.

31. Melnick, W., Miller, D. A., Marini, D. A., Thomson, C. L. 1971. Growing asparagus. Extension Service Bulletin, University of Massachusetts.

32. Morras, F., Servazzi, O. 1972. Fusarium diseases of asparagus. Studi Sassonessi III, 18:211-227 (ABSTR.).

33. Pergola, G., Garibaldi, A. 1972. Experimental observations on the best methods of applying systemic fungicide against philoxera wilt of carnations. Annali dele Instituta Sperimentale per la Floricultura, 3(1):79-90 (ABSTR.).

34. Putnam, A. R. 1972. Efficacy of a zero-tillage cultural system for asparagus produced from seed and crowns. J. Amer. Soc. Hort. Sci. 97(5):621-624.

35. Putnam, A. R., Lacy, M. L. 1977. Asparagus management with no-tillage. Research Report, Farm Science series, Michigan State Agricultural Exp. Sta. No. 339.

36. Rhode, R. A., Jenkins, W. R. 1957. Basis for resistance of asparagus officinalis var. altilis L. to the stubby-root nematode Trichodorus christei, Allen University of Maryland Ag. Exp. Sta. bulletin A-97.

37. Ries, S. M., Otterbacher, A. G. 1974. The effects of Benlate on field establishment of strawberries. Transactions of the Illinois State Horticultural Society. 107:84-85.

38. Scheer, F. H., Ellison, J. H. 1960. Asparagus performance as related to seedling vigor. J. Amer. Soc. Hort. Sci. 76:370-375.

39. Sonada, R. M. 1977. Effect of benomyl drenches on Fusarium crown rot of tomatoes. Research Report, Ag. Research Center, Fort Pierce, RL-2.

40. Springer, Brown,. 1974. Asparagus root rot fungicide and nematicide tests. Results of 1974. American Phytopath. Soc. 30:59.

41. Staunton, W. P. 1971. Fusarium wilt of tomato. Mededlingen von de Faculteit Londbawetenschappen, Rijksuninersiteit Gert, 36(3):1193-1201 (ABSTR.).

42. Steel, R. G. D. and Torrie, J. H. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., N.Y.

43. Strider, D. L. 1977. Methods of application of benomyl for Rhizoctonia root rot control in pointsettia. Plant Disease Reporter. 61(9):746-748.

44. Takatori, F. H., Stillman, J., Souther, F. 1974. Influence of planting depth on production of green asparagus in California. California Agriculture, January, 1974.

45. Tiedjkens, V. A. 1925. Some physiological aspects of Asparagus officinalis. J. Amer. Soc. Hort. Sci. 1925.

46. Van Bakel, J. J. M., Krom-Kerstens, J. J. A. 1976. Footrot in asparagus caused by Fusarium oxysporum f. sp. aspargi. Netherlands Journal of Plant Pathology, 76:320-325.

47. Van Bakel, J. J. M., Krom-Kerstens, J. J. A. 1974. Dead stem disease of asparagus caused by Fusarium culmorum. Netherlands Nournal of Plant Pathology. 80:104-109.

48. Van Bakel, J. J. M., Von Bethe, J. G. C. 1974. The asparagus miner fly (Ophiomyzea simplex (Leow) Spencer) and the appearance of footrot (Fusarium oxysporum Schlect) in asparagus. Gewasbescherming 5(1):1-4 (ABSTR.).

49. Von der Brooke, H., Von Ashe, L. 1966. Pathogenicity of Fusarium spp. on asparagus. Meded. Rijksfacult. Landbwetensch. Gent. 31:915-924 (ABSTR.).

50. Welker, W. V., Jr. 1974. Chemical weed control in direct-seeded asparagus. Proceedings of the Northeast Weed Science Society. Philadelphia 28:234.

51. Wessels,P. H., Thompson, H. C. 1937. Asparagus fertilizer experiment on Long Island. Cornell University Ag. Exp. Sta., Ithaca, N.Y. Bulletin 678.

52. Wiebe, J. 1970. Seedling response of asparagus strains and cultivars to soil steaming. Report for 1970 of the Horticultural Research Institute of Ontario, 60-64.

53. Yang, 1976. Effect of benomyl on Asparagus officinalis shoot and root development in culture media. Hort. Science 11(5): 473-474.

54. Young, R. E. 1937. Yield-growth relationships in asparagus. J. Amer. Soc. Hort. Sci. 35:576-577.