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BARD

FINAL REPORT

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**Wild Emmer Wheats as Potential Sources of
Resistance to Take-All Disease, Caused by
Gaeumannomyces Graminis Var. *Tritice***

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Title

Wild emmer wheats as potential sources of resistance to Take-all
disease, caused by *Gaeumannomyces graminis* var *tritici*

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ABSTRACT

The work covered by this BARD grant was for a one-year trial period to determine if the investigators could reliably detect small differences in resistance in small grain cereals to infection by the take-all pathogen, Gaeumannomyces graminis var. tritici. Using a number of techniques and isolates of the fungus, work done in both Israel and Montana showed that the known differences in susceptibility between wheat, barley, rye, and oats, could be detected. A tube assay system was particularly effective for such work, such that several accessions of Aegilops were found to be resistant to take-all. As a result, we feel that we have the technology in place to detect small levels of resistance to take-all and determine if any of the wild emmers carry such resistance.

OBJECTIVES

The objectives of this one year trial grant were to develop and perfect the techniques necessary to detect small increments of resistance to Gaeumannomyces graminis var. tritici that might exist in small grain cereals using hosts of known reaction, eg wheat, barley, rye, triticale, and oats.

INTRODUCTION

The take-all disease of wheat caused by Gaeumannomyces graminis var. tritici (Ggt) and other cereals is a worldwide malady that can be a severely limiting factor in the production of various small grain cereals. Other than crop rotation, there is little that a grower can do to control this disease. There are no cultivars that have been developed with high levels of resistance. The original purpose of the research supported by this BARD grant was to evaluate the wild emmer wheats of Israel as potential sources of resistance. However, the reviewers of this proposal suggested that we spend a year developing and evaluating the various techniques for screening for small increments of resistance. This we have done, and we feel successfully. The following report summarizes the work done on this project.

MATERIALS AND METHODS

ISRAEL

The aim of the Israel portion of this study was to assess three methods for detection of resistance to take-all in cereal entries under laboratory conditions. Specific objectives were: 1. To compare point inoculation versus uncontrolled number of infection sites. 2. To compare ranking of resistance based upon a) assessment of percentage of lesioned root (% of total length), b) rate of infected roots (% of total root number), and c) loss of shoot dry weight. 3. To study the effect of inoculum type and size on expression of resistance.

ASSAY METHODS

1. Tube Assay. Conical tip, 15 ml plastic centrifuge tubes with a drainage hole at the bottom are filled up to 9 ml with

vermiculite. The inoculum consists of either PDA disks (13mm), cut from the edges of 2-3-wk-old Ggt colonies, or colonized grain particles (oat kernels, ground and sieved to 0.5-2.0 mm). The inoculum is placed on the vermiculite and covered by 4 ml of additional vermiculite. Pregerminated seeds (48 hr) are planted one per tube and covered by a 1 cm layer of vermiculite. Tubes, held in racks of 50, in vertical position, are watered to field capacity twice weekly. After 21 days the root system is washed free of vermiculite and each seminal root is visually assessed for percentage of discoloration due to Ggt, and given an infection score (0-5) as described by Jensen and Jorgensen (1973).

This assay was repeated during the year for over 20 times with various types and doses of inoculum, different isolates, and with numerous minor differences in culture age, length of incubation and growth-room conditions.

2. Slanted Sleeve Assay. Transparent polyethylene sleeves, (170 x 45 mm), partly sealed at one end, are filled with vermiculite and wet to field capacity. One pregerminated seed is planted and the sleeves are covered with black plastic sheet and held inclined (45°) in trays to cause root growth along and in contact with the lower wall. Fertigation is provided once weekly. Inoculation is performed at predetermined points (point inoculation), usually ca. 40 mm below the seed, 8 days after planting, on several roots per plant, by placing one grain of inoculum in contact with the root, through a small incision made in the plastic. Uninoculated roots left in each sleeve serve as controls. Development of runner hyphae and lesions are monitored at time intervals.

Two experiments were conducted; colonized oat grain served as inoculum. Incubation of Exp. 1 was 49 days, and of Exp. 2, 14 days.

3. Pot Assay. Pots (square, black plastic, 800 ml, tapering towards the bottom) are filled up with 400 ml of a 2:1 mixture of

sandy-loam and vermiculite. Inoculum mixture of soil and colonized grains (40 ml) is added as a layer of ca. 1 cm and the pots are filled with pot mixture up to 700 ml. The pots are wet to ca. 75% field capacity and 5 pregerminated seeds are planted. Pots are fertigated for 4-5 weeks after which the root system is visually assessed (infection score of each root) and dry weight of the shoot is recorded (after oven drying).

Four experiments were conducted, two of which were designed as split treatments to also assess the effect of inoculum type and size.

Standard cultivars. The cultivars used in this study were:

Wheat (Triticum aestivum) - Barkai

Barley (Hordeum vulgare) - DRO 32

Rye (Secale cereale) - Explorer (C.I. 15) or
Wesser (C.I. 33)

PREPARATION OF VARIOUS INOCULUM TYPES

Wheat Straw Vermiculite: Air-dried, brittle wheat straw is cut with scissors into fine pieces. Equal volumes of straw (50 ml = 7.7 g) and vermiculite (50 ml = 8.3 g) are mixed and soaked overnight in water (70 ml + 100 mg NH_4NO_3). Soaked mixture is autoclaved twice for 30 minutes. The medium is inoculated with squares of a PDA culture of Ggt and incubated at 29 C until uniform colonization of the medium is complete.

Maize Meal Vermiculite: Aliquots of 35 ml of maize meal and vermiculite (=1.5 g maize meal + 6 g vermiculite) were moistened with 15 ml of water and autoclaved 2 x for 20 min in 150 ml Ehrlenmeyer flasks. Inoculation and incubation as described above.

Maize Meal and Sand: Aliquots of 34 ml (=1.5 g maize meal + 48.5 rough quartz sand) were moistened with 10 ml water and

autoclaved 2 x for 20 min in 150 ml Ehrlenmeyer flasks. Inoculation and incubation as described above.

Millet kernel: Twenty gram seeds are washed well under a stream of tap water, on a screen, until no more dirt is visible in the water, seeds are then soaked overnight in tap water. Soaked seeds are rinsed again under a stream of water and boiled slowly for 30 min, starting with a total volume of 100 ml and finishing with 50 g of boiled seeds, all water being absorbed or evaporated. Autoclaving, inoculation and incubation as described above.

Oat kernel: Two hundred fifty ml (vol) oat kernels + 200 ml tap water, autoclaved twice for 30 minutes each time in a 1 L Ehrlenmeyer flask, are inoculated with PDA squares from one 9 cm Petri-dish filled by a Ggt colony and incubated at 29 C in darkness until all kernels are well colonized (3-4 weeks). Colonized kernels are air-dried in ethanol-disinfected trays, hermetically covered by two layers of ethanol-disinfected tissue-paper, under a continuous flow of compressed air filtered through sterile 0.45u filters. Dried kernels are ground for 3 seconds (dry) in a Waring blender and fractionated through sieves into three fractions: < 0.5 mm; 0.5-2.0 mm; > 2.0 mm. Whole dried kernels and separate fractions are stored at room temperature. Generally, the fraction 0.5-2.0 mm was used for inoculations.

PREPARATION OF VARIOUS INOCULUM DOSES

☁ Fraction 0.5-2.0 mm of colonized oat kernels was used as inoculum in the following concentrations: 2, 1, 0.5, 0.25, and 0.1 gr/l pot mix, as a layer in Pot Assay. Four pots with 9 plants of each plant species were used for each inoculum dose.

ISRAEL RESULTS

1. ASSESSMENT OF THREE ASSAY METHODS

Slanted Sleeve Assay. The results of two experiments are presented in Table 1. Based on disease indices, ranking of the standards, wheat, barley and rye would be: susceptible, moderately and highly resistant, respectively. Two factors contribute to this ranking, namely length of lesion and proportion of roots that developed infection. When infection did develop on barley and rye, there was no substantial difference in lesion length. However, percentage of infected roots was markedly lower (less than half) on rye than on barley. Although disease development in the two experiments was extremely different, the relative disease indices of the standards are similar. It appears that the much shorter incubation period in Exp. 2 (14 days) did not affect the relative ranking. It should be noted that in this experiment, roots were older at inoculation.

Pot Assay. The results of three experiments are presented in Table 2. (The results of Exp. 1 are averages of all five inoculum types, pooled together and compared to the controls, Table 6). The results show decreasing levels of infection and yield loss in wheat, barley and rye. Loss of shoot dry weight in inoculated rye (resistant) was negligible (not significantly different from the non-inoculated control), while growth retardation in infected barley was prominent. There is a close agreement between the averages of relative infection scores and loss of shoot dry weight (Table 2).

Tube Assay. This test was conducted consecutively for over 20 times during the year, using various types and doses of inoculum, different isolates, and with various minor differences in culture age, length of incubation and growth-room conditions. These experiments (Table 3) repeatedly show that the relative

scores of the standards was in decreasing order from wheat to barley and to rye. There were large variations in scores between assays, e.g. wheat scores ranged from 1.9 to 4.2. When potency for infection was high or low, it was reflected in all standard cultivars. Thus, the relative ranking of barley and rye was usually consistent. Therefore, we suggest to include these standards as markers in every screening test. Resistance was composed of two components, a reduced rate of infected roots and smaller lesions.

The results of a recent, typical, test (Table 4) reveal that the percentage of infected roots in barley was similar to the rate in wheat, while in rye the infection rate was only 68%.

2. EFFECT OF INOCULUM TYPE

Five types of inoculum were evaluated with both Tube and Pot Assays.

(A) Tube Assay. The results (Table 5) show a considerable difference in infection scores of wheat, inoculated by different inoculum types. Millet seed and oat kernel were the most potent, maize meal, either with vermiculite or with sand, was intermediate, and wheat straw was the least effective.

(B) Pot Assay. The results in this experiment (Table 6) did not reveal a consistent potency of any of the inocula. While the infection scores on wheat were within a narrow range, on barley and rye there were larger differences. However those differences were inconsistent. The effect of inoculum type on disease severity, as expressed by loss of dry weight, was inconsistent and statistically significant in only a few permutations, e.g. on wheat, maize meal in sand was more infectious than wheat straw; on barley, oat kernel inoculum was more potent than millet kernels. On rye, there was no statistically significant difference between all inoculum types.

3. EFFECT OF INOCULUM DOSE

The results of this experiment showed no significant differences between shoot dry weight of plants subjected to the various inoculum levels, due to too great intra-treatment variability in plant size and plant dry weight. This could have been a result of great variability in seed weight. It was concluded that experiments should be carried out with pre-weighed seeds which will be in the range of $\pm 10\text{mg}$ group.

MATERIALS AND METHODS

MONTANA

The goal of the Montana portion of this project was to compare the virulence of numerous isolates of Ggt to hosts varying in susceptibility using several techniques for pathogenicity tests.

ASSAY METHODS:

Tube assay (Conetainers). Plastic 40 ml cones were filled in a layered fashion as follows: nonabsorbent cotton was placed in the bottom, followed by 20 ml of sand or vermiculite, the inoculum, 10 ml of vermiculite, 1 pregerminated seedling (48hrs) which was then covered with vermiculite. The seedlings were watered with a 20-20-20 fertilizer solution throughout the experiment. After 5 weeks the plants were removed from the conetainers and the roots were carefully washed and rated for disease. Next the roots were removed and the plants were oven dried at 72 C for 48 hours. When dried, the weight of the leaf tissue was taken and recorded. This assay was repeated during the year with various types and doses of inoculum, with a range of isolates and with different host plants.

Rating method. The seedling roots were placed in a petri dish filled with water and visually rated under a dissecting microscope

at 10x power using the following scale:

- 0= No lesions or discoloration present
- 1= Less than 25% of the roots infected
- 2= 25% to 50% of the roots infected
- 3= 50% to 75% of the roots infected
- 4= 75% to 100% of the roots infected
- 5= 100% of the roots and the culm infected
- 6= Total infection, plant dead or dying

Standard Cultivars. The cultivars used in this study were:

Wheat (Triticum aestivum) Pondera
Triticale
Barley (Hordeum vulgare) Klages, Volbar, Dawn
Rye (Secale cereale) Aroostook
Oats (Avena sativa) Freedom

Isolates. Most of the 44 Ggt strains were from previously isolated cultures originating in Montana. Some were from out of state and out of the country. All had been isolated from wheat, barley or triticale.

PREPARATION OF INOCULUM

1. Nutrient Agars. The Ggt isolates were grown on several types of nutrient agar plates: Potato Dextrose; Czapeks Solution (Sucrose, Sodium Nitrate, Dipotassium Phosphate, Magnesium Sulfate, Potassium Chloride, Ferrous Sulfate); 1/5 Strength Potato Dextrose; Wheat leaf extract; Corn meal; or simply water agar. The plates were allowed to grow at room temperature for 10 days. After this, 14mm disks were cut from the edges of the colonies and placed in the containers. Potato Dextrose agar was most commonly used.

MONTANA RESULTS

To evaluate and select isolates of Ggt with varying degrees of virulence toward wheat, a number of isolates were tested in two separate tests. The results of these tests are given in Table 7. A few of the isolates were of very low virulence, eg #542, while others were of intermediate virulence, eg #552 and #586. Most were of very high virulence. One reason for doing this work was to have access to isolates of moderate or low virulence, the use of which might make detection of small increments of resistance somewhat easier.

To determine whether we could differentiate the varying susceptibility of wheat, barley, triticale, rye and oats, we used 10 isolates of Ggt varying in virulence. The results of such tests are given in Table 8. This clearly shows that we can detect these differences with oats being highly resistant, rye being slightly susceptible, followed by barley and triticale being increasingly more susceptible with wheat the most susceptible of these small grains.

To further test our system for differentiating small differences in susceptibility, three cultivars of barley reported to differ in their reaction to Ggt were tested, along with rye and wheat, to represent the extremes of reaction. The results are presented in Table 9. This again, clearly shows that our system of testing can detect small differences in susceptibility. It also shows that using an isolate of relatively low virulence, eg #542, does not allow better differentiation of susceptibility.

Another parameter for measuring resistance or susceptibility to Ggt is the dry weight of the foliage that develops on an infected plant. The data in Table 10 show a comparison between disease rating scores when roots are examined versus leaf dry weight. There is a very good correlation between the two indicating that the somewhat subjective system of disease scoring is mirrored in the dry weight of the plant where human subjectivity is removed from the judgment.

DISCUSSION

MONTANA AND ISRAEL

The main objective of this year's work was to determine whether the system we were using in Israel and Montana to assess susceptibility to Ggt was precise enough to detect small differences. With all three Israeli methods, ranking of the standards was clear, showing a decreasing order of both infection and inhibition of plant growth, from wheat through barley to rye. The relative infection scores assessed in Tube Assay and in Pot Assay and the relative loss of shoot dry weight were similar in magnitude. If we consider an entry with an infection score of approximately 50% or less of that of a comparable wheat cultivar as resistant, rye could be classified as resistant and barley as moderately susceptible. This ranking concurs with numerous field observations. In the Slanted Sleeve Assay even though barley had a disease index two times higher than rye, both barley and rye were markedly less infected than wheat, and could thus be ranked as resistant. It appears that with the Slanted Sleeve method, field resistance can be expected when relative disease index of approximately 25% is demonstrated.

Point inoculation of roots in sleeves (Table 1) demonstrated two factors of resistance, namely restriction of lesion development and lower rate of infection. Likewise, the results in the Pot Assay (Table 2) and the results of Tube Assays (not shown) point to the same mechanism, although the rates of infected roots in barley and rye were not as low as in point inoculation. In pots and tubes there appear to be multiple infection points.

The suitability of the Tube Assay to detect resistance was proven in a program of screening accessions of *Aegilops*. Accession 34-4B was consistently resistant in 6 sets of experiments. The infection scores were 1.4, 1.5, 1.6, 1.7, 1.8, 1.8 (average 1.6). This resistance reaction was subsequently confirmed by a Pot Assay. Recently, Conner et al. (1988) reported resistance to Ggt derived from a related accession of *Aegilops squarrosa*, both in pots and

under field conditions.

We plan to employ in our large-scale screening program (if our new proposal is approved) both the Tube and Slanted Sleeve assays. The advantages of the former are reliability and ease of performance. The Slanted Sleeve Assay is more sensitive, allowing detection of even a small degree of resistance, and is not difficult to conduct. However, resistance originating mainly from low infection rate may not hold up under multiple inoculation points in nature. Selected accessions would be subsequently evaluated by the Pot Assay, under more natural conditions, by which the disease effect on the plant can also be monitored. Resistance to take-all must eventually be verified under field conditions.

In Montana using hosts of known reaction, ie oats, rye, barley, triticale, and wheat, we were able to verify that our system can be used effectively. This was tested using a number of isolates of Ggt that varied in their virulence. This was corroborated with other tests where we used cultivars of barley recently reported to vary in their reaction to Ggt. We were also able to determine that our system of scoring roots was highly correlated with the objective technique of evaluating plant reaction using foliage dry weight. This, too, provides us with confidence that we will be able to detect small differences in susceptibility when working with the wild emmer wheats using the easy and quick technique of rating roots for infection.

Table 1. Israel. Slanted Sleeve assay of standards (14-30 replicates)

Plant	<u>Lesion length</u>		<u>Infected roots</u>		<u>Disease index</u>	
	mm	Relative	% of total	Relative	Calculated	Relative

Exp. 1						
Wheat	45.7	100	81	100	37.0	100
Barley	27.1	59	54	67	14.6	39
Rye	31.5	69	20	25	6.3	17
Exp. 2						
Wheat	12.8	100	91	100	11.7	100
Barley	6.9	54	67	74	4.6	39
Rye	6.8	53	31	34	2.1	18

Calculated from infected roots only.

Disease index = lesion length x percent of infected roots.

Table 2. Israel. Pot Assay of standards (Exp. 1= summary of results of assessment of various inoculum types, ~~Exp. 2 and 3~~ experiments 2 and 3 were conducted with millet kernel inoculum.)

Plant	<u>Infection score</u>		<u>Infected roots</u>		<u>Loss of shoot dry wt. (%)</u>	
	(0-5)	Relative	% of total	Relative	(Control=0%)	Relative
Exp. 1.						
Wheat	4.2	100	96	100	33.7*	100
Barley	3.0	71	81	84	18.4*	55
Rye	1.6	38	51	53	13.3	39
Exp. 2.						
Wheat	4.8	100	100	100	53.5*	100
Barley	3.6	75	96	96	47.3*	88
Rye	1.8	37	53	53	3.8	7
Exp. 3.						
Wheat	4.7	100	100	100	28.5*	100
Barley	2.8	60	81	81	18.4*	65
Rye	0.8	17	43	43	8.1	28
Average (experiments 1-3)						
Wheat		100		100		100
Barley		69		87		69
Rye		31		50		25

* Loss of shoot dry weight with [*] significantly different from uninoculated control (t-test, $p \leq 5\%$).

Table 3. Israel. Tube Assay of standard cultivars (culture inoculum)
(average of 20 experiments, 5-15 replicates each)

Plant	<u>Infection score</u>	
	(0-5)	Relative
Wheat	3.1	100
Barley	2.1	68
Rye	1.5	48

Table 4. Israel. Tube Assay of standard cultivars (culture inoculum)
(Exp. 37, average of 10 replicates)

Plant	<u>Infection score</u>		<u>Infected roots</u>	
	(0-5)	Relative	% of total	Relative
Wheat	2.9	100	100	100
Barley	2.4	83	100	100
Rye	1.5	52	68	68

Table 5. Israel. Infection scores of wheat assessed in Tube Assay with various types of inoculum.

Inoculum type	Infection score
Wheat straw	0.8
Maize Meal & Vermiculite	1.8
Maize Meal & Sand	1.6
Millet kernel	3.0
Oat kernel	2.5

(5 replicates).

Table 6. Israel. Comparison of five inoculum types in Pot Assay of standards

Plant/ inoc.	<u>Infection score</u> (0-5)	<u>Infected roots</u> % of total	<u>Loss of dry shoot wt. (%)</u> (Control=0%)
Wheat			
I	4.6	100	19 b
II	3.3	86	39 bc
III	4.2	95	41 c
IV	4.3	95	36 bc
V	4.3	100	30 bc
Barley			
I	3.7	92	24 bc
II	4.0	84	20 bc
III	2.7	79	20 bc
IV	2.5	75	6 ab
V	2.2	78	27 c
Rye			
I	1.6	48	16 ab
II	1.9	49	2 ab
III	0.8	32	8 ab
IV	1.8	63	16 ab
V	1.6	64	25 b

Inoculum types were as follows:

- I = Wheat straw-vermiculite
- II = Maize meal-vermiculite
- III = Maize meal-sand
- IV = Millet kernels
- V = Oat kernels

Table 7. Montana. Pathogenicity of various isolates of Gaeumannomyces graminis var. tritici on Pondera spring wheat using plugs of mycelium on PDA as inocula.

ISOLATE	<u>Infection Score</u> (0-5)		
	Exp. #1	Exp. #2	Mean
401	2.40	2.20	2.30
528	3.67	3.00	3.34
529	4.33	2.50	3.42
530	3.67	2.50	3.09
531	2.50	2.80	2.65
532	3.20	2.50	2.85
533	4.00	2.17	3.19
534	3.20	2.20	2.70
535	4.00	2.40	3.20
536	5.00	3.40	4.20
537	3.60	3.40	3.50
538	3.50	1.80	2.65
539	4.00	2.20	3.10
540	3.00	1.80	2.40
541	4.00	3.20	3.60
542	1.00	.00	.50
544	4.00	2.40	3.08
545	3.75	2.40	3.08
546	3.83	3.40	3.62
547	2.25	3.00	2.63
548	4.50	4.60	4.55
549	3.40	3.00	3.20
550	4.00	3.40	3.70
551	2.75	3.40	3.08
552	2.25	2.75	2.50
553	4.00	2.83	3.42
554	3.00	2.80	2.90
555	4.00	3.40	3.70
556	4.00	3.40	3.70
557	4.25	3.40	3.83
558	3.80	4.00	3.90
570	1.00	.00	.50
586	3.60	2.00	2.80
587	4.00	3.20	3.60
589	4.25	2.00	3.13
590	4.00	3.75	3.88
591	3.75	3.40	3.58

Table 8. Montana. Susceptibility of various host species to isolates of Gaeumannomyces graminis var tritici which may vary in virulence using mycelial plugs on PDA as a source of inoculum.

PLANT	<u>Infection Score</u> (0-6)										<u>Mean</u>
	<u>ISOLATE #</u> <u>531</u>	<u>540</u>	<u>542</u>	<u>535</u>	<u>552</u>	<u>586</u>	<u>536</u>	<u>546</u>	<u>558</u>	<u>590</u>	
OATS	.33	.00	.00	.43	.00	.00	.10	.00	.29	.44	.16
RYE	.38	.00	.14	.57	.00	.00	1.20	.00	.44	1.11	.38
BARLEY	1.88	.38	.22	2.00	.60	.89	1.80	4.75	2.22	2.38	1.71
TRITICALE	3.10	.10	.10	4.20	.90	.56	3.80	5.75	4.40	4.00	2.69
WHEAT	4.30	.20	.20	5.40	1.50	1.00	5.18	6.00	5.33	4.67	3.38
	9.99	.68	.66	12.6	3.00	2.45	12.08	16.50	12.68	12.60	

Table 9. Montana. Susceptibility of three cultivars of barley to Ggt in comparison to rye and wheat when inoculated with mycelial plugs on PDA.

PLANT	INFECTION SCORE (0-6)						Mean
	ISOLATE # <u>540</u>	<u>542</u>	<u>552</u>	<u>586</u>	<u>546</u>	<u>558</u>	
RYE	.42	.12	.00	.33	.00	1.67	.42
DAWN	.50	1.33	.00	1.50	.00	2.25	.93
VOLBAR	1.33	.43	.20	1.00	.14	3.30	1.07
KLAGES	2.79	.45	1.47	1.05	3.90	4.20	2.31
PONDERA	1.88	.72	1.80	1.90	5.20	5.72	2.87
	6.92	3.05	3.47	5.78	9.24	17.14	

Table 10. Montana. Virulence of various isolates of Gaeumannomyces graminis var tritici to Pondera spring wheat as determined by disease score on infected roots and foliage dry weight.

ISOLATE	<u>EXP. #1</u>		<u>EXP. #2</u>	
	Dis. Score	Dry Wt.(mg)	Dis. Score	Dry Wt.(mg)
531	2.80	.54		
540	1.80	1.17	1.88	.73
542	0.00	1.24	.72	1.06
535	2.40	.86		
552	2.75	.68	1.80	.74
586	2.00	1.16	1.90	.74
536	3.40	.56		
546	3.40	.46	5.20	.29
548	4.60	.30	5.72	.22
558	4.00	.55		
590	3.75	.50		
591	3.40	.56		
CK	.00	1.08	.00	.85

DESCRIPTION OF COOPERATION

During the course of the period in which this grant was in place, the investigators in Israel and Montana were in close contact with each other using the Bitnet form of message transmission. This allowed us to share data and ideas on a daily basis if needed. In addition, isolates of Gaeumannomyces graminis var. tritici from Montana which were of known virulence were sent to Israel for use in their program. In a blind test, the Israeli investigators were able to detect the same virulence patterns as the Montana investigators thus indicating that our systems of growing, infecting, and rating the disease on infected plants was comparable. Finally, Dr. Solel was able to spend one week in Montana during the late stages of this project to observe the Montana work, offer comments and suggestions, and assist in the preparation of a new research proposal based on this first year "trial" project.

MAIN ACHIEVEMENTS

The main achievements were the development and use of procedures that allowed the reliable and consistent detection of small differences in resistance to take-all that exist in various small grain cereals. This lays the foundation, then, for the use of such techniques in exploring the potential resistance to take-all that may be found in the wild emmer wheats.

LIST OF PUBLICATIONS

Solel, Z., and Anikster, Y. 1988. Susceptibility of wild emmer wheat from Eastern Galilee to take-all disease. *Phytoparasitica* 16:76 (Abstract)

הספריה המדעית
למדעי החקלאות
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