RELATION OF LEAF RUST SEVERITY TO GROWTH OF YOUNG WHEAT PLANTS

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CHAPTER I

INTRODUCTION

The increased importance of winter wheat for livestock pasture in the southern plains area of the United States has led to an advance of two to three weeks in the average planting date for this crop. The extra time period has, in turn, permitted three to four extra generations of the leaf rust fungus to occur during the autumn period. With such an increase in the disease development period, it is not uncommon to find severe epiphytotics of the disease in certain areas or in certain years (22).

Almost all studies on the effect of the leaf rust fungus, Puccinia recondita Rob ex. Desm. f. sp. tritici Eriks. & E. Henn., on the wheat plant have been made on grain yield (4, 10). Until very recently, little had been done on the effect of this disease on growth of the developing plant (8). Williams (20, 21) found that high severities of the disease on seedling plants drastically reduced both foliar and root growth. The question remained, however, whether lesser severities were significant in limiting growth and development. It was the purpose of this study to determine the influence of light to moderate severities of the leaf rust disease on foliar and root growth of young wheat plants.

CHAPTER II

REVIEW OF LITERATURE

Leaf rust of wheat is known to be one of the most destructive and widely distributed diseases of wheat (17). On susceptible cultivars it causes a reduction in the yield of straw and grain, increases the water requirement of the crop and hastens the date of maturity (9, 10).

That leaf rust leads to the premature death of wheat leaves is a matter of common observation. In severe epiphytotics, all wheat foliage may be destroyed before, or a few days after, heading. Considering that part of the function of leaves is the manufacture of food for storage in the seeds, any reduction in photosynthetic tissues generally will result in decreased yields (4). Leonard and Martin (11) stated that when wheat plants are infected with leaf rust in an early growth stage, the yield of susceptible cultivars may be reduced as much as 94 percent, while in a resistant cultivar an abundant flecking of the leaves caused by aborted infections may result in a maximum reduction in yield of grain of only 15.2 percent.

Johnston and Miller (10) in 1934 stated that the yield of straw was less affected by leaf rust infection than other plant parts. In their studies, the yield of straw of a susceptible cultivar heavily infected with leaf rust at an early stage of growth was reduced by about one-third.

Correlation of growth of roots and foliar parts in wheat is usually pronounced and maintenance of a proper balance between root and shoot growth is of great importance. Injury to one generally hinders growth of the other (19).

While the effect of leaf rust infection on the wheat leaf is quite striking, the effect on roots may be equally so. Johnston and Miller (10) found that heavy rust infection on susceptible cultivars resulted in rapid and severe deterioration of roots. This was indicated by root discoloration, a decrease in the number of fibrous roots, and a marked loss in total root weight. In the same paper they also reported that the roots of plants that were leaf rust-free until flowering were nearly as severely injured as those of plants rusted from the seedling stage to maturity. In the former case an extensive root system developed but was greatly reduced by rust infection, whereas in the latter case the root system never became as extensive as in the former and the roots that did develop were unable to persist long in a healthy condition.

Stripe rust seems to have a similar effect on wheat. Hendrix and his associates (6, 7, 12, 13, 14) reported on several observations of the effect of stripe rust on wheat plants. They found that the stripe rust-infected plants developed less vigorous roots than non-infected plants. Their measurements of roots from plants infected with stripe rust showed reduced stele-cylinder diameters, reduced numbers of pericycle cells, and reduced numbers of phloem cells. In most cases, the size of the above described reductions was associated with the severity of rust infection. They also reported that the mitotic index in root cells of stripe rust-infected plants was smaller than that of non-infected plants. All of these changes were associated with the

deterioration and discoloration of infected roots (13). The root volume of infected plants was reduced from 82.6 to 32.4 percent depending on the stage of growth at which infection occurred. Infection at an early stage of growth was more destructive than infection initiated later. The dry weight of infected wheat roots was similarly affected.

More recently, Williams (20) has reported the discoloration and deterioration of roots of wheat plants infected with Puccinia recondita f. sp. tritici. He found a reduction of 77.1 percent in root dry weight and 66.3 percent in root volume of roots from infected young wheat plants. Regrowth of wheat seedlings infected with leaf rust following clipping to simulate grazing was extensively retarded. The original foliar growth was also severely retarded. In his studies, the use of resistant and susceptible isogenic lines proved to be valuable for comparing the effect of leaf rust on forage production. The forage production of these lines in the field was essentially the same in the absence of leaf rust, but when the disease was severe, the forage production of the resistant line was nearly double that of the susceptible line.

CHAPTER III

MATERIALS AND METHODS

For the present work, a culture of Puccinia recondita f. sp. tritici designated "2AAG+" was selected because it was one of the more significant races present in Oklahoma. It was isolated from a field collection made in southwestern Oklahoma, in May, 1970. This culture is similar to race UN 2 (1) and, in addition, possesses virulence on the wheat cultivars "Westar" and "Agent" (22).

Ten cultivars of wheat, Triticum aestivum L. em. Thell., were used in this investigation. They were:

"Comanche", C.I. 11673 (CMN) (2), a hard red winter wheat released from Kansas (18), has good agronomic characteristics but does not exhibit any resistance to leaf rust in the seedling stage. It does, however, exhibit some type of adult plant resistance in the field. The Comanche cultivar has also been used as recurrent parent for isolation of leaf rust genes in Oklahoma (22).

"Chinofuz", C.I. 15350 (CNF), is a short-statured line, that attains only approximately half the height of the other cultivars used in this study. This cultivar is resistant to the Agent-virulent culture, but susceptible to certain other leaf rust cultures in the seedling stage. In the adult stage it appears to be resistant to all cultures in the field. The cultivar was developed in Oklahoma from a cross

originally made at Purdue University, Lafayette, Indiana, for leaf rust resistant germ plasm and not for commercial production (22).

"Nicoma", C.I. 13874 (NCM), an Oklahoma release for commercial production, has early maturity and good baking quality. It is susceptible to all cultures of leaf rust used for testing in the seedling stage; however, it has some degree of adult plant resistance to races presently found in Oklahoma (22).

"Centurk", C.I. 15075 (CNR), was recently released from Nebraska. It possesses high yielding ability and is widely adapted. This cultivar has partial resistance to leaf rust, being resistant to most cultures found in the population but susceptible to the culture used in this study.

"McCall", C.I. 13842 (M.C), is a recent Washington release. It performs very well in warm soil in the seedling stage and is recommended for low-rainfall areas in eastern Washington. It is completely susceptible to leaf rust (15).

"Wanser", C.I. 13844 (WSR), another recent Washington release, is similar to McCall in growth habit and leaf rust susceptibility (16).

"Morocco", W 1103 (MRO), originated in Australia, and was thought to be universally susceptible to leaf rust (22).

"Danne", C.I. 13876 (DNE), is one of the widely grown cultivars in Oklahoma. It has a high yield potential, but is susceptible to leaf rust at all stages of growth.

Besides the cultivars mentioned above, a pair of near isogenic lines was used. This near isogenic pair consisted of leaf rust resistant and susceptible selections from the cross Transfer/5* Comanche (TF/5*CMN).

The abbreviations designated above for the cultivars Nicoma, Centurk, Danne, and Morocco were only for use in this study. No abbreviations for these cultivars have been designated according to the system proposed by Briggle et al (2).

These cultivars were divided into two groups for this study. One group was composed of Comanche, Morocco, Danne, Chinofuz, and Nicoma and this group was used in experiments 1 and 2. McCall, Wanser, Centurk, and the resistant and susceptible near-isogenic lines /TF/5*CMN (R1) and TF/5*CMN (S1)/ were considered as group 2 and were used in experiments 3 and 4.

In each experiment, 15 "Arasan" (50% Thiram)-treated seeds of each cultivar were planted in each of 40, 10.16 cm-pots. Each pot was firmly packed with 400 grams of a uniformly mixed soil composed of six parts of clay loam, one part fine sand, and one part peat moss. The seeds were uniformly spread on top of the soil surface and firmly covered with an additional 100 grams of the soil mixture. Water was slowly added to each pot until the water began to drain at the base of the pot.

The pots were then placed in the growth chamber (Sherer-Gillet Model CEL 25-7) and arranged in 2 replications with 5 wheat cultivars and 4 treatments randomized in each replication. The growth chamber was adjusted to provide a light intensity of 2153 lx. at plant height. A photoperiod of 12 hours of light and 12 hours of darkness was provided. The temperature was maintained at 21 ± 1°C during both the light and dark periods.

Soil moisture was maintained near optimum and the plants never were subjected to moisture stress. Beginning the third day after planting, the pots were watered every other day with 80 cc of a solution

containing "Hyponex" fertilizer (7-6-19, N-P-K formulation) at the rate of 2 grams per liter.

The wheat seedlings were thinned to ten plants per pot five days after planting. There were four pots of each cultivar and the following treatments were randomly assigned to one pot of each cultivar: (1) untreated control; (2) inoculated with P. recondita f. sp. tritici at age six days; (3) inoculated with P. recondita f. sp. tritici at age six and ten days; and (4) inoculated with P. recondita f. sp. tritici at age six, ten and fourteen days.

The first inoculation of wheat seedlings was made when the plants were six days old. Pots of each cultivar to be inoculated were removed from the growth chamber and placed in moist chambers containing a thin layer of water in the bottom to maintain high humidity. The plants were sprayed with a solution containing tap water and surfactant, "Tween 20" (polyoxyethelene 20 sorbitan monolaurate) at 3 to 4 drops/ 1000 ml water. The plants were then inoculated using the brushing technique described by Browder (3). The inoculated plants were then sprayed again and the tops of the moist chambers were covered for a period of twelve hours. The plants were then returned to the growth chamber for disease development.

Similarly, the second and third inoculations were made by repeating the process when the plants were ten and fourteen days old. The leaf rust infection readings based on the modified Cobb scale (5) were made on the tenth day after the third inoculation.

The measurements of foliage and root growth of the young wheat plants were made at 40 days. The pots were removed from the growth chamber and soaked in a sink half-filled with water until the soil was

saturated. Then the contents of each individual pot were washed by running a fine stream of tap water over the root mass until the soil was thoroughly washed away.

The foliage and root portions were separated by cutting washed plants with scissors at a point immediately above the basal node. Foliar and root portions from each pot were placed separately in small paper bags, and weighed while still fresh. A root volume for the total of all plants in each pot was obtained by placing the roots from each pot in a 100 ml graduated cylinder and measuring the displacement of water.

After weighing, the samples were placed in a drying oven designed to operate at 62°C for 72 hours; after which, the oven-dry samples were again weighed.

In one experiment the inoculations were made on plants ten and twenty days old, and only two inoculations were made. In this experiment, the plants were maintained in the growth chamber until 60 days old.

CHAPTER IV

RESULTS

Leaf rust severity recorded ten days after the third inoculation for five wheat cultivars in the first experiment is presented in Table I. The readings were based on the modified Cobb scale (5). The wheat seedlings inoculated three times had severity readings that averaged 23 percent more than plants inoculated only once. The first experiments were designed to observe the effect of such variation in leaf rust severity on growth of the young wheat plants of five of the wheat cultivars (Comanche, Morocco, Danne, Chinofuz, and Nicoma) used in the study. This effect was measured by wet and dry weights of forage and root portions, and the root volume of each group of ten plants tested.

Since water was used to separate the soil from the plants, the actual amount of water that still adhered to the roots after washing could not be equated from one group of plants to another. Therefore, fresh weight, particularly of the roots, were somewhat variable and perhaps less reliable indications of growth than oven-dry weights, and are not presented here.

It is evident from data obtained (Table II) that the number of inoculations, and therefore the leaf rust severity, did affect the growth of young wheat plants. Considering the average of all cultivars, the fresh and dry weight of foliar portions of the plants inoculated once at six days were not different from the non-inoculated plants.

TABLE I

RELATIONSHIP OF THE NUMBER OF INOCULATIONS TO THE SEVERITY OF LEAF RUST ON SEEDLINGS OF 5 WHEAT CULTIVARS

Cultivar[1]	Response[2]	Percent Severity[3] Number of Inoculations 0	1	2	3
CNF	R	0	25	25	45
MRO	S	0	50	60	70
CMN	I	0	70	70	90
NCM	I	0	72	82	90
DNE	S	0	75	90	85
MEAN		0	60	65	75

[1]Abbreviations as follows:
CNF = Chinofuz
MRO = Morocco
CMN = Comanche
NCM = Nicoma
DNE = Danne

[2]R = Resistant
S = Susceptible
I = Intermediate

[3]Average of 2 replications based on modified Cobb scale

TABLE II

EFFECT OF LEAF RUST INFECTION ON FOLIAR GROWTH OF
WHEAT SEEDLINGS OF CERTAIN CULTIVARS
EXPERIMENT 1

	Weight in gms[1]									
	Fresh					Oven-Dry				
	Number of Inoculations					Number of Inoculations				
Cultivars[2]	0	1	2	3	Mean	0	1	2	3	Mean
CNF	8.44	8.30	5.53	5.71	6.99	1.06	1.04	0.69	0.75	0.88
MRO	8.18	6.47	3.67	2.82	5.28	0.99	0.80	0.49	0.44	0.68
CMN	8.11	8.74	7.04	4.48	7.09	1.18	1.25	1.01	0.73	1.04
NCM	7.49	9.12	6.40	4.97	6.99	1.20	1.41	1.09	0.83	1.13
DNE	8.31	6.99	5.12	3.77	6.04	1.18	1.09	0.85	0.62	0.93
MEAN	8.10	7.92	5.55	4.35		1.12	1.12	0.83	0.67	

LSD 0.05 Cultivar Means	0.82	0.13
LSD 0.05 Inoculation Means	0.75	0.11

[1] Means of 2 replications of 10 plants

[2] Abbreviations as follows: CNF = Chinofuz, MRO = Morocco, CMN = Comanche
NCM = Nicoma, DNE = Danne

Subsequent inoculations, however, definitely reduced the growth of foliage by an average of 26 and 40 percent respectively.

The cultivar Comanche had the best foliar growth, but probably was not different from Chinofuz and Nicoma in this repsect. It is significant that of these cultivars Chinofuz is resistant to the culture used in the study and both Comanche and Nicoma express resistance in the field (Figure 1). The only completely susceptible winter wheat cultivar in the study, Danne, which expresses no resistance to leaf rust in greenhouse tests or in the field produced significantly less forage than the other winter wheats. The forage production of the spring wheat cultivar Morocco was significantly less than all other cultivars tested.

A remarkable decrease in root growth of rusted plants is clearly demonstrated in this study. The root weight and root volume measurements are shown in Table III. The root growth of wheat seedlings inoculated three times was drastically reduced compared to roots of plants not inoculated or inoculated only one time. The average oven-dry root weights of plants inoculated one, two, and three times showed a reduction of 15, 45, and 58 percent less than the healthy plants, respectively. Root volume followed the same trend with almost identical percentages of reduced growth.

The effect of leaf rust on root growth was most pronounced on the cultivar Morocco. This effect is best seen in the diagramatic illustration in Figure 2. This work was repeated with similar results (Tables IV and V and Figures 3 and 4). In this experiment the superiority in growth of the cultivar Chinofuz, which has a specific type of resistance, was more clearly evident.

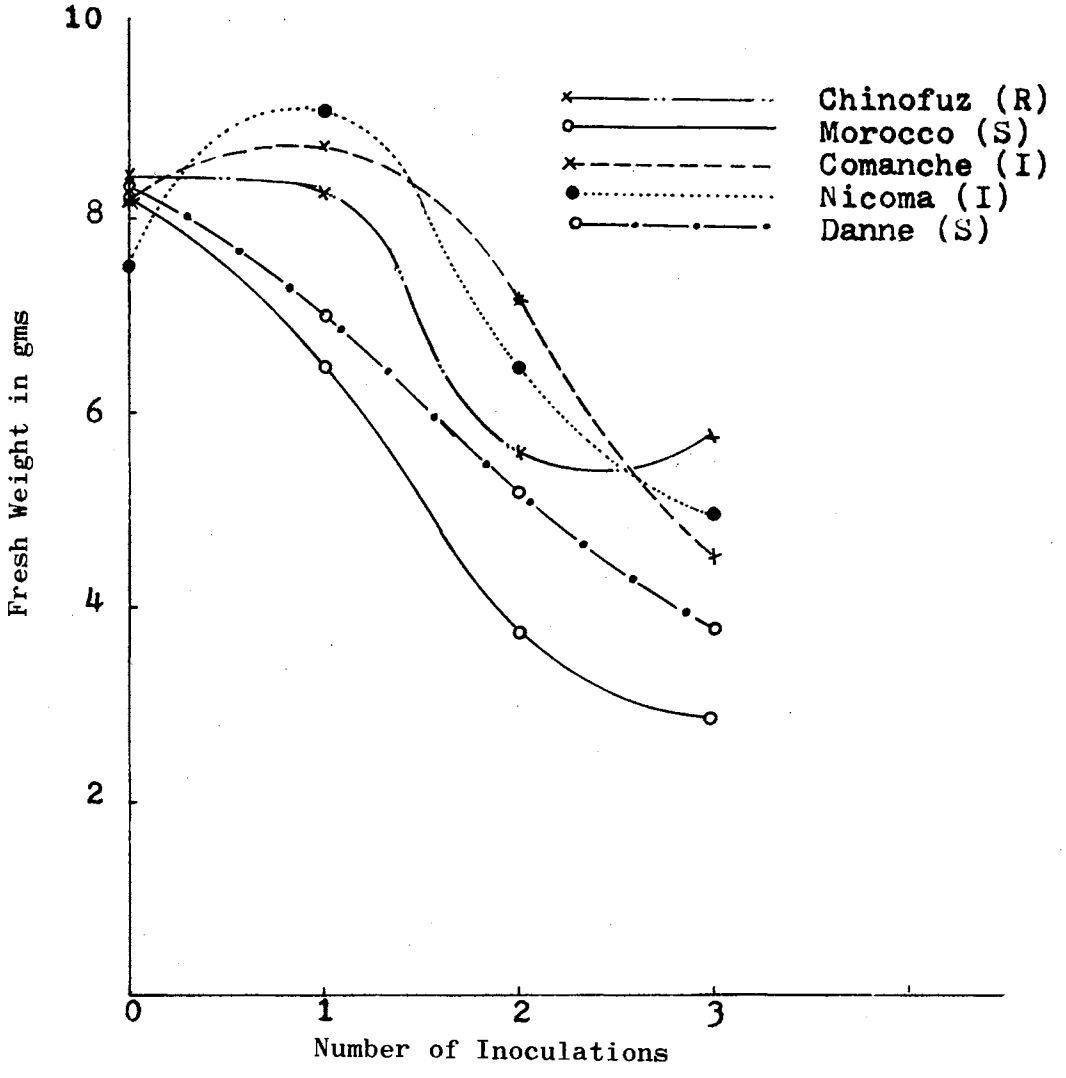

Figure 1. The Effect of the Number of Leaf Rust Inoculations on Fresh Weight of Foliage Produced by 40 Day-Old Wheat Seedlings of 5 Cultivars Resistant (R), Intermediate (I), or Susceptible (S) to the Disease (Experiment 1)

TABLE III

EFFECT OF LEAF RUST INFECTION ON ROOT GROWTH OF WHEAT SEEDLINGS OF CERTAIN CULTIVARS
EXPERIMENT 1

Cultivar[2]	Oven-Dry Weight in gms[1]					Volume in ml[1]				
	Number of Inoculations					Number of Inoculations				
	0	1	2	3	Mean	0	1	2	3	Mean
CNF	0.50	0.44	0.26	0.31	0.38	5.5	4.3	3.5	3.3	4.2
MRO	0.48	0.34	0.18	0.12	0.28	5.8	4.5	2.6	1.9	3.7
CMN	0.72	0.52	0.34	0.27	0.46	5.7	5.3	4.0	3.0	4.5
NCM	0.61	0.54	0.47	0.31	0.48	5.8	5.3	4.5	4.0	4.9
DNE	0.57	0.52	0.37	0.17	0.41	5.8	5.5	3.5	2.3	4.3
MEAN	0.57	0.47	0.32	0.23		5.7	4.9	3.6	2.9	

LSD 0.05 Cultivar Means	0.10	NS
LSD 0.05 Inoculation Means	0.09	0.9
LSD 0.05 C x I Means	NS	2.0

[1]Means of 2 replications of 10 plants

[2]Abbreviations as follows: CNF = Chinofuz
MRO = Morocco
CMN = Comanche
NCM = Nicoma
DNE = Danne

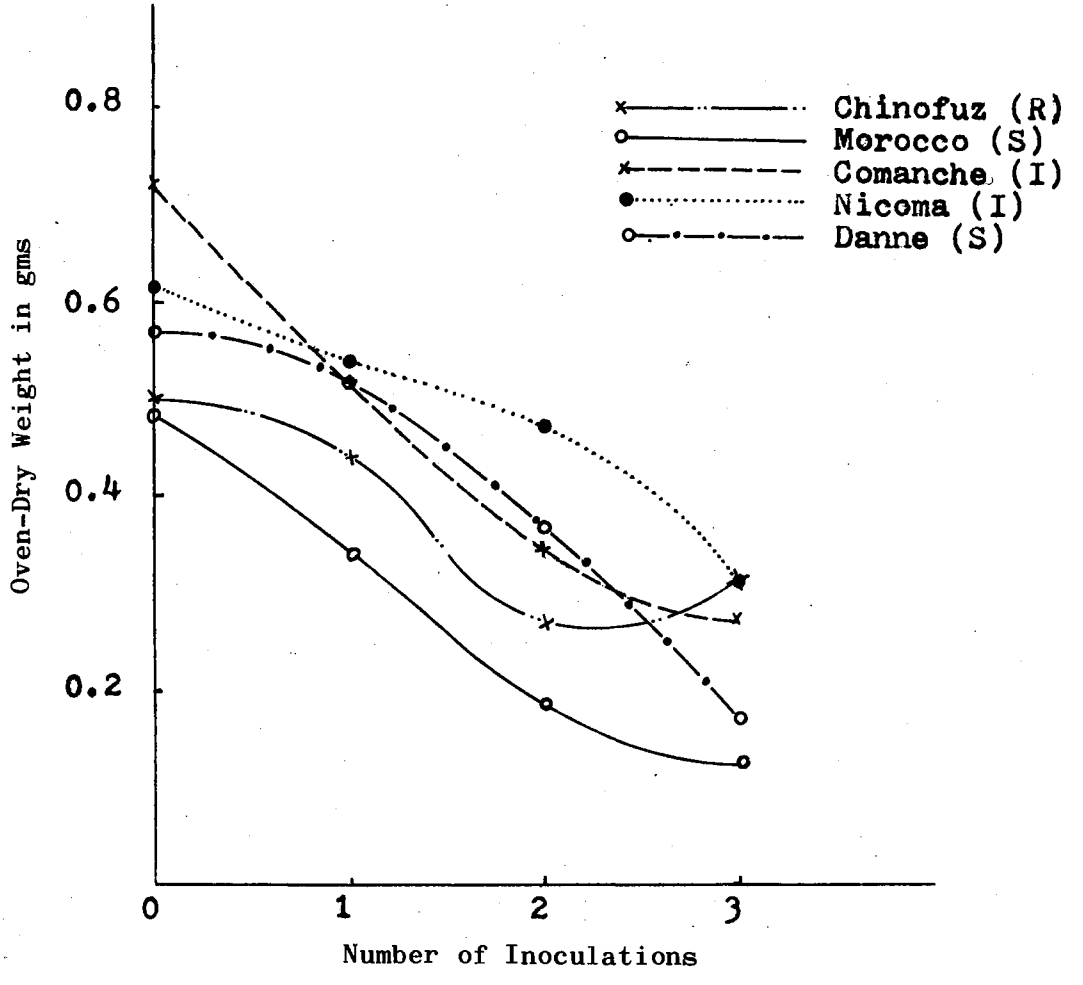

Figure 2. The Effect of the Number of Leaf Rust Inoculations on Oven-Dry Weight of Roots Produced by 40 Day-Old Wheat Seedlings of 5 Cultivars Resistant (R), Intermediate (I), or Susceptible (S) to the Disease (Experiment 1)

TABLE IV
EFFECT OF LEAF RUST INFECTION ON FOLIAR GROWTH OF WHEAT SEEDLINGS OF CERTAIN CULTIVARS
EXPERIMENT 2

	Weight in gms[1]									
	Fresh					Oven-Dry				
	Number of Inoculations					Number of Inoculations				
Cultivar[2]	0	1	2	3	Mean	0	1	2	3	Mean
CNF	7.93	7.41	5.44	6.40	6.79	0.93	0.89	0.66	0.80	0.82
MRO	9.50	4.88	3.17	0.93	4.62	1.09	0.58	0.41	0.15	0.55
CMN	9.32	5.89	4.19	2.76	5.54	1.12	0.66	0.53	0.36	0.67
NCM	8.22	7.23	4.37	3.10	5.73	1.12	0.92	0.63	0.43	0.78
DNE	7.66	5.35	3.67	2.63	4.83	0.90	0.66	0.52	0.38	0.62
MEAN	8.52	6.15	4.17	3.16		1.03	0.74	0.55	0.42	

LSD 0.05 Cultivar Means	0.78	0.01
LSD 0.05 Inoculation Means	0.69	0.10
LSD 0.05 C x I Means	1.57	0.22

[1]Means of 2 replications of 10 plants

[2]Abbreviations as follows: CNF = Chinofuz, MRO = Morocco, CMN = Comanche, NCM = Nicoma, DNE = Danne

TABLE V

EFFECT OF LEAF RUST INFECTION ON ROOT GROWTH OF WHEAT SEEDLINGS OF CERTAIN CULTIVARS
EXPERIMENT 2

Cultivar[2]	Oven-Dry Weight in gms[1]					Volume in ml[1]				
	Number of Inoculations					Number of Inoculations				
	0	1	2	3	Mean	0	1	2	3	Mean
CNF	0.47	0.40	0.26	0.27	0.35	6.0	5.3	3.0	3.5	4.4
MRO	0.58	0.18	0.10	0.01	0.22	6.0	3.1	1.7	0.5	2.8
CMN	0.48	0.18	0.08	0.03	0.19	4.5	2.5	2.2	0.9	2.5
NCM	0.48	0.27	0.18	0.04	0.24	5.0	3.3	2.1	1.1	2.9
DNE	0.35	0.27	0.10	0.02	0.19	4.0	3.3	1.6	1.2	2.5
MEAN	0.47	0.26	0.14	0.07		5.1	3.5	2.1	1.4	

LSD 0.05 Cultivar Means	0.10	1.0
LSD 0.05 Inoculation Means	0.09	0.9

[1]Means of 2 replications of 10 plants

[2]Abbreviations as follows: CNF = Chinofuz
MRO = Morocco
CMN = Comanche
NCM = Nicoma
DNE = Danne

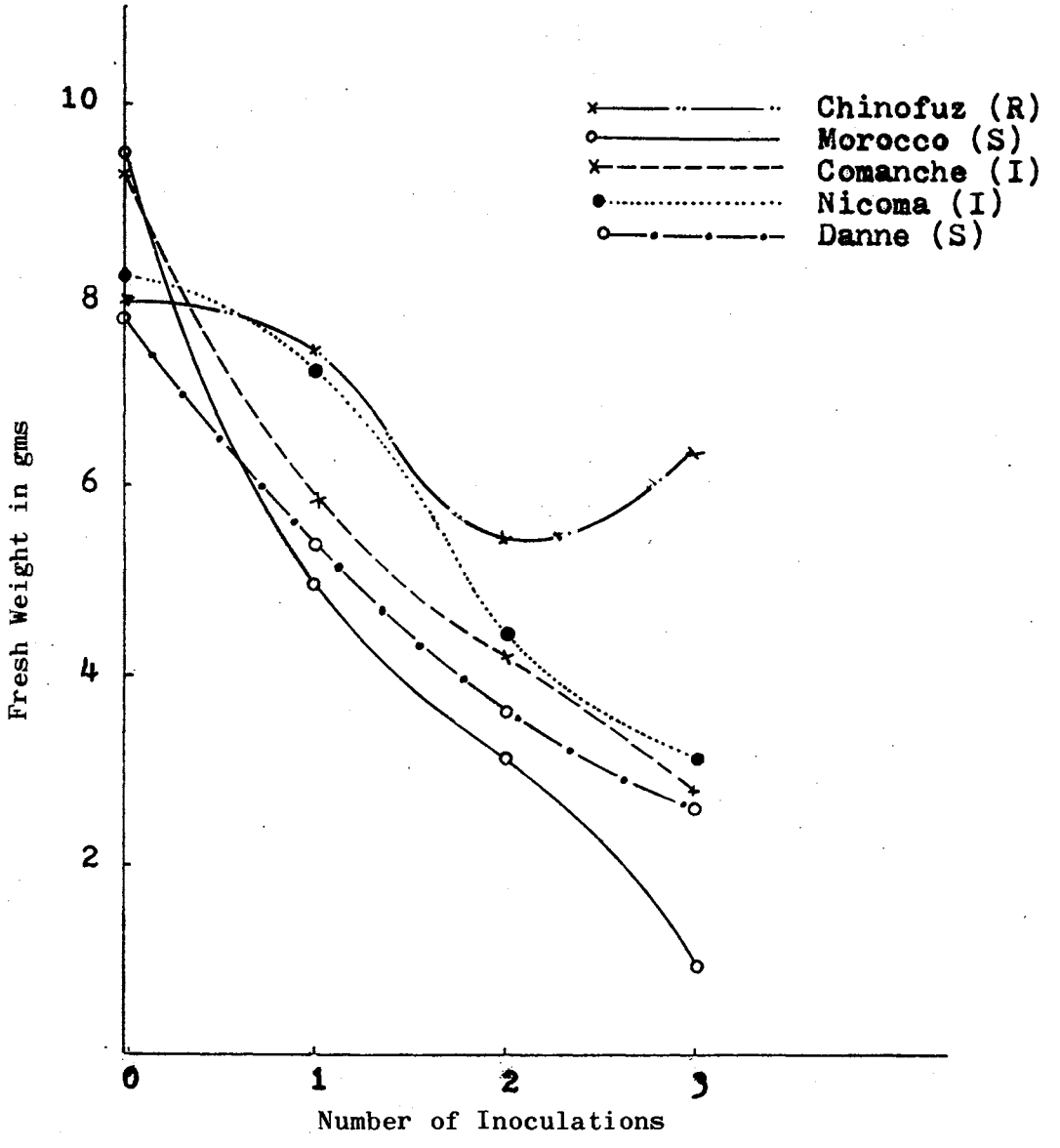

Figure 3. The Effect of the Number of Leaf Rust Inoculations on Fresh Weight of Foliage Produced by 40 Day-Old Wheat Seedlings of 5 Cultivars Resistant (R), Intermediate (I), or Susceptible (S) to the Disease (Experiment 2)

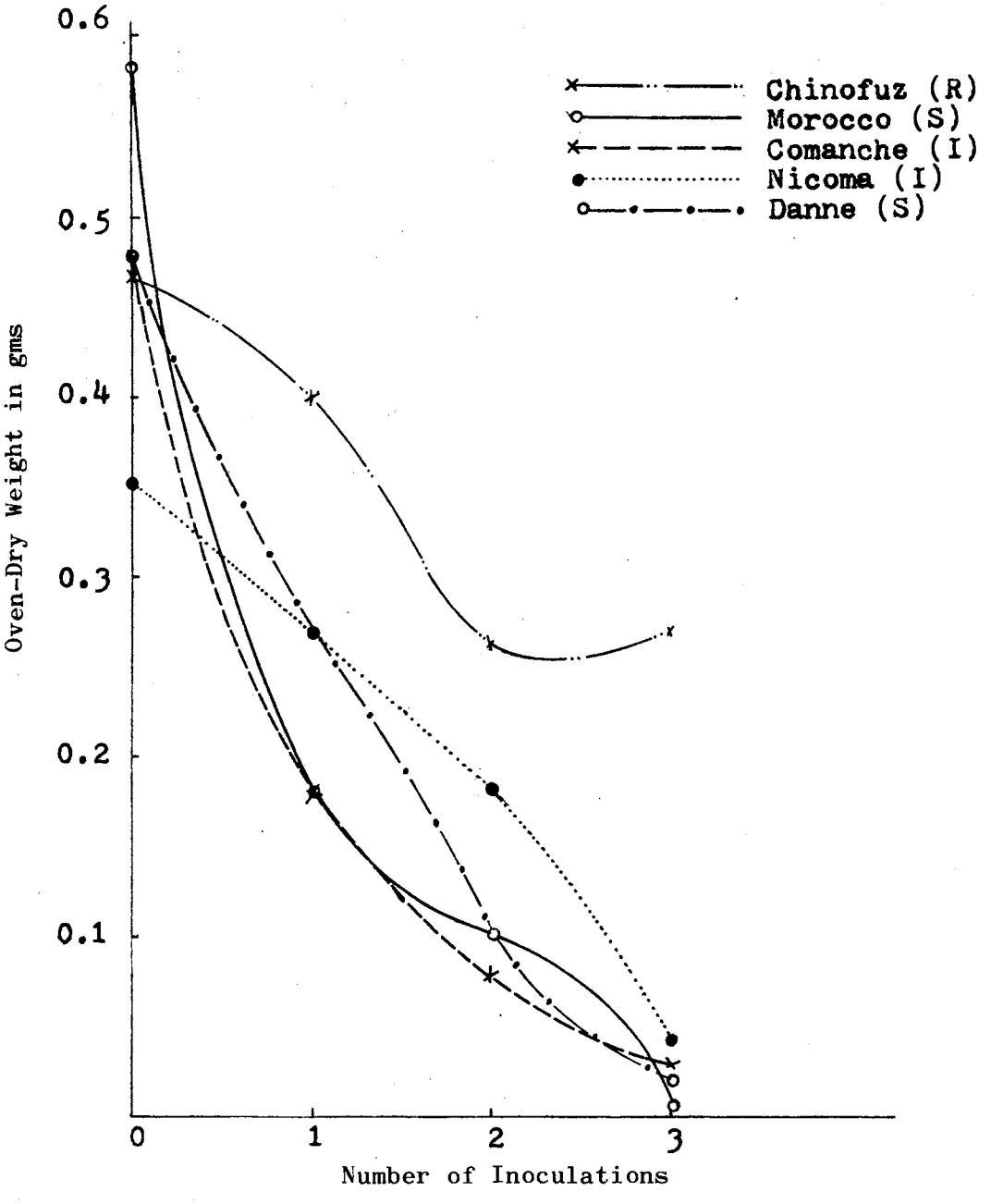

Figure 4. The Effect of the Number of Leaf Rust Inoculations on Oven-Dry Weight of Roots Produced by 40 Day-Old Wheat Seedlings of 5 Cultivars Resistant (R), Intermediate (I), or Susceptible (S) to the Disease (Experiment 2)

One of the problems of early fall planting of winter wheat is warm soil temperature. Certain cultivars developed for warm soil planting in the Washington state area have been imported to utilize this characteristic in hard red winter wheat improvement in Oklahoma. Therefore, another experiment was conducted using the cultivars McCall and Wanser recently released from Washington. In addition, the cultivar Centurk, recently released from Nebraska and widely adapted in the central plains area, and two lines of a cross involving the cultivar Comanche isogenic for resistance and susceptibility to leaf rust were used. This experiment was made in the same manner as the previous two experiments. The rust severities which developed are given in Table VI, and foliar and root growth measurements are reported in Tables VII and VIII. *Diagramatic illustrations of the effect of multiple leaf rust inoculations on the forage and root growth of these cultivars are presented in Figures 5 and 6. The forage and root production of the resistant isogenic line was not significantly affected by the increased inoculation while the susceptible line showed a significant reduction in both forage and root growth. The cultivars McCall and Wanser proved to be susceptible to leaf rust and also showed a significant reduction in forage and root growth. Growth of Centurk was intermediate between the resistant isogene and the leaf rust susceptible cultivars. A photograph of the roots of the cultivar McCall (Figure 7) illustrates that root production was decreased as the number of inoculations increased. The effect of the first inoculation was precipitous on susceptible cultivars like McCall in every experiment. The reduction continued following subsequent inoculations, but less drastically in most cases. Figure 8 compares

TABLE VI

RELATIONSHIP OF THE NUMBER OF INOCULATIONS TO THE SEVERITY OF LEAF RUST ON WHEAT SEEDLINGS OF 5 CULTIVARS

Cultivars[1]	Response[2]	Percent Severity[3] Number of Inoculations 0	1	2	3
R1	R	0	5	10	15
CNR	I	0	30	35	40
S1	S	0	40	50	65
WSR	S	0	50	50	60
M.C	S	0	70	70	70
MEAN		0	40	40	50

[1]Abbreviations as follows:
R1 = Resistant isogenic line
CNR = Centurk
S1 = Susceptible isogenic line
WSR = Wanser
M.C = McCall

[2]R = Resistant
S = Susceptible
I = Intermediate

[3]Average of 2 replications based on modified Cobb scale

TABLE VII

EFFECT OF LEAF RUST INFECTION ON FOLIAR GROWTH OF WHEAT SEEDLINGS OF CERTAIN CULTIVARS
EXPERIMENT 3

	Weight in gms[1]									
	Fresh					Oven-Dry				
	Number of Inoculations					Number of Inoculations				
Cultivar[2]	0	1	2	3	Mean	0	1	2	3	Mean
R1	11.66	11.65	12.47	10.46	11.56	1.16	1.29	1.35	1.10	1.23
CNR	12.00	11.79	9.33	8.31	10.36	1.35	1.33	1.08	0.96	1.18
S1	14.11	10.81	10.22	4.90	10.01	1.50	1.16	1.12	0.52	1.07
WSR	14.97	13.46	8.70	7.49	11.16	1.68	1.46	1.00	0.92	1.26
M.C	13.39	8.11	7.56	5.47	8.63	1.44	0.80	0.76	0.58	0.89
Mean	13.23	11.16	9.65	7.32		1.43	1.20	1.06	0.82	

LSD 0.05 Cultivar Means	NS	0.23
LSD 0.05 Inoculation Means	1.85	0.21

[1]Mean of 2 replications of 10 plants

[2]Abbreviations as follows: R1 and S1 = Resistant and Susceptible isogenic lines respectively from the cross Transfer/5* Comanche, CNR = Centurk, WSR = Wanser, M.C = McCall

TABLE VIII

EFFECT OF LEAF RUST INFECTION ON ROOT GROWTH OF WHEAT SEEDLINGS OF CERTAIN CULTIVARS
EXPERIMENT 3

Cultivar[2]	Oven-Dry Weight in gms[1]					Volume in ml[1]				
	Number of Inoculations					Number of Inoculations				
	0	1	2	3	Mean	0	1	2	3	Mean
R1	0.32	0.39	0.39	0.32	0.36	3.3	4.0	4.0	3.5	3.7
CNR	0.41	0.42	0.33	0.25	0.35	4.5	4.8	3.5	2.5	3.8
S1	0.38	0.27	0.26	0.12	0.26	4.3	3.0	3.0	1.8	3.0
WSR	0.63	0.47	0.29	0.25	0.41	7.3	5.0	3.3	3.0	4.7
M.C	0.61	0.21	0.25	0.14	0.30	6.8	2.8	3.0	1.5	3.5
Mean	0.47	0.35	0.30	0.21		5.2	3.9	3.4	2.5	
LSD 0.05 Cultivar Means			0.10					NS		
LSD 0.05 Inoculation Means			0.09					0.9		

[1]Means of 2 replications of 10 plants

[2]Abbreviations as follows: R1 and S1 = Resistant and Susceptible isogenic lines respectively from the cross Transfer/5* Comanche, CNR = Centurk, WSR = Wanser, M.C = McCall

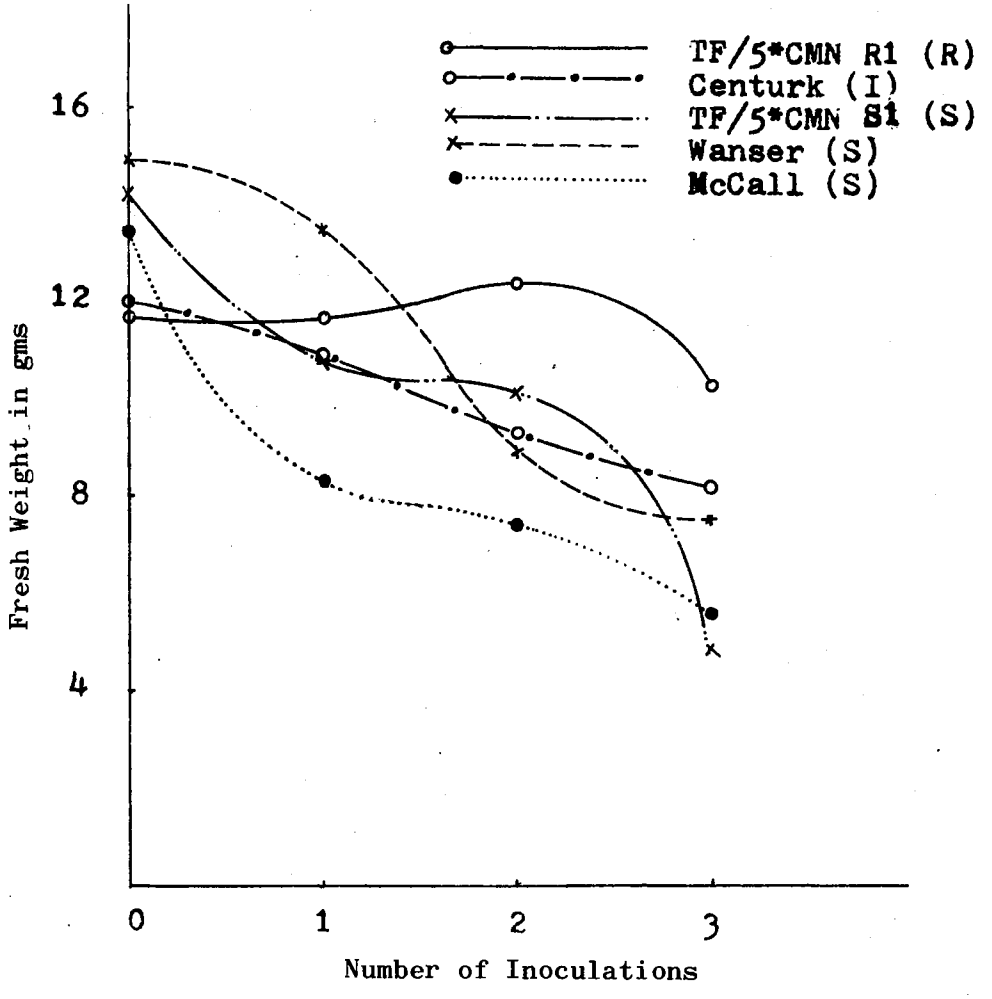

Figure 5. The Effect of the Number of Leaf Rust Inoculations on Fresh Weight of Foliage Produced by 40 Day-Old Wheat Seedlings of 5 Cultivars Resistant (R), Intermediate (I), or Susceptible (S) to the Disease (Experiment 3)

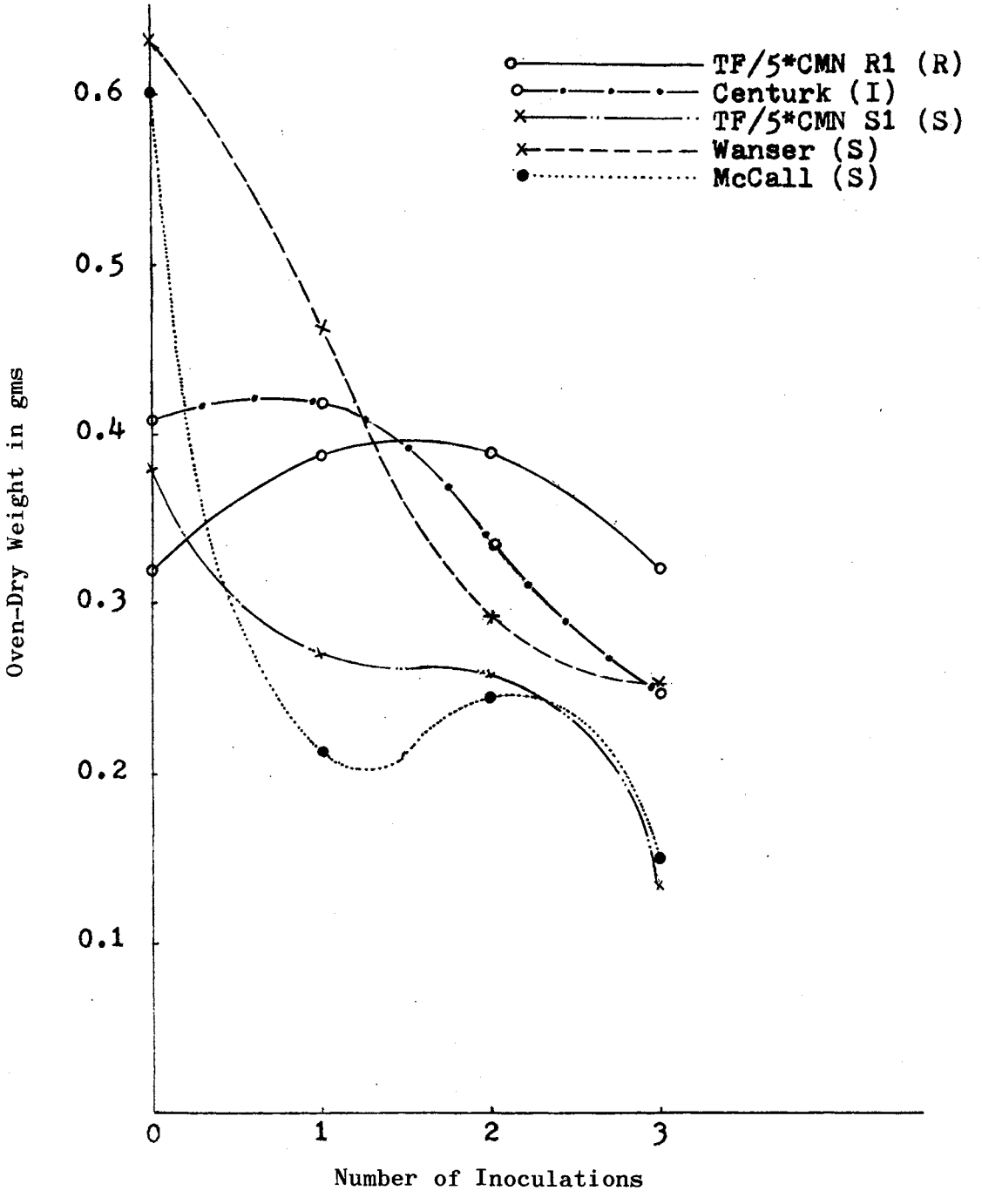

Figure 6. The Effect of the Number of Leaf Rust Inoculations on Oven-Dry Weight of Roots Produced by 40 Day-Old Wheat Seedlings of 5 Cultivars Resistant (R), Intermediate (I), or Susceptible (S) to the Disease (Experiment 3)

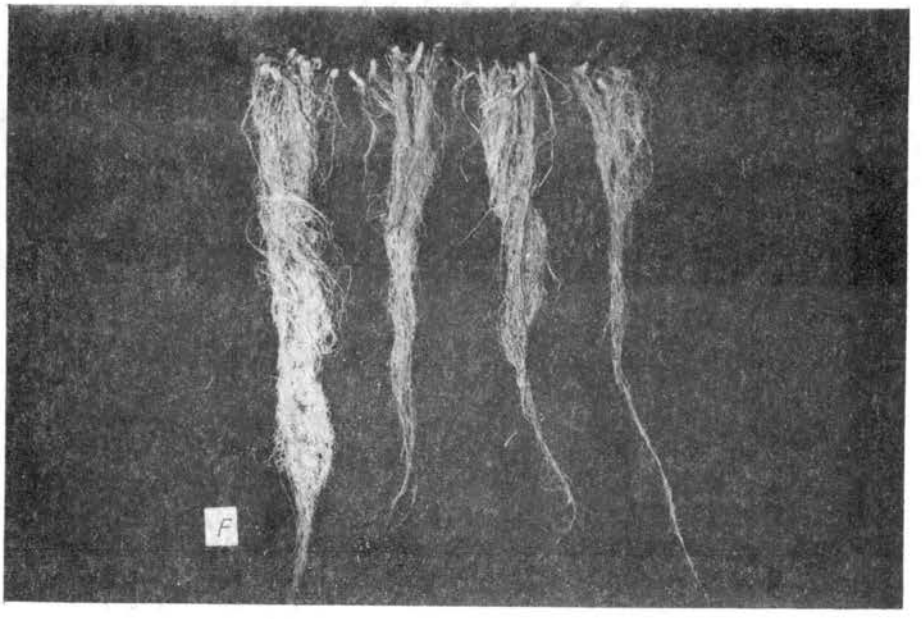

Figure 7. A Comparison of the Root Systems of the Susceptible Cultivar "McCall" Inoculated with Leaf Rust Puccinia recondita f. sp. tritici. Uninoculated Control, One Inoculation, Two Inoculations, and Three Inoculations, Respectively from Left to Right.

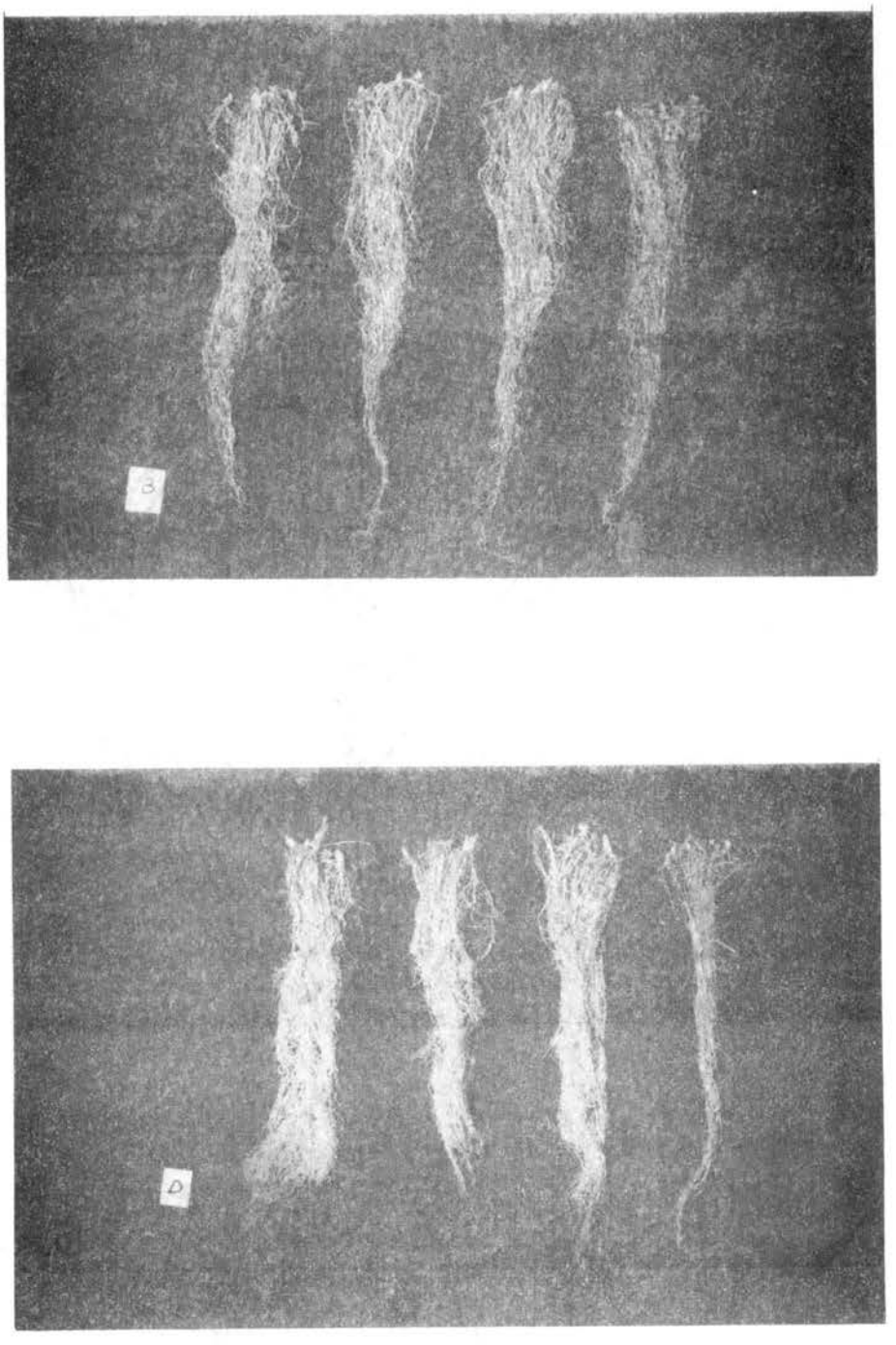

Figure 8. A Comparison of the Root Systems of a Leaf Rust Resistant (Above) and Susceptible Isogenic Lines Inoculated with Puccinia recondita f. sp. tritici. In Each Case the Uninoculated Control is on the Left Followed by Plants Inoculated One, Two, and Three Times from Left to Right.

the effect of multiple leaf rust inoculations on the growth of the roots of the resistant and susceptible isogenic lines.

Throughout the previous experiments it was rather obvious that the first inoculation had a severe effect on foliar and root growth. Consequently, the second group of cultivars were again used in an experiment to study the relation of rust severity to age of plants at the time of inoculation. One group of plants was inoculated 10 days after planting, a second group was inoculated at 20 days, and the third group was inoculated both at 10 and 20 days. A fourth group remained rust free.

The age of plants in relation to leaf rust infection and disease development did affect the growth of young wheat plants (Tables IX and X). The plants inoculated at 20 days produced 23, 40 and 43 percent less oven-dry forage weight, root weight, and root volume respectively than the plants inoculated at 10 days. The growth of wheat seedlings inoculated twice at 10 and 20 days were reduced more than either single inoculation.

So far as foliar growth is concerned the effect of the inoculation made at 20 days was almost twice as great as a single inoculation at 10 days, and the effect of two inoculations, at least on the susceptible cultivars, was almost 25 percent greater than the single inoculation at 20 days and 50 percent greater than the single inoculation made at 10 days (Figure 9). However, root growth was more drastically affected by the inoculation made when the plants were 10 days old than by the inoculation made at 20 days (Figure 10). The effect of two inoculations was only slightly greater than one inoculation made at 20 days.

TABLE IX

COMPARISON OF THE EFFECT OF LEAF RUST INFECTION ON FOLIAR GROWTH OF WHEAT SEEDLINGS INOCULATED AT 10 AND AT 20 DAYS OF AGE, AND TWO CONSECUTIVE INOCULATIONS AT 10 AND 20 DAYS OF AGE
EXPERIMENT 4

	Weight in gms[1]									
	Fresh					Oven-Dry				
	Inoculated at					Inoculated at				
Cultivar[2]	None	10 Days	20 Days	10 and 20 Days	Mean	None	10 Days	20 Days	10 and 20 Days	Mean
R1	21.12	16.36	13.14	11.66	15.57	2.84	2.04	1.77	1.49	2.03
CNR	19.64	15.20	10.77	11.32	14.23	2.83	1.89	1.45	1.54	1.93
S1	21.32	14.48	7.29	2.62	11.43	3.01	1.74	1.02	0.42	1.55
WSR	18.47	16.08	11.34	7.40	13.45	2.25	2.14	1.43	0.97	1.70
M.C	17.47	12.65	11.19	6.84	12.03	2.44	1.52	1.54	1.06	1.64
MEAN	19.60	14.95	10.84	7.97		2.67	1.86	1.44	1.09	
LSD 0.05 Cultivar Means			2.68					NS		
LSD 0.05 Inoculation Means			2.40					0.32		

[1]Means of 2 replications of 10 plants

[2]Abbreviations as follows: R1 and S1 = Resistant and Susceptible isogenic lines respectively from the cross Transfer/5* Comanche, CNR = Centurk, WSR = Wanser, M.C = McCall

TABLE X

COMPARISON OF THE EFFECT OF LEAF RUST INFECTION ON ROOT GROWTH OF WHEAT SEEDLINGS INOCULATED AT 10 AND AT 20 DAYS OF AGE, AND TWO CONSECUTIVE INOCULATIONS AT 10 AND 20 DAYS OF AGE
EXPERIMENT 4

	Oven-Dry Weight in gms[1]					Volume in ml[1]				
		Inoculated at					Inoculated at			
Cultivar[2]	None	10 Days	20 Days	10 and 20 Days	Mean	None	10 Days	20 Days	10 and 20 Days	Mean
R1	1.16	0.52	0.45	0.34	0.62	10.0	4.8	4.0	3.3	5.5
CNR	1.10	0.48	0.27	0.41	0.56	11.5	4.3	3.0	4.3	5.8
S1	1.39	0.37	0.18	0.08	0.50	13.3	4.0	1.3	0.8	4.8
WSR	0.91	0.96	0.39	0.19	0.61	8.0	9.0	3.3	1.8	5.5
M.C	1.00	0.42	0.35	0.25	0.50	8.5	4.0	3.5	2.5	4.6
MEAN	1.11	0.55	0.33	0.25		10.3	5.2	3.0	2.5	
LSD 0.05 Inoculation Means			0.19					1.9		

[1]Means of 2 replications of 10 plants

[2]Abbreviations as follows: R1 and S1 = Resistant and Susceptible isogenic lines respectively from the cross Transfer/5* Comanche, CNR = Centurk, WSR = Wanser, M.C = McCall

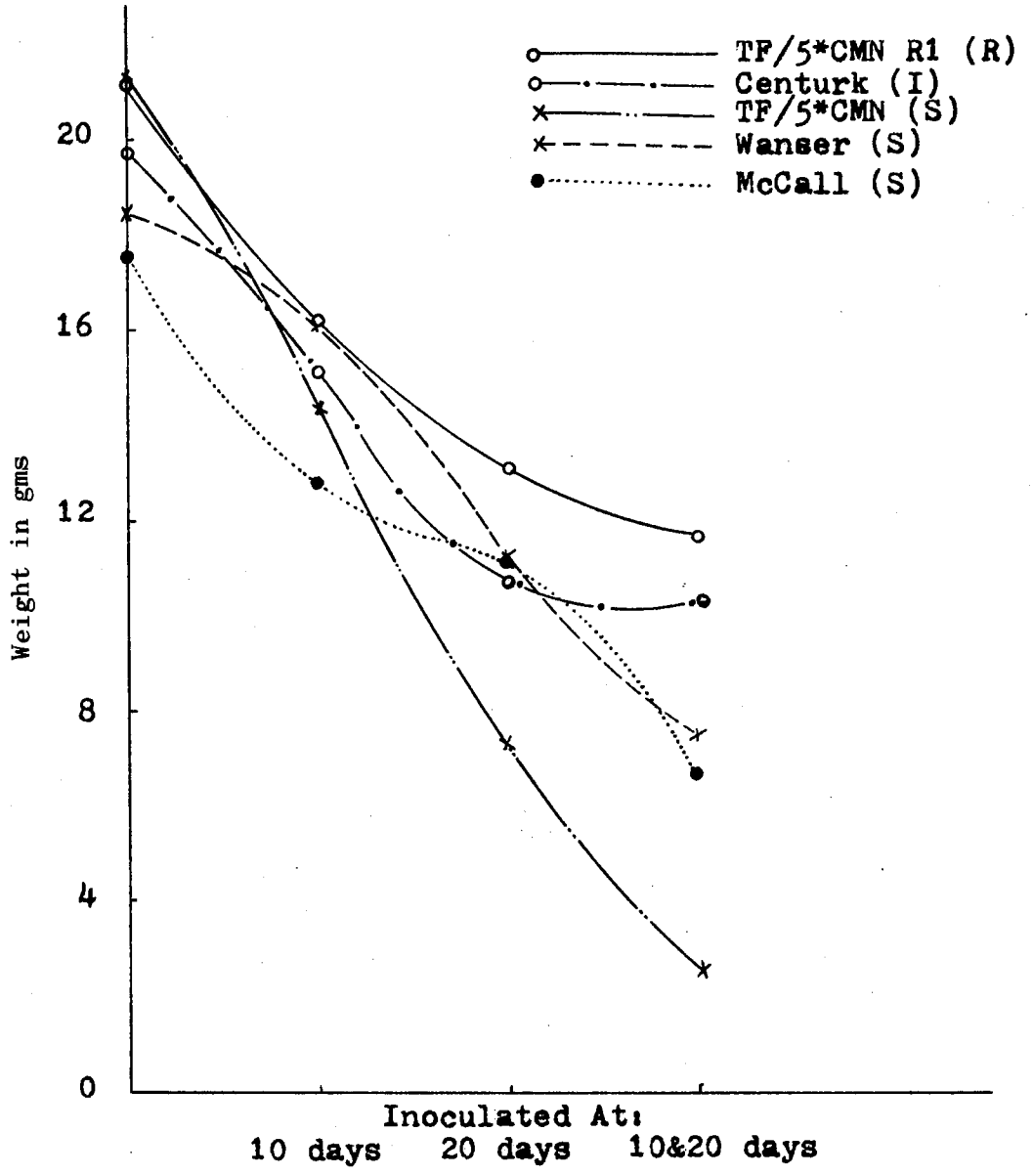

Figure 9. A Comparison of the Effect of Leaf Rust Infection on Foliar Growth of Wheat Seedlings Inoculated at 10 and at 20 Days of Age, and Two Consecutive Inoculations at 10 and 20 Days of Cultivars Resistant (R), Intermediate (I), and Susceptible (S) to the Disease

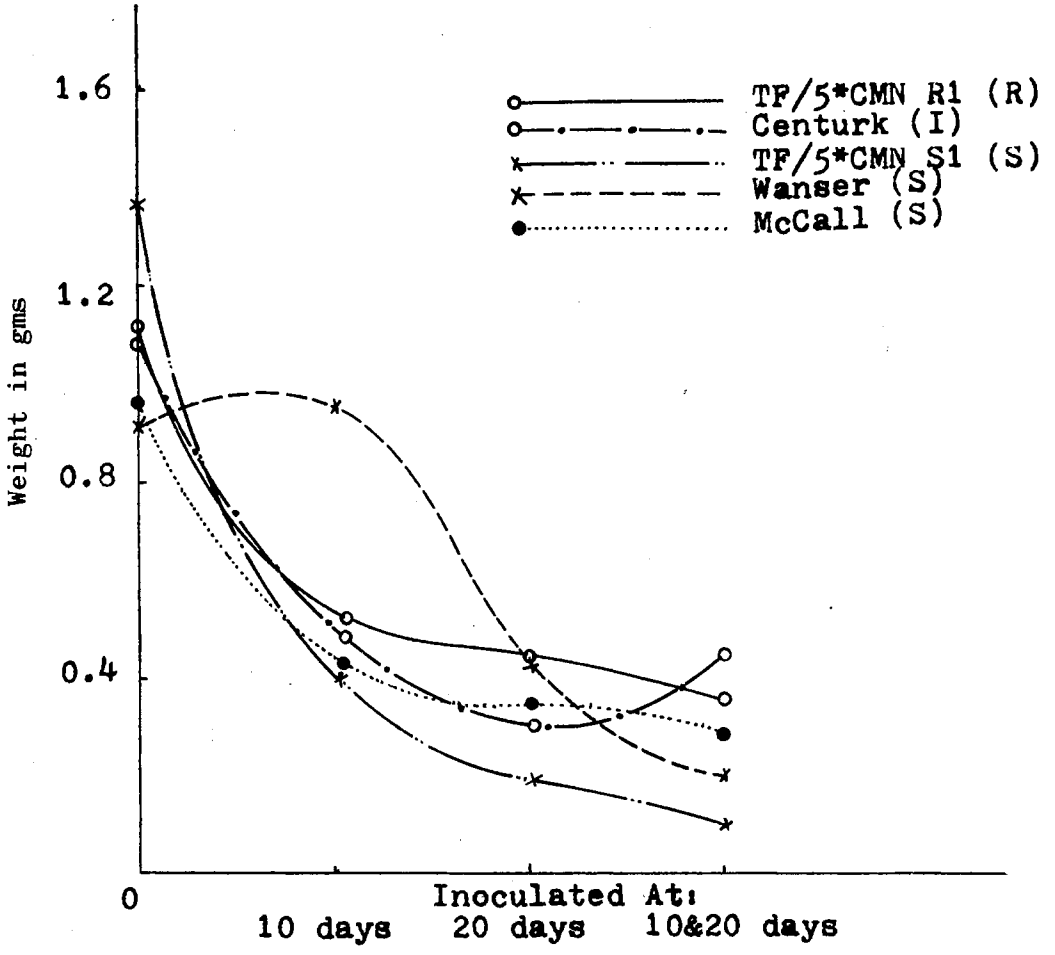

Figure 10. A Comparison of the Effect of Leaf Rust Infection on Root Growth of Wheat Seedlings Inoculated at 10 and at 20 Days of Age, and Two Consecutive Inoculations at 10 and 20 Days of Cultivars Resistant (R), Intermediate (I), and Susceptible (S) to the Disease

CHAPTER V

DISCUSSION

Parasitism of the wheat leaf rust fungus has a very serious effect on growth of the host in various ways (9, 10, 20). Results of these experiments also indicate that growth of young wheat plants were severely affected by leaf rust. Forage yield of wheat seedlings was decreased as severity of disease increased. More surprising, however, was the serious effect of the disease on root growth. Such effects had been shown for stripe rust disease on wheat, but on older plants. In this study, the root growth of plants inoculated at six days of age was seriously affected and the damage increased as the severity increased. Indeed, in the last experiment it was shown that inoculations made at twenty days of age caused only slightly more damage than inoculations made at ten days.

Throughout these studies the growth of the resistant cultivars "Chinofuz" and the resistant isogenic line were less affected than the other cultivars tested. Such a response might be expected, but it was interesting to note that root growth even of these resistant cultivars was reduced by inoculation in some cases. The response of the susceptible cultivars Danne, Morocco, McCall, Wanser, and the susceptible isogenic line was the most serious of the cultivars tested, which might also be expected. What was interesting, however, was the intermediate response of cultivars like Nicoma, Centurk, and Comanche. These

cultivars all show some degree or type of resistance in the field (22), but in the seedling stage (as in these experiments) we have what appears to be a completely susceptible response.

In most cases, even the susceptible cultivars inoculated three times produced more roots than were actually recovered during the washing process. This was due to the fact that the small fibrous roots of these cultivars were dead or dying and were broken off and washed away. It was noted throughout these experiments that the roots of rust-infected susceptible cultivars were discolored and deteriorating compared to the resistant cultivars and to the rust-free control plants. Williams (20) noted similar discoloration of roots of inoculated plants, but it is a difficult characteristic to measure. Perhaps the small deteriorating roots would not be lost using a mist chamber such as was described by Martin and Hendrix (14). However, the added weight of root growth produced by the salvage of such roots would only be misleading since it was obvious that they were contributing nothing to the further growth of the plant.

The effect of leaf rust, particularly on root development, of young seedling plants has several practical implications. That rusted plants require more water to produce the same amount of foliar growth as healthy plants has been demonstrated by Johnston and Miller (9) and by Williams (20). Rusted plants must produce their foliar growth with much less root volume. Consequently, rusted plants would be much more subject to moisture stress than healthy plants. It is also obvious that plants with reduced root development would be more subjected to temperature stress during the winter growth period. In summary, plants severely rusted in the autumn would be more subject to winter injury;

begin spring growth more slowly; be delayed in maturity. Late maturing wheat in the southern plains area is much more subject to high temperature stress and storm damage. Roots damaged by rust infection would also be more subject to invasion by root rotting organisms such as Helminthosporium sativum P. K. & B. and others.

It was of interest also, that while the later infection (20 day-old seedlings) produced the most damage, the increase in damage by the later inoculation over the early (10 day-old seedlings) inoculation was only a fraction of the damage caused by the early infection itself. This suggests that even light severities of rust on very young seedlings can be quite damaging.

CHAPTER VI

SUMMARY

1. Two groups of winter wheat cultivars (group 1 containing Comanche, Morocco, Chinofuz, Danne, and Nicoma; group 2 containing McCall, Wanser, Centurk, and a resistant and a susceptible isogenic line from the cross Transfer/5* Comanche) were used to evaluate the effect of leaf rust severity on growth of wheat seedlings in a growth chamber.
2. Different levels of leaf rust severity were obtained by different numbers of inoculation. In three experiments inoculations were made on six, ten, and fourteen days after planting and in a fourth experiment inoculations were made at ten and twenty days after planting. Growth was measured by fresh and dry weights and by root volume either 40 or 60 days after planting.
3. Growth of each of the susceptible cultivars was more severely affected as the severity increased. The resistant cultivars were much less affected by the disease.
4. The number of inoculations affected not only the growth of wheat forage but also produced a deleterious effect on root systems. Foliar growth was reduced as much as 50 percent and root growth by as much as 70 percent following three inoculations. Root growth was reduced as much as 30 percent by a single inoculation.

5. The age of wheat seedlings at the time of inoculation also affected foliar and root growth significantly. Plants inoculated at ten days of age were nearly as severely damaged as plants inoculated at twenty days of age.

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