EFFECT OF LEAF RUST INFECTION ON THE GROWTH OF WHEAT SEEDLINGS

By

JOHN RAY PYZNER

Bachelor of Science

Southwestern Oklahoma State University

Weatherford, Oklahoma

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Thesis Adviser

Dean of the Graduate College

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CHAPTER I

INTRODUCTION

The possible daily production of 1.5 pounds of beef per acre on winter wheat pasture has greatly increased the farmers interest in winter wheat for livestock pasture (5). Many wheat farmers are even planting earlier in the fall to increase the grazing potential of their wheat. In fact, much of Oklahoma's wheat is planted now in early September to allow sufficient growth for grazing to begin in mid October to early November (4). While the early planting of winter wheat increases its grazing potential, it increases the possibility of leaf rust development tremendously.

Much research has been done on the effect of leaf rust on the quantity of quality grain produced. However, little attention has been given to the effect of leaf rust on seedling wheat and its relation to the production of fall and winter forage.

The purpose of this study was to determine the effect of a light leaf rust severity on the growth of seedling wheat plants at temperatures that would correspond to early and mid autumn temperatures.

CHAPTER II

REVIEW OF LITERATURE

Leaf rust is the most destructive disease of wheat on a major part of the four hundred million acres of wheat producing land. Vast areas of Russia, Poland, Argentina, India, China, Australia, and the southern Great Plains of North America are included. However, few United States wheat researchers considered leaf rust a major limiting factor to production until the leaf rust epiphytotic of 1938 destroyed over 100 million bushels of wheat (3).

Felice Fontana in 1767 published the first figures on the damage done by wheat rust. He was also the first to realize that the rust disease was caused by a fungus that was parasitic on the wheat plant (3).

Weiss (24) found that infection of wheat by either leaf rust or stem rust resulted in a significant reduction in yield of straw and grain. The yield reduction was found to be independent of the soil moisture supply.

Johnston and Melchers (8), Williams (25), and Vanitchayangkul (23) all observed discoloration and lower dry weights on root systems of leaf rust infected plants. Hendrix and associates (6, 7, 14, 15) have also observed a similar discoloration and reduction of root growth on wheat plants inoculated with stripe rust.

Mains (13) observed that wheat plants inoculated with leaf rust at 40 days of age were slightly stunted and developed more tillers than non-rusted plants. Many tillers of the rusted plants however, did not develop heads, and the heads produced were somewhat later in maturing. Also, the lower leaves of the rusted plants died considerably in advance of non-rusted plants. The principal form of grain loss with leaf rust infected plants was found to be the decreased number of heads, and the decrease in kernels per head. There was also considerable shriveling of grain, but this was believed to be secondary to the loss of yield due to reduction in kernel numbers.

Caldwell (2) also found that a lower kernel number was the most important factor in yield loss due to leaf rust. He calculated that approximately 75% of the loss was due to the number of kernels and the remaining 25% was due to loss in kernel weight. There was also a reduction in the proportion of vitreous kernels in the grain from rusted plants.

Keed and White (9) found that most of the yield loss from rust was caused by a reduction in individual grain weight, which resulted in lower bushel weight and lower protein content. The amount of rust infection at the milk stage of growth was the best indicator of the resultant reduction in yield.

Chester (3), on the other hand, used the severity of leaf rust at different stages of crop development as an indicator of expected loss of yield. In this case it was assumed that the percent of infection would continue to increase to near 100% if enough growing time remained before maturity. Kingsolver (10) found similar evidence for stem rust. It was observed also that the number and distribution of favorable periods for stem rust infection determined to a great extent the rate of rust increase (12).

Neill (17) found that test plots of wheat dusted with sulfur outyielded the undusted plots from 17-96%. The amount of increase in yield was directly correlated with the relative severity of leaf and stem rust in seven of eight varieties tested.

Mains (13) showed that winter wheat seedlings planted early in the fall and inoculated with leaf rust would have a much greater amount of winter injury than plants planted later in the season and inoculated with leaf rust. Although the inoculation rate was the same, the leaf rust severity that ultimately developed on the late planted wheat was considerably lower due to a shorter growth period before the weather became too cold for infection to occur.

Johnston and Melchers (8) found that leaf rust reaction of many wheat varieties varied with age. They believed this to be a major factor in the field resistance shown by some varieties. They also found that the lower older leaves of many varieties were more susceptible to leaf rust than the younger leaves, although in some varieties the opposite seemed to be true.

Samborski and Peturson (21) found that a heavy infection of leaf rust initiated at an early stage of plant development materially reduced the yield, kernel weight, and bushel weight of one susceptible and three resistant varieties of spring wheat. The yield loss in the susceptible variety was 58% whereas in the resistant varieties it ranged from 12 to 28%. They indicated that a direct relationship existed between the density of inoculum and the amount of necrosis on varieties that are resistant but not immune. The loss in yield on the resistant varieties was believed to have been caused by the destruction of photosynthetic tissue at the leaf rust infection sites. However, Caldwell (2) did not find any appreciable loss of yield with the resistant varieties.

Comparisons by Levine (11) of the damage done by leaf rust and by stem rust on spring wheat indicated that moderately severe stem rust caused a greater reduction in yield than very severe leaf rust. He also found that when leaf rust or stem rust was prevented from attacking wheat until after the plants had reached the filling stage, the effect was just as favorable as when the development of either rust was checked as the plants reached the jointing stage.

The damage caused by epiphytotics of wheat leaf rust was illustrated by the season of 1971-72 in Georgia. Warm moist weather conditions throughout the winter in conjunction with a new race of leaf rust that attacked the commonly grown wheat varieties caused such severe losses that some wheat acreage was never harvested (18).

Williams (25) found that regrowth of clipped wheat (simulating grazing) was greatly retarded in plants severely infected with leaf rust. It was also found that there was 32% less survival of 42 day old rusted wheat seedlings after foliage clipping. These observations were thought to be the result of reduced root growth on the rusted plants. A leaf rust severity of 100% was found to have reduced the growth of wheat plant roots by 50% six weeks after planting.

CHAPTER III

MATERIALS AND METHODS

A uniform soil mixture of three parts clay loam, one part fine sand, and one part peat moss was mixed with a Lindig soil shredder and passed through a 3.17 mm mesh screen. Nine hundred cc of soil was firmly packed into 12.7 cm clay pots. A piece of newsprint approximately 15 sq cm in size was placed over the drain hole of each pot to prevent the soil from escaping.

The wheat (Triticum aestivum L. em. Thell.) cultivar Danne, CI 13876, was used as the test plant in all experiments of this study. It is a triumph type hard winter wheat widely grown in Oklahoma. It is susceptible to all known races of leaf rust at all stages of growth (22).

In each replication, 35 "Arasan" (50% Thiram) treated seeds were uniformly spread on top of the soil surface in each of the twenty clay pots used in each growth chamber. The seeds were then covered with an additional 100 cc of soil.

The pots were placed into shallow plastic saucers, 11.7 cm in diameter, and then placed in a growth chamber. The pots were arranged in five columns with four pots per column. Two hundred ml of tap water were then slowly added to each pot. Beginning the third day after planting, the pots were watered every other day with 100 ml of "Hyponex" fertilizer solution (7-6-19, N-P-K formulation) at a rate of two grams per liter of water in addition to the plain tap water required to maintain the soil moisture near optimum throughout the experiment.

Two growth chambers were used in this study, however, they were not operated simultaneously as one experimental group. Each experiment was conducted individually. One chamber was a Percival model MB-60, and the other a Sherer-Gillett model CEL27-7HL. Both chambers were set for a photoperiod of 12 hours of light and 12 hours of darkness. Both chambers were also adjusted to provide a light intensity of 11,836 to 19,368 lux at plant height. In both chambers the highest light intensity was located near the middle of the chambers and the weakest intensity was located in the corners. Prior to inoculation of the plants, both chambers were set at a constant temperature of 24 C which is optimum for germination of most varieties of wheat (19).

The wheat seedlings were thinned to 13 plants per pot seven days after planting. The test plants were sprayed from a distance of 45.7 cm with three mg of leaf rust spores, Puccinia recondita f. sp. tritici, suspended in 0.1 ml of mobilsol 100, an isoparaffinic nonphytotoxic oil (20). The spore suspension was placed in a 00 gelatin capsule and attached to an atomizer developed and described by Browder (1). The spraying was performed in a plastic hood, dimensions of 61.0 cm by 45.7 cm by 30.5 cm, at a force of 211 gm per sq cm. The leaf rust race UN 9 was used in all inoculations of this study (26). It produces a type 4 pustule on the wheat cultivar Danne. The control plants were sprayed with 0.1 ml of mobilsol 100 without spores.

The pots were then randomized in four glass covered moisture 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 the rate of three to four drops per 1000 ml of water, and left in the moisture chamber for 12 hours, and then placed in one of the growth chambers. A randomized block experimental design was used in which two control pots and two test pots were randomized in each of 5 columns. A test temperature of either 17 C night - 21 C day or 21 C night - 27 C day was set into the growth chamber used. Each temperature regime was replicated in each growth chamber.

Seven days after inoculation leaf rust pustules were counted, and all pots were thinned to ten plants. Uniformity of the desired level of infection was the criterion used in thinning the rusted plants. A rust severity of five to ten percent by the modified Cobb scale (16) (approximately 30 pustules per leaf) was desired. The control pots were also thinned to ten plants.

The plants were harvested thirty days after planting. The roots were washed free of soil by running a stream of tap water over the root mass. Tiller counts and length of foliage were taken immediately. The length was measured from the basal node to the tip of the longest leaf blade. The foliage and root portions were separated by cutting the plants with scissors at the basal node. Root volume was obtained by placing the roots from each pot into a 100 ml graduated cylinder and measuring the water displacement. Fresh plant weights of foliage and roots were made on a Mettler P1210N balance. These weights were made after blotting each plant sample uniformly with paper towels for three minutes.

The plant samples were dried by placing them in size 10 paper bags which were then placed in a Power-o-matic-60 drying oven at 43 C. The samples were removed after 96 hours and weighed on a Mettler P1200 balance.

CHAPTER IV

RESULTS

Fresh foliage weights, fresh root weights, and root volume data are presented only for replication 2 in chamber 2 for the plants held at the 21 C day - 17 C night temperature regime. Water was used to separate the soil from the plants making the actual amount of water adhering to the roots and foliage difficult to control. In these particular trials the amount of blotting to remove excess water from foliage and roots was not consistent from sample to sample, which resulted in inconsistent measurements of foliage and root fresh weights and root volume.

The data for the 4 trials (2 replications in each of 2 growth chambers) at the low temperature regime are presented in Tables I and II. Although the level of rust infection was inconsistent, varying from an average of about 30 pustules per 10-plant sample to over 300, there was little or no difference in the effect on the growth of the plants. Coefficients of variation were similar (Table III); therefore, all four trials were used to provide the means presented in Table IV. No significant differences in growth between the rusted and non-rusted plants were evident at this temperature regime.

TABLE I

WHEAT SEEDLING FOLIAGE AND ROOT GROWTH OF LEAF RUST INOCULATED PLANTS VERSUS NON-INOCULATED PLANTS HELD AT A 21 C DAY - 17 C NIGHT TEMPERATURE REGIME FOR 30 DAYS IN CHAMBER ONE

	Replication 1			Replication 2		
Test Response	Non-Rusted	Rusted	Difference	Non-Rusted	Rusted	Difference
Pustule Number	0	316	------	0	90	------
Tiller Number	30.30	32.60	+2.30	27.40	28.70	+1.30
Plant Length	324.53[a]	344.10[a]	+19.57	477.81[a]	486.87[a]	+9.08
Dry Foliage Weight	1.94[b]	1.87[b]	-0.07	1.79[b]	1.86[b]	+0.07
Dry Root Weight	0.98[b]	0.98[b]	0.00	0.57[b]	0.58[b]	+0.01

[a]Length in cm

[b]Weight in gms

TABLE II

WHEAT SEEDLING FOLIAGE AND ROOT GROWTH OF LEAF RUST INOCULATED PLANTS VERSUS NON-INOCULATED PLANTS HELD AT A 21 C DAY - 17 C NIGHT TEMPERATURE REGIME FOR 30 DAYS IN CHAMBER TWO

	Replication 1			Replication 2		
Test Response	Non-Rusted	Rusted	Difference	Non-Rusted	Rusted	Difference
Pustule Number	0	37	-----	0	336	-----
Tiller Number	17.30	16.60	-0.70	29.00	29.90	+0.90
Plant Length	453.48[a]	451.05[a]	-2.43	421.23[a]	437.37[a]	+16.14
Root Volume	-----	-----	-----	10.35[b]	9.85[b]	-0.50
Fresh Foliage Weight	-----	-----	-----	16.46[c]	15.55[c]	-0.91
Fresh Root Weight	-----	-----	-----	6.41[c]	6.39[c]	-0.02
Dry Foliage Weight	1.63[c]	1.60[c]	-0.03	1.93[c]	1.85[c]	-0.08
Dry Root Weight	0.61[c]	0.59[c]	-0.02	0.55[c]	0.50[c]	-0.05

[a]Length in cm

[b]Volume in ml

[c]Weight in gms

TABLE III

COMPARISON OF COEFFICIENTS OF VARIATION FOR WITHIN CHAMBER REPLICATIONS

Test Response	Replications Within Chamber	
	21 C	27 C
Tiller Number	8%	18%
Plant Length	6%	5%
Root Volume	--	4%
Fresh Foliage Weight	--	2%
Fresh Root Weight	--	11%
Dry Foliage Weight	9%	3%
Dry Root Weight	4%	21%

TABLE IV

WHEAT SEEDLING FOLIAGE AND ROOT GROWTH OF LEAF RUST INOCULATED PLANTS VERSUS NON-INOCULATED PLANTS HELD AT A 21 C DAY - 17 C NIGHT TEMPERATURE REGIME FOR 30 DAYS[a]

Test Response	Non-Rusted	Rusted[b]	Difference	LSD[c]
Tiller Number	26.00	26.95	+0.95	2.03
Plant Length	419.26[d]	429.85[d]	+10.59	22.95
Dry Foliage Weight	1.82[e]	1.79[e]	-0.03	0.15
Dry Root Weight	0.68[e]	0.66[e]	-0.02	0.03

[a]Means of 10-plant samples from each of 2 replications in 2 growth chambers

[b]Mean number of pustules per 10-plant sample = 195

[c]0.05 level

[d]Length in cm

[e]Weight in gms

The data for the four trials at the high temperature regime are presented in Tables V and VI. In this case, also, the amount of rust varied somewhat between trials (from an average of about 300 pustules per 10-plant sample to over 500). Since the differences in coefficients of variation (Table III) between trials were negligible the four trials were averaged and analyzed statistically. The 4-trial means are given in Table VII.

Plants grown at the 27 C - 21 C temperature regime showed a significant difference between leaf rust inoculated and healthy plants in many growth responses. Differences in root volume, fresh foliage weight, and dry foliage weight were significant at the 1% level; differences in tiller number and fresh root weights were significant at the 5% level; but differences in dry root weights and plant lengths were not significant.

Figure 1 is a comparison of a leaf rust inoculated plants held at the 27 C - 21 C temperature regime after 30 days. The measurable differences are not readily apparent. The most readily observed difference between these plants is the primary leaf (Figure 2). The primary leaves of the leaf rust inoculated plants normally died approximately a week prior to harvest (23 days of age). The non-inoculated wheat seedlings usually maintained healthy green primary leaves until the plants were harvested (30 days of age). This phenomenon was seen in both experimental

TABLE V

WHEAT SEEDLING FOLIAGE AND ROOT GROWTH OF LEAF RUST INOCULATED PLANTS VERSUS NON-INOCULATED PLANTS HELD AT A 27 C DAY - 21 C NIGHT TEMPERATURE REGIME FOR 30 DAYS IN CHAMBER ONE

	Replication 1			Replication 2		
Test Response	Non-Rusted	Rusted	Difference	Non-Rusted	Rusted	Difference
Pustule Number	0	534	-----	0	318	-----
Tiller Number	36.80	30.90	-5.90	28.40	23.20	-5.20
Plant Length	381.70[a]	383.45[a]	+1.75	365.47[a]	359.75[a]	-5.72
Root Volume	13.95[b]	12.05[b]	-1.90	11.10[b]	9.40[b]	-1.70
Fresh Foliage Weight	19.16[c]	16.78[c]	-2.38	14.07[c]	11.81[c]	-2.26
Fresh Root Weight	11.15[c]	9.60[c]	-1.55	7.74[c]	6.83[c]	-0.91
Dry Foliage Weight	3.00[c]	2.69[c]	-0.31	2.09[c]	1.84[c]	-0.25
Dry Root Weight	1.15[c]	0.95[c]	-0.20	0.72[c]	0.64[c]	-0.08

[a]Length in cm

[b]Volume in ml

[c]Weight in gms

TABLE VI

WHEAT SEEDLING FOLIAGE AND ROOT GROWTH OF LEAF RUST INOCULATED PLANTS VERSUS NON-INOCULATED PLANTS HELD AT A 27 C DAY - 21 C NIGHT TEMPERATURE REGIME FOR 30 DAYS IN CHAMBER TWO

	Replication 1			Replication 2		
Test Response	Non-Rusted	Rusted	Difference	Non-Rusted	Rusted	Difference
Pustule Number	0	311	-----	0	376	-----
Tiller Number	12.70	12.00	-0.70	23.40	19.00	-4.40
Plant Length	452.21[a]	437.86[a]	-14.35	409.80[a]	413.32[a]	+3.52
Root Volume	4.70[b]	3.90[b]	-0.80	8.55[b]	7.55[b]	-1.00
Fresh Foliage Weight	11.39[c]	9.99[c]	-1.40	12.66[c]	11.00[c]	-1.66
Fresh Root Weight	3.69[c]	3.08[c]	-0.61	5.95[c]	5.11[c]	-0.84
Dry Foliage Weight	1.43[c]	1.28[c]	-0.15	1.65[c]	1.47[c]	-0.18
Dry Root Weight	0.37[c]	0.29[c]	-0.08	0.50[c]	0.44[c]	-0.06

[a]Length in cm

[b]Volume in ml

[c]Weight in gms

TABLE VII

WHEAT SEEDLING FOLIAGE AND ROOT GROWTH OF LEAF RUST INOCULATED PLANTS VERSUS NON-INOCULATED PLANTS HELD AT A 27 C DAY - 21 C NIGHT TEMPERATURE REGIME FOR 30 DAYS[a]

Test Response	Non-Rusted	Rusted[b]	Difference	LSD[c]
Tiller Number	25.33	21.28	-4.05	4.05
Plant Length	402.30[d]	398.60[d]	-3.70	20.84
Root Volume	9.58[e]	8.23[e]	-1.35	0.30
Fresh Foliage Weight	14.32[f]	12.39[f]	-1.93	0.30
Fresh Root Weight	7.13[f]	6.15[f]	-0.98	0.73
Dry Foliage Weight	2.04[f]	1.82[f]	-0.22	0.06
Dry Root Weight	0.69[f]	0.58[f]	-0.11	0.13

[a]Means of 10-plant samples from each of 2 replications in 2 growth chambers

[b]Mean number of pustules per 10-plant sample = 385

[c]0.05 level

[d]Length in cm

[e]Volume in ml

[f]Weight in gms

Figure 1. A Comparison of Leaf Rust Inoculated Wheat Plants (Right) With Non-Inoculated Wheat Plants (Left) After 30 Days at a 27 C Day - 21 C Night Temperature Regime

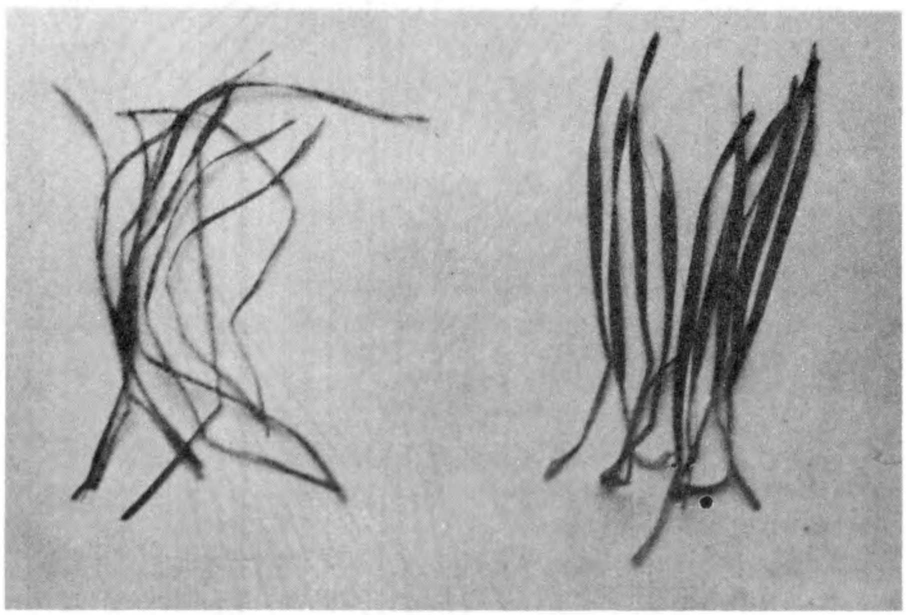

Figure 2. A Comparison of Primary Leaves From Leaf Rust Inoculated Plants (Left) With Primary Leaves From Non-Inoculated Wheat Plants (Right) After 30 Days at a 27 C Day - 21 C Night Temperature Regime

temperatures, although measurements of other growth responses were not the same at the two temperatures.

CHAPTER V

DISCUSSION

Williams (25) has already shown the effect of high severities of leaf rust on the growth of wheat seedlings. Although such severe leaf rust infection does occur frequently, lower levels of severity are more often encountered. The question naturally arises then, can leaf rust infections of 5-10% severity adversely affect the growth of seedling wheat to a measurable extent. These experiments showed that such an infection at seven days of age can reduce plant growth an average of about 15% when the plants were held at a 27 C day - 21 C night temperature regime. However, the same level of infection at the temperature regime of 21 C day - 17 C night produced no significant reductions in plant growth due to rust infection. The cause of the difference between the two temperature regimes is not known at this time. It does seem likely, however, that there was more water loss from the plants at the higher temperatures than at the lower temperatures. Since one of the principle sources of damage to plants by rust is the excess loss of water (24) it seems reasonable to assume that this factor is at least partially responsible. It would be interesting to make a similar study in which the moisture levels were controlled.

This study indicates that the wheat grower is exposing his wheat crop to potentially much greater leaf rust damage when he plants early when temperatures are still high. Early planting not only allows time for more leaf rust generations resulting in higher rust severities, but also exposes his rusted wheat crop to high temperatures which according to this study result in more damage than the same level of rust at lower temperatures. This results in both a lower forage yield and makes the plants more susceptible to low winter temperatures and moisture stress.

Considerable variation in rust severity occurred between the various trials. The inoculation procedure and equipment was the same for all trials, but it was found that during one trial the temperature rose to 29 C for a substantial portion of the period that the plants were held in the moist chamber following inoculation. In that trial the amount of infection was very low. Chester (3) stated that leaf rust infections were very erratic above 27 C. It is possible, therefore, that high temperatures during this period could be the cause of the low infection rate for that particular trial.

Coefficients of variation were extremely high for chamber replications as might be expected. However, the coefficients of variation within each chamber replication were relatively low. By repeating each trial of each temperature regime in each growth chamber adequate comparisons of rusted versus non-rusted and between temperature regimes could be made.

CHAPTER VI

SUMMARY

1. The winter wheat variety Danne was used to evaluate the effect of leaf rust infection (5-10% severity) on 30 day old wheat seedlings. Two temperature regimes, 21 C day - 17 C night and 27 C day - 21 c night, were used. The study was replicated twice in each of two growth chambers.
2. Leaf rust infection at a level of 5-10% severity reduced the growth of wheat seedlings up to 15% at the temperature regime of 27 C day - 21 C night.
3. The same level of infection produced no significant reduction in growth at a temperature regime of 21 C day - 17 C night.
4. Primary leaves of wheat seedlings with 5-10% leaf rust severity normally died within 20 days of inoculation in both temperature regimes tested.

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VITA

John Ray Pyzner

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF LEAF RUST INFECTION ON THE GROWTH OF WHEAT SEEDLINGS

Major Field: Plant Pathology

Biographical:

Personal Data: Born in Chickasha, Oklahoma, May 17, 1946, the son of Mr. and Mrs. John S. Pyzner.

Education: Graduated from Cement HIgh School, Cement, Oklahoma, in May, 1964; received Bachelor of Science degree in Biology from Southwestern Oklahoma State University in 1968; completed requirements for the Master of Science degree at Oklahoma State University in May, 1975.

Personal Experience: Research assistant, Department of Botany, Smithsonian Institution, Washington, D. C., 1968; Communication Officer, U. S. Navy, 1969-1972; graduate teaching assistant, Department of Botany and Plant Pathology, Oklahoma State University, 1972-1974; Diagnostic Laboratory Technician, Department of Plant Pathology, Oklahoma State University, 1974-1975.