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Effect of *Fusarium graminearum*, N-level and their Interaction on Wheat Productivity

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ABSTRACT. An experiment was conducted in 1990/91 and repeated in 1991/92 to study the effects of *Fusarium graminearum* the causal agent of foot and root rot and N-level on wheat grain yield, yield components, plant height and heading date. Four nitrogen levels; 0, 138, 276 and 414 kg N/ha were applied to soils noninfested or infested with the fungus. The presence of *F. graminearum* caused a remarkable root rot and significantly reduced wheat grain yield, yield components and plant height. On the other hand, heading date was not influenced by the fungal infection. N-level had significant effects on all studied characteristics in both seasons. The third level of N (276 kg/ha) maximized the grain yield. Concerning the interaction between the fungus and N-level, the highest grain yield losses were found when either higher N-level or no nitrogen were applied to wheat plants in the infested soil. The third and second N-levels were optimum in the noninfested and infested soils, respectively.

Based on the these results the common assumption that application of high N-level to overcome wheat grain yield losses caused by foot and root rot disease is not justified.

Spring wheat (*Triticum aestivum* L.) is the major field crop produced in central Saudi Arabia, with about 360,000 ha planted annually (Ministry of Agriculture and Water 1987). Over 95% of the wheat area is sown to the cultivar Yecora Rojo.

Foot and root rot caused by *Fusarium graminearum* is the most serious disease affecting wheat production causing about 35% annual loss in grain yield (El-Meleigi

1988, El-Meleigi *et al.* 1990 and 1993). Because of the continuous cultivation of wheat in soils naturally poor in organic matter, application of urea as a nitrogen fertilizer is commonly practiced by farmers for high yields. The effect of nitrogen fertilizer on wheat yield and its components has been investigated (Black 1982, Eissa *et al.* 1990, and Shehab El-Din 1993). However, the magnitude of yield increase would depend on nitrogen source, level and time of application (Ghandorah 1986, Vaughan *et al.* 1990 and El-Hefnawy *et al.* 1991). In Saudi Arabia, Rawajfih *et al.* (1984), indicated that wheat grain yield increased with increments of nitrogen level up to 400 kg N/ha, while Ghandorah (1985) found significant responses in grain yield to increased nitrogen level from zero to only 100 kg N/ha. For sandy soils of the Gassim region, Rabie *et al.* (1991) recommended 230 kg N/ha, while Shehab El-Din (1993) concluded that the optimum nitrogen level lies between 253 and 299 kg N/ha.

Fusarium foot and root rot is favored by severe water stress and heavy nitrogen fertilization (Cook and Veseth 1991). However, the impact of nitrogen treatments on the severity of that disease in dry lands, as in the Gassim region, has not been investigated. Therefore, the objective of this study was to investigate the effect of the soil-borne *Fusarium graminearum,* N-level, and their interaction, on grain yield and yield components of wheat.

Materials and Methods

The present study was carried out at the Experimental Farm of the College of Agriculture and Veterinary Medicine, King Saud University, Gassim Branch, during the 1990/91 and 1991/92 wheat growing seasons. The soil of the experimental site is classified as sandy, poor in organic carbon and nitrogen (Rabie *et al.* 1991). The widely distributed commercial wheat cultivar Yecora Rojo was used in this study.

The experiment was set up in a split-plot design with four replications. The main and sub-plots were assigned for the infestation and fertilization treatments, respectively. Each sub-plot consisted of 6 rows; 5 m long and 20 cm apart. The phosphorus fertilizer was applied in the form of triple super phosphate 46% P_2O_5 at a rate of 180 kg/ha by basal dressing during land preparation.

The experiment was planted and repeated on December 16 and 10 of 1990 and 1991, respectively, using a seeding rate of 180 kg/ha. Irrigation was applied using a central pivot system during the two growing seasons.

Inoculum of *F. graminearum* was prepared as described by El-Meleigi *et al.* (1990). Wheat grains were autoclaved in 500 ml Erlenmeyer flasks, then inoculated with the fungus and incubated at 25°C for 3-4 weeks. The colonized wheat grains were dried in a stream of sterilized air in a laminar flow hood at 25°C for 24h. The dried inoculum was distributed into plastic bags, 5 g each and stored at 5°C until used in the field within the next 24h.

The fungal inoculum was mixed with wheat seeds prior to sowing by hand in the field. Each 5 m row received 5 grams of inoculum. Non infested plots were used as check treatments.

Four levels of nitrogen; 0, 138, 276 and 414 kg N/ha were used in the form of urea 46% N. Four equal splits from each level, were applied during the four wheat critical growth stages; seedling, tillering, booting and heading.

Due to the Gulf War reading of the incidence of root rot in the field was not obtained in the 1990/91 growing season. Therefore, the percentage of wheat plants developed root rot in the field was determined only in the second season, as follows. At the heading stage, 20 plants were lifted at random from the border rows of each sub-plot. The roots were washed thoroughly with running tap water and examined with a 10X lens. The percentage of wheat plants showing visible root rot symptoms was determined. Selected representative samples of diseased and apparently healthy roots were dissected, surface sterilized by dipping in 1% NaOCl for 1 min and then washed with sterilized water. Root tissues were blotted dry on filter paper and plated on acid potato dextrose agar, pH 5.0 and incubated at 25°C for one week in an illuminated incubator. Organisms associated with the root tissues were identified to confirm the role of *F. graminearum* in the development of root rot symptoms.

The central four rows of each sub-plot were hand harvested to avoid the border effect. After threshing, grain yield for each sub-plot was weighed and adjusted to ton/ha. One week before harvesting, number of spikes/m^2 was recorded by hand counting one randomly selected row from the central rows of each sub-plot. To determine number of kernels/spike from each sub-plot, ten randomy selected main spikes were collected, threshed, their kernels were counted and the average was calculated. Moreover, a 1000 - seed random sample from each sub-plot was hand counted and weighed to determine kernel weight. Plant height was recorded by calculating the average length of five randomly selected plants from each sub-plot, measuring from the ground level up to the end of main spikes excluding awns. When approximately 50% of the plants were headed, number of days from sowing to heading date was determined.

The combined analysis of variance for the two seasons was computed and the statistical comparisons of means were made according to the methods of Steel and Torrie (1980).

Results and Discussion

The results of the effect of soil infestation with *F. graminearum* and application of N levels in the 1991/92 growing season are presented in Fig. 1. The disease was highly visible in the infested soil where 31 to 55% of the plants showed root rot symptoms. On the other hand, the occurrence of root rot in occurrence of the disease was confirmed by isolation of *F. graminearum* from all discolored and rotted tissues. The highest level of disease occurrence was found in the sub-plots fertilized with 276 kg N/ha (Fig. 1).

The combined analysis of variance for the two growing seasons presented in Table 1, indicated that growing seasons had significant effects on the studied agronomic traits. Except for plant height and number of days to heading, significant effects existed for the interaction between season and the infestation. Moreover, the interaction between season and nitrogen level showed significant effects on number of kernels/spike, kernel weight and plant height. Therefore, the results of each season are discussed separately.

The analyzed data, presented in Table 2, indicated that artificial soil infestation with *F. graminearum* has significantly reduced grain yield, number of kernels/spike and kernel weight in both season. Significant and non-significant reductions in number of spikes/m^2 and plant height were also detected in the two seasons, respectively. On the other hand, number of days to heading was not influenced by fungal infection.

The grain yields and other traits, were generally lower in season 1990/91 than in 1991/92 regardless of infection with *F. graminearum* (Table 2). However, greater losses due to infestation were more evident in the first season where wheat growth was affected by adverse climatic conditions prevailing at Gassim area during that season.

Data presented in Table 2 revealed that nitrogen fertilization level had significant effects on all studied traits in both seasons. However, 276 kg/ha was the best for maximizing grain yield (2.33 and 4.13 ton/ha) in both seasons. Generally, corresponding increases in number of spikes/m^2 were associated with the increment of nitrogen levels in both seasons. The application of high nitrogen fertilization

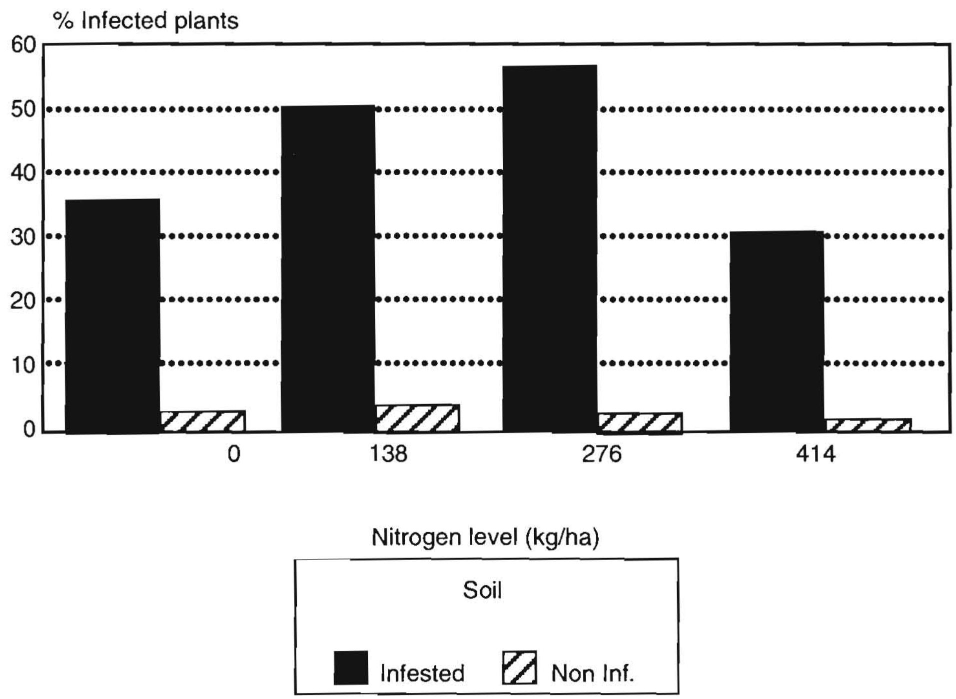

Fig. 1. Effect of Nitrogen level and *Fusarium graminearum* on incidence of wheat root rot in the field

Table 1. Combined analysis of variance for wheat grain yield and some other agronomic traits as affected by four nitrogen levels in soils not infested and infested with *Fusarium graminearum*

Source	Mean Squares					
	Grain yield	No. of spikes/m^2	No. of Kernels/spike	1000 kernel weight	Plant height	Days to heading
Reps (R)	0.17	1799.85	16.96	1.49	1.85	0.14
Seasons (S)	45.75**	463250.39**	3627.05**	1061.21**	2730.06**	8395.14**
R X S	0.29	525.31	2.67	2.17	22.10	0.56
Infestation (I)	17.52**	22838.77**	264.88**	102.09**	210.25**	4.52
S X I	3.24	17457.02**	38.13**	17.61**	20.25	0.14
S X I X R	0.12	816.39	1.59	2.31	7.42	0.87
Fertilization (F)	9.99**	26197.27**	405.93**	112.63**	232.60**	95.89**
S X F	0.05	258.06	102.35**	34.97**	24.19**	1.31
I X F	2.16**	967.27	15.08**	6.94	39.71**	0.27
S X I X F	0.12	6127.02**	14.15**	3.12	50.96**	0.81
S X I X F X R	0.15	634.89	2.77	2.71	3.41	0.37

**Significant at 0.01 level of probability

Table 2. Means of grain yield and other agronomic traits of wheat as affected by *Fusarium graminearum*, N-levels and their interaction in 1990/91 and 1991/92 seasons

		Grain yield (Ton/ha)		No. of spikes /m^2		No. of kernel /spike		1000 kernel weight (g)		Plant height (cm)		Days to heading	
		90/91	**91/92**	**90/91**	**91/92**	**90/91**	**91/92**	**90/91**	**91/92**	**90/91**	**91/92**	**90/91**	**91/92**
Inoculation													
Non-noculated		2.51	3.75	250	387	29.3	42.8	34.4	43.6	52.4	64.3	74	77
Inoculated		1.01	3.15	179	382	23.7	40.3	32.9	40.0	47.6	61.8	73	76
L.S.D. 0.05		0.18	0.53	22	NS	1.2	1.6	0.6	2.3	2.3	NS	NS	NS
	0	0.69	2.29	159	326	21.6	315	33.0	45.5	42.8	59.0	71	73
N-levels	138	2.30	3.90	217	380	29.8	42.2	36.6	43.2	51.6	65.4	73	77
(kg/ha)	276	2.33	4.13	239	421	28.4	45.0	32.9	41.5	53.5	64.6	75	78
	414	1.73	3.50	242	412	26.3	47.7	31.5	36.8	52.1	63.3	76	79
L.S.D. 0.05	0.05	0.05	0.48	19	25	1.5	2.0	1.2	2.1	2.0	1.8	0.8	1.3
	0	0.95	2.08	172	349	23.1	31.7	33.1	47.1	49.8	60.3	71	74
Non-inoculated	138	3.08	4.06	246	398	32.1	43.2	37.6	44.0	52.3	67.8	73	77
	276	3.30	4.89	275	400	33.1	45.5	33.7	43.9	53.5	66.3	75	78
	414	2.71	3.97	304	400	29.1	51.0	33.0	39.3	54.0	63.0	77	79
	0	0.43	2.49	146	303	20.1	31.3	33.8	44.0	35.8	57.8	71	73
Inoculated	138	1.51	3.73	187	362	27.6	41.1	35.7	42.5	51.0	63.0	73	76
	276	1.36	3.37	202	441	23.8	44.4	32.0	39.2	53.0	63.0	75	78
	414	0.75	3.04	179	424	23.5	44.5	30.0	34.3	50.3	63.5	76	79
L.S.D. 0.05		0.05	0.68	39	36	2.1	2.8	1.7	NS	2.9	2.6	NS	1.8

levels during the tillering stage stimulates tiller initiation (Gravell *et al.* 1988 and Shehab El-Din 1993). While number of kernels/spike responded positively to the incremental addition of nitrogen level in the second season, the largest number of kernels/spike was obtained when 138 kg N/ha were added in the first one. On the other hand, heavy kernels were obtained when 138 kg N/ha or no N was applied in the two growing seasons, respectively. However, the enhancement of grain yield, in the second season, could be attributed to the increase of the three yield components. The tallest plants were obtained when 276 and 138 kg N/ha were applied in the two growing seasons, respectively. Generally, increasing nitrogen level, in both seasons resulted in steady delay in heading date. Similar results were reported by Ghandorah (1985), Gravelle *et al.* (1990).

The different response of the studied traits from one season to another could be due to changes in climatic conditions and/or heterogeneity of the soil (Jacobsen and Westermann 1988 and Shehab El-Din 1993).

Concerning the interaction between the fungus and N-level, the highest grain yield losses were found when either high levels of nitrogen or no nitrogen were applied to wheat plants in soil infested with *F. graminearum*. This appears contradictory with the results presented in Fig. 1 where root rot incidence was most prevalent when 138 or 276 kg N/ha were applied. This could be due to the vigorous growth of root system of wheat plants when appropriate levels of nitrogen are added. Consequently, the extension of roots in the soil exposes such roots to more fungal inocula leading to extensive root rot symptoms.

The vigorous growth of wheat plants supplied with appropriate amounts of N, may compensate for the losses due to the disease. This is not the case when the nitrogen fertilizer was not adequate or was in excess of the requirement of wheat plant.

In conclusion, the common assumption that application of high N level in order to overcome wheat grain losses caused by *F. graminearum,* as practiced by most farmers in central Saudi Arabia, is not justified according to these results. Regardless of growing season, the application of 276 kg N/ha was the optimum treatment in noninfested sandy soil, while the 138 kg N/ha was adequate in the *F. graminearum* infested soil. Moreover, application of 414 kg N/ha was not justified irrespective of soil infestation with *F. graminearum* or growing season.

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تأثير *Fusarium graminearum* ، مستوى النيتروجين والتفاعل بينهما على انتاجية القمح

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أجريت تجربة في موسم ٩٠/ ١٩٩١ وأعيدت في ٩١/ ١٩٩٢ لدراسة تأثير كل من فطر *Fusarium graminearum* ، الفيوزاريوم جرامينرم - المسبب لمرض عفن التاج والجذور - ومستوى التسميد النيتروجيني على محصول الحبوب ، مكونات المحصول ، طول النبات ، وتاريخ التزهير في القمح . أضيفت أربعة مستويات من السماد النيتروجيني هي : صفر ، ١٣٨ ، ٢٧٦ و ٤١٤ كجم نيتروجين للهكتار لكل من الأراضي الغير معدية والمعدية بالفطر .

وقد أظهرت النتائج أن العدوى بالفطر قد تسببت في إحداث المرض بصورة واضحة كما أدت إلى نقص معنوي في محصول الحبوب ومكونات المحصول وطول النبات . ولم يكن للفطر تأثيراً يذكر على صفة تاريخ التزهير . كما أثر السماد النيتروجيني معنوياً في جميع الصفات المدروسة في كلا الموسمين وكان المستوى الثالث هو الأفضل للحصول على أعلى محصول حبوب . وبالنسبة للتفاعل بين

الإصابة بالفطر ومستوى التسميد وجدت أكبر خسارة للمحصول عند اضافة المستوى العالي من السماد أو عدم اضافة السماد على الإطلاق إلى الأراضي المعدية . كما تبين أن المستوى الثالث كان هو المستوى الأمثل للأراضي الغير معدية بينما كان المستوى الثاني كافياً للأراضي المعدية . وبناء على ما سبق ، يكون افتراض ان اضافة جرعات زائدة عن الحد الأمثل من السماد النيتروجيني لتعويض الفقد الناتج في محصول الحبوب - نتيجة للإصابة بمرض عفن الجذور - لا أساس له من الصحة .