Plant Pathology Journal

ISSN 1812-5387

science alert

ANSInet
an open access publisher
http://ansinet.com

Plant Pathology Journal 5 (2): 143-149, 2006
ISSN 1812-5387

Pathogenicity of Turkish Crown and Head Scab Isolates on Stem Bases on Winter Wheat under Greenhouse Conditions

[1]Berna Tunali, [2]Julie Nicol, [1]F. Yelda Erol and [1]Gülay Altiparmak
[1]Department of Plant Protection, Faculty of Agriculture,
University of Ondokuz Mayıs, Kurupelit, Samsun, 55139, Turkey
[2]CIMMYT International, PK 39, Emek, Ankara, 06511, Turkey

Abstract: Fifty one *Fusarium* isolates from crown tissue across 32 locations of Central Anatolian plateau. The 51 isolates which represented 13 different species were assessed for *Fusarium* pathogenicity against the winter wheat Pehlivan. Virulence ratings were variable with *F. culmorum*, *F. pseudograminearum* and *F. graminearum* causing the greatest severity and reduced plant weight. A strong negative correlation between plant weight and disease severity, other species including *F. subglutinans*, *F. oxysporum*, *F. equiseti*, *F. acuminatum*, *F. solani*, *F. verticilloides* were weak pathogens on Pehlivan and under these conditions would not be considered as pathogens.

Key words: *Fusarium* crown rot, wheat, pathogenicity

INTRODUCTION

The genus *Fusarium* is one of the widespread and economically important groups of fungi with more than hundred species attacking most botanical species. On wheat and barley many different species are known to be associated with both the root rotting symptoms commonly known as Crown Rot (CR) and foliar spike infestation commonly known as *Fusarium* head scab. *F. pseudograminearum* (O'Donnell and Aoki) (= *F. graminearum* group 1, telemorph, *Gibberella coronicola*), *F. culmorum* Wm. G.Sm) Sacc., *Microdochium nivale* (Fr.) Samuels and I.C. Hallett (= *F. nivale*, Telemorph, *Monographella nivalis*) and *F. avenaceum* (Fr.:Fr.) Sacc. (Telemorph. *G. avenacea*), *F. acuminatum* (Ellis and Eve) and *Bipolaris sorokiniana*(Sacc.) *Shoemaker* (Telemorph. *Cochliobolus sativus*) are reported to cause crown rot of wheat (*Triticum aestivum* L.) (Burgess *et al.* 1975; Cook, 1981; Hill and Fernandez, 1983; Specht and Rush, 1988; Smiley and Patterson, 1996) while *Fusarium* head blight (FHB) of wheat (*Triticum aestivum L.*) is caused by several pathogenic species of the genus; these are *Fusarium graminearum*, *F. culmorum*, *F. avenaceum*, *F. sambucinum* var. coeruleum, *F. crookwellense* and *F. sporotrichoides F. graminearum* is usually primer pathogen in warmer areas, *F. culmorum* frequently predominant and most aggressive to cereal plants in countries of intermediate temperature, whereas *F. avenaceum* often predominates in cooler growing areas (Arsenuik *et al.*, 1991; Miedaner *et al.*, 1993).

FHB occurs in all regions of the world where humid conditions exist during the flowering and grain filling stages (Cook, 1981; Sutton, 1982; Wiese, 1987; Wilcoxon *et al.*, 1988). Major epidemics have occurred in such diverse regions as eastern and western Europe, the regions of the former USSR, China and Brazil.

Turkey is among the 10 largest wheat (*Triticum aestivum* L.) producers worldwide with a production varying between 16-21 million tones and average yield is around 2 t ha^{-1} from this 9.35 M ha (Braun *et al.*, 2001). More than half of the wheat area located on the Central Turkey under rainfeld or supplementary irrigation conditions, where a cereal fallow rotation predominates. The continental climate is characterized by cold winters and hot dry summers. Under such conditions drought stress is common and it is well appreciated that the damage cause by this root rotting complex occurs especially under such moisture-restricted conditions (Piening *et al.*, 1976; Cook, 1981; Bailey *et al.*, 1989).

Aktaş *et al.* (1996) reported that *F. pseudograminearum* is more wide-spread than *F. culmorum* in Northeast part of Marmara coastal region of Turkey. However, on the Central Anatolia Plateau surveys conducted in 1994/95 and 2000 to 2004 find more

Corresponding Author: Berna Tunali, Department of Plant Protection, Faculty of Agriculture, University of Ondokuz Mayıs, Samsun, Turkey, Kurupelit, Samsun, 55139, Turkey Fax: +90 362 312 19 19

than 10 species of *Fusarium* isolated from crown and sub-crown tissue with *F. culmorum* being the most commonly isolated *Fusarium* (Aktaş *et al*., 1999). Recent yield losses studies in % in Central Anatolia Plateau have confirmed that Cereal Root Rots are associated with significant yield losses of mean 36.2% with commonly cultivated winter wheats in 1994/95 (Aktaş *et al*., 1999). Three year yield loss studies on the Central Anatolian Plateau with dryland root rot complex including *F. pseudograminearum, F. culmorum* and *Bipolaris sorokiniana* found losses 24% for 12 commonly cultivated bread wheats (Hekimhan *et al*., 2004).

Most of pathogenicity test for *Fusarium* root rot have identified *F. culmorum* and *F. graminearum* (= *Syn. F. pseudograminearum)* as the most pathogenic species, although *F. avenaceum* is also reported in some papers as equally pathogenic or more pathogenic than *F. culmorum* and *F. graminearum* (Arsenuik *et al*., 1993; Jenkinson and Parry, 1994).

In Australia a survey with over 415 samples indicated that *F. culmorum* was widely distribution in soil but was detecting in plants in only half as many locations as *F. pseudograminearum*. Several other were isolated including *B. sorokiniana*, *M. nivale* and *F. avenaceum*.

Studies by Demirci and Dane (2003) with *Fusarium* isolates from Northeast of Turkey in Erzurum and testing their pathogenicity on wheat indicated that *F. acuminatum*, *F. equiseti*, *F. oxysporum* and *F. solani* were slightly virulent. The highest disease severity was caused by isolates of *M. nivale* (= *Syn. F. nivale)*.

Fusarium graminearum was the primary pathogen responsible for FHB epidemics on Northwest part of Anatolia of Turkey in 2001/02 years. *F. culmorum* has been proved most aggressive to wheat plants and secondary pathogen in the Region. Although *F. oxysporum*, *F. chlamydosporum*, *F. solani*, *F. heterosporum*, *F. equiseti and F. poae*, occurred at least in 4 counties of 9 wheat growing counties in the survey.

Akinsanmi *et al*. (2004) reported that *F. graminearum* was predominantly isolated from the head and *F. pseudograminearum* from the crown atleast 14% of *F. graminearum* isolates originated from the crown rot under field conditions. Overall isolates from crown and stubble were more aggressive for crown rot, whereas isolates from the flag leaf node were more aggressive for *Fusarium* head blight, but both fungal species could cause either disease.

The aim of this study is to establish the seedling pathogenicity of various isolates of *Fusarium* on the winter wheat Pehlivan. Plant weight and disease parameters were compared for inoculated and non inoculated (control) pots in greenhouse condition. To present knowledge this is also the first report the ability of FHB disease agents from a survey of wheat crops in Northwest Anatolia on FCR infections in greenhouse conditions.

MATERIALS AND METHODS

Collections and maintenance of isolates: The survey was conducted maturing stage of wheat growing areas of Central and Northern part of Anatolia (Fig. 1). Thirty two locations were sampled in June 2005, with sites being selected arbitrarily based on an approximate distance apart of 25 km, the presence of mature plants and the accessibility of the field from the road side. Five crown and sub crown rot diseased plants were collected from each site.

Stems of plants washed with top water then 3 pieces of crown and sub crown internodes tissues were surface sterilized with 1% NaOCl solution for three minutes, rinsed in sterile distilled water and plated on modified potato dextrose agar ¼ strength PDA (9 g PDA, Merck, 10 g Bacto agar, 1 liter distilled water) amended with streptomycin sulfate (100 mg L^{-1}) and Oxytetracyline (60 mg L^{-1}). Plates were incubated seven days under cool white fluorescent at 25°C, 15 h photoperiod and colonies developing on ¼ strength PDA were sub cultured and then transferred CLA (Carnation Leaf Agar) medium at same condition as ¼ strength PDA. Fungal cultures on CLA medium were identified and transferred to fresh media. A small scrape of macro conidia from a sporodochium was preferred to obtain 1-10 conidia in a drop under a stereo microscope. WA (Water agar) plates were seeded by pouring the conidial suspension over the surface. The plates were incubated described by Burgess *et al*. (1994). Plates were examined using a stereo microscope. A single germinated conidium's was removed on a small square of agar using a transfer needle. *Fusarium* species and their isolates were transferred to fresh potato dextrose agar (1/2PDA) and CLA. *Fusarium* species were identified based on descriptions of some authors (Booth, 1977; Gerlach and Nirenberg, 1982; Nelson *et al*., 1983; Toussoun and Nelson, 1985; Burgess *et al*., 1994). After identification study, isolates were stored on silica-gel at 5°C in refrigerate (Windels, 1988).

Pathogenicity test: Inoculum was prepared using seven days old monosporic isolates of each of the *Fusarium* species on SNA (Synthetic nutrient agar) medium amended with Streptomycin sulfate (100 mg L^{-1}) and Oxytetracycline (60 mg L^{-1}). In addition to the isolates collected in the 2005 survey (1-32), 18 additional isolates

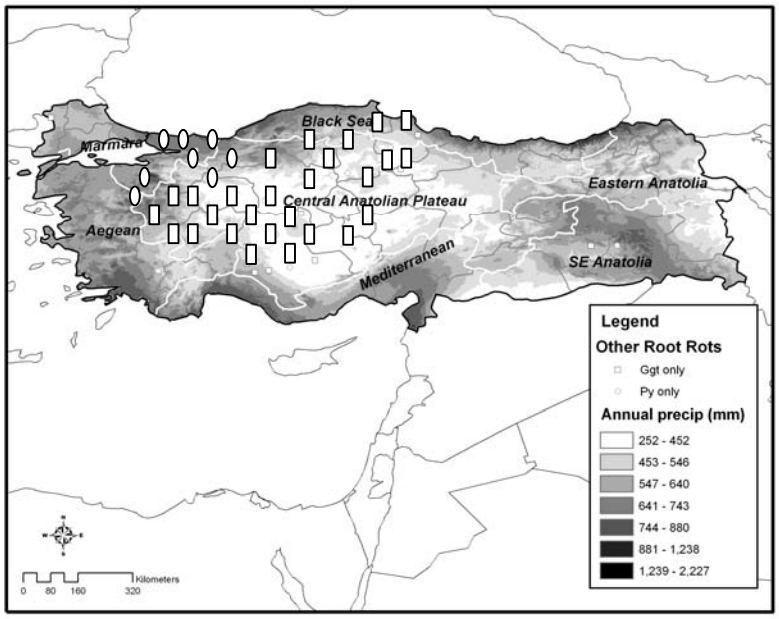

Fig. 1: The location of sampled for *Fusarium* species in Central and Northern part of Anatolia, Turkey

were included in the pathogenicity test which was collected from the same region using similar methodology collected from the same region in 2003. All *Fusarium* species isolated from wheat spikes with the exception of the five *F. pseudograminearum* which like the 2005 samples came from the crown tissue. Plants were grown into plastic pots (8 cm in diameter by 16 cm in height) with autoclaved commercial potting soil and local loam soil. Seeds of the winter wheat cultivar "Pehlivan" were surface sterilized for 3 min in a 1% aqueous solution of NaOCl and rinsed twice in sterile distilled water than placed into the 7 day old fungus culture plates on CLA medium which were shaken by hand for 20 sec A 1 cm diameter, agar plug with mycelium and spores was cut from periphery of the agar cultures and placed agar- side up at the bottom of three 3 cm deep holes made previously in each pots (Fernandez, 2005) into each of this holes one Pehlivan wheat seed inoculated from the agar plate was placed on top of the agar and then they were covered with 3 cm of potting soil. For control treatments an agar plug with no fungus on was used. Three pots were used for each fungal isolate and treatments were arranged in a completely randomized plot with three replicates (each pot was one replicate). Plants were watered to field capacity when drought symptoms first appeared in any pots. Plants were incubated at temperatures of approximately 25°C in the greenhouse under a 16 h photoperiod under fluorescent lights.

Plants emergence was obtained 15 days after planting and at day 70, each of three plants per plot were washed carefully. Each individual plant was then rated for combined discoloration of crown and sub crown internodes on percent tissue are discolored. Infections for each plants of per fungal isolate tested were assessed using a 0-3 scale as follows: 0 = No discoloration, 1 = trace to 25%, 2 = 25 to 50% and 3 = 50>%. All isolates plants dried between 2 layers of paper towels and the fresh weight recorded. Three pieces of crown and sub crown internodes tissues were put into CLA medium for re inoculation to confirm successful infection by inoculated fungus.

Statistical analysis: The experimental design was a Completely Randomized Plots with three replications. Percentage data (disease severity (%)) were arcsin-transformed before the tests. MSTATC program was used to carry out statistical analysis. Means showing significance statistically were compared using Least Significance Difference (LSD) test at 0.01 probability levels. MS excel program was used to generate the figures showing differences among *Fusarium* species for disease severity.

RESULTS

A total of 32 fields were surveyed and 160 plant samples collected during the surveys were isolated *Fusarium* species by using ¼ strength PDA and CLA media.

Table 1: Disease severity and average plant weight of the winter wheat "Pehlivan" inoculated 51 isolates of *Fusarium*, representing 13 *Fusarium* species compared to controls in the greenhouse after 70 days

No.	Sample No.	Fungus	Disease severity (%)	Plant weight 3 plants per pot (g)
1	3-1	*F. avenaceum*	55.53 g-k**	1.21 d-m**
2	3-3	*F. avenaceum*	63.03 d-k	1.93 a-f
3	4-4	*F. verticilloides*	25.90 k-p	1.54 b-I
4	5-3	*F. culmorum*	92.57 abc	0.46 l-s
5	6-1	*F. culmorum*	92.57 abc	0.60 k-s
6	6-4	*F. culmorum*	100.00 a	0.21 o-s
7	6-5	*F. culmorum*	92.60 a-d	0.41 l-s
8	8-2	*F. pseudograminearum*	100.00 a	0.12 r-s
9	8-5	*F. verticilloides*	62.97 e-k	1.51 b-j
10	11-2	*F. chlamydosporum*	29.60 k-o	1.44 b-k
11	12-1	*F. acuminatum*	22.00 l-p	2.40 ab
12	13-1	*F. culmorum*	85.20 a-g	0.38 m-s
13	14-4	*F. subglutinans*	14.80 nop	2.90 a
14	15-3a	*F. acuminatum*	14.80 l-p	2.36 abc
15	15-3b	*F. culmorum*	100.00 a	0.00 s
16	15-2	*F. subglutinans*	14.80 nop	2.19 a-d
17	16-5	*F. culmorum*	92.57 abc	0.44 l-s
18	18-1	*F. culmorum*	100.00 a	0.00 s
19	18-5a	*F. verticilloides*	18.50 m-p	1.98 a-f
20	18-5b	*F. subglutinans*	51.83 h-l	1.17 d-n
21	19-1	*F. acuminatum*	55.53 g-k	1.63 b-h
22	22-2	*F. verticilloides*	48.10 h-m	1.33 b-l
23	22-3	*F. subglutinans*	7.40 op	2.05 a-e
24	22-4	*F. verticilloides*	29.60 k-o	1.64 b-h
25	23-2	*F. equiseti*	29.60 k-o	1.74 a-h
26	24-1	*F. culmorum*	100.00 a	0.08 rs
27	24-3	*F. culmorum*	88.53 a-f	0.68 i-s
28	24-4	*F. culmorum*	100.00 a	0.00 s
29	25-3	*F. chlamydosporum*	33.30 j-o	1.87 a-g
30	25-4	*F. solani*	62.97 e-k	1.58 b-i
31	25-5	*F. culmorum*	85.17 a-e	0.21 o-s
32	26-1	*F. semitectum*	51.83 h-l	0.76 h-s
33	26-5	*F. acuminatum*	55.57 g-k	1.75 a-h
34	28-2	*F. culmorum*	88.90 abc	0.55 j-s
35	29-3	*F. oxysporum*	51.83 h-l	1.02 e-p
36	30-1	*F. crookwellense*	55.17 g-k	0.90 g-r
37	31-2	*F. equiseti*	33.30 j-o	1.92 a-f
38	32-3	*F. oxysporum*	40.70 j-n	1.01 e-p
39*	33(2)	*F. graminearum*	92.57 abc	0.37 n-s
40*	34(4)	*F. graminearum*	73.37 c-j	0.96 f-q
41*	35(5)	*F. graminearum*	92.23 abc	0.18 p-s
42*	36(2)	*F. culmorum*	96.30 ab	0.23 o-s
43*	37(34)	*F. pseudograminearum*	96.30 ab	0.15 qrs
44*	38(38)	*F. pseudograminearum*	96.30 ab	0.23 o-s
45*	39(40)	*F. pseudograminearum*	77.80 a-h	0.55 k-s
46*	40(41)	*F. pseudograminearum*	100.00 a	0.12 rs
47*	41(42)	*F. culmorum*	59.23 f-k	1.06 e-o
48*	42(43)	*F. semitectum*	44.43 i-n	1.71 a-h
49*	43(45)	*F. pseudograminearum*	81.50 b-i	0.56 j-s
50*	44(46)	*F. graminearum*	96.30 ab	0.23 o-s
51*	45(E3)	*F. solani*	25.90 k-p	1.25 c-m
52		Control	3.70 p	1.99 a-f
LSD			24.440	0.339

**: Significant at 0.01 level. *: from 39 to 51 isolates collected in 2003 from spikes except five *F. pseudograminearum*

After the identification study, 13 *F. culmorum*, 5 *F. verticilloides*, 4 *F. subglutinans*, 3 *F. acuminatum*, 2 *F. avenaceum*, 2 *F. equiseti*, 2 *F. oxysporum*, 2 *F. chlamydosporum*, 1 *F. pseudograminearum*, 1 *F. solani*, 1 *F. semitectum* were isolated from 32 fields.

The effect of the different fungal species and isolates were significant (p = 0.01) for both measurement taken (Table 1). Disease severity indices and plant weights were correlated for the composite of all treatments and also for *F. culmorum*, *F. pseudograminearum*, *F. oxysporum* and others. *F. culmorum* caused the greatest reduction on plant emergence and survival with very few plants emerged after the seeds were inoculated or by harvest time. Growth of the surviving plants was retarded most by *F. culmorum, F. pseudograminearum* and *F. graminearum* (Fig. 2). Influence of three pathogens on disease severity % compared with noninoculated controls. There were no differences among, for the means of 15 isolates of *F. culmorum* (Fc), 4 isolates of *F. graminearum* (F.gr) and 6 isolates of

Table 2: Influence of three pathogens on disease severity compared with noninoculated controls

Fusarium species	Disease severity (%)
F. culmorum	91.58 a**
F. graminearum	88.62 a
F. pseudograminearum	91.98 a
Control	3.70 b
LSD	

**: Significant at 0.01 level

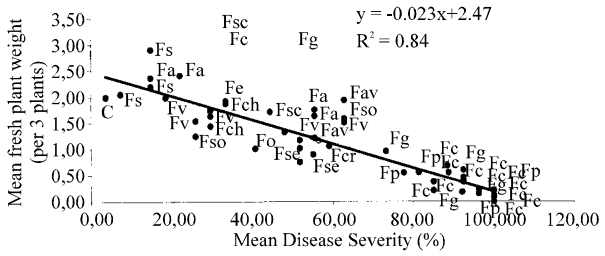

Fig. 2: Relationship between crown rot and fresh plant weight of *Fusarium* spp. Isolates tested against Pehlivan winter wheat in greenhouse conditions (F.a: *F. acuminatum*, F.av: *F. avenaceum*, F.c: *F. culmorum*, F.ch: *F. chlamydosporum* F.cr: *F. crookwellence*, F.e: *F. equiseti*, F.g: *F. graminearum*, F.o: *F. oxysporum*, F.p: *F. pseudograminearum*, F.s: *F. solani*, F.se: *F. semitectum*, F.s: *F. subglutinans*, F.v: *F. verticilloides*)

F. pseudograminearum (F.pse) All fungal isolates caused discoloration of all crown and subcrown internodes. *F. culmorum, F. pseudograminearum, F. graminearum* caused the greatest discoloration on both plants parts (Table 2), where as *F. chylamydosporum, F. oxysporum* and *F. acuminatum* caused the least discoloration, which was not different from the control treatment. Several of the *Fusarium* isolates obtained from the head of wheat were also found to give a similar level of infection as some of the more virulent crown rot isolates. Crown and sub crown internodes tissues were put into CLA medium from inoculated plants of all isolates of *Fusarium* spp. Those were re-isolated successfully.

DISCUSSION

F. culmorum, F. pseudograminearum and *F. graminearum* were pathogenic on subcrown and crown internodes under greenhouse conditions. *F. culmorum* affected plant emergence and growth to a greater extent than either *F. pseudograminearum* or *F. graminearum*. As with the work of Akinsanmi *et al*. (2004), *F. graminearum* isolates obtained from spikes of wheat plants. *F. graminearum* was caused discoloration of crown and subcrown internodes tissue to a similar extent as the crown rot implicated pathogens *F. culmorum* and *F. pseudograminearum* under greenhouse conditions. Fernandez (2005) demonstrated that *Fusarium* species derived from infected heads and subcrown internodes/crown of wheat had similar relative pathogenicity on heads indicating that, infected seed and plant tissue might be contributing to both root/crown infections and the survival of the fungus. Infected plant parts at or below soil level might than be a source of inoculum for infection of heads the following seasons or might constitute a significant fungal survival mechanism under dry conditions.

Akinsanmi *et al.* (2004) found that *F. pseudograminearum* isolates that were more aggressive for FCR(Fusarium Crown Rot) were those originating from paddocks with wheat following wheat, whereas those from fields with wheat following maize or sorghum were highly aggressive for FHB species *F. graminearum*. However in their studies it was clear that 20% of isolates caused severe to highly severe FHB and FCR.

Infected *F. acuminatum*, *F. equiseti*, *F. oxysporum*, *F. solani* and *Microdochium nivale* have been reported to cause subcrown and crown rot on winter wheat in Erzurum province, Turkey (Demirci and Dane, 2003). Similarly, Fedel-Moen and Harris (1987) in Southern Australia have demonstrated the potential importance of other *Fusarium* spp. such as *F. equiseti*, *F. acuminatum* and *F. oxysporum* that generally are considered less virulent members of the root and crown-inhabiting mycoflora associated with the crown rot syndrome.

Extensive studies in the USA with more than 1200 *Fusarium* isolates representing 19 species confirmed *F. graminearum*, *F. culmorum* and *B. sorokiniana* to be major causals agents of crown rot. However in addition they were able to demonstrate that some isolates of *F. acuminatum*, *F. oxysporum*, of *F. reticulatum* and *F. sporotrichoides* were capable of causing death of wheat plants in preliminary greenhouse tests (Smiley *et al*., 1996).

Mergoum *et al.* (1998) reported that, seedling root inoculation with *F. acuminatum* significantly reduced survival, number of tillers, plant height of wheat seedlings under both water-stress and non- water-stress conditions. In this study *F. acuminatum* caused discoloration of crown and sub-crown internodes, but it did not reduced plant weight.

This study clearly indicated that the three species of *Fusarium*, *F. culmorum*, *F. pseudograminearum* and *F. graminearum* are the most pathogenic species and groups of *Fusarium* isolates in this seedling test with the

winter wheat cultivar Pehlivan. Although many other *Fusarium* isolates were isolated from the crown tissue their role in pathogenicity seems to be less important as also reported several author studies (Uoti, 1976; Arsenuik *et al*., 1993). To confirm the seedling reaction holds true to the whole plant growth stage it would be necessary to conduct a similar experiment under field conditions to confirm the final relationship to yield which can also be visually assessed through the formation whiteheads.

The study also clearly confirms as with other findings that there is clear evidence that the predominant FHB, *Fusarium* species *F. graminearum* is just as capable of causing crown rot as two species most frequently associated with this (*F. culmorum* and *F. pseudograminearum*) (Table 2). As reported by other authors it is important gain greater understanding into the role of this fungus in crown rot in addition over winter survival in soil and plant tissue and implications for both FHB and FCR.

Recent extensive cereal surveys in Turkey over a major cereal producing regions has clearly identified *F. culmorum* as the main *Fusarium* species isolated from crown tissues (Aktaş *et al*., 1999).

Given the widespread distribution and dryland environment frequently associated with drought stress and cereal predominated cropping systems it is necessary to investigate both genetic and management practices to control these important soil borne pathogens.

ACKNOWLEDGMENT

We appreciate to Aysun Pekşen for statistical analysis from Ondokuz Mayıs University. Her assistance is gratefully acknowledged.

REFERENCES

Akinsanmi, O.A., V. Miller, S. Simptendorfer, D. Backhouse and S. Chakraborty, 2004. Identity and pathogenicity of *Fusarium* spp. Isolated from wheat fields in Queensland and northern New South Wales. Australasian. J. Agric. Res., 55: 97-107.

Aktaş, H., H. Bostancıoğlu, B. Tunalı and E. Bayram, 1996. Determination of the root rots disease agents, their interference with cultural practices and evaluation of varieties and lines against to important ones in Sakarya Region. Plant Protect. Bull., 36: 151-167.

Aktaş, H., E. Kınacı, A.F. Yıldırım, L. Sayın and A. Kural, 1999. Determination of root and foot rot pathogens which are problems in Konya province and research and solution. Cereal Symposium Book. Konya, 392-403.

Arsenuik, E., T. Gora and H.J. Czember, 1993. Reaction of triticale, wheat and rye accessions to graminaceous *Fusarium* spp. Infection at the seeding and adult plant growth stages. Euphytica, 70: 175-183.

Bailey, K.L., H. Harding and D.R. Knott, 1989. Disease progression in wheat lines and cultivars differing in levels of resistance to common root rot. Can. J. Plant Pathol., 11: 273-278.

Booth, C., 1977. *Fusarium* laboratory guide to the identification of the major species. Commenwealth Mycological Institute, Ferry Lane, Kew Surrey, pp: 58.

Braun, H.J., N. Zencirci and F. Altay *et al*., 2001. Turkish Wheat Pool. In 'World Wheat Book-A History of Wheat Breeding'. (Eds. Bonjean, A.P. and W.P. Angus) Lavoisier Publishing: Paris France, pp: 851-879.

Burgess, L.W., A.H. Wearing and T.A.Toussounn, 1975. Survey of Fusaria associated with crown rot of wheat in Eastern Australia. Aust. J. Agric. Res., 26: 791-799.

Burgess, L.W., B.A. Summerell, S. Bullock, K.P. Gott and D. Backhouse, 1994. Laboratory manual for *Fusarium* research. 3rd Edn., *Fusarium* Research Laboratory University of Sydney and Royal Botanic Gardens: Sydney, pp: 133.

Cook, R.J., 1968. *Fusarium* root and foot rot of cereals in the Pacific Northwest. Phytopathology, 58: 127-131.

Cook, R.J, 1981. Fusarium Diseases of Wheat and Other Small Grains in North America. In *Fusarium* Diseases. Biology and Taxonomy. P.E. Nelson, T.A. Toussoun and R.J. Cook, Eds. The Pennsylvania State University Press, University Park, pp: 30-25.

Demirci, E. and E. Dane, 2003. Identification and pathogenicity of *Fusarium* spp. from stem bases of winter wheat in Erzurum, Turkey. Phytoparasitica, 3: 170-173.

Fedel-Moen, R. and J.R. Harris, 1987. Stratified distribution of *Fusarium* and *Bipolaris* on wheat and barley with dry land root rot in South Australia. Plant Pathol., 36: 447-454.

Fernandez, M.R and Y. Chen, 2005. Pathogenicity of *Fusarium* species on different plant parts of spring wheat under controlled conditions. Plant Dis., 89: 164-169.

Gerlach, W. and H. Nirenberg, 1982. The genus *Fusarium*. A pictorial atlas. Kommissionsverlag Paul Parey, Berlin und Hamburg, pp: 406.

Hekimhan, H., A. Bağcı, J. Nicol, T. Arısoy and S. şahin, 2004. Dryland root rot: a major threat to winter cereal production under sub-optimal growing conditions. 4th Intl. Crop Sci. Congress, 26-1 Oct., Brisbane, Australia. www.regional.org.au/au/cs.

Hill, D.P. and J.A. Fernandez, 1983. Fungi associated with common root rot of winter wheat in Colorado Wyoming. Plant Dis., 67: 795-796.

Jenkinson, P. and D.W. Parry, 1994. Isolates of *Fusarium* species from common broad leaved weeds and their pathogenicity to winter wheat. Mycol. Res., 98: 776-780.

Mergoum, M., J.P, Hill and J.S. Quick, 1998. Evaluation of resistance of winter wheat to *Fusarium acuminatum* by inoculation of seedling roots with single, germinating macroconidia. Plant Dis., 82: 300-302.

Miedaner, T., D.C. Borchardt and H.H. Geiger, 1993. Genetic analysis of inbred lines and their crosses for resistance to head blight (*Fusarium culmorum*, *F. graminearum*) in winter wheat rye. Euphytica, 65: 123-133.

Nelson, P.E., T.S. Tousson and W.F.O. Marasas, 1983. *Fusarium* species an illustrated manual for identification. Pennsylvania State University Press, University Park.

Piening, L.J., T.G. Atkinson, J.S. Horricks, R.J. Ledingham, J.T.Mills and R.D. Tinline, 1976. Barley losses due to common root rot in the prairie provinces of Canada, 1970-1972. Can. Plant Dis. Survey, 56: 41-45.

Smiley, R.W., H.P. Collins and P.E. Rasmussen, 1996. Diseases of wheat in long-term agronomic experiments at Pendleton, Oregon. Plant Dis., 80: 813-820.

Smiley, R.W. and L.M. Patterson, 1996. Pathogenic fungi associated with *Fusarium* foot rot of winter wheat in the semiarid Pasific Northwest USA. Plant Dis., 80: 944-949.

Specht, L.D. and C.M. Rush, 1998. Fungi associated with root and foot rot of winter wheat and populations of *Bipolaris sorokiniana* in the Texas panhandle. Plant Dis., 72: 959-969.

Sutton, J.C., 1982. Epidemiology of wheat head blight and maize ear rot caused by *Fusarium graminearum*. Can. J. Plant Pathol., 4: 195-209.

Toussoun, T.A. and P.E. Nelson, 1995. A pictorial guide to the identification of *Fusarium* species. FUSARIUM. The Pennsylvania State University Press. University Park and London, pp: 43.

Uoti, J., 1976. The effect of five *Fusarium* species on the growth and development of spring wheat and barley. Ann. Agric. Fenniae Ser. Phytopathol., No. 62, 15: 254-262.

Wiese, M.V., 1987. Compendium of wheat diseases. The American Phytopathology Society. Minnesota, pp: 106.

Windels, C.E., P.M. Burns and T. Kommedahl, 1988. Five-year preservation of *Fusarium* species on silica gel and soil. Phytopathology, 78: 107-109.

Wilcoxon, R.D., T. Kommedahl, E.A. Ozmon and C.E. Windels, 1988. Occurrence of *Fusarium* species in scabby wheat from Minnesota and their pathogenicity to wheat. Phytopathology, 78: 586-589.