Stubble Management and the Site of Penetration of Wheat by *Fusarium graminearum* Group 1

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We are grateful to the Wheat Industry Research Committee of New South Wales and the National Soil Conservation Program for financial assistance.

Accepted for publication 26 March 1990 (submitted for electronic processing).

ABSTRACT

Summerell, B. A., Burgess, L. W., Klein, T. A., and Pattison, A. B. 1990. Stubble management and the site of penetration of wheat by *Fusarium graminearum* Group 1. Phytopathology 80:877-879.

Stubble management affected the site of penetration of wheat by *Fusarium graminearum* Group 1. When infested stubble was retained on the soil surface in a relatively undisturbed state, penetration occurred principally through the crown and basal stem regions. Penetration occurred through the scutellum, subcrown internode, and lower crown regions when stubble was incorporated or when stubble was burned and the remains incorporated. Differences in the site of penetration reflected the distribution of inoculum after the three stubble management practices. Regardless of the site of penetration, basal tissue regions were colonized to a similar extent by harvest maturity.

Crown rot, a dryland disease of wheat (*Triticum aestivum* L.) caused by *Fusarium graminearum* Schwabe Group 1 (7), is important in the central and northern areas of the eastern wheat belt of Australia (1,10) and has been reported in the Pacific Northwest of the United States (5) and South Africa (16). In Australia, the disease is most common in regions where rainfall is summer dominant and spring wheats are grown during winter, often using subsoil moisture accumulated and stored during the summer fallow (1). In these regions, retention of wheat stubble residues on the soil surface reduces soil erosion and conserves soil moisture (6). Stubble retention results, however, in an increase in crown rot incidence, whereas traditional practices involving a stubble burn usually cause a reduction in disease incidence (14). This is because *F. graminearum* Group 1 persists as hyphae in the residues of the host stems (17), which can be colonized parasitically to the fourth internode or higher (14). Retention of stubble residues on the soil surface results in an increase in inoculum levels (14) and also permits the fungus to survive for extended periods (13). Stubble incorporation does not significantly reduce crown rot incidence (14), even though this practice is unfavorable for survival of *F. graminearum* Group 1 (13).

Purss (11) reported that infection of wheat by *F. graminearum* Group 1 occurred primarily via the subcrown internode and coleoptile, but dramatic changes in stubble management systems have occurred in recent years (6). In this paper, we report studies on the impact of three stubble management treatments: stubble retention, stubble incorporation, and stubble burning on the principal site of penetration by the crown rot fungus in wheat.

MATERIALS AND METHODS

Experiments were conducted at two locations at the University of Sydney's Livingston Farm, Moree, New South Wales, during the 1987 and 1988 wheat seasons (May–November). Wheat (cultivar Sunstar) had been grown at both locations in the previous season. The soil type at both sites was a neutral (pH = 6.4 in 0.01 mol L^{-1} $CaCl_2$), self-mulching gray clay, the characteristics of which have been summarized (13) together with the relevant climatic data. A randomized complete block design with four replicates was used at both locations. Plots were 20 × 50 m and 50 × 200 m at locations A and B, respectively. Cultivar Sunstar, susceptible to crown rot (3), was planted on 10 June 1987 and 5 June 1988.

Stubble management treatments were imposed on 18 December 1986 and on 15 December 1987. Treatments were as follows: stubble retention with subsurface tillage with a blade plough; stubble incorporation with an offset disk plough; and stubble burned and the remains incorporated with an offset disk plough. Chlorsulfuron (75% w/w) was applied at 20 g ha^{-1} as a preplant herbicide.

In 1987, 50 plants were sampled at random from each plot (200 plants per treatment) at tillering (growth stage [g.s.] 24), stem elongation (g.s. 32), booting (g.s. 43), late milk development (g.s. 77), soft dough stage (g.s. 85), and harvest maturity (g.s. 91) (15). Plants at location B were sampled at tillering and at harvest. In 1988, plants were sampled at the same stages at both locations. Plants were sampled every 5 m along a diagonal transect, in 10 lots of five plants. The plants were stored at 4 C until they were assessed, normally within 3 days of sampling. Extra plants were sampled from the stubble burn plots and all plots at location B in 1987 to compensate for the lower recovery of *F. graminearum* Group 1. An estimate of the disease incidence in each plot had previously been determined by sampling 10 plants at the five-leaf stage (g.s. 15).

The basal section of each plant, including the scutellum (excluding the seed remains), subcrown internode, crown, and a basal 4-cm section of the main tiller, was removed, washed under a fine spray of water for 30 min, surface disinfested (1% NaOCl in 10% ethanol), and plated on modified potato-dextrose agar (MPDA) (4). Plates were incubated at 25 C day/20 C night with a 12-hr photoperiod for 6 days. *F. graminearum* Group 1 was identified according to the characteristics outlined by Burgess et al (4). The site of penetration was assessed from 10 randomly selected plants per plot from which *F. graminearum* Group 1 was recovered.

RESULTS

F. graminearum Group 1 was isolated principally from the stem and crown regions of plants in the stubble-retained treatment (Fig. 1A). The fungus rarely was recovered from the subcrown internode and the scutellum. In the stubble-incorporated and stubble-burned treatments (Fig. 1B and C, respectively), *F. graminearum* Group 1 was isolated primarily from the crown and subcrown internode. The fungus was recovered from the scutellum relatively frequently but rarely from the stem in these two treatments.

There was no significant location difference in 1987 and 1988 as determined by Bartlett's test of homogeneity of error variances of separate analyses of variance (12). Frequency of recovery from the tissue samples at tillering was similar in 1987 and 1988, and, thus, only the combined data from both locations in 1988 are shown in Figure 1.

At location A in both seasons, samples were taken at six dates through the season. *F. graminearum* Group 1 was recovered at all tissue sites from an increasing number of plants in all treatments as the season progressed, indicating that the fungus extensively colonized the stem base, crown, and subcrown internode with time (data not shown). There was no significant difference ($P = 0.05$) in the sites at which *F. graminearum* Group 1 was recovered from plants at the final sample (harvest) in any of the three treatments because all sites in the majority of infected plants were colonized by the fungus.

The frequency of recovery of *F. graminearum* Group 1 at harvest maturity was not significantly different in the stubble-retained and stubble-incorporated treatments in both seasons at location A, and at location B in 1988 (Table 1). There was a significant difference ($P = 0.05$) between the two treatments at location B in 1987. The recovery of the fungus from plants in the stubble-

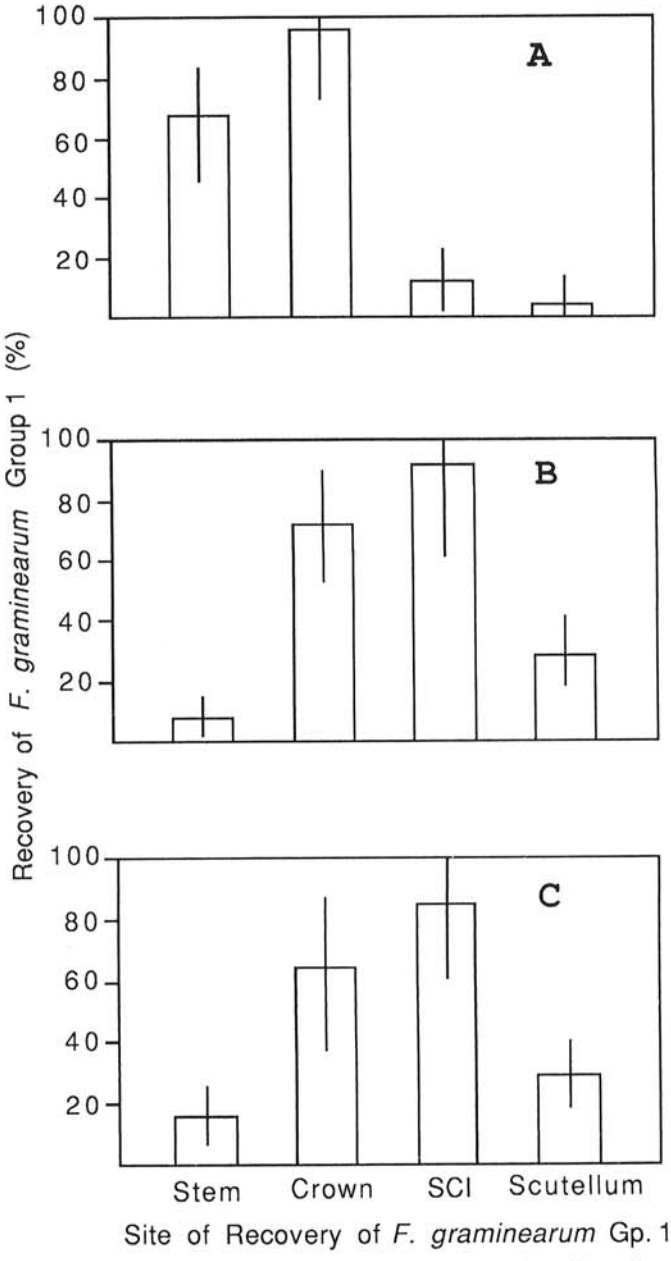

Fig. 1. Recovery of *Fusarium graminearum* Group 1 from four tissue sites in wheat plants at the tillering stage after three stubble management treatments at two locations at Moree, New South Wales, Australia, in 1988. Treatments were: **A,** retained; **B,** incorporated; **C,** burned. Data were analyzed by assuming a binomial distribution, and the 95% confidence intervals are indicated on each graph. Data represent means of 80 observations. SCI = subcrown internode.

burned treatment was significantly lower ($P = 0.05$) than the other treatments at location A in 1987 and at location B in both years; recovery was lower than the stubble-retained treatment in 1988 at location A.

DISCUSSION

The sites at which *F. graminearum* Group 1 was isolated from plants indicated that the distribution of the primary source of inoculum, the infested stubble, was the main factor influencing the site of fungal penetration. Where the majority of stubble (>90%) was retained on the soil surface forming a heavy mulch in close contact with the stem and crown region, the fungus was isolated predominantly from that region and was recovered at a much lower frequency from the subcrown internode and scutellum at the tillering stage. In contrast, where the majority of stubble (approximately 70%) was in the top 10 cm of the soil profile and only a small amount was on the soil surface (approximately 30%), fungal penetration occurred via the subcrown internode, crown, and, rarely, through the stem region. The crown was located in the upper 4 cm of soil. Data for the incorporated treatment are similar to those of Purss (11), who found that the crown and subcrown internode were the principal sites of penetration in wheat plants grown with conventional farming methods involving one or more tillage operations.

A stubble mulch prolongs the period of moist conditions around the plant base after rain, favoring infection by *F. graminearum* Group 1 (9). Thus, it is likely that penetration in this region will be facilitated both by the close proximity of inoculum and the favorable environmental conditions resulting from the stubble mulch.

It is not known if the change in the principal site of penetration changes the development of disease or inoculum production. The site of penetration did not appear to influence host colonization, and infected plants were colonized similarly in all three treatments (13). Thus, changes in the site of penetration are unlikely to influence final host colonization and, hence, inoculum buildup. We have shown that the fungus was able to penetrate the plant at all growth stages. Indeed, a few plants in each treatment had been penetrated but not colonized at harvest maturity. This finding is similar to that of Purss (11) and Burgess et al (1). Earlier infection of the subcrown internode and the crown in the incorporated treatment may enhance the development of whiteheads caused by disruption of moisture uptake (8), and this aspect of disease development needs to be examined in more detail. In the stubble-retained treatment, early stem colonization may result in the production of sporodochia on the stem nodes, enhancing the possibility of head blight caused by *F. graminearum* Group 1, which is favored by wet conditions at anthesis. A recent outbreak of head blight was associated with stubble retention and the formation of sporodochia on nodes (2).

Routine assessments of the incidence of plants infected by the crown rot fungus normally have involved plating of the subcrown internode and a small region of the crown of large numbers of plants (3,8). We conclude that it would be preferable to sample plants close to maturity, from the milk stage onward, to increase the recovery of *F. graminearum* Group 1. Sampling plants early in the season may decrease the possibility of estimating the true level of infection. If seeds were sown with stubble retained on the surface and crown rot levels were assessed by plating the subcrown internode and a small region of the crown, then it is possible that some infected plants might be classified as uninfected simply because the infected tissue section was not plated.

The increasing use of conservation tillage involving the retention of stubble residues on the soil surface has increased crown rot incidence and the demand for wheat cultivars with some resistance to the disease. Screening for resistance in wheat to the crown rot fungus frequently involves artificial inoculation with colonized wheat chaff (3). The selection of resistant wheat cultivars for conservation tillage systems should involve a screening technique in which inoculum is placed around the crown, simulating the field situation.

TABLE 1. Recovery of *Fusarium graminearum* Group 1 at harvest maturity from wheat cultivar Sunstar at two locations at Moree, New South Wales, Australia, after three cultivation treatments in 1987 and 1988

Stubble treatment	Percent recovery of *F. graminearum* Group 1			
	Location A		Location B	
	1987	1988	1987	1988
Retained	57 A[z]	92 A	24 A	44 A
Incorporated	58 A	83 AB	14 B	45 A
Burned	14 B	72 B	2 C	20 B

[z] Numbers followed by the same uppercase letter in each column are not significantly different at $P = 0.05$ according to least significant difference tests. Values represent means of 200 plants infected by *F. graminearum* Group 1. Percent data were transformed to square root ($x + 0.5$) for statistical analyses.

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