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Effect of fertilizer on root rot of barley on stubble and fallow land

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The effects of fertilizer (levels of N and P) on common root rot [*Cochliobolus sativus* and *Fusarium* spp.] and grain yield of nine cultivars of barley on fallow and stubble land were examined. Yield losses caused by common root rot averaged over nine cultivars were 16% on fallow land, whether fertilized or not. However addition of fertilizer to stubble significantly reduced yield losses about 40%-30%. Fertilizer did not significantly affect the incidence of root rot on fallow land (range 30 to 35%) but did significantly reduce the incidence of the disease on stubble land from 76% to 56%. On both stubble and fallow land the number of heads per plant was increased by added fertilizer and decreased as the incidence of root rot increased. Added fertilizer did not affect yields on fallow land but significantly increased yields by 55% on stubble land.

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Les effets des engrais (concentrations diverses de N et de P) sur le piétin commun causé par *Cochliobolus sativus et Fusarium* spp. ainsi que sur le rendement de neuf cultivars d'orge cultivés sur jachère et sur chaume ont fait l'objet d'une étude. Les pertes moyennes attribuables au piétin pour les 9 cultivars s'élevaient à 16% pour la culture sur jachère, avec ou sans amendement. Toutefois, l'addition d'engrais aux champs de chaume a réduit significativement (P = 0,05) les pertes de rendement qui sont passées de 40 à 30%. L'application d'engrais n'a pas d'effet sensible sur l'incidence du piétin dans les jachères (elle varie de 30 à 35%), mais réduit sensiblement celle-ci dans les champs de chaume (elle est passée de 76 à 56%). Dans les deux situations, le nombre d'épis par plant a augmenté sous l'action de l'engrais et diminué lorsque la maladie s'aggravait. L'addition d'engrais n'a pas modifié le rendement des cultures sur jachère, mais a poussé celui des cultures sur chaume de 55%.

Available plant nutrients in the soil affect both plant development and the growth of the soil microflora, including plant pathogens. It is, however, difficult to separate the effects of a nutrient on a pathogen from those on the host plant when studying plant diseases caused by soil- or seed-borne pathogens. The addition of nitrogen to the soil has been shown to intensify root rot in cereals (Ledingham 1970, Garrett 1976, Kaufmann & Williams 1964), although the opposite effect has also been demonstrated (Afanas'eva & Chulkina 1977). Common root rot developed less rapidly on wheat in soil high in phosphorus than in soil low in phosphorus (Verma et al. 1975). Pittman and Horricks (1972) however were unable to show any root rot suppressing effects from additional phosphorus. Russell and Sallans (1940) reported variable root rot response to phosphorus in wheat over a 3 year period. Such conflicting reports of disease-fertilizer interaction may reflect differential cultivar reactions, stage of growth at which infection occurs, or differences in indigenous levels of available plant nutrients in different soils in which the experiments were conducted.

Piening (1973) compared the differential yield response to common root rot [*Cochliobolus sativus* (Ito et Kurib.) Drechsl. ex Dastur and *Fusarium* spp.] of 10 barley cultivars on fallow soil without added fertilizer. That paper served as a basis for the present investigation into the yield response of nine barley cultivars to common root rot as influenced by added fertilizer on summerfallow and stubble land; the beneficial effects of fertilizers in reducing root rot are also discussed.

Materials and methods

The barley cultivars Galt, Jubilee, Gateway, Olli, Paragon, Centennial, Bonanza, Conquest, and Parkland were sown on fallow and wheat stubble land. The following fertilizer treatments were applied to fallow-sown barley 1) no fertilizer, 2) 15 kg/ha phosphorus and no nitrogen, 3) 44 kg/ha phosphorus and no nitrogen, 4) 15 kg/ha phosphorus and 34 kg/ha nitrogen. On stubble land each cultivar received 1) no fertilizer, 2) no phosphorus and 67 kg/ha nitrogen, 3) 15 kg/ha phosphorus and 67 kg/ha nitrogen, 4) 15 kg/ha phosphorus and 34 kg/ha nitrogen. Each fertilizer treatment was replicated four times for each cultivar in a randomized block design. Each cultivar — fertilizer treatment consisted of a 4-row plot, 5 m long. Rows were spaced at 23 cm and approximately 300 seeds were planted in each row. The wheat stubble land was adjacent to the fallow site. Nitrogen was applied as ammonium nitrate and phosphorus was applied as triple superphosphate. All P treatments and N treatments up to 34 kg/ha were placed with the seed. Where 67 kg/ha N was applied, 34 kg/ha was placed with the seed and the remainder banded near the seed.

When plants reached the firm dough stage, a sample of at least 250 plants was pulled randomly from the two center rows of each plot and separated into two categories, a healthy category containing clean and slightly lesioned subcrown internodes and a diseased category containing moderately and severely diseased subcrown internodes. Root rot incidence was calculated as the percentage of plants in the diseased category out of the total number of plants rated. The number of heads per plant was recorded from each of 4 categories or from 2: diseased and clean plants with the subcrown severely, moderately, and slightly infected and from those with no root rot lesions. Losses for each sample were calculated using the formula derived by Machecek (1943).

$$\text{Percent loss in yield} = 100 - \left(\frac{w}{w_1 \times N} \times 100\right)$$

where w is the total weight of grain from the sample, w_1 the average weight of grain per plant from plants in the healthy category in the sample, and N the total number of plants in the sample. A separate 1.2 m^2 area was harvested from the two center rows for total plot yield.

Results and discussion

Root rot on fallow-sown barley. In this study the yield loss due to root rot of the nine barley cultivars on fallow land without added fertilizer (Table 1) compared reasonably well with the yield loss of these cultivars in a previous study (Piening 1973). The relative order of yield loss due to root rot of the cultivars was similar, though not identical in the two studies. The yield loss for the nine cultivars without added fertilizer averaged 16% in both studies, with 40% of plants infected in the previous report by Piening (1973) and 35% infected in the present investigation (Table 2).

The addition of N and/or P to fallow-sown barley did not significantly alter the incidence of root rot or the yield loss of the nine barley cultivars from that of the nonfertilized barley. Analyses of these data failed to show any cultivar-fertilizer interaction. The nutrient supply in the fallow soil was probably adequate for maximum yields because the added fertilizer did not increase yields (Table 3). Added N and/or P did, however, increase the numbers of heads per plant, but since yields were not increased (Table 4), plants with additional heads may have had smaller kernels. Root rot significantly decreased the number of heads on barley growing on fallow.

Root rot on stubble-sown barley. This study was conducted on stubble land to test the effects of added N and P on root rot of barley. The average yield of the nine barley cultivars increased by 55%

Table 1. Percent yield loss due to common root rot of nine barley cultivars with and without fertilizer on fallow and stubble land

	Fertilizer* applied to fallow				
Cultivar	N_0P_0	N_0P_{15}	N_0P_{44}	$N_{34}P_{15}$	Avg
Galt	20	21	17	10	17 bc**
Jubilee	15	14	20	23	18 bc
Gateway	39	30	34	31	33 a
Olli	17	27	23	27	23 b
Paragon	8	5	13	15	10 e
Centennial	14	16	6	9	11 cd
Bonanza	12	9	9	22	13 cd
Conquest	14	13	6	20	13 cd
Parkland	8	17	11	10	11 cd
Avg	16	17	15	18	
	Fertilizer* applied to stubble				
Cultivar	N_0P_0	$N_{67}P_0$	$N_{67}P_{15}$	$N_{34}P_{15}$	Avg
Galt	39	32	23	24	30
Jubilee	44	32	42	28	36
Gateway	52	41	32	37	41
Olli	34	28	38	38	34
Paragon	41	28	25	21	29
Centennial	38	34	29	27	32
Bonanza	40	28	22	27	29
Conquest	28	30	27	20	26
Parkland	41	34	31	33	35
Avg	40a	32b	30b	28b	

* kg/ha N and/or P

**Values within a row or within a column followed by different letters are significantly different according to Duncan's multiple range test, P = 0.05.

Table 2. Percent common root rot of plants of nine barley cultivars on fertilized and non-fertilized fallow and stubble land

	Fertilizer* applied to fallow				
Cultivar	N_0P_0	N_0P_{15}	N_0P_{44}	$N_{34}P_{15}$	Avg
Galt	52	33	30	53	42 b
Jubilee	39	37	32	28	34 b
Gateway	74	55	56	53	59 a
Olli	62	54	55	56	57 a
Paragon	16	13	22	24	19 d
Centennial	21	19	21	28	22 cd
Bonanza	15	16	15	13	15 d
Conquest	20	15	16	19	17 d
Parkland	22	27	38	26	28 bc
Avg	35	30	32	33	
	Fertilizer* applied to fallow				
Cultivar	N_0P_0	$N_{67}P_0$	$N_{67}P_{15}$	$N_{34}P_{15}$	Avg
Galt	91	71	49	63	66 b
Jubilee	78	59	65	63	66 b
Gateway	89	94	63	66	78 a
Olli	86	76	68	60	72 ab
Paragon	66	47	49	38	50 de
Centennial	69	62	46	45	56 cd
Bonanza	67	40	36	36	44 e
Conquest	75	56	46	38	54 de
Parkland	69	84	48	58	64 bc
Avg	76 a	65 b	52 c	52 c	

* kg/ha N and/or P

**Values within a row or within a column followed by different letters are significantly different according to Duncan's multiple range test P = 0.05.

Table 3. Yield of grain (kg/ha) from nine barley cultivars with and without fertilizer on fallow and stubble land

	Fallow		Stubble	
Cultivar	No fertilizer	Fertilizer*	No fertilizer	Fertilizer*
Gateway	5219	5802	1926	3562
Olli	5152	5309	2262	3517
Parkland	5331	5242	2419	3875
Galt	6261	5578	2229	3763
Paragon	6070	5611	2352	3674
Jubilee	5564	5309	2229	3629
Conquest	5746	5645	2475	3786
Bonanza	6194	6518	2834	3786
Centennial	5723	5824	2800	3875
Avg	5696 a**	5649 a	2392 a	3719 b

* Average of three fertilizer treatments.
**Values within fallow and stubble followed by different letters are significantly different according to Duncan's multiple range test, P = 0.05.

when N and P fertilizers were applied to stubble land (Table 3), indicating that this soil may have been deficient in these elements. However some of the increased yield might be attributable to the reduced incidence of root rot because of increased plant resistance due to the addition of N or P. Root rot incidence averaged 76% for the nine barley cultivars on nonfertilized stubble. Applying N (67 kg/ha) alone or with P (15 kg/ha) to stubble land significantly reduced the root rot incidence to 65% and 52%, respectively (Table 2). The average yield loss due to root rot of the nine barley cultivars on nonfertilized stubble land was 40%, whereas the addition of N or N plus P significantly reduced the yield loss to 32% and 28%, respectively (Table 1). Nitrogen and P also significantly increased the numbers of heads of both diseased and healthy barley on stubble. Diseased barley had significantly fewer heads than healthy barley on fertilized and nonfertilized stubble land.

Table 4. Effect of fertilizer and no fertilizer on the numbers of heads produced per plant of 9 barley cultivars on fallow and stubble land

	Root rot infection				
Fertilizer treatment	Severe	Moderate	Slight	Healthy	Avg
Fallow					
N_0-P_0	2.1	2.6	2.8	3.3	2.7 a
N_0-P_{15}	2.0	3.1	3.2	3.6	3.0 b
N_0-P_{34}	1.9	3.1	3.2	3.6	3.0 b
N_{34}-P_{15}	2.6	3.4	3.2	3.7	3.0 b
Avg	2.15 a*	3.05 b	3.1 b	3.55 c	
Stubble					
N_0-P_0	1.4	1.7	1.7	2.1	1.7 a
N_{67}-P_0	1.8	2.2	2.5	2.8	2.3 b
N_{67}-P_{15}	1.9	2.4	2.5	3.1	2.5 c
N_{34}-P_{15}	1.9	2.3	2.5	3.0	2.4 bc
Avg	1.75 a	2.15 b	2.3 c	2.75 d	

*Values within a row or within a column followed by different letters are significantly different according to Duncan's multiple range test, P = 0.05.

Only limited comparisons can be made of the incidence of root rot of barley on fallow and stubble. Without added fertilizer, root rot incidence and yield loss were almost twice as high on stubble as on fallow. This may be due to the inherent difference in the N and P status of these soils. This study does not reveal how the addition of N and P reduced root rot. There are several possible reasons for the higher incidence of root rot on stubble. A greater number of spores of *C. sativus* might be expected on residue from a preceding susceptible crop than on fallow land. Unpublished data by Piening, however, revealed similar concentrations of conidia in soil from fallow and barley stubble land. Also the greater amount of biological activity from decomposing straw might affect the pathogenic potential of *C. sativus*. Differences in root rot incidence in barley on stubble and fallow might also be due to differences in moisture or C/N ratio but these factors probably would not be altered much when N and P are added to stubble soil. However root rot was reduced significantly when N and P were added to stubble land. The addition of 34 kg/ha N and 15 kg/ha of P to stubble soil did not reduce the root rot incidence (52%) or yield loss (28%) to the levels found in barley from nonfertilized fallow (35% and 16% respectively) nor did fertilizer on stubble stimulate the grain yield (3719 kg/ha) to the level of nonfertilized fallow-grown barley (5696 kg/ha).

The higher yield on stubble land may have resulted in part from the addition of fertilizer and in part from increased disease resistance, as was evident by less severe disease symptoms on the subcrown internodes. Verma et al. (1975) noted the generally more rapid lesion development on the subcrown internode due to *C. sativus* in Manitou wheat growing in soils low in phosphate. Afanas-

'eva and Chulkina (1977) attributed a reduction in root rot of wheat from added phosphate to increased activity of other microbes in the rhizosphere of the wheat which decreased the numbers of conidia of *C. sativus*. Unfortunately we can make no conclusions from these data to explain the mechanism as to how phosphorus and, to a lesser extent, nitrogen reduce visual symptoms of root rot. It is also known that phosphorus stimulates root development and consequently a more vigorous root system may compensate for the roots destroyed by the root rot pathogens.

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