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Effect of tillage systems, mulches and nitrogen fertilization on spring barley (*Hordeum vulgare*)

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Abstract. Yield, N uptake, weeds and diseases of spring barley were examined under five mulching practices (white mustard, phacelia, oat-pea mixture, straw mulch, and no mulch), three tillage systems (conventional, reduced and no-tillage) and three doses of nitrogen fertilization (0, 50 and 100 kg N ha^{-1}). In general the grain yield of spring barley for cover crops was 10-31% higher compared with the no-mulch treatment. A mulch of straw provided a smaller barley grain yield than the no-mulch treatment. Compared to conventional tillage, grain yield under reduced tillage and no-tillage were 7 and 12% less, respectively. Spring barley sowing after a mixture of oat-pea led to decreased a negative response of reduced and no-tillage. Grain yield after treatment with legume cover crops and without N fertilization was similar compared as the rates 50 kg N ha^{-1} after white mustard or phacelia and as the rate 100 kg N ha^{-1} without mulches. There was no evidence of tillage x N fertilization interaction on grain yield, dry matter production and plant-N uptake. Cover crops and straw mulch significantly decreased total weed populations compared with the treatment without mulch. Total weed density increased from 108 plants per m^2 in the no-tillage to 322 plants per m^2 for reduced tillage, and to 416 plants per m^2 for the conventional tillage over mulch. Higher infestation of spring barley with stem base and root diseases was observed in reduced and no-tillage in comparison with the conventional soil tillage and after straw mulch and no-mulch than after cover crops.

Key words: spring barley, cover crops, tillage systems, nitrogen fertilization, grain yield, N uptake, weed and diseases infestation

INTRODUCTION

Cover crops and conservation tillage systems provide many benefits to crops, including erosion control, water conservation, reduced temperature fluctuations, improved soil structure, and suppression of weeds (Richards et al., 1996; Deryło, 1997; Soane & Ball, 1998; Swanton et al., 1999). Long-term benefits are derived from the buildup of organic matter resulting in increased soil health, production of healthy crops and bountiful yields. Cover crops sown after the main crop and allowed to grow through the autumn and into mind/late winter could take up nitrate-N, thus reducing the amount at risk of leaching. Therefore as much as possible of the retained N should be recovered in the next crop, enabling a reduction of fertilizer N (Richards et al., 1996; Garwood et al., 1999; Justes et al., 1999).

The effects of tillage systems on cereals grain yield have been studied previously but results are unclear. Reduced and no tillage may give more yield than conventional tillage, especially in dry years. The no tillage system led to occasionally diminished yield through decreased N availability, which suggests that cereals under reduced tillage and no tillage may require additional N fertilizer to reach production levels similar to those of conventional tillage. Potential causes of this yield depression included slow mineralization, increased N immobilization, denitrification, leaching, and surface runoff losses, but the effect of tillage systems depends heavily on the previous crop (Arshad & Gill, 1997; Canterro-Martinez et al., 2003; Angas et al., 2006; Martin-Rueda et al., 2007).

Cover crops may suppress weed populations through physical suppression, competition for water, light, and nutrients, or allelopathy, however this influence is often inconsistent (Swanton et al., 1999). Research has shown that tillage systems influenced weed density and species composition (Stevenson et al., 1997). Several studies have documented that conservation tillage increased the density of perennial weeds, some annual grasses, and volunteer crops (Buhler et al., 1994; Tørresen et al., 2003). However, more research is needed on the direct effect of tillage on weed population changes over several seasons, because the weed seed shed during the first year of the experiment would remain on the soil surface and lead to a large increase in density the following year. In no-till systems, the post-harvest residues left on the field surface become a direct source of fungal diseases, especially those which infect roots (Rothrock, 1992; Bailey, 1996; Bailey & Lazarovits, 2003). The effect of tillage systems on subsequent disease severity depends heavily on the previous crop. Management of the interaction between the pathogen and the residue may be achieved through modifications in the local environment (Bailey, 1996; Bailey & Lazarovits, 2003). Alternative crops such as cover crops used to diversify cereal grain cropping systems play a valuable role in breaking the life cycle of fungal diseases (Janzen & Schaalje, 1992; Jenkyn et al., 2001; Krupinsky et al., 2002).

The aim of this work was to study the effect of cover crops, tillage systems and N fertilizer rate on grain yield, N uptake, weed- and disease-infestation of spring barley.

MATERIALS AND METHODS

Field studies were conducted from 2001–2003 at Research Station Brody of the Agricultural University of Poznan, Poland, on a sandy loam soil (Albic Luvisols, 1.4% organic matter, and pH 6.5). The experimental design was as randomized complete blocks with a three-way factorial and four replications. Each year spring barley (*Hordeum vulgare* var. Atol) was sowed on land that had been previously cropped to winter wheat. The sowing rate was 400 seeds per 1 m^2. Treatments included five mulching practices with three tillage systems and three doses of nitrogen fertilization. The tillage systems were conventional tillage with mouldboard ploughing, reduced tillage with a shallow stubble cultivator and no–tillage. The mulches were three cover crops (*Sinapis alba, Phacelia tanacetifolia* and *Avena sativa-Pisum sativum* mixture), winter wheat straw mulch, and no mulch. Cover crops were sowed after harvest of winter wheat (*Triticum aestivum* ssp. *vulgare*) in early August. In the spring, cover crops and straw mulch were incorporated into the soil by ploughing in conventional tillage or by shallow stubble cultivator in a reduced tillage system. Two N treatments at rates 50 and 100 kg N ha^{-1} were used and included a zero N content.

The fertilizer rates were applied at 26 kg P ha^{-1}, 81 kg K ha^{-1} in the autumn. The herbicide program on tillage systems used preplanting and postemergence applications. In early spring before planting, 3 dm^3 ha^{-1} glyphosate herbicide was applied on all plots with reduced tillage and direct drilling to control perennial weed and volunteers from the previous crop. For weed control during the growing season postemergence application of Stork 50 WG (tifensulfuron–methyl 25.0% and carfentrazone–ethyl 25.0%) at the rate of 60 g ha^{-1} was applied to spring barley. The seeds were dressed with Raxil 060 FS fungicide (60 ml per 100 kg seeds) containing tebuconazole (6.0%). For disease control Sportak Alpha 380 EC fungicide (prochloraz 30.0% and carbendazim 8.0%) at the rate 1.5 l ha^{-1} was applied on all plots at GS 31–32 growth stage.

In the spring after crop emergence and prior to herbicide application, weed species density and aboveground fresh weights were determined in 1 m^2 areas of each plot. The level of infection of spring barley with the stem base and root diseases was quantified by observing 30 randomly removed plants per each plot. The assessment of the infestation was carried out at GS 73 growth stage (Zadoks et al., 1974). Crop infestation with the stem base and root diseases was evaluated visually on the basis of the occurrence at the bottom portions of the culms and roots of characteristic spots, discolorations and necroses. For each of the diseases, the percentage of plants with symptoms (irrespective of their intensity) as well as the infestation index was calculated.

The degree of infestation with the take all and the brown foot diseases was assessed according to the three-point scale (Windels & Wiersma, 1992). Grain and straw yields were estimated from a harvested area of 15 m^2 on each plot using a plot combine harvester. A subsample of grain and straw was taken from each plot to determine moisture, grain weight and N content. Nitrogen in the grain and straw was determined by near infra-red spectrophotometry using InfraAlyzer 500 (Bran+Luebbe) that was calibrated with the standard Kjeldahl method. Number of ears was counted from 0.5 m^2 on each plot before harvest. After recording a thousand grain weight the number of grain per ear was calculated.

The harvest index was calculated as the ratio of grain dry matter yield to the total dry matter yield (grain+straw). N uptake was estimated by the product of dry matter of grain or straw and N concentration of grain or straw. The nitrogen harvest index was calculated as the ratio of grain N accumulation to the total plant N accumulation (grain+straw).

Standard analysis of variance (ANOVA) was performed to determine the main factors and the interactions. Mean separations were made for significant effects with *LSD* and *Tukey* tests at probability $P \leq 0.05$.

The weather conditions varied markedly during the experimental period (Table 1).

Table 1. Weather characteristics.

Year	Average monthly temperatures (°C)					
	March	April	May	June	July	mean
2001	2.6	8.1	14.8	15.3	20.3	12.2
2002	5.1	8.8	16.7	18.3	20.4	13.9
2003	3.4	8.2	16.0	19.8	19.6	13.4
1961–1999	2.7	7.5	12.8	16.2	17.7	11.4
Year	Monthly precipitation (mm)					
	March	April	May	June	July	sum
2001	70.8	37.3	34.7	75.6	53.4	271.8
2002	58.1	33.2	48.9	52.6	40.6	233.4
2003	19.9	21.1	20.1	35.0	96.7	192.8
1961–1999	36.1	39.1	56.6	67.1	78.3	277.2

During the vegetation period of spring barley, the mean air temperature was above the long-term mean, with the exception of June 2001. Growing season precipitation from 2001–2003 (from sowing to harvest) was 201, 175 and 173 mm, respectively. Greater variations of precipitation occurred during the period April–June. In this period the higher precipitation was in the years 2001 (148 mm) and 2002 (135 mm) in comparison with the last year (76 mm). In conclusion, weather conditions were more favorable to the development of spring barley in 2001 and 2002 than in 2003.

RESULTS AND DISCUSSION

Grain yield and yield components

Spring barley grain yields were significantly affected by mulches, tillage systems and N fertilization (Table 2).

The results of mulch establishment varied among mulch types. Over all years the oat-pea mixture gave the highest recorded grain yield (4.94 t ha^{-1} mean of years). Grain yield for cover crops was 10-31% higher compared with no-mulch treatment. Mulch of straw provided lower barley grain yield than no-mulch treatment, especially in the 2002 season (14.5%). The yield of spring barley varied significantly with tillage systems, both for the individual years and for the 3-year period as a whole. Compared to conventional tillage, grain yield under reduced tillage and no-tillage were 7 and 12% less, respectively. The analysis of variance showed interaction affects mulches x tillage for grain yield of spring barley (Table 3). The effect of the tillage systems depended upon the mulches. Spring barley sowing after the mixture of oat-pea led to a decreased negative response of reduced and no-tillage.

There were no significant differences between tillage systems on the plots with a cover crop of oat-pea mixture. A negative response for no-tillage compared to reduced tillage was observed in no-mulch treatments only. Most studies on cereal production comparing conventional and ploughless tillage have given controversial results, apparently depending on soil type, crop rotation and local climatic conditions (Nyborg et al., 1995; Arshad & Gill, 1997; Halvorson et al., 2000; Małecka & Blecharczyk, 2002; Cantero-Martinez et al., 2003; Angas et al., 2006; Martin-Rueda et al., 2007).

Table 2. Grain yields of spring barley for mulches, tillage systems and nitrogen fertilization, t ha^{-1}.

Treatments	Year			Mean
	2001	2002	2003	2001–2003
Mulch:				
None	4.32	3.46	3.43	3.77
Straw	4.16	2.96	3.35	3.49
White mustard	4.75	4.10	3.95	4.27
Oats+pea	5.64	4.69	4.50	4.94
Phacelia	4.63	4.09	3.87	4.16
$LSD_{0.05}$	0.30	0.51	0.43	0.23
Tillage systems:				
Conventional	5.16	3.99	4.06	4.40
Reduced	4.62	3.84	3.83	4.10
No-till	4.32	3.75	3.57	3.88
$LSD_{0.05}$	0.28	0.14	0.19	0.21
N rate, kg ha^{-1}:				
0	3.82	2.87	3.30	3.33
50	4.79	3.94	3.88	4.20
100	5.50	4.76	4.27	4.84
$LSD_{0.05}$	0.22	0.23	0.24	0.21

Table 3. Effect of mulches and tillage systems on grain yield of spring barley, t ha^{-1} (mean 2001–2003).

Mulch	Tillage systems		
	conventional	reduced	no-till
None	4.12	3.81	3.37
Straw	3.84	3.45	3.17
White mustard	4.54	4.24	4.03
Oats+pea	5.05	4.89	4.88
Phacelia	4.47	4.09	3.92
$LSD_{0.05}$		0.29	

Table 4. Effect of mulches and nitrogen fertilization on grain yield of spring barley, t ha^{-1} (mean 2001–2003).

Mulch	Nitrogen rate (kg ha^{-1})		
	0	50	100
None	2.87	3.73	4.70
Straw	2.68	3.56	4.22
White mustard	3.38	4.42	5.00
Oats+pea	4.38	5.08	5.36
Phacelia	3.32	4.22	4.94
$LSD_{0.05}$		0.33	

Reduced mineralization of plant residues in addition to mechanical difficulties affecting seed placement have often been considered responsible for the low yields obtained with reduced and no-tillage systems (Lopez-Fando & Almendros, 1995).

Average grain yield increased significantly with increasing N rates (Table 2). The greatest fertilizer rate (100 kg ha^{-1}) tended to increase grain yield 15% as compared with rate 50 kg ha^{-1}. No significant difference was observed between the rates 50 and

100 kg N ha^{-1} on the plots with mixture of oat-pea (Table 4). Grain yield after treatment with legume cover crops and without N fertilization was similar as compared to the rate of 50 kg N ha^{-1} after white mustard or phacelia and to the rate 100 kg N ha^{-1} without mulches.

Legume cover crops offer an effective method of incorporating atmospheric N into the soil and improving nitrogen fertility (Janzen & Schaalje, 1992; Richards et al., 1996; Garwood et al., 1999). It provides a way to address significant management challenges to producers interested in reducing fertilizer N inputs or producing crops without fertilizer N. The positive effect of other cover crops on barley grain yield decreased with an increased N fertilizer rate. With straw mulch treatment the average grain yield response to N applications was less than in the other treatments which removed straw. These results were generally similar to earlier results (Nyborg et al., 1995; Procházková et al., 2002). The problems emerged from a probably increased N immobilization caused by straw addition during the first years of the experiment, but disappeared thereafter, and from a possible inhibitory effect on germination, emergence, growth and yields of following crops. The transition from intensive to conservative tillage systems will require the modification of N dynamics in the soil-plant system, on crop productivity, and on efficiency of N fertilizer use. During the first few years of a change in tillage systems, farmers tend to increase N rates to secure high yields (Wienhold & Halvorson, 1999). However, in some cases this increase is not necessary, because the availability of N improves in a few years (Cantero-Martinez et al., 2003; Angas et al., 2006). This was in agreement with our results in which no significant interaction between N rates and tillage systems was observed.

In the present paper, yield components such as ears per 1 m^2, grains per ear and grain weight were also quantified (Table 5).

Table 5. Yield components of spring barley for mulches, tillage systems and nitrogen fertilization (mean 2001–2003).

Treatment	Ears per 1 m^2	Grains per ear	1000 grain weight (g)
Mulch:			
None	504	16.7	45.7
Straw	467	16.8	45.2
White mustard	553	17.2	45.6
Oats+pea	618	17.5	46.3
Phacelia	547	16.7	46.3
$LSD_{0.05}$	36.5	0.39	0.58
Tillage systems:			
Conventional	590	17.1	44.3
Reduced	528	16.9	46.4
No-till	495	17.0	46.7
$LSD_{0.05}$	18.5	ns	0.48
N rate, kg ha^{-1}:			
0	454	15.9	46.1
50	544	17.1	46.1
100	616	17.9	45.2
$LSD_{0.05}$	14.8	0.26	0.38

ns–no significance

Lower yields resulted first of all from fewer ears per m^2. The mean of years with higher ears per m^2 were on the plots with cover crops rather than with straw mulch and none. The effect of mulches on grains per ear and grain weight varied by year. Number of ears per m^2 and grain weight were significantly influenced by the main effect of tillage systems. The number of ears was higher under conventional tillage than under other tillage systems, however, the opposite result was observed for grain weight. The number of ears per m^2 and grains per ear increased with increasing N rate both for the individual years and for the studied period as a whole. The effect of N fertilizer on grain weight differed by individual year. In 2001 grain weight decreased with increasing N rate; in 2002 grain weight was maximum with the medium N rate. In 2003 grain weight increased with increasing N rate, with no difference between the rates 50 and 100 kg N ha^{-1}. For the 3-years as a whole, the greatest fertilizer rate (100 kg N ha^{-1}) had an adverse effect on grain weight. Our results are comparable with results of other research (Campbell et al., 1993; Cantero-Martinez et al., 2003).

Total dry matter and nitrogen accumulation at maturity

Total dry matter production and N accumulation at maturity were affected more by N fertilization and mulches than by tillage systems (Table 6).

Table 6. Mean total aboveground dry matter, N accumulation and harvest index of spring barley at maturity as affected by mulches, tillage systems and nitrogen fertilization (mean 2001–2003).

Treatments	Total dry matter (t ha^{-1})	Grain dry matter (t ha^{-1})	Harvest index	Total N accumulation (kg ha^{-1})	Grain N accumulation (kg ha^{-1})	Nitrogen harvest index
Mulch:						
None	5.96	3.20	0.54	74.1	56.4	0.76
Straw	5.49	2.97	0.54	69.7	53.2	0.76
White mustard	6.93	3.63	0.52	84.1	62.7	0.75
Oats+pea	7.94	4.20	0.53	103.9	78.8	0.76
Phacelia	6.68	3.54	0.53	85.5	63.7	0.75
$LSD_{0.05}$	0.49	0.20	ns	4.3	3.1	ns
Tillage systems:						
Conventional	7.06	3.74	0.53	88.9	66.3	0.71
Reduced	6.56	3.49	0.53	82.5	63.0	0.76
No-till	6.18	3.30	0.53	79.0	59.9	0.76
$LSD_{0.05}$	0.31	0.18	ns	3.1	3.2	0.04
N rate, kg ha^{-1}:						
0	5.20	2.83	0.54	61.4	46.4	0.76
50	6.73	3.57	0.53	83.3	62.5	0.75
100	7.86	4.11	0.52	105.7	80.1	0.76
$LSD_{0.05}$	0.29	0.17	ns	2.9	2.8	ns

ns–no significance

Total above-ground biomass for mixture of oat-pea, white mustard and phacelia were 33, 16 and 12% higher compared with the no-mulch treatment. Reduced tillage and no-tillage resulted in less biomass than conventional tillage (7–12%). The highest N accumulation in total dry matter followed the mixture of oat-pea (103.9 kg ha^{-1}). On the other treatments N accumulation ranged between 69.7-85.5 kg ha^{-1} (33–18% less). Conventional tillage achieved slightly but significantly greater total N accumulation than ploughless treatments. Generally, total dry matter and N accumulation is favoured in tilled plots in wet years and in no-tillage during dry ones (Arshad & Gill, 1997; Cantero-Martinez et. al., 2003; Tørresen et al., 2003; Martin-Rueda et al., 2007). Nitrogen application increased above-ground dry matter and N accumulation in the whole plant. The greater N accumulation was associated with total dry matter rather than with protein concentration (data not shown). The positive relationship between rate of fertilizer N and total dry matter and plant N accumulation at maturity is consistent with the results of others (Bulman & Smith, 1993; Nyborg et al., 1995; Cantero-Martinez et al., 2003). In our investigation there was no evidence of tillage x N fertilization interaction on dry matter production and plant-N uptake. Other authors described different types of interactions between tillage systems and N fertilization on dry matter production. This type of response is produced when some factor other than nitrogen is the greater determinant of yield (Nyborg et al., 1995; Halvorson et al., 2000; Cantero-Martinez et al., 2003; Angas et al., 2006). Harvest index and nitrogen harvest index were not affected by mulches or N fertilization. Tillage systems had significant effect only on nitrogen harvest index. It was smaller for conventional tillage than for the reduced and no-tillage system.

Cover crops may also have provided some of the non-N benefits to the subsequent crops: reduced incidence of root and leaf diseases, reduced weed populations, increased nutrient availability (Janzen & Schaalje, 1992; Arshad & Gill, 1997).

Weeds

The effects of mulches, tillage systems and nitrogen fertilization on weeds are shown in Table 7.

Cover crops and straw mulch significantly decreased total weed populations compared with the treatment without mulch (mean by 20%). Previous research reported that weed suppression usually increases as amount of crop residues increases (Teasdale et al., 1991).Total weed density increased from 108 plants per m^2 in the no-tillage to 322 plants per m^2 for reduced tillage, and to 416 plants per m^2 for the conventional tillage over mulch. Some studies have indicated that reduced tillage can increase population of weeds (Buhler et al., 1994; Tørresen et al., 2003); in others, weed communities were influenced more by location, crop, and year than by tillage system (Teasdale et al., 1991; Swanton et al., 1999). The treatments had lower effects on weed biomass than on weed density. Compared with no-mulch treatment, cover crops reduced mean weed biomass by 8%. There was no difference between straw mulch and no-mulch treatment in weed biomass. Fresh weight of weeds increased from 120 g m^{-2} in no-tillage to 204 g m^{-2} for the reduced tillage and 207 g m^{-2} for conventional tillage. This is in agreement with previous research which showed higher weed biomass after tillage with a uniform soil seed density (Teasdale et al., 1991).

Table 7. Effect of mulches, tillage systems and nitrogen fertilization on density and fresh weight of weeds (mean 2001–2003).

Treatments	Density (No. m^{-2})	Fresh weight (g m^{-2})
Mulch:		
None	337	184
Straw	253	194
White mustard	269	176
Oats+pea	269	154
Phacelia	282	177
$LSD_{0.05}$	35.3	13.6
Tillage systems:		
Conventional	416	207
Reduced	322	204
No-till	108	120
$LSD_{0.05}$	20.8	11.5
N rate, kg ha^{-1}:		
0	269	105
50	280	199
100	297	226
$LSD_{0.05}$	10.3	9.2

The dominant weed species across all treatments were *Viola arvensis*, *Veronica hederifolia*, *Chenopodium album*, *Polygonum convolvulus, Stelaria media*, and *Thlaspi arvense. Viola arvensis* and *Chenopodium album* density increased in conventional tillage compared with reduced and no-tillage systems. Species that increased in density in no-tillage system were *Taraxacum officinale, Plantago major, Geranium pusillum, Poa annua,* and *Brassica napus.* Several studies have documented that conservation tillage increased the density of perennial weeds, some annual grasses, and volunteer crops but a significant problem arose after several years of research (Swanton et al., 1999). Total weed populations and increase in fresh biomass of weeds were directly related to fertilizer N rates.

Diseases

The occurrence of stem base and root diseases in spring barley depended on experimental factors (Table 8).

The dominant pathogens identified in our experiment were *Gaeumannomyces graminis* (Sacc.) v. Arx et Olivier causing the take-all disease, and *Fusarium* spp. causing brown foot rot. On average, the results of three-year investigations showed a significantly higher infestation of spring barley with stem base and root diseases after straw mulch and no-mulch than after cover crops. It was observed in the percentage of culms with symptoms of the take-all and the brown foot rot and the infestation index. Results of our investigations confirm the above-mentioned reports of other researchers. The use of a break crop in cereal rotation plays a valuable role in breaking the life cycle of fungal diseases in the soil (Bailey, 1996; Krupinsky et al., 2002; Bailey & Lazarovits, 2003).

Table 8. The infection of spring barley by stem base and root diseases depending on mulches, tillage systems and nitrogen fertilization (mean 2001–2003).

Treatments	*Gaeumannomyces graminis*		*Fusarium* spp.	
	% of infection stems	infection index	% of infection stems	infection index
Mulch:				
None	43.4	126	73.6	157
Straw	56.2	158	73.7	159
White mustard	31.8	41	49.7	81
Oats+pea	28.7	35	49.0	81
Phacelia	30.6	43	49.8	89
$LSD_{0.05}$	15.8	31.2	19.4	30.9
Tillage systems:				
Conventional	31.9	42	50.4	81
Reduced	38.5	99	64.0	127
No-till	44.0	101	63.3	132
$LSD_{0.05}$	5.2	10.6	5.6	15.1
N rate, kg ha^{-1}:				
0	42.2	122	66.4	144
50	37.8	62	56.2	108
100	34.4	58	54.9	88
$LSD_{0.05}$	4.2	15.6	3.5	18.2

The results of the Brody investigation indicated a negative influence of reduced tillage and no-tillage on the infestation of spring barley with stem base and root diseases in comparison with the conventional soil tillage. Reduced tillage and no-tillage leaves more crop residues on the soil surface, and this in turn may cause higher soil moisture content and lower temperature favouring the occurrence of stem base and root diseases (Rothrock, 1992; Bailey, 1996). On the other hand, the plant residues left on the soil surface result in increased organic matter in the topsoil and hence increased biological activity which can reduce pathogen populations in the soil (Krupinsky et al., 2002). That is why research results concerned with the impact of soil tillage systems, especially no-tillage, on the occurrence of fungal diseases are quite inconsistent. According to many researchers, the impact of tillage systems on fungal diseases is much smaller than the effect exerted by environmental conditions (weather, soil), crop sequence, cultivars and type of seed dressing (Rothrock, 1992; Bailey, 1996). Both the infestation index and the percentage of plants with symptoms of take-all and brown foot rot disease depended on nitrogen fertilization. The stem base and root disease severity was significantly higher in the plots where spring barley was grown without N fertilization in comparison with fertilized plots. Balanced and adequate fertility for any crop reduces plant stress, improves physiological resistance, and decreases disease risk (Krupinsky et al., 2002).

CONCLUSIONS

1. Total dry matter, N accumulation and grain yield of spring barley for cover crops was higher compared with no-mulch treatment; mulch of straw provided less growth and yield of barley. Grain yield following treatment with legume cover crops and without N fertilization was similar compared to the rate of 50 kg N ha-^{1} after white mustard or phacelia and to the rate of 100 kg N ha-1 without mulches.

2. Compared to conventional tillage, grain yield under reduced tillage and no-tillage was 7 and 12% less, respectively. There were no significant differences between tillage systems on the plots with a cover crop of oat-pea mixture. A negative response for no-tillage compared to reduced tillage was observed in no-mulch treatments only. The differences in spring barley yield among treatments resulted first of all from ears per m2.

3. Cover crops and ploughless treatments decreased total weed populations. Species that increased in density in the no-tillage system were Taraxacum officinale, Plantago major, Geranium pusillum, Poa annua, and Brassica napus.

4. Both the infestation index and the percentage of plants with symptoms of stem base and root disease depended on the previous crop and tillage systems. Spring barley grown after cover crops was less affected by take-all and brown foot rot than after straw mulch and no-mulch. In comparison with the conventional tillage, a significantly higher infestation of spring barley by the Gaeumannomyces graminis and Fusarium spp. was observed in objects where reduced tillage and direct drilling were applied.

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