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DRY MATTER ACCUMULATION, NITROGEN AND PHOSPHORUS UPTAKE IN WINTER TRITICALE GENOTYPES DIFFERING IN MINERAL ELEMENTS UTILIZATION EFFICIENCY

ABSTRACT

In our previous studies we found the considerable genotypic variation in N, P, K utilization efficiency at shooting phase of winter triticale plants. The objective of this study was to confirm whether, genetic differences in mineral element utilization at the shooting phase, were related to productivity as well as was nitrogen and phosphorus accumulation by winter triticale plants during entire growth period.

The experiment was conducted at reduced level of mineral elements in water culture (50% of standard Hoagland solution) under controlled environments (growth chambers) to full maturity.

The efficient winter triticale genotypes showed significantly higher dry matter, nitrogen and phosphorus content and N, P utilization efficiency during the whole growth period. Furthermore these genotypes had higher grain yield and harvest index in comparison to inefficient genotypes. The efficient winter triticale genotypes accumulated most of biomass in post-anthesis period and N, P uptake remained high until the late maturation.

Key words: triticale, genotypic variation, nitrogen, phosphorus, utilization efficiency

INTRODUCTION

Inputs have increased considerably over the last thirty years in the production of cereals in Europe. Fertilisers and chemicals to control weeds, diseases and lodging have been commonly used. However, in recent years, this high input management system has been criticized due to overproduction and pollution. A demand for varieties better suited and friendly to environment or low-input management systems is likely to arise (Le Gouis *et al.* 1999).

The criteria of selection of nutrient efficient genotypes are not quite clear. The method used by us for determination of nitrogen and phosphorus utilization efficiency (Siddiqi and Glass 1983), was applied for triticale plants in the shooting phase. Considerable genotypic variation in the mineral element utilization was

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found and four types of response to different concentrations of nutrient solution in winter triticale plants were recognized (Ciepły and Oracka 1989, 1990, 1994). This can be treated as the basis to distinguish genotypes as utilizing nutrients effectively and ineffectively (Ciepły and Oracka 1996).

The objective of this study was to confirm whether, genetic differences in mineral element utilization at the shooting phase, was related to productivity as well as to the nitrogen and phosphorus accumulation by winter triticale plants during entire growth period. We also evaluated if these parameters were related to growth yield under low level of mineral elements.

MATERIALS AND METHODS

Four efficient winter triticale genotypes (MAH 7885-7; MAH 10434-122; LAD 956/84; CZR 134/84) and three inefficient ones (CHD 1840/33; CHD 1024/84; LAD 1588/84) were selected for the study. The efficient genotypes were found, in the earlier studies (Ciepły and Oracka, 1996), as genotypes with high value of N, P, K utilization efficiency and biomass production .

Germinated seeds were vernalised during 60 days at 4°C. The seedling were transferred to plastic tanks filled with 40l of 0.5 standard concentrations of Haagland solution at pH 6.5. The standard concentration of modified Hoagland No.2 solution contained the following salt concentrations:

- macronutrients: $Ca(NO_3)_2{\cdot}4H_2O$ - 950 mg×l^{-1}, KNO_3 - 610 mg×l^{-1}, $MgSO_4{\cdot}7H_2O$ - 490 mg×l^{-1}, $NH_4H_2PO_4$-120 mg×l^{-1}
- micronutrients: H_2BO_3 - 2.86 mg×l^{-1}, $MnCl_2{\cdot}4H_2O$ - 1.81 mg×l^{-1}, $CuSO_4{\cdot}5H_2O$ - 0.08 mg×l^{-1}, $ZnSO_4{\cdot}7H_2O$ - 0.22 mg×l^{-1}, $Na_2MoO_4{\cdot}2H_2O$ - 0.09mg×l^{-1}, EDTA Fe-Na - 0.014 mg×l^{-1}.

The nutrient solution was renewed every 4 days and aerated by 10 min every hours.

Plants were placed in a growth chamber kept under conditions given in Table 1

Table 1

Conditions of growing plants

Days of plant growth	Temperature (0C) day/ night	Length of day/ night [h]	Photon flux density (PhAR) [mmol m2 s^{-1}]
1-5	7/2	12/12	120
6-17	10/6	12/12	120
18-38	12/8	12/12	350
39-70	15/10	14/10	350
71-159	18/13	16/8	350

Light in growth chamber was provided by Metal Halide Lamps NACHROMA type NCE -1000 W.

Sampling were commenced from the third leaf phase until maturity (10 harvest) in 3 replicates of four plants each. Plants were separated into roots and the leaves, stems, grains, glumes of main and tiller shoots. From this sample the plants dry matter (105°C) was recorded.

Standard procedures (Kjeldahl digestion and ammonium molibdenian photometry) were used to determine nitrogen and phosphorus contents in dry matter. On the basis of these data the following indexes were calculated:

- N, P utilization efficiency (as biomass per unit of N, P concentration Siddiqi and Glass 1983),
- harvest index (as the ratio of grain dry weight to the total aboveground dry weight),
- N, P harvest index (as grain N, P content to the total aboveground N, P content),
- efficiency of N, P utilization for total biomass production (as total biomass at maturity produced per unit of total N, P taken up – Papakosta 1994),
- efficiency of N, P utilization for grain (as grain weight produced per unit of total N, P taken up).

Data were processed by the analysis of variance procedures (ANOVA), differences were tested using Tukey's test.

RESULTS

Dry matter accumulation.

During whole growth period the total dry matter of the entire plants of efficient genotypes as well as its parts was significantly higher than the inefficient ones (Table 2).

Differences between the rate of dry mass accumulation the efficient and inefficient genotypes were observed between shooting phase and maturity (Fig. 1). The plant dry mater of efficient genotypes increased uniformly to full maturity, while in the case of the inefficient ones the biggest accumulation of the plant dry matter was found at the beginning of milk maturity. Dry matter of leaves and stems of efficient lines increased up to full maturity. The peak of the dry matter accumulation for leaves and stems of inefficient lines occurred at early stage of the milk maturity phase and afterwards the dry matter decreased. The root dry matter of efficient genotypes increased till the milk maturity, while for the inefficient ones it was observed only to the beginning of the milk maturity.

Nitrogen and phosphorus concentration.

Nitrogen concentration ($mg \times g^{-1}$) in leaves and stems of efficient and inefficient lines was decreasing considerably the stages of development. Concentration of N was higher in leaves than in stems. Nitrogen concentration in roots remained almost constant during whole growth and was higher than in above-ground parts of plants for both types of genotypes (Fig. 2).

Phosphorus concentration in leaves and stems was decreased during plant growth, but at given stage of growth it was higher in stems than in leaves (Fig. 2). P concentration in roots was increasing almost until maturity and was higher than in leaves or stems. The lower phosphorus concentration in the plant parts of the efficient genotypes was observed through the whole plant growth. No significant differences between the both genotypes tested were found in grain N, P concentration.

Table 2

Dry matter, N and P content and utilization efficieny (NUE, PUE) of efficient (e) and inefficient (ine) winter triticale plants

Days of vegetation		21	33	43	54	64	77	90	106	121	159
Phenophases	ine	L	T	T	T	S	S	S	H	Msm	Mf
	e	L	T	T	S	S	S	H	Msm	Mm	Mf
Tillers number	ine				0.5	1.2	1.4	2.6	2.8	3.8	3.0
	e				0.8	1.7	2.9	4.9	5.2	5.3	6.1
Dry matter [g/plant]											
ears	ine							0.07	1.20	3.06	7.48
	e							0.74	4.59	12.59	21.29
leaves	ine		0.05	0.15	0.82	1.60	1.98	3.47	3.72	4.72	3.94
	e		0.07	0.21	1.25	2.21	3.69	5.87	6.17	6.24	7.31
stems	ine	0.028	0.07	0.24	0.41	1.00	1.66	3.66	4.90	7.07	6.11
	e	0.034	0.10	0.41	0.71	1.61	3.69	8.26	13.26	13.58	15.16
roots	ine	*0.017	0.06	0.14	0.33	0.58	0.62	0.67	1.02	1.42	1.24
	e	*0.018	0.08	0.21	0.51	0.82	1.14	1.48	2.13	2.83	2.51
plant	ine	0.045	0.17	0.53	1.55	3.18	4.26	7.87	10.83	16.27	18.78
	e	0.052	0.25	0.83	2.46	4.64	8.51	16.34	26.14	35.24	46.26
Nitrogen content [mg/plant]											
ears	ine							1.8		8.3	117.7
	e							18.6		46.8	331.8
leaves	ine		2.3	7.0	35	68	69	111	115	126	73
	e		3.8	9.0	57	99	128	203	203	166	134
stems	ine	1.22	3.3	10.9	15	31	43	78	101	121	77
	e	1.58	4.4	17.9	26	52	89	169	233	189	167
roots	ine	*0.30	1.7	4.3	9	19	18	22	39	55	43
	e	*0.28	2.6	6.1	14	28	38	49	84	110	88
plant	ine	1.53	7.4	22.1	60	118	130	213	255	310	311
	e	1.86	10.8	33.1	96	179	254	439	520	513	721
NUE [$g^2 \times mg^{-1}$]	ine	0.001	0.004	0.013	0.040	0.086	0.140	0.291	0.470	0.871	1.138
	e	0.002	0.005	0.021	0.063	0.121	0.286	0.610	1.322	2.437	2.975

Table 2

continued

Days of vegetation		21	33	43	54	64	77	90	106	121	159
Phenophases	ine	L	T	T	T	S	S	S	H	Msm	Mf
	e	L	T	T	S	S	S	H	Msm	Mm	Mf
Phosphorus content [mg/plant]											
ears	ine							0.7		2	36
	e							4.5		12,1	105
leaves	ine		0.4	1.2	7	13	11	23	23	30	18
	e		0.6	1.5	9.5	15	17	29	32	29	28
stems	ine	0.32	0.8	2.3	4.4	9	12	22	30	41	30
	e	0.34	1	3.6	7.1	13	22	45	75	71	67
roots	ine	*0.12	0.7	1.6	3.5	7	5	8	14	20	15
	e	*0.11	0.8	2.3	5.2	9	9	15	27	34	27
plant	ine	0.45	1.9	5.1	14.9	28	28	53	67	92	99
	e	0.45	2.5	7.4	21.8	37	48	94	134	146	227
PUE [$g^2 \times mg^{-1}$]	ine	0.005	0.016	0.056	0.162	0.362	0.643	1.172	1.788	2.974	3.584
	e	0.006	0.024	0.093	0.277	0.582	1.506	2.866	5.093	8.544	9.472

* differences are not significant

L - 3-4 leaves; T- tillering; S - shooting; H - heading; M - maturity; Msm-start of milk maturity, Mm- milk maturity, Mf-full maturity, ine - inefficient; e - efficient

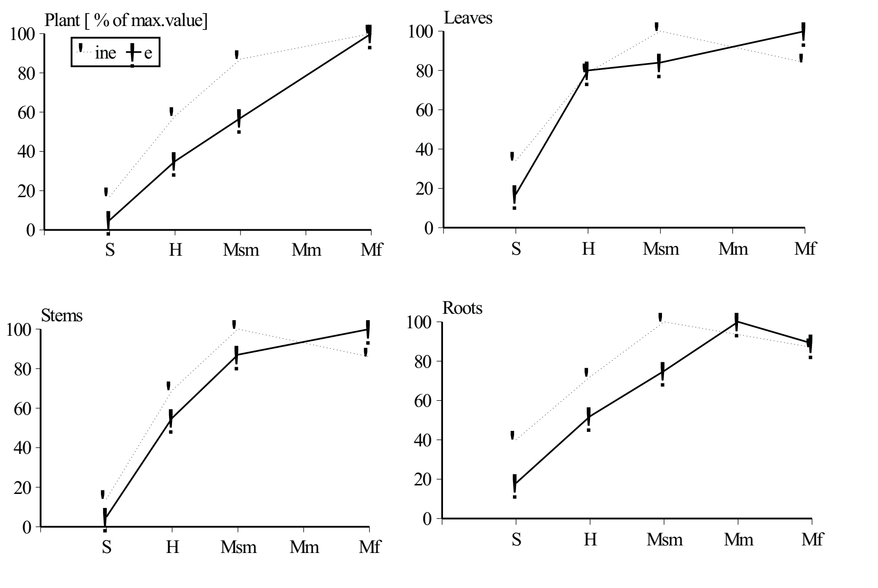

Fig.1. Increase of dry matter in plant and plant organs during vegetation (% of maximum values) by efficient (e) and inefficient (ine) winter triticale genotypes

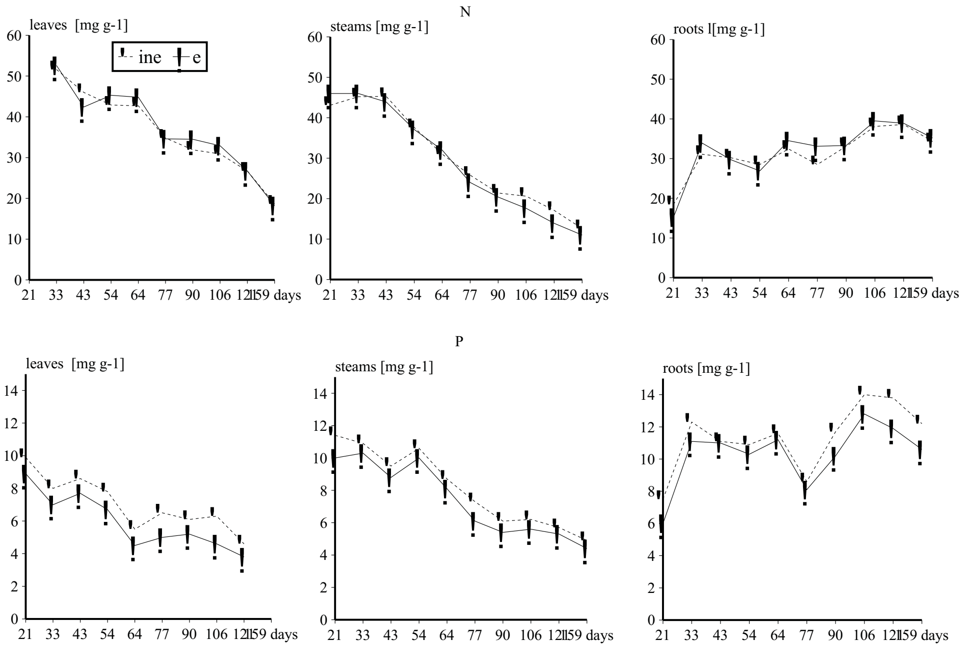

Fig.2 Nitrogen and phosphorus concentration in leaves, stems and roots of efficient (e) and inefficient (ine) winter triticale genotypes throughout vegetation.

Table 3

Harvest index (HI), nitrogen and phosphorus harvest index (N, P HI), efficiency of N, P utilization for total biomass production and for grain of efficient and inefficient winter triticale genotypes.

Parameters	Nitrogen		Phosphorus	
	efficient	inefficient	efficient	inefficient
N and P HI	0.45	0.39	0.44	0.37
Efficiency utilization [g g-1] (biomass)	69.2	65.4	218.4	209.5
Efficiency utilization [g g-1] (grain)	25.3	21.6	79.8	69.2
HI	0.37			0.33

Nitrogen and phosphorus accumulation

During the whole growth period the efficient genotypes accumulated significantly higher quantities of nitrogen and phosphorus than the inefficient ones. The efficient genotypes showed also significantly higher utilization efficiency of nitrogen and phosphorus during growth period in comparison to inefficient ones (Table 3).

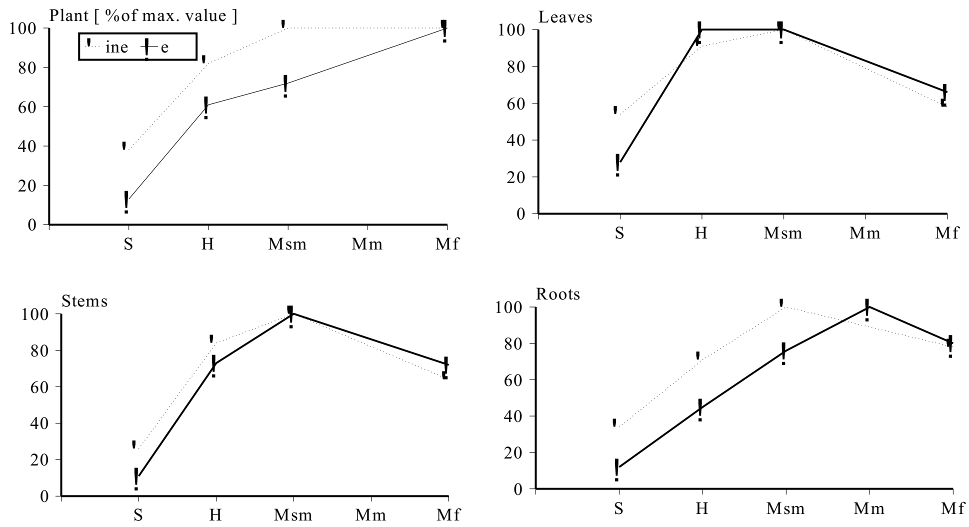

Fig. 3 Increase of N content in plant and plant organs during vegetation (% of maximum values) by efficient (e) and inefficient (ine) winter triticale genotypes. S-shooting, H- heading, Msm- start of milk maturity, Mm – milk maturity, Mf – full maturity

Patterns of nitrogen and phosphorus accumulation during the whole growing period were different for the efficient and inefficient genotypes (Fig. 3 and 4). The plant nitrogen and phosphorus content accumulated by the efficient genotypes increased up to the full maturity, while in the case of the inefficient ones maximum amount of plant nitrogen had been accumulated to the beginning of milk maturity. For both types of the genotypes the increase of N and P accumulation in leaves and stems was observed up to the beginning of milk maturity. The decline in nitrogen and phosphorus content in leaves and stems was higher for inefficient lines than for the efficient ones. The amount of nitrogen and phosphorus accumulated in the plant parts relatively to that from the entire plants varied as the growth continued and small difference was observed between the investigated groups (Fig. 5). The efficient genotypes showed higher N and P accumulation in ears during heading and maturity.

A significant positive correlation from 0.90 to 1.00 was found between plant N, P content and dry matter and N, P utilization efficiency.

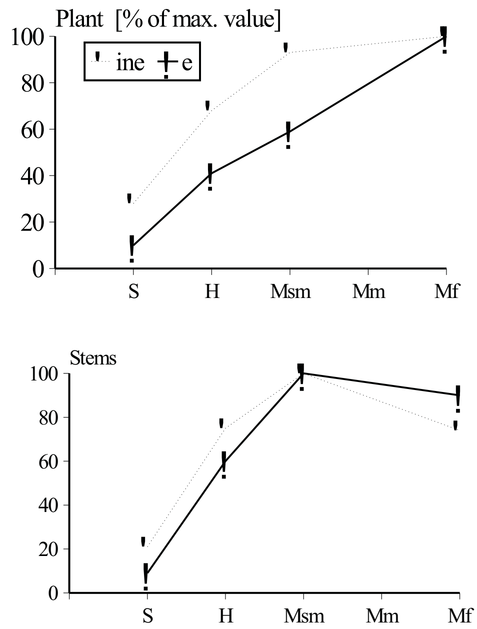

Fig. 4 Increase of P content in plant and plant organs during vegetation (% of maximum values) by efficient (e) and inefficient (ine) winter triticale genotypes S-shooting, H- heading, Msm- start of milk maturity, Mm – milk maturity, Mf – full maturity

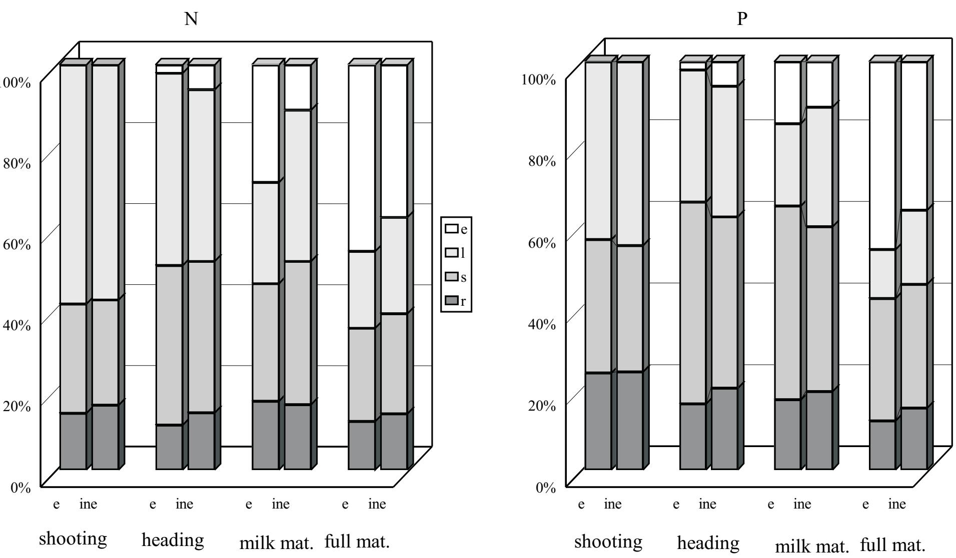

Fig. 5 Nitrogen and phosphorus distribution among plant organs during vegetation in efficient (e) and inefficient (ine) winter triticale genotypes. r - roots, s – stems, l- leaves, e – ears

Harvest index, nitrogen harvest index, phosphorus harvest index were higher in the efficient genotypes than in the inefficient ones. Also, efficiency of N, P utilization for biomass and for grain production were higher in the efficient genotypes (Table 3).

DISCUSSION

This study presents evidence, that winter triticale efficient genotypes had greater biological and grain yield, higher harvest index and N, P harvest index, as well higher efficiency of N, P utilization than inefficient genotypes. During the entire growth period efficient genotypes showed significantly higher dry matter content, phosphorus and nitrogen accumulation and N, P utilization efficiency, in contrast with the inefficient ones. These results make possibile selection of genotypes with the high efficiency of nutrients utilization.

Higher productivity of efficient genotypes was closely associated with greater number of tillers per plant and greater number of grains per spike. The greater number of grains per spike of efficient line resulted from greater number of floret primordia and maturity florets per spike (Kozdój, Ciepły and Oracka 1998). Triboi and Ntonga (1993) showed that, number of floret primordia in spikelets depends on the nutrition factors, especially of nitrogen. Our studies showed that, greater volume of dry matter produced during heading-anthesis phases and greater nitrogen and phosphorus uptake in the efficient genotypes, could influence production of greater number of grains per spike and grain yield per plant. The higher grain yield of efficient genotypes could result from current photosynthesis. Additionally, there was found in the efficient genotypes about 13 days shorter duration of vegetative period and about 15 days longer grain filling period (Kozdój et al. (1998). Osaki et al (1997 a) reported that the photosynthetic rate (dry matter increase) and root activity (nutrient absorption) remained constant during maturation in the high-yielding varieties. It suggests that in these varieties, roots and shoots interact mutually in this way, that high photosynthetic rate secures high root activity supplying sufficient amount of photosynthates to the roots and high root activity makes high photosynthetic rate supplying sufficient amount of nutrients to shoots. Furthermore, Osaki et al (1997 b) suggested that, the dry matter accumulation is strongly regulated by nitrogen accumulation, and crops with high biological yield display high ability of nitrogen absorption during maturation.

In inefficient genotypes N and P uptake was terminated at milk maturity, at the same time most of N and P had been taken up by ears. These genotypes showed significant decline N and P content in leaves and stems during grain filling period, while N and P absorption in efficient genotypes remained high until the late maturity. It is therefore assumed that, root activity of efficient genotypes was high and remained strong until late maturation. During the whole growth the higher total of N and P uptake in efficient genotypes was rather related to the root system size, than to the N, P uptake rate (Ciepły and Oracka 1997 a, b). Pre-anthesis N uptake in cereal crops can reach 75% to 90% of the final N accumulated by plants (Heitholt et al.1990). However, under high N fertilisation and available soil moisture, the contribution of post-anthesis N uptake may increase substantially (Bulman and Smith 1993). Jones et al (1992) clearly indicated that, the cultivars accumulating major part of N, P close to maturity, have higher grain yields in contrast to the cultivars accumulating a major part of total N, P during the earlier stages of the vegetation period. Plants can absorb N in excess of their current growth needs and they utilize this excess for the later growth. Demand for nitrogen needed for growth of generative storage organs is covered mainly by internal sources, e. g. N remobilization from roots, stems, leaves and glumes (Engels and Marschner 1995). The remobilization of N from vegetative tissues is associated with the process of senescence, a large amount of vegetative N retranslocated to the grain could reduce the total amount of N assimilated in the plant because of reduced leaf activity and consequently reduce the total amount of N available to the grain (Bulman and Smith 1993, Ono et al. 1996).

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