ORIGINAL PAPER

LEAF AREA INDEX IN WINTER WHEAT: RESPONSE ON SEED RATE AND NITROGEN APPLICATION BY DIFFERENT VARIETIES

M. BAVEC, K. VUKOVIĆ, S. GROBELNIK MLAKAR, Č. ROZMAN and F. BAVEC

University of Maribor, Faculty of Agriculture, Vrbanska 30, 2000 Maribor, Slovenia, e-mail: martina.bavec@uni-mb.si

Manuscript received: March 26, 2007; Reviewed: October 9, 2007; Accepted for publication: October 12, 2007 2005

ABSTRACT

The most important photosynthesis acceptor – leaf area vary among cultivation measures and it is limited factor for creating exact growth models in common winter wheat. The objective of this study was to investigate changes of leaf area index (LAI) affected by agricultural treatments – 4 sowing rates and 9 nitrogen treatments based on fertilising rates, target values based on soil mineral nitrogen and plant sap tests target values including different varieties. Increasing sowing rates from 350 to 800 viable seeds m^{-2} increased LAI at EC 75 stage from 2.9 to 5.5, where LAI 4.1 at 500 seeds m^{-2} did not vary between lower and higher rates; also at EC 85 stage LAIs did not differ significantly. At EC 75 stage LAI differed among control and nitrogen treatments from 1.0 to 6.5 and at EC 85 stage from 0.1 to 2.4, with differences in interaction among varieties. Higher nitrogen rates for first and second top dressing increased LAI in both stages compared without dressing treatments. Due to significant differences among LAI as consequence of production system, we suggest to take this into account in every prediction and modelling of growth in winter wheat.

KEY WORDS: leaf area index, winter wheat, nitrogen, sowing rate

IZVLEČEK

Listna površina, kot najpomembnejši fotosintetski akceptor je odvisna od pridelovalnih ukrepov in je omejitveni dejavnik za izdelavo natančnih rastnih modelov navadne ozimne pšenice. Cilj te študije je preveriti spremembe indeksa listne površine (LAI) pod vplivom agrotehničnih ukrepov – 4 gostot setve, 9 odmerkov dušika temelječih na odmerkih gnojil in temelječih na ciljnih vrednostih Nmin-a ter hitrih nitratnih rastlinskih testov vključujoč različne sorte. Povečevanje setvene norme od 350 do 800 kalivih semen m^{-2} povečuje LAI v fazi EC 75 od 2.9 do 5.5, medtem ko med njima in 500 kalivimi zrni m^{-2} značilnih razlik med LAI ni bilo; tudi v fazi EC 85 med LAI nismo ugotovili značilnih razlik. V fazi EC 75 je LAI variral od 1.0 v kontrolnem obravnavanju do 6.5 v gnojilnih obravnavanjih, v fazi EC 85 pa od 0.1 do 2.4, s tem da so bile značilne razlike tudi v interakciji s sortami. Višji odmerki dušika za prvo in drugo dognojevanje povečujejo LAI v obeh fazah v primerjavi z obravnavanji brez dognojevanja. Zaradi značilnih razlik med LAI kot posledica agrotehnike, priporočamo upoštevati razlike med LAI pri vsakem načrtovanju ali modeliranju rasti ozimne pšenice.

KLJUČNE BESEDE: indeks listne površine, ozimna pšenica, dušik, setvena norma

INTRODUCTION

Research of winter wheat canopy, associated plant physiology and its modelling [4, 9] help to precise growth and development, but canopy (mainly defined like leaf area as main photosynthesis acceptor, and expressed as leaf area index = LAI) depends on air temperature and its humidity [11], in some genotypes on ultraviolet-B radiation [12] and responses to CO_2 and ozone [6], agricultural practice like irrigation [15, 16] and morphological characteristics of genotypes. Represented by Evert [7] modelling photosynthesis has received much attention and photosynthesis is often represented inadequately detailed in plant productivity models, because less emphasis has been placed on the modelling of leaf area dynamics, and relationships between plant growth, elevated CO_2 and LAI are not well understood. The lack of data about forming LAI in winter wheat affected by different sowing densities was found. Also research of nitrogen efficiency on LAI and its importance is based mainly on nitrogen fertilisation rates [14, 16] without nitrogen target rates based on available nitrogen in the soils and/or plant sap tests, except analysed chlorophyll a [17].

In our case we agreed with Evert [6], who concluded that progress in estimating plant growth is unlikely to be achieved without improving the modelling of LAI. It depends on better understanding of the processes of substrate allocation, leaf area development and senescence, and the role of LAI in controlling plant adaptation to environmental changes. In wheat LAI formation was obtained by tillering [3, 5], likely also in grain sorghum [13] and by number of leaves per plant [8, 9, 18]. Increasing LAI (which may be changed by production system), decreases light interception and net assimilation rate depending on plant morphology [10, 18]. On this basis we can only speculate about differences in LAI formation and it performance depending on seed sowing density, effects of nitrogen affected also by different genotypes i.e. varieties. Therefore, the objective of this study was to investigate LAI performance of different winter wheat varieties under different sowing densities and nitrogen applications based on the soil available (mineral) nitrogen and stalk sap tests.

MATERIAL AND METHODS

Field experiments were conducted on sandy loam soil in Maribor, Slovenia (43^o 34'N, 15^o 38'E) the Podravje area (north-east of Slovenia with 40-year long term rainfall 1045 mm and average temperature 9.4 ^{o}C). In experimental site climatic circumstances in the years 2003/4 did not vary (rainfall sum from October to Jun was 529 mm) in comparison with long term period, except a small shortage of water in May of 2nd year (rainfall sum 46 mm) and warmer July (20.7 ^{o}C) than long term average (20.3 ^{o}C).

The experimental design was a randomised complete block with treatments arranged as split plot design (Latin rectangle) with four replications. In Experiment I, 7 winter wheat varieties and four seed sowing rates (Table 1) under nitrogen supply (treatment G in Table 2) and in Experiment II 2 winter wheat varieties and 10 nitrogen fertilisation treatments (Table 2) were performed. From A to J treatment 1st top dressing was based on mineral nitrogen to soil depth 0.9 m ($N0_3$-N + NH_4-N based on $CaCl_2$ extraction), and for 2nd and 3rd top dressing on the basis of nitrate sap test and chlorophyll meter (Hydro N tester) readings. The dimension of each subplot was 5 x 2 m^2. Seeds were sowed in eight-rows with Wintersteiger equipment in 12-cm row spacing. Seeding took place in the mid of October (optimal for this area). Common agriculture practice was used. Yield was harvested with Wintersteiger harvester for trials in the mid of July.

10 plants with complete tillers per plot were collected from the middle of each plot when more than 75% of plants were at stage of medium milk development in the seeds (EUCARPIA: EC 75, Zadoks growth stage 75) and at stage of soft dough development in seeds (EC 85). The individual green leaf areas (about 9000 leaves in experiment I, 12800 in experiment II) were measured using a personal computer and a scanner, which enabled counting the number of black dots on the screening picture of leaves and determining leaf area [1, 2]. Leaf area is expressed as leaf area index (LAI), which represents leaf area per plot area. Analyses of variance (ANOVA) for LAI was conducted using SPSSX 7.5, where the significance of factor effects was determined and the significance of treatments means was tested by Tukey's test at $P \leq 0.05$.

RESULTS AND DISCUSSION

LAI influenced by sowing rates at different winter wheat varieties

The data of the effects of sowing density and nitrogen applications on winter wheat leaf area performance showed that in spite of intensive productive tillering (to 2.7) in low sowing density, increasing sowing density from 350 to 800 viable seeds m^{-2} showed increasing trends of LAI at EC 75 stage from 2.9 to 5.5, respectively. In average LAIs (4.1) are significantly equal at 500 viable seeds m^{-2} with lower and higher sowing rates, but between their LAIs are significantly different. Significant differences among LAIs were noted by variety x sowing

Table 1. The effect of different numbers of viable seeds m^{-2} $area^{-1}$ on LAI at EC 75 stage by different winter wheat varieties
Preglednica 1. Vpliv različnega števila kalivih semen m-2 na indeks listne površine v fazi EC 75 pri različnih sortah ozimne pšenice.

Variety	Seeds m^{-2} 350	500	650	800
Ana	3.6c	4.6b	5.2ab	6.3a
Justus	3.1b	4.0b	5.3ab	6.6a
Krona	3.8b	6.5a	7.4a	7.2a
Marija	2.9b	4.1a	3.9a	4.0a
Mihelca	1.8b	2.6ab	2.9ab	3.7a
Profit	3.5b	4.5b	6.4a	8.0a
Soissons	1.9b	2.5b	3.5a	2.9a
Average	2.9b	4.1ab	4.9a	5.5a

Different letters within a row indicate significantly different means at the 95% confidence level (Tukey's test)

Table 2. Descriptions of treatments of top dressing with different nitrogen rates for varieties Marija and Soissons and their effects on green LAI at EC 75 and EC 85 stages.
Preglednica 2. Opis obravnavanj za dognojevanje z različnimi odmerki dušika za sorti Marija in Soissons ter njihov vpliv na indeks zelene listne površine v fazah EC 75 in EC 85

Treatment	Top dressing (kg N ha^{-1}) 1st	2nd	3rd	LAI Marija EC 75	Marija EC 85	Soissons EC 75	Soissons EC 85
A	0	0	0	1.5d	0.5c	1.0e	0.3c
B	30	30	0	4.6c	0.1c	3.3c	0.3c
C	60	30	0	7.0a	0.4c	4.3b	0.7b
D	60	60	0	6.5ab	1.3c	5.8a	1.1b
E	60	30	40	5.7b	1.8a	4.3b	2.1a
F	120-Nmin = 0	0	50	1.8d	1.5ab	1.4e	0.8b
G	120-Nmin = 0	30	40	3.6c	2.4a	2.1d	1.1b
H	180-Nmin = 30	30	40	4.4c	2.6a	2.2d	0.8b
I	150-Nmin = 0	30	40	3.1c	1.6ab	2.2d	0.7b
J	90-Nmin = 0	60	40	6.1ab	2.5a	3.2c	3.2c

Different letters within a column indicate significantly different means at the 95% confidence level (Tukey's test) density interaction (Table 1). At EC 85 stage the LAIs was not significantly different among sowing densities and varied from 1.9 to 2.5 (data not shown).

In the case of varieties Ana, Justus and Mihelca increasing sowing density increased LAI at EC 75 stage (Table 1). This may be obtained by decreased light interception and net assimilation rate depending on specific plant morphology of varieties [10, 18]. In addition, decreased LAIs from EC 75 stage to EC 85 stage and no significant effect of sowing density on LAI differences at EC 85 stage depend on higher leaf senescence in high sowing densities. Leaf senescence and uniformity of LAIs at EC 85 may be caused also by shortage of water in May. In addition to comments on sowing density, differences of LAI may be obtained (often represented data without LAI description) by variety vs. specific nitrogen efficiency.

LAI influenced by different nitrogen supply

At EC 75 and 85 stages LAI significantly differed among nitrogen treatments within varieties (Table 2).

The significantly higher LAIs by both varieties at EC 75 stage were formed by treatments with rate of 60 kg N ha^{-1} for 1st top dressing and additional 2nd top dressing. Higher nitrogen rate for 1st top dressing (E, D, and C) was the main reason for higher tillering 2.8 to 3.1 tills $plant^{-1}$ in comparison with other treatments when the tillering was lower than 2.3, which is consistent with Sharma et al. [18], Frederick and Camberato [8] and Heidmann et al [9] results. In the case of variety Soissons the increasing of nitrogen rates i.e. E treatment influenced increasing LAI, likely was a usually represented [14, 16, 17], but the effects of nitrogen application in variety Marija differed, possibly due to high value of LAI at EC 75 stage.

The effects on LAI at EC 85 stage differ between varieties, but at both varieties the highest LAIs at this stage were obtained by additional 3rd application (treatment E). By variety Marija target values (E to J) shows less expressed senescence than by variety Soissons.

CONCLUSION

Because leaf area changes differs up to five times and varied significantly among varieties associated with sowing density and the nitrogen fertilisation, this facts need to take into account for planning i.e. modelling of physiology and production in winter wheat. Determination of LAI (incl. chlorophyll readings) can be useful for prediction of grain yield and grain quality in practice.

REFERENCES

[1] Bavec F. and Bavec M., Effect of maize plant double row spacing on nutrient uptake, leaf area index and yield. Rost. Vyr. (2001) 47:135-140.

[2] Bavec F. and Bavec M., Effects of plant population on leaf area index, cob characteristics and grain yield of early maturing maize cultivars (FAO 100-400). Eur. J. Agron. (2002) 16: 151-159.

[3] Bavec M., Bavec F., Varga B., Kovačević V., Relationship among yield, it's quality and yield components in winter wheat (Triticum aestivum L.) cultivars affected by seeding rates. Bodenkultur. (2002) 53: 151-159.

[4] Bindraban P. S., Impact of canopy nitrogen profile in wheat on growth. Field Crop Res. (1999) 63: 63-77.

[5] Evers J. B., Vos J., Fournier C., Andrieu B., Chelle M. and Struik P. C., Towards a generic architectural model of tillering in Gramineae, as exemplified by spring wheat (Triticum aestivum). New Phytol. (2005) 166: 801-812.

[6] Evert F. and Pleijel H., Phenological development, leaf emergence, tillering and leaf area index, and duration of spring wheat across Europe in response to CO_2 and ozone. Eur. J. Agron. (1999) 10: 171-184.

[7] Evert F., Modelling plant responses to elevated CO_2: How important is leaf area index? Ann. Bot. (2004) 93: 619-627.

[8] Frederick J. R. and Camberato J. J., Water and nitrogen effects on winter wheat in South eastern coastal plain. Physiological responses. Agron. J. (1995) 87: 527-533.

[9] Heidmann T., Thomsen A. and Schelde K., Modelling soil water dynamics in winter wheat using different estimates of canopy development. Ecol Moddeling (2000) 129: 229-243.

[10] Karimi M. M. and Siddique K. H. M., Crop growth and relative growth rate of old and modern wheat cultivars. Aust. J. Agric. Res. (1991) 42: 13-20.

[11] Kostrej A. and Balogh Z., Relationships between air temperature and humidity regime and growth characteristics of winter wheat. Rost. Vyr. (1996) 42: 1-4.

[12] Yuan L., Yanquan Z., Haiyan C., Jianjuan C., Jilong Y. and Zhide H., Intraspecific responses in crop growth and yield of 20 wheat cultivars to enhanced ultraviolet-B radiation under field conditions. Field Crop Res. (2000) 67: 25-33.

[13] Lafarge T. A., Broad I. J. and Hammer G. L., Tillering in grain sorghum over a wide range of population densities: Identification of a common hierarchy for tiller emergence, leaf area development and fertility. Ann. Bot. (2002) 90: 87-98

[14] Lonhard E. B. and Nemeth I., Effect of N-

fertilisation on the seasonal dynamics of leaf-area and yield in wheat. Novenytermeles (1994) 43: 317-325.

[15] Pal S. K., Kaur J., Thakur R., Verma U. N. and Singh M. K., Effect of irrigation, seeding date and fertiliser on growth and yield of wheat (Triticum aestivum). Indian J. Agron. (1996) 41: 386-389.

[16] Rahman M. A., Karim A. J. M. S., Hoque M. M. and Egashira K., Effects of irrigation and nitrogen fertilisation on photosynthesis, leaf area index and dry matter production of wheat on clay terrace soil in Bangladesh. J. Fac. Agric. Kyushu University (2000) 45: 289-300.

[17] Serrano L., Fillela I. and Penuelas J., Remote sensing of biomass and yield of winter wheat under different nitrogen supplies. Crop Sci. (2000) 40: 723-731.

[18] Sharma K., Dhingra K. K. and Dhillon M. S., Physiological indices for high yield potential in different genotypes of wheat. Environ. Ecol. (1994) 12: 717-719.