THE RELATIONSHIP BETWEEN THE LEAF AREA OF SPRING BARLEY CANOPY AND GRAIN YIELD BASED ON AGRONOMICAL AND ENVIRONMENTAL FACTORS

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INTRODUCTION

The productivity of barley canopy like other cereal species depends to high degree on the value of the leaf area (expressed as LAI: Leaf Area Index) in consecutive plant developmental stages [6, 8, 9, 12, 13]. The utilisation of the main part of photosynthetic active radiation (PAR) by barley canopy and the accumulation of big quantities of biomass is possible only when the LAI value is high from the early developmental stage to its maturity.

The physiological indicator which takes into account both the LAI and the time of its duration is LAD (Leaf Area Duration). LAD is a product of growth time and the average LAI in the corresponding period [12]. For spring barley canopy productivity the LAD from plant emergence, to the beginning of the inflorescence stage is especially important [6].

The LAI and LAD values depend on many agronomical factors *e.g.*: early sowing causes bigger LAI values and when there is a longer period between the plant emergence stage to the inflorescence one, the result is a bigger value of LAD [7, 11]. Nitrogen fertilization modifies the leaf area of plants in the canopy causing bigger LAI [1, 5].

There are hulled and hulless cultivars of barley. The traditional morphotype is hulled, whereas hulless ones just started to be cultivated. Hulless forms, *i.e.* of very small share of hulls in grains are needed, especially for the effective feeding of animals.

The aim of the research was to evaluate the influence of environmental (different weather in two studied years) and agronomical (sowing date and rate of nitrogen fertilization) factors on LAI in vegetation periods and the resulting LAD. The important part of the research is the evaluation of the relationships between LAI, LAD and the grain yield of two different genotypes of spring barley (one with hulled and the other with hulless grain).

MATERIAL AND METHODS

The experiment was conducted during 2001 and 2002 at the Experimental Farm of Warsaw

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University of Life Sciences in Chylice in central Poland as a split-plot design (AB-C) with 4 replications.

The soil of the experimental fields was black-earth (*Mollic gleysols*), its detailed characteristic in 2001 and 2002 is shown in table 1. The soil pH in 2001 was slightly acidic and in 2002 was close to neutral, the content of mineral nitrogen in the soil was low in both years.

Weather conditions during the barley growth period (April – July) in both years were different (tab. 2).

In 2001 it was quite good in respect of the quantity of rainfall and its distribution in time, while in year 2002 there was a shortage of rainfall at the beginning of the barley growth period. Studied factors and their levels were as follows:

T a b l e 1

Soil properties of the experiment in years

	Year of experiment	
	2001	2002
Usefulness of soil	good wheat soil	very good rye soil
Type of soil	*Mollic gleysols*	
N_{min} total kg.ha^{-1} (0–60 cm)	25.2	36.8
% of N in all forms (0–30 cm)	0.11	0.09
P mg.1 kg^{-1} of soil (0–30 cm)	112.2	43.2
K mg.1 kg^{-1} of soil (0–30 cm)	153.6	117.1
pH_{KCl} (0–30 cm)	5.8	6.5

T a b l e 2

Monthly precipitation (mm) and average monthly air temperatures [°C] during vegetation period of barley in years 2001–2002

Month	April	May	June	July
Monthly precipitation [mm]				
2001	92.5	24.6	64.3	104.3
2002	11.1	66.4	71.7	43.0
Precipitation requirements [mm] by barley plants according to Dzieżyc et al. (1987)				
	39	59	82	87
Average monthly temperatures [°C]				
2001	8.9	11.4	11.9	18.4
2002	8.5	17.4	17.3	20.3

A – cultivar (Rasbet, hulled and Rastik hulless), B – sowing date (early – 04.04 and 28.03, delayed – 30.04 and 18.04, in years 2001 and 2002, respectively), C – rate of nitrogen fertilization (0, 30, 60 and 90 kg N.ha^{-1}), provided in ammonium nitrate form.

Rates of 30 and 60 kg N.ha^{-1} were applied before sowing, while a rate of 90 kg N.ha^{-1} was divided in two parts: 60 kg N was applied before sowing and an additional dose 30 kg N during culm elongation. In each year 350 grains per m^2 of *cv.* Rasbet and 400 of *cv.* Rastik (because of the worsening emerging ability in the field) were sown. The area of one plot was 30 m^2.

The ratio of leaf area and other assimilatory parts of plants in barley canopy to land area on which are these plants grown, LAI (expressed in m^2. m^{-2}) was evaluated using a ceptometer AccuPAR model PAR-80 (Decagon Inc., USA). Measurements of LAI were taken every two weeks on dates which are shown in table 3, except for the first measurement which was made on plots with a delayed sowing date, because of the very small leaf area (beginning of plants growth).

T a b l e 3

Times of measurements of leaf area index (LAI) and corresponding developmental stages (according to Zadoks et al. 1974)

LAI measurements	Years	2001		2002	
	Sowing date	04.04.	30.04.	28.03.	18.04.
1	date of measurement	08.05.		01.05.	
	developmental stage	DC 21	DC 11	DC 21	DC 12
2	date of measurement	22.05.		16.05.	
	developmental stage	DC 25	DC 21	DC 31	DC 23
3	date of measurement	06.06.		28.05.	
	developmental stage	DC 39	DC 31	DC 51	DC 37
4	date of measurement	19.06.		13.06.	
	developmental stage	DC 51	DC 45	DC 71	DC 59
5	date of measurement	03.07.		02.07.	
	developmental stage	DC 75	DC 59	DC 87	DC 83

DC11-DC30 Seedling growth and tillering, DC31-DC39 culm elongation, DC40-DC49 booting, DC50-DC69 flowering, DC 71-DC87 kernel development.

LAD was calculated as a product of the average LAI in two subsequent measurements and the corresponding halftime period between measurements (as an area of trapezium). The LAD values ($m^2.m^{-2}.d^{-1}$) were expressed in a cumulative way from the beginning of the barley plants growth to its subsequent stages. Also, a cumulative LAD for the whole vegetation was calculated.

During the harvest, on each plot the grain yield was evaluated and expressed as 85% of dry mass in $t.ha^{-1}$. Obtained data statistically analysed using STATGRAPHICS ver. 4.1. The effects of the examined factors for the values

T a b l e 4

LAI [$m^2.m^{-2}$] of barley canopy during vegetation period in relation to studied factors

Measurement number	1	2	3	4	5
2001					
Time of measurement	08.05.	22.05.	06.06.	19.06.	03.07.
Cultivar					
Rasbet	0.62	1.31	2.37	3.14	3.72
Rastik	0.80	1.25	2.22	2.83	3.02
$LSD_{0.05}/LSD_{0.01}$	0.18/0.24	0.19/0.24	0.24/0.31	0.20*/0.27	0.21*/0.28**
Sowing date					
Early	0.71	1.96	3.12	3.49	3.66
Late	–	0.60	1.47	2.48	3.08
$LSD_{0.05}/LSD_{0.01}$		0.19*/0.24**	0.24*/0.31**	0.20*/0.27**	0.21*/0.28**
N fertilization					
0 kg $N.ha^{-1}$	0.55	0.91	2.05	2.53	2.93
30 kg $N.ha^{-1}$	0.65	1.26	2.21	2.89	3.36
60 kg $N.ha^{-1}$	0.78	1.44	2.40	3.31	3.49
90 kg $N.ha^{-1}$	0.87	1.52	2.53	3.22	3.71
$LSD_{0.05}/LSD_{0.01}$	0.25*/0.32	0.28*/0.35**	0.34*/0.42**	0.29*/0.36**	0.31*/0.39**
Average	0.71	1.28	2.30	2.99	3.37
2002					
Time of measurement	01.05.	16.05.	28.05.	13.06.	02.07.
Cultivar					
Rasbet	0.26	0.74	1.57	2.48	2.53
Rastik	0.33	0.72	1.36	2.11	1.87
$LSD_{0.05}/LSD_{0.01}$	0.05*/0.07*	0.08/0.11	0.20*/0.26	0.17*/0.22**	0.18*/0.24**
Sowing date					
Early	0.29	1.17	1.92	2.40	2.43
Late	–	0.29	1.01	2.18	1.97
$LSD_{0.05}/LSD_{0.01}$		0.08*/0.11**	0.20*/0.26**	0.17*/0.22**	0.18*/0.24**
N fertilization					
0 kg $N.ha^{-1}$	0.26	0.65	1.23	2.00	2.00
30 kg $N.ha^{-1}$	0.32	0.73	1.44	2.25	2.15
60 kg $N.ha^{-1}$	0.30	0.77	1.65	2.45	2.32
90 kg $N.ha^{-1}$	0.29	0.77	1.54	2.47	2.34
$LSD_{0.05}/LSD_{0.01}$	0.07/0.09	0.11*/0.014	0.28*/0.35**	0.24*/0.32**	0.25*/0.33**
Average	0.30	0.73	1.47	2.30	2.20

* – significant difference at α = 0.05; ** – significant difference at α = 0.01

of LAI and LAD were evaluated using an analysis of variance and multiple comparisons. The Pearson's correlation coefficient was estimated between grain yield with LAI and LAD (separately for different factors levels).

RESULTS

The experiment proved that the LAI was modified by an interaction of weather conditions and experiment factors. The bigger values of LAI in subsequent measurements and a faster development of the leaf area during the first stages of growth were observed in 2001 (tab. 4). The rate of plant growth and leaf area development were influenced positively by good weather conditions. The most LAI in 2001 was 3.37 $m^2.m^{-2}$, much bigger than in 2002 (2.30 $m^2.m^{-2}$). The difference was 1.07 $m^2.m^{-2}$, which means that max. LAI in 2001 was greater by 46.5% than in 2002.

The significant differences were observed between examined cultivars. LAI values in both years measured after booting were bigger for *cv.* Rasbet comparing with *cv.* Rastik. The maximum values of LAI in 2001 were observed in the last measurement (3.72 $m^2.m^{-2}$ for *cv.* Rasbet and 3.02 $m^2.m^{-2}$ for *cv.* Rastik 18.8% less). In 2002 the maximum LAI was 2.53 $m^2.m^{-2}$ for *cv.* Rasbet and 2.11 $m^2.m^{-2}$ for *cv.* Rastik (16.6% less).

The LAI values in subsequent measurements indicate that the canopy of both cultivars (Rasbet and Rastik) showed similar dynamics of leaf growth during the beginning of the growth period (to the end of tillering). In the further developmental stages (from booting) the increase of LAI was much lower for *cv.* Rastik compared to *cv.* Rasbet.

An early sowing date, compared to delayed sowing date caused bigger LAI values in both years during all growing periods (tab. 4).

Maximal LAI values for plots with early sowing dates were 3.66 $m^2.m^{-2}$ in 2001 and 2.43 $m^2.m^{-2}$ in 2002, and for plots with delayed sowing were 0.58 $m^2.m^{-2}$ (15.8%) smaller in 2001 and 0.25 $m^2.m^{-2}$ (10.3%) in 2002.

The relatively big values of LAI (about 2 and bigger) were observed in 2001 about three weeks later for plots with delayed sowing, than for plots with an early sowing date; in 2002 the respective time difference was two weeks between the early and delayed sowing dates.

The LAI values in 2001 and 2002 significantly differed between rates with higher nitrogen fertilisation (60 or 90 kg N per ha) and rate 0 kg $N.ha^{-1}$. In 2001 significant differences were observed in all measurements and the biggest LAI values were for the rate 90 kg $N.ha^{-1}$, except for the fourth measurement, in which the biggest LAI value was for the rate 60 kg $N.ha^{-1}$. In 2001 the LAI values in all measurements, at

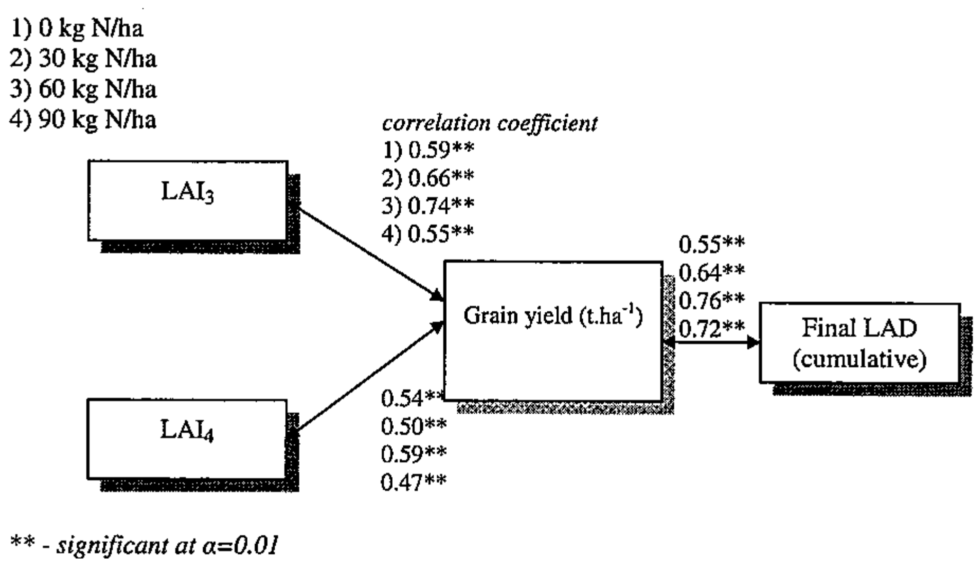

Fig. 1. Grain yield of spring barley in dependence on LAI and LAD

rate 90 kg $N.ha^{-1}$ were bigger than the LAI values at rate 0 kg $N.ha^{-1}$, 0.32 (58.2%), 0.61 (67.0%), 0.48 (23.4%), 0.69 (27.3%) and 0.78 $m^2.m^{-2}$ (26.6%), respectively.

In 2002 for every measurement, except the first, significant differences between the rates of nitrogen fertilisation were observed. The smallest LAI was found at rate 0 kg $N.ha^{-1}$, and the biggest ones were observed at 60 kg N or 90 kg $N.ha^{-1}$.

Differences between LAI at rate 0 kg $N.ha^{-1}$ and 60 kg $N.ha^{-1}$ in subsequent measurements

T a b l e 5

Cumulative LAD [m^2 m^{-2} d] of barley canopy during vegetation period in relation to studied cultivars

Measurement number	1	2	3	4
2001				
Time of measurement	22.05.	06.06.	19.06.	03.07.
Cultivar				
Rasbet	11.3	38.9	74.7	122.7
Rastik	11.5	37.6	70.4	111.4
$LSD_{0.05}/LSD_{0.01}$	1.7/2.3	3.6/4.8	5.1/6.8	6.4*/8.5**
Sowing date				
Early	18.7	56.8	99.8	149.8
Late	4.2	19.7	45.4	84.4
$LSD_{0.05}/LSD_{0.01}$	1.7*/2.3**	3.6*/4.8**	5.1*/6.8**	6.4*/8.5**
N fertilization				
0 kg $N.ha^{-1}$	8.3	30.4	60.1	98.3
30 kg $N.ha^{-1}$	11.0	37.1	70.2	113.9
60 kg $N.ha^{-1}$	12.8	41.5	78.7	126.3
90 kg $N.ha^{-1}$	13.7	44.0	81.4	129.8
$LSD_{0.05}/LSD_{0.01}$	2.4*/3.0**	5.1*/6.4**	7.2*/9.6**	9.1*/11.4**
Average	11.4	38.3	72.6	117.1
2002				
Time of measurement	16.05.	28.05.	13.06.	02.07.
Cultivar				
Rasbet	6.5	20.4	52.7	100.3
Rastik	6.6	19.1	46.8	84.6
$LSD_{0.05}/LSD_{0.01}$	0.7/0.9	2.0/2.6	4.3*/6.7	6.6*/8.8**
Sowing date				
Early	11.0	29.5	64.1	110.0
Late	2.2	9.9	35.5	75.0
$LSD_{0.05}/LSD_{0.01}$	0.7*/0.9	2.0*/2.6**	4.3*/6.7	6.6*/8.8**
N fertilization				
0 kg $N.ha^{-1}$	5.8	17.1	43.0	80.9
30 kg $N.ha^{-1}$	6.7	19.7	49.2	91
60 kg $N.ha^{-1}$	6.9	21.4	54.2	99.5
90 kg $N.ha^{-1}$	6.8	20.7	52.8	98.5
$LSD_{0.05}/LSD_{0.01}$	1.0*/1.3**	2.8*/3.5**	6.1*/7.6**	9.4*/11.8**
Average	6.6	19.8	49.8	92.5

* – significant difference at $\alpha = 0.05$; ** – significant difference at $\alpha = 0.01$

were from 0.04 to 0.45 $m^2.m^{-2}$ (15.4 to 34.1%).

Cumulative LAI values were bigger in 2001, in which the weather conditions were better than in 2002. The final cumulative LAD in 2001 was 117.1 $m^2.m^{-2}.d^{-1}$ and was bigger by 18.0 $m^2.m^{-2}.d^{-1}$ (18.2%) than that in 2002 (tab. 5). LAD values differed significantly between examined cultivars (tab. 5). In 2001 and 2002 the final LAD was significantly bigger for *cv.* Rasbet than for *cv.* Rasbet. In 2001 the final average LAD for *cv.* Rasbet was 122.7 $m^2.m^{-2}.d^{-1}$ while that for *cv.* Rastik was 11.3 units (9.2%) lower. Differences between leaf area index for *cv.* Rasbet and *cv.* Rastik in this year during the early growth stages were not significant.

In 2002 significant differences between LAD for studied cultivars were observed from the third to the fifth measurement. The bigger LAD values were observed for *cv.* Rasbet. The final LAD value for *cv.* Rasbet was higher by 15.5 $m^2.m^{-2}.d^{-1}$ (17.0%).

In both years much lower LAD values were observed when the delayed sowing date was used than for the early sowing date. It was caused by smaller LAI and a shorter growth period. For the delayed sowing date the LAD values in the second measurement (22.05 and 16.05) were smaller by 14.5 (2001) and 19.6 $m^2.m^{-2}.d^{-1}$ (2002) comparing with the early sowing date. Differences were bigger in the later growing stages. The final LAD for the early sowing date was 149.8 in 2001 and 120.9 $m^2.m^{-2}.d^{-1}$ in 2002, while the same values of LAD for the delayed sowing date were smaller by 65.4 $m^2.m^{-2}.d^{-1}$ (43.7%) and 43.8 $m^2.m^{-2}.d^{-1}$ (36.2%), respectively.

In 2001 the final LAD was the highest (129.8 $m^2.m^{-2}.d^{-1}$) for plots with the rate 90 kg $N.ha^{-1}$ and the smallest (98.3 $m^2.m^{-2}.d^{-1}$) for the rate 0 kg $N.ha^{-1}$ *i.e.* 24,3% less. In the next year the highest LAD was observed for the rate 60 kg $N.ha^{-1}$ (106.4 $m^2.m^{-2}.d^{-1}$), while the smallest one was for the rate 0 kg $N.ha^{-1}$ (86.7 $m^2.m^{-2}.d^{-1}$ 18.5% less).

Relationships between LAI, LAD and grain yield

The correlation coefficients between grain yield and LAD and LAI values were estimated for both years, separately for every year, and for factors levels (cultivars, sowing date, and nitrogen dose). In the research the third and fourth measurement dates of LAI occurred in the beginning of the booting stage to the dough kernel development. Correlation between grain yield and LAI values was analysed for these LAI measurements. Additionally, the correlation between the final (cumulative) LAD value and grain yield was determined. Estimated correlation coefficients for both years and separately for 2001 and 2002 proved, that the grain yield to a bigger degree was determined by the LAI value in the third measurement (06.06 and 28.05 in 2001 and 2002, respectively), than in the fourth LAI measurement (fig. 1). It indicates that the LAI was more important for grain yield in the earlier growth stages.

The estimation of relationships, separately, for examined cultivars indicates that the corre-

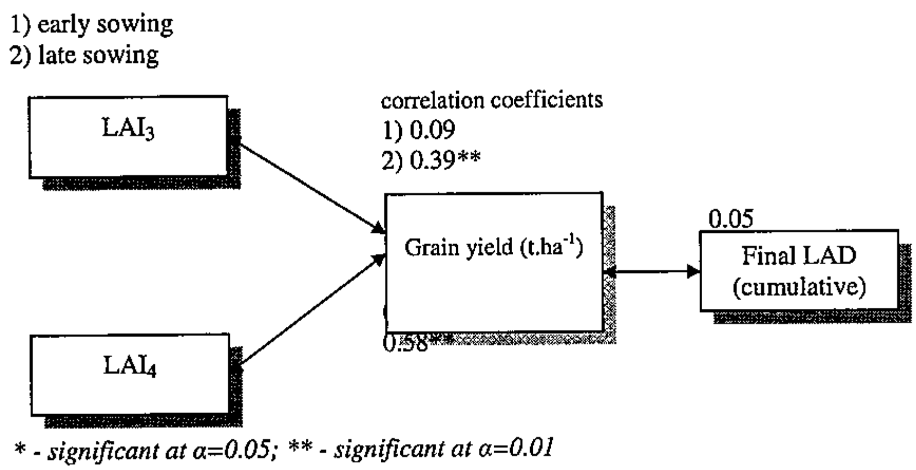

Fig. 2. Grain yield of of spring barley *cvs* Rasbet and Rastik in dependence on LAI and LAD

lation between LAI values in the third and the fourth measurements and the grain yield were bigger for *cv.* Rastik (r = 0.68 and r = 0.57, for the 3rd and 4th measurements, respectively) than for *cv.* Rasbet (r=0.67 and r=0.44, for subsequent measurements, respectively, fig. 2).

Grain yield for *cv.* Rastik was much more strongly correlated with LAD (r=0.74) than grain yield for *cv.* Rasbet (r=0.64). These results prove that the quantity and time duration of LAI were more important in grain yield determination for *cv.* Rastik than for *cv.* Rasbet.

The relationship between the grain yield and values of LAI and LAD were modified by the sowing date.

The correlation coefficients values between grain yield and LAI for plots with the delayed sowing date were bigger (0.39 and 0.58 in subsequent measurements) than for plots with the early sowing date (r = 0.09 and 0.21, fig. 3). The correlation coefficient between grain yield and LAD for the delayed sowing date was much bigger (r=0.60) than for the early sowing date (r=0.25).

The correlation between LAI, LAD and grain yield for plots with the delayed sowing date indicates a bigger importance of the leaf area and its time duration for quantity of grain yield, compared to the early sowing date.

Correlations between LAI in the third measurement and grain yield were the biggest for the rate 60 kg N.ha^{-1} (r=0.74), and the smallest for rates 0 kg N.ha^{-1} (r=0.59) and 90 kg N.ha^{-1} (r=0.55) (fig. 4). The highest correlation coeffi-

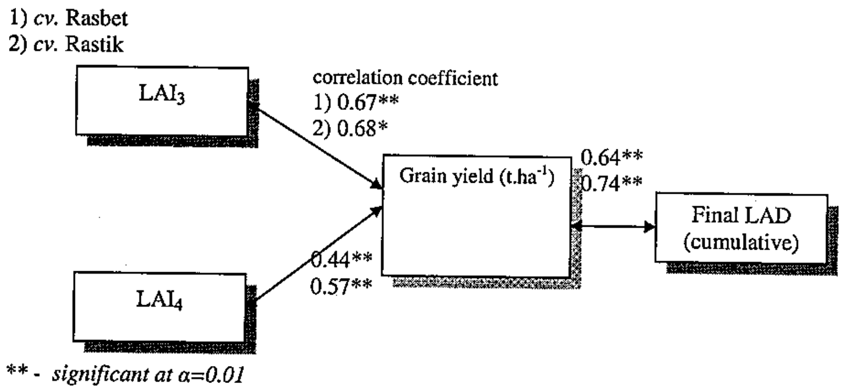

Fig. 3. Grain yield of spring barley in dependence on LAI and LAD for sowing dates

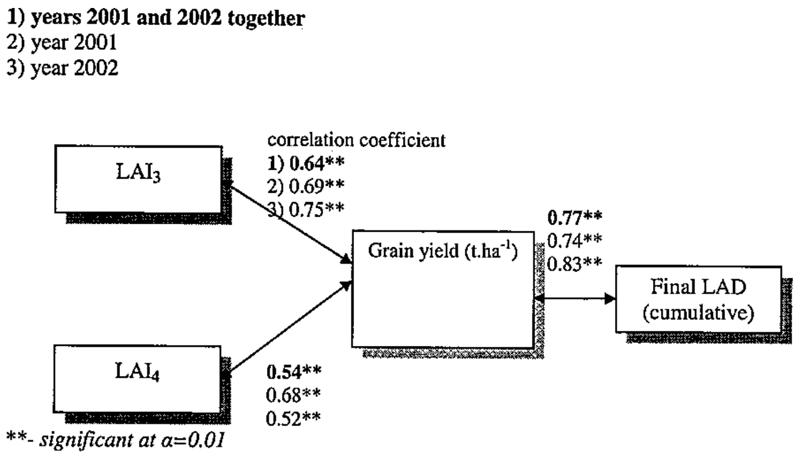

Fig. 4. Grain yield of spring barley in dependence on LAI and LAD for rates of nitrogen fertilization

cient for LAI in the fourth measurement and grain yield was for the rate 60 kg $N.ha^{-1}$ (r=0.59), and the smallest for the rate 90 kg $N.ha^{-1}$ (r=0.47).

DISCUSSION

The leaf area expressed as LAI and LAD was bigger in 2001. In 2002, when the amount of rainfall was lower, the maximum LAI and cumulative LAD were much smaller.

The nitrogen fertilisation causes a bigger LAI [5] and leaf area of single plant of barley [1]. The leaf area of plant canopy, represented as LAI value has a crucial importance in the utilisation of photosynthetic active radiation by crop plants [3]. The easy measurement of this index, enhances concern of LAI for monitoring the state of growth and crops yield modeling. The LAI depends on rates of leaf and stem growth, which in turn, are determined mainly by temperature. Temperatures that are either too high or too low, limits LAI. The first causes a decrease in a number of leaves and lateral stems, the second limits growth and causes the faster decay of leaves. The impact of a high temperature on plants is connected with the influence of drought. Moreover, the LAI is modified by nitrogen fertilisation, water availability and to a smaller degree by the sowing date and density. Shortage of nitrogen decreases LAI because of the limitation of leaf growth and because of the acceleration of leaf senescence [4, 10]. Shortage of water can cause quicker leaf decay [10]. The smaller increase in LAI for *cv.* Rastik compared with cv. Rasbet from the beginning of culm elongation was caused by earlier leaf decay and quicker maturing of *cv.* Rasbet plants. According to B e r t h o l d s s o n [2], earlier decreasing of LAI can be characteristic for cultivars with stable protein content (like cv. Rasbet). Higher LAI in all growth periods for barley plants for plots with an early sowing date was caused by an earlier emerging and quicker appearing of the subsequent developmental stages and longer duration of all developmental stages.

LAI and LAD were strongly influenced by sowing dates. Delayed sowing dates caused a reduction in leaf area. Values of LAI and LAD were positively correlated with grain yield. P e l t o n e n - S a i n i o et al. [11] and G r a s h o f f and d'A n t u o n o [5] in their research with spring barley proved the positive correlation between LAI and LAD and grain yield. B a r c z a k [1] proved the positive correlation between the area of flag leaf and all the plant area with grain yield and protein content in grain.

In our research, correlations between LAI and LAD with grain yield were modified by cultivar. The strongest correlations were found for hulles *cv.* Rastik than for hulled *cv.* Rasbet. Correlation coefficient for the delayed sowing date was bigger comparing with the correlation coefficient for the early sowing date.

Applied nitrogen fertilisation did not affect strongly the correlations between grain yield and the leaf area of canopy. Grain yield to the great extent was determined by LAD than by LAI (higher r values).

CONCLUSIONS

1. In both years of the experiment, LAI and LAD were much bigger for early sowing dates (compared with delayed sowing dates) and for higher nitrogen rates (compared to plots without nitrogen fertilisation).
2. Strong positive correlations between LAI, LAD and grain yield prove that for a high grain yield it is necessary for plants to develop a big enough leaf area per ground unit area (LAI).
3. The weaker relationships between LAI and grain for the rate 0 kg $N.ha^{-1}$ were caused by the low level of yields for this dose, and for the rate 90 kg $N.ha^{-1}$ because of the lack of grain yield increase for high LAI (from 3 to 5 $m^2.m^{-2}$).
4. Correlations between final LAD values and grain yield were the highest for the rate 60 kg $N.ha^{-1}$ (r=0.76), and the smallest for the rate 90 kg $N.ha^{-1}$ (r=0.55).
5. The leaf area of spring barley should be big enough during the period from the booting stage to the dough development stage. Big leaf area causes intensive biomass accumulation, and the effect of this is an increase in grain yield.

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SUMMARY

The aim of the research was to evaluate the influence of environmental and agronomical factors on LAI and LAD in a vegetation period of two spring barley cultivars. The second part of the research was the evaluation of the relationships between LAI, LAD and grain yield. The experiment was conducted during 2001 and 2002 on the Experimental Farm of Warsaw University of Life Sciences in central Poland as a split-plot design (AB-C). There were the following factors of the experiment: A – cultivar (Rasbet, hulled and Rastik hulless); B – sowing date (early and delayed approximately 3 weeks); C – rate of nitrogen fertilisation (0, 30, 60 and 90 kg $N.ha^{-1}$), provided in ammonium nitrate form. During all growth periods LAI values were evaluated on each plot, and then the cumulative LAD values were calculated. At harvest, on each plot the grain yield was evaluated and expressed as 85% of dry mass in $t.ha^{-1}$. The obtained results show that in both years of the experiment, LAI and LAD were much bigger for the early sowing date, compared to the delayed sowing date; and for higher nitrogen rates, compared to plots without nitrogen fertilisation. Positive correlations between LAI, LAD and grain yield were observed. Stronger correlations were observed for plots with a late sowing date than for those with an early sowing date. The differences between correlations for both cultivars were similar. Correlations between final LAD values and grain yield were the highest for the rate 60 kg $N.ha^{-1}$ (r=0.76), and the smallest for the rate 90 kg $N.ha^{-1}$ (r=0.55).

Key words: spring barley, sowing date, N-fertilization, weather conditions, hulled and hulless genotypes, lai, lad, grain yield