interrow width and plant density results in changes in the individual productivity of field bean plants towards reduction with a negative influence on the level of grain yield per unit of area.

So, the formation of a rational optical-biological structure for field bean sowings is growing in importance as it is one of the determining factors when studying and evaluating the models of bean field sowing growing technology.

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PHOTOSYNTHETIC RADIATION USE EFFICIENCY OF DIFFERENT OAT CULTIVARS UNDER DIFFERENTIATED NITROGEN FERTILIZATION

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Abstract

In a field experiment conducted with two oat's morphotypes (hulled and naked), fertilized with differentiated nitrogen rates (0, 30, 60, 90 and 120 kg N ha^{-1} the biomass production of plants in canopy was evaluated using indices of energetic analysis, coefficient of radiation use efficiency (RUE) by the plants in the canopy among others. It was found the hulled oat's morphotype characterizes with bigger degree of transformation radiant energy into biomass as compared to the naked one (on average for whole experiment the energy yield for cv. Chwat was 15.0 while fot cv. Akt 13.6 MJ m^{-2}. Maximum transformation of radiant energy into biomass was found for traditional morphotype at 90 kg N ha^{-1}, while for naked one already at 30 kg N ha^{-1}, (respectively). Radiation use efficiency (RUE) for grain production was bigger in cv. Chwat as compared to cv. Akt, being 2.77 and 1.49 g d.m. MJ^{-1}, respectively. RUE for biomass production also was bigger in hulled morphotype, being 3.36 *vs* 3.20 g d.m. MJ^{-1} in naked one. The rate 90 kg N ha^{-1} for cv. Chwat and 30 kg N-ha^{-1} for cv. Akt seem to be physiologically optimal.

Key words

Nitrogen, fertilization, oat, PAR, solar radiation, RUE

Introduction

According to the model elaborated by Monteith (1977) there is a possibility to present biomass production as a linear function of photosynthetic active radiation (PAR, wavelength 400-700 nm) intercepted by a canopy. Varlet-Grancher *et al.* (1993) improved this semi-empiric model of dry matter accumulation in canopy, by relating PAR to energy yield of crop. The basic component of both models is a concept of radiation use efficiency (RUE), being the ratio of total biomass produced and unit of PAR intercepted by the canopy (Faber, 2000). RUE is also principal tool in modeling plant growth and dry matter accumulation, especially in canopy, where there is no limitation of development due to unavailability of water or mineral nutrients, and eventually to other unfavorable climatic conditions, diminishing value of RUE (Stockle and Kiniry, 1990; Runyon *et al.* 1994; Ruimy *et al.*, 1995). The RUE depends mainly on the crop, developmental phase, intensity of CO_2 assimilation, nitrogen nutrition of plants, occurrence and severity of eventual droughts, temperature and degree of plant infestation with diseases (Faber, 2000, Reynolds *et al.* 2000). It is strictly joint to the canopy architecture, being according to Ross (1981) 'a set of features involving shape, size, geometry and external structure of plant'. A reciprocal of RUE is used in Varlet-Grancher formula.

A substantial progress in breeding cereals has been observed last years in Poland. Forms with reduced contribution of hulls to grain in the case of hulled species (barley, oat) were developed. Such new forms are called hulless (barley) or naked (oat), in the literature (Nita, 1999). Developing of these forms may increase both nutritional and forage value of grain. Newly introduced to the national register oats cultivars differ among others in the view of needs to fertilize them with nitrogen. Apropriate nitrogen fertilization enables this crop to develop and maintain the adequate for effective PAR absorption canopy, thus affecting the yielding. Recognition of physiological responses of plants forming oat canopy to differentiated nitrogen fertilization will enable much better exploitation of yielding potential of newly registered varieties.

The aim of investigation was to evaluate a capacity of solar energy absorption and its use for biomass production in two oat morphotypes (hulled or naked) cultivated under differentiated nitrogen fertilization.

Materials and Methods

Two factorial field experiment in randomized blocks with 4 replications was conducted in Department of Agronomy of Warsaw University of Life Sciences experimental field Chylice. The soil was a degraded black earth formed from clay sand of ice accumulation on light burden clay and was that of rye good complex. There were two oat cultivars investigated: Chwat (hulled morphotype) and Akt (naked one). Nitrogen was provided as ammonium nitrate at 5 rates (0, 30, 60, 90 and 120 kg N ha^{-1}). The all rates 30 and 60 kg N ha^{-1} were applied two days presowing (27.03), whereas in the case of rates 90 and 120 kg N ha^{-1} , first 60 kg N ha^{-1} were provided also presowing, while the remaining 30 or 60 kg N ha^{-1} at culm growth (30.05). Thus, with two cultivars and 5 rates of nitrogen fertilization there were 10 experimental combinations resulting in 40 plots (20 for each cultivar). Plot area was 30 m^2 (12 m x 2,5 m).

During vegetation on five occasions 1.05 (32 day after emergence DAE, according to Zadocks et al., 1974), 16.05 (47 DAE), 28.05 (59 DAE), 13.06 (75 DAE) and 28.06 (90 DAE) above ground plant dry mass (g m^{-2}) to calculate maximum dry matter biomass and PAR transmission to the bottom of canopy were determined. The latter was done one directly above canopy, then three times at its bottom with two replicates, using AccuPAR Model PAR-80 (Decagon Inc., USA). Grain yield was determined at harvest.

Taking into account data characterizing global radiation reaching the canopy (R_s) measured at experimental field Chylice meteorological station, PAR recorded by ceptometer and crop biomass, the following indices (Varlet-Grancher et al. 1993) were calculated: $e_b = CdW_c / PAR_c$ - biological efficiency of transformation PAR intercepted by canopy, $e_c = 1 - PAR_c/PAR_i$ - efficiency of PAR absorption by the canopy, RUE, e - energy yield being a product of e_b, e_c, e_r and R_s; assuming the e_r fraction of R_s global solar radiation in the PAR range as 0.476 (according to station and ceptometer instructions) and C - free energy released during hydrolysis of chemical bonds of photosynthetic products as 17 KJ g^{-1} (Varlet-Grancher et al., 1993); dW_c - biomass formed in given time period. Obtained data were analyzed using two-way ANOVA (Statgraphics 3.1). First order factor was cultivar, second one – rate of nitrogen fertilization.

Results

Differences in above ground dry matter biomass of oats were much smaller as compared for that in grain yield (Table 1). It points to much better distribution of assimilates in cv. Chwat than cv. Akt. On average, naked morphotype yielded worse by 52.8 % as compared to traditional one.

Table 1. Grain yield in dependence on cultivars and nitrogen fertilization, t ha^{-1}

Cultivars	Nitrogen rate, kg N ha^{-1}	Biomass d.m., g m^{-2}	Grain yield, g m^{-2}
Chwat	0	3260	2755
	30	3652	3058
	60	4465	3188
	90	4580	3266
	120	4018	3058
	Mean	3995	3065
Akt	0	3240	1385
	30	4083	1429
	60	3806	1741
	90	3747	1853
	120	4153	1836
	Mean	3806	1649

In the case of hulled morphotype nitrogen fertilization up to 90 kg N ha^{-1} increased both biomass dry matter and grain yield, while with the hulless one although the effect of this rate was the same in the case of grain yield, the 30 kg N ha^{-1} was quite enough for canopy growth.
Efficiency of PAR absorption by the oat canopy fertilized or not fertilized with applied in experiment nitrogen rates was higher in traditional cultivar Chwat (Table 2, significance of differences see Table 4). Nitrogen fertilization affected efficiency of PAR absorption by the canopy (e_c) as well as that of biological transformation of intercepted radiation in both studied oat morphotypes.

Table 2. Indices of energetic analysis in dependence on cultivars and nitrogen fertilization

Cultivars	Nitrogen rate, kg N ha^{-1}	Indices of energetic analysis	
		e_c	e_b
Chwat	0	0.596	0.034
	30	0.617	0.038
	60	0.656	0.046
	90	0.668	0.047
	120	0.651	0.042
	Mean	0.638	0.041
Akt	0	0.559	0.034
	30	0.604	0.042
	60	0.625	0.039
	90	0.622	0.039
	120	0.624	0.043
	Mean	0.607	0.039

e_b – biological efficiency of transformation PAR intercepted by canopy,
e_c – efficiency of PAR absorption by the canopy, RUE,
e_r – 0.476 the fraction of global solar radiation in the PAR range

Value of e_c for cv. Chwat, was increasing with fertilization rate up to 90 kg N ha^{-1}, while efficiency of PAR absorption in cv. Akt canopy increased with fertilization rate up to 60 kg N ha^{-1}. Efficiency of biological transformation of PAR absorbed by the canopy (e_b) was similar for control treatment of both cultivars. In the case of cv. Chwat taken across the combinations it was a bit higher in cv. Chwat as compared to cv. Akt (0.041 vs 0.039). The e_b in this cultivar increased following nitrogen fertilization till the rate of 90 kg N ha^{-1}. In naked morphotype fertilization with 30 kg N ha^{-1} caused substantial increment of e_b by 0.009 as compared to the control. Combinations fertilized with 60 or 90 kg N ha^{-1} characterized with a bit less e_b values comparing to that fertilized with 30 kg N ha^{-1}. The combination of naked morphotypes given the highest fertilization rate of nitrogen (120 kg N ha^{-1}) showed maximum biological efficiency of PAR transformation. Analysis of energy yield (e) of studied cultivars showed again cv. Chwat prevailed over cv. Akt in this respect (Fig. 1).

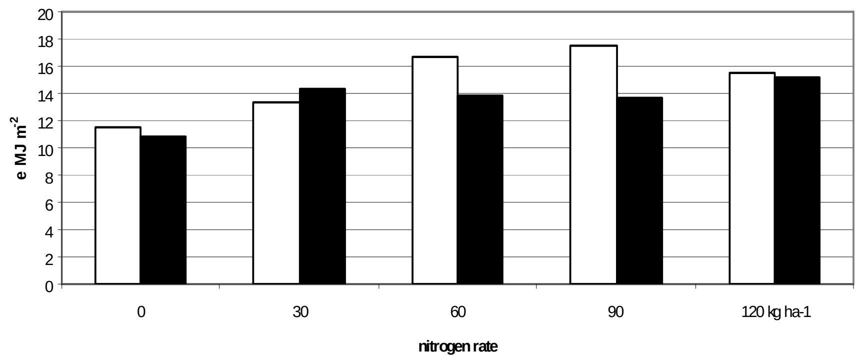

Figure 1. Energy yield (e) (MJ m^{-2}) in dependence on cultivars and nitrogen fertilization (□ – cv. Chwat, ■ – cv. Akt).

The range of e for cv. Chwat varied from 11.4 to 17.9 MJ m^{-2} , on average 15 MJ m^{-2}, while that for cv. Akt from 10.6 to 15.2 and averaged 13.6 MJ m^{-2}. The data on mean energy yield of biomass for global radiation energy 1191 MJ m^{-2} reaching canopy during vegetation indicate efficiency of use this energy which was 1.26 % for cv. Chwat and 1.24 % cv. Akt.

The radiation use efficiency in biomass production across studied cultivars and rates ranged 2.72 – 3.85 g MJ^{-1} (Fig. 2).

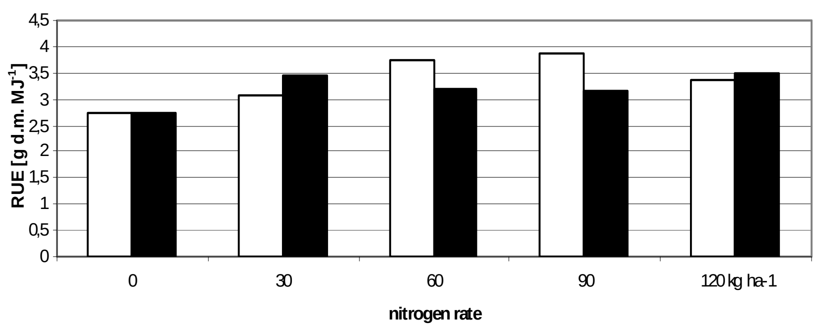

Figure 2. Radiation use efficiency of PAR (RUE) values for whole photosynthetic production in dependence on cultivars and nitrogen fertilization, g d.m. MJ^{-1} (□ – cv. Chwat, ■ – cv. Akt)

On average, in traditional cultivar it was 3.36, while in naked one 3.20 g MJ^{-1}. The highest RUE increase for new morphotype was found already between the control and 30 kg N ha^{-1}. The value found at 30 kg N ha^{-1} was simultaneously the highest for this cultivar. RUE for cv. Chwat till 90 kg N ha^{-1} was still increasing, at this rate it was the highest, but the highest increase was observed 30 vs 60 kg N ha^{-1}.

On the average, grain RUE across vegetation period was nearly twice higher in cv. Chwat as compared to cv. Akt (2.77 vs 1.49 g MJ^{-1}, Table 3).

Table 3. Radiation use efficiency (RUE) for grain yield in dependence on cultivars and nitrogen fertilization, g d.m. MJ^{-1}

Cultivars	Nitrogen rate, kg N ha^{-1}	RUE grain, g.d.m. MJ^{-1}
Chwat	0	2.38
	30	2.91
	60	2.94
	90	2.96
	120	2.65
	Mean	2.77
Akt	0	1.23
	30	1.31
	60	1.60
	90	1.65
	120	1.64
	Mean	1.49

When analyzed across all applied nitrogen rates, a significant increase in RUE for nitrogen treatments *vs* control ones is visible. It was the highest with 30 kg N ha^{-1}, already. Further increase in fertilization to 60 and 90 kg N ha^{-1} did not increase RUE, moreover oat under 120 kg N ha^{-1} do manifest a decline in this index. When about Akt it was until 60 kg N ha^{-1} the significant increase of RUE occurred. Increasing thereafter nitrogen rate was not effective at all.

Table 4. Influence of analyzed factors – summary of analysis of variance.

Energy trait	Source of variation		
	Cultivar	Nitrogen rate	Cultivar x Nitrogen rate
1	2	3	4
e_b	n.s.	*	*
e_c	*	*	**
e	n.s.	n.s.	n.s.
RUE grain	**	n.s.	n.s.
RUE biomass	*	*	n.s.

n.s. – not significant difference ; * - significant at α=0.05 ; ** - significant at α=0.01

Discussion

The data gathered in literature show no more than 5.0 % PAR reaching canopy level is transformed. However, they were averaged across many experiments conducted in various locations all over the World, under various climatic conditions (Hay and Walker, 1997). Obtained in this experiment data are a bit smaller than reported for other cereal species by Nichiporovich (1988). Increases of energy yield followed the similar way as increasing biological efficiency of transformation PAR absorbed for both oat morphotypes. Interestingly, there was similar energy yield found for both varieties at the rate of 120 kg N ha^{-1}. The compensation of these yields was reached following significant drop of e value for cv. Chwat as compared to 90 kg N ha^{-1} and due to substantial increase in cv. Akt comparing with 30 kg N ha^{-1}. These two rates much more stimulated e in respective cultivars. It can be that traditional oat morphotype characterizes with increasing energy yield till some given level of fertilization is reached (90 kg N ha^{-1} in our experiment) and further increase in fertilization rate does not ameliorate analyzed physiological parameters. If so, then, naked morphotype, represented here by registered in 1997 cv. Akt seems to be still unstable when about reaction to nitrogen fertilization. Both, the drop of e_b for cv. Akt at 60 or 90 kg N ha^{-1} and unexpected increase in this parameter at 120 kg N ha^{-1} as well as the maximum efficiency of PAR absorption at 60 kg N ha^{-1} indicate that the application of rates higher than 60 kg N ha^{-1} under conditions of performed experiment is not necessary.

The obtained RUE in our experiments are conformed by literature ones (Aufhammer 1998, Hay and Walker 1997). Data from the literature show radiation use efficiency in biomass production used to increase with the level of nitrogen fertilization (Muchov and Davis, 1988; Sinclair and Horie, 1989; Hammer and Wright, 1994). It was confirmed with traditional oat morphotype, represented by cv. Chwat in our experiment. On the contrary, the lack of such relationship in naked morphotype, represented by cv. Akt proved the variety seems to be adapted to effective use of smaller nitrogen rates for biomass production. Morphologically, cv. Akt differs from traditional morphotype only in the respect to reduction of hull share in grain, whereas other features e.g., plant height are nearly the same as in traditional one. Very interesting seems to be to compare the degree of relationship between nitrogen fertilization and RUE for just now developed naked, semidwarf oat morphotypes. The semidwarf one, having only 1.28 % contribution of hull to the grain mass, yet characterizing with short culm (enabling some limitation of energy losses for fotoassimilate transport from leaves to kernels and their accumulation there (Starck 2003) should be an intensive form, same as in the case of e.g. wheat and triticale.

Following some correction of grain yield of cv. Chwat involving average contribution 25.0 % of hull (according to data of Breeding Company Strzelce Ltd.), the yielding of cv. Akt was smaller by 28.3 %. The experiment referred now was conducted in unfavorable for oat growth and development conditions, what enabled us to register bigger negative response of cv. Akt under these conditions.

It seems the higher RUE in cv. Chwat resulted, even after substraction of hulls from the grain, in 28.01 % higher grain yield as compared to cv. Akt. It means that leaving aside the unfavorable weather conditions, the production potential of cv. Akt was significantly smaller in the experiment. Noteworthy, differences between studied morphotypes in dry matter yield produced during vegetation were smaller than in the case of grain yield. It points to less profitable distribution of photoassimilate to the grain in cv. Akt, comparing to the traditional one.

The obtained in the experiment data show the importance of nitrogen effective use by the analyzed oats in the view of environmental effect. Physiologically optimum nitrogen rate 30 kg N ha^{-1} found for naked cv. Akt and quite small increase in yield in traditional cv. Chwat fertilized with physiologically optimum rate 90 kg N ha^{-1} prompt the possibility to limit nitrogen input to the environment. Furthermore mentioned above improved semidwarf morphotype of naked oat if it confirms the effective use of smaller nitrogen rate combined with high yielding would be an interesting solution.

Conclusions

Hulled oat morphotype represented by cv. Chwat characterizes both with higher efficiency of solar radiation absorption and biological transformation of intercepted PAR than naked morphotype, represented by cv. Akt.

Physiologically optimum nitrogen rate for new morphotype of oat is 30 kg N ha^{-1}, as there is negligible decline of PAR absorption by the canopy, while efficiency of biological transformation of intercepted radiation and energy yield are at maximum.

Physiologically optimum nitrogen rate for traditional oat morphotype is 90 kg N ha^{-1}, as there is maximum of efficiency of PAR absorption by the canopy, efficiency of biological transformation of intercepted radiation and energy yield of biomass.

Similar experiment should be conducted with the newly released semidwarf morphotypes of naked oat.

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THE INFLUENCE OF PERMANENT GRASSES ON WINTER WHEAT PRODUCTIVITY IN ORGANIC AND SUSTAINABLE FARMING SYSTEMS

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Abstract

The trial was conducted in light loamy *Dystric Albeluvisol* in Western Lithuania. The influence of mixture (80 % *Trifolium pratense* L. (Tp) cv. Liepsna + 20 % *Phleum pratense* L. (Pp) cv. Gintaras II) as green manure on the productivity of wheat was investigated in the organic farming system.

No pesticides and mineral fertilisers were used in Cattle manure 60 t ha^{-1} was applied only. Red clover aftermath was used as green manure. Mineral fertilisers and pesticides according to plant needs and 60 t ha^{-1} of cattle manure were applied in the sustainable farming system. Perennial grasses were grown for hay. Independently of the farming system red clover content in sward during the trial execution was 98.0-99.4 %. The dry mater (DM) yield of red clover regrowth was low (1.17-1.24 t ha^{-1}), because of the lack of precipitation. Higher winter wheat yield (6.72 t ha^{-1}) was obtained from the sustainable farming system. Maintenance with nutrients was better in sustainable than in the organic farming system, where the wheat yield was 1.8 times lower. Less nitrogen and phosphorus (2.8 and 2.6 times respectively) were applied to soil with green manure in the organic farming system when compared with the sustainable farming system.

Key words

Red clover, organic and sustainable farming systems, winter wheat

Introduction

The maintenance of potential soil fertility is related to soil humus conservation (Teit, 1990). Humus reduction is often observed in intensive farming systems (Abdallahi and Dayegamiye, 2000; Tate, 1991). In order to preserve soil fertility organic material, should be applied. Plants are attributed as being one of the major factors responsible for soil fertility.