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LEEK HYBRID YIELD POTENTIONAL AND RELATION ON ADAPTATION TO LIGHT INTERCEPTION UNDER NITROGEN SUPPLY

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We have studied the effect of nitrogen supply on growth as well as relation on adaptation to light interception of leek (*Allium porrum* L.,) hybrid Alita, genotype of known genetic background. During the vegetative and generative plant growth phases, besides genetic potential many factors affect their productivity. The aim was to investigate genome expression dependent on nitrogen nutrition and light interception. Nitrogen in correlation with light availability has important effect on the growth of plants and the formation of leaf area, what it is necessary for yield of dry matter. Investigation has been done in open field grown leek commercial hybrid Alita (*Allium porrum* L.,) to consider the way of its genotype response to correlation of light interception and nitrogen nutrition. Investigated traits are leek crop productivity, light interception and chemical analyses of plants. Leek crop productivity was determined through

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the dry matter production, leaf area development and light interception. Analyses of leek plants comprehended chemical determination and calculation of total nitrogen concentration, nitrogen critical concentration in dry matter, nitrogen demand and, nitrogen uptake in leek crop. Correlation among investigated parameters was assigned to comprehensive hypothetical model of growth and productivity of leek crop grown at open field.It was shown that for nitrogen uptake (Nu), nitrogen demand (ND) and total nitrogen concentration (Nt) parameters variants of mineral nutrition plays significant role (p_{Nu}=0.002; p_{ND}=0.045; p_{Nt}=0.011). Obtained results indicated that correlation of nitrogen and light interception could be used as criteria in plant breeding.

Key words: leek hybrid, light interception, nitrogen, dry matter, yield

INTRODUCTION

Crop productivity depends on genotype and environment interaction, influencing numerous processes that occur in plants throughout their ontogeny. Nitrogen in correlation with light interception has important effect on the growth of plants and the formation of leaf area, what it necessary for the production of dry matter (RAHN *et al.* 2010). Nitrogen source for higher plants is nitrate, transported into root cells where is stored in the vacuole and is either reduced in the cytoplasm to ammonium by the nitrate assimilatory pathway (HIREL and LEA, 2002) or transported to the leaves, where it can be stored or reduced (CRAFORD, 1995). The distribution of nitrate assimilation throughout the plants depends on the plant species, age and environmental factors, being the nitrate supply one of the most important factors (WOODALL and FORDE, 1996). Nitrate reductase (NR) is genetically a highly regulated enzyme throughout a hierarchy of transcriptional and post-translational controls (CAMPBELL, 2002). Regulation of NR responds to different factors, such as light, chloroplast factors, reduced nitrogen compounds etc. However, nitrate is the main signal that induces the accumulation of NR (STITT, 1999). Nitrate assimilation takes place both in leaves and in roots (HELDT, 1997)

The present study put special attention to a role of nitrogen dynamics parameters of dry matter synthesis in leek commercial hybrid Alita (*Allium porrum* L.,) and light interception of the canopy on investigated hybrid plants (BREWSTER, 2008). That is important as it could provide information about optimal nitrogen mineral nutrition of leek hybrid, as well as monitoring it during all growth phases through vegetation phase. Mathematical analysis could also allow modeling the effect of light interception and nitrogen on dry matter production and yield of leek crop (RAHN et *al*. 2010). It means that there is a considerable interest in investigations of leaf area development, light interception and canopy expansion. Highly intensive research could focus on the relationship between absorption of photosynthetic active radiation and leaf area development. Results of BOOIJ et *al*. (1996) showed an exponential increase of absorbed photosynthetic active radiation with the increase in leaf area index. Traditionally, the calculations of the optimum of crop nitrogen fertilization are based on the determination of nitrogen content in crop, or in soil. However, according to BOOIJ and MEURS (2002) the system based on measurement of parameters of photosynthetic active radiation is equally reliable as a system based on determining only available nitrogen in soil. Furthermore, MANDAL and SINHA (2004) asserted that the system based on photosynthetic active radiation measurements and calculation of light interception was easier for application and, therefore, they recommended it. The aim of the presented research was to test the relationship between light interception and nitrogen dynamics parameters in dry matter accumulation in leek hybrid grown at open field.

MATERIALS AND METHODS

Dutch leek (*Allium porrum*L.) hybrid Alita has been grown outdoors, on the cambic soil at Agronomy Faculty experimental field Radmilovac in conventional practice of leek growing for three years. Material has been harvested in vegetative growth phase (DE SWART *et al.* 2004, CENTRE FOR GENETIC RESOURCES, 2011). Nitrogen application was done in the particular variants: a) full dose immediately before planting, 250kgN/ha + 0 (variant: 250+0); b) full dose twenty days after planting, 0+250kgN/ha (variant: 0+250); c) and half the dose immediately before planting and half the dose of twenty days after planting, 125kgN/ha + 125kgN/ha (variant: 125+125). Leek plants were sampled on 91^{st} day after planting, during vegetative growth phase of 12 to 14 leaves (SALIBA-COLOMBANI *et al.* 2001. RABINOWITCH and CURRAH, 2002). Dry matter content (W) of plant samples was determined by drying (at 105°C) for approximately 24 hours. Nitrogen critical concentration (Nc) was calculated by the equation for leek [% Nc = 1.35 (1+1.77 exp-0.26W)] according to GREENWOOD and DRAYCOTT (1989). Nitrogen uptake of leek (Nu) of leek plants calculating according to BOOIJ *et al.* (1996): Nu = W* Nt (W - production of dry matter, t/ha, and Nt – total nitrogen concentration in dry matter, %). Leaf area was determined by leaf scanning procedure and computer processing (Photo Shop software), and leaf are index (LAI) was calculated according to LARCHER (2003) as ratio of total leaf area and land **area**. Leaf area index is an indicator of ground coverage by canopy. The LI-COR Quantum Sensor (LI-190SA Quantum Sensor) was used to measure light interception IPAR at the time of solar maximum elevation (±1 h) every ten days during the vegetation period of leek. Light interception (I) was calculated according to STUTZEL (1995) as it is in still valid and correct. Determination of light interception (IPAR or I) was based on measurements of photosynthetic active radiation interception (mcromol/s/m^2) on the crop and the soil surface (the crop) and leaf area index, light interception calculated crop of leeks (SAVIĆ and STIKIĆ, 2005). Determination of total nitrogen in the dry matter was done by applying traditional distillation micro - Kjeldahl method. Critical nitrogen concentration in the plant material, according to GREENWOOD & DRAYCOTT (1989) means the minimum concentration of nitrogen in the plant at the moment of achieving maximum growth. In addition, the asymptotic function, which was set by LANDSBERG (1977), is in scientific usage even nowadays to describe that relationship. Critical nitrogen concentration in the plant material is calculated by the following formula

Nc = 1.35 * (1 + B * e-0, 26W) where variables are:

Nc - the critical concentration of nitrogen in the dry matter (%);
W - dry matter (t/ha);
B - coefficient (its value depends on the crop).

GREENWOOD and DRYCOTT(1989) determined the value of the coefficient B for 26 vegetable crops. Thus, according to these authors, the leek value B is 1.77, so that the equation for this kind of vegetable is: Nc = 1.35 * (1 +1.77 * e - 0, 26W). Nitrogen demand of leek crop was calculated by formula given by GREENWOOD (1986) and GREENWOOD *et al.* (2010). Nitrogen demand is the multiplied values of dry matter production of plants (W) and the critical concentration of nitrogen in the dry matter (Nc) represent the minimum concentration of nitrogen in the dry matter needed for maximum plant growth. Based on that fact, the need for nitrogen (ND) of leek plants was calculated according to the equation:

ND = (W * Nc) / 0.7 where variables are

ND - nitrogen demand (kg/ha);W - production of dry matter (t/ha);
Nc - the critical concentration of nitrogen in the dry matter (%)
0. 7 - coefficient of efficiency of nitrogen utilization from soil.

Nitrogen uptake (kg N/ha) of leek crop calculated by multiplying the dry matter production of crop (t/ha) and nitrogen concentration (%) in dry matter (BOOIJ *et al.*, 1996) according to the equation:

Nu = W * Nt where variables are

Nu - nitrogen uptake (kg/ha);
W - production of dry matter (t/ha);
Nt - total nitrogen concentration in dry matter (%)

At the same time, a significant indicator of the nitrogen uptake and dry matter is universal formula in the GREENWOOD-*et al*. (1990):

ln (Nu) = 4.05 +0.5 ln (W) where variables are
Nu - nitrogen uptake (kg N/ha);
W - production of dry matter (t / ha);
4.05 and 0.5 - coefficients

Statistical analysis - The results were presented as mean values with standard deviation (SD) for evaluated parameters. To evaluate the presence of statistical significance between different variants of mineral nutrition has been used Unifactorial ANOVA test. For comparison of means between two different variant of mineral nutrition in observed parameters, student's t test was used. The statistical significance was set at $p<0.05$.

RESULTS AND DISCUSSION

The principal route by which inorganic nitrogen is incorporated into organic compounds is the assimilatory nitrate reduction pathway as a vital biological process in higher plants, algae, and fungi. Nitrate assimilation is a highly regulated process because of its dependence on photosynthesis for energy and reductants as well as the toxicity of the metabolites of this pathway, nitrite and ammonium. Accordingly, gene expression and enzyme activity of the various proteins involved in this pathway are regulated by both internal and external stimuli such as nitrate itself, carbon and nitrogen metabolites, growth regulators, light, temperature and carbon dioxide concentration (ASLAM *et al.*, 1997).

LEA and co-workers (2006) have shown that the posttranslational regulation of NR is apparently much more important than the transcriptional regulation for setting the levels of amino acids, ammonium, and nitrate in N. *plumbaginifolia*. Control of NR gene transcription facilitates long-term responses to the nitrate signal (hrs to days), whereas post-translational regulation allows rapid changes in NR activity (mins to hrs). Results obtained and presented in this paper similarly to BOOIJ et *al.* (1996) showed that dry matter production increasing during the vegetation period without of significant statistical difference for all variants of nitrogen application. Leaf area index in leek crop increased with increasing dry matter production (SAVIĆ, 2010). The relationship between LAI and W, followed a highly significant exponential curve [LAI=8.77(1-e-0.16W), r^2=0.97]. Similarly, in all applied treatments intercepted photosynthetic active radiation was exponentially dependent on leaf area index's development. It was shown by equation I=1-e-0.187LAI, r^2=0.99. The results of several authors on leek demonstrated that during the vegetation period of leek critical nitrogen concentration decreased with the increase in dry matter production asymptotically approached the X-axis (GREENWOOD and DRAYCOTT, 1989; TEI *et al.*, 2002; RILEY and VAGEN, 2003;TEI *et al.*, 2003). The relationship between dry matter production and nitrogen concentration in dry matter also showed similar tendency, with the lowest nitrogen concentration values in the 125+125 treatment.

Correlations between investigated parameters showed that nitrogen treatment led to increased values of some parameters. The split-dose treatment induced the highest increase in dry matter production, leaf area and values of light interception parameters. The variant 250+0 most intensively influenced dry matter production and growth of leek in the initial stages of growth. Towards the end of vegetation, however, the 125+125 treatment with nitrogen proved the best method of application in terms of timing, followed by 0+250, while the lowest results achieved by the 250+0 treatment (SAVIĆ *et al.*, 2006). Consequently, one-off application of the entire dose of nitrogen immediately before planting out (250+0), and 20 days after planting out (0+250) had a more significant effect on the production of dry matter in the first half of the growing period of leek. The obtained experimental results showed that light interception parameters and dry matter production increased over the vegetation period of leek crop, and light interception had significant influence on dynamics on nitrogen parameters in dry matter of leek crop (SAVIĆ *et al.*, 2006).

Table 1.Dry matter production and nitrogen parameters in different variants of mineral nutrition in leek canopy

Parameters for N=10	DAP (day after planting)	Variant 250+0	Variant 125+125	Variant 0+250
		Experimental data	Experimental data	Experimental data
W (t/ha) Dry matter	91	4.67±0.92	5.47±0.57	4.99±0.87
Nu (kgN/ha) Nitrogen uptake	91	159.38±19.37	191.37±21.42	165.78±17.14
Nc (%) nitrogen critical concentration in dry matter	91	2.06±0.23	1.93±0.31	2.00±0.11
ND (kgN/ha) Nitrogen demand	91	137.42±9.29	150.56±12.39	142.79±11.62
Nt (%) Total nitrogen concentration in dry matter	91	3.17±0.21	2.85±0.12	3.23±0.42

Namely the study revealed the importance of light interception and dry matter parameters for the information about leek nitrogen and dynamic of nitrogen parameters. In order to show it focus were on statistical examination of dynamics of nitrogen parameters on 91st day after transplanting, as it is period important for harvesting leek crop and its productivity (SAVIĆ, 2010). The nitrogen parameters in correlation with mineral nutrition for the leek field crop on the 91st day of transplanting are presented in Tab. 1. Statistical interpretations of evaluated parameters in experimental model for 91st day after planting are presented in Tab. 2.

Obtained results stressed out that type of variant used in mineral nutrition did not correlate with dry matter production parameter significantly. However, when comparisons between two means of different variants were applied it was shown that to the certain degree type of nutrition 125+125 resembles to be significantly more effective than 250+0 variant. These results imply to the possible assumption that even though we found non-significant correlation, the most effective variant for dry matter production parameter was 125+125 and the least effective were 250+0. Concerning the nitrogen uptake parameter, obtained results clearly pointed out that the variant of mineral nutrition plays significant role. Namely, as for dry matter production parameter the most effective variant of mineral nutrition is 125+125. Regarding other two variants of nutrition, it was found that these two are equally less effective ($p=0.444$). The variant of nutrition for the evaluation of critical nitrogen concentration parameter did not correlate closely with the values after the 91st day of harvest. It was shown as well that all three variants were equally effective when comparison between two means was applied, suggesting that for the Nc parameter productivity all of evaluated modules of nutrition could be equally effective and could be applied in practice (SAVIĆ, 2010). When nitrogen demand parameter was analyzed in our study, it was shown that variant of mineral nutrition correlate with the values of ND (SAVIĆ *et al*. 2004). As for dry matter production, it was shown as well that the more effective variant is 125+125, while less effective was 250+0 variant. It was shown that for Nt parameter variant of nutrition correlate with the Nt values, with type of 125+125 nutrition to be most effective, while other two variants were shown to be equally less effective ($p=0.691$). It could be seen that present study put special attention to a role of nitrogen parameters dynamics in dry matter of leek crop and light interception of the canopy, which could provide information about optimal nitrogen mineral nutrition of leeks, as well as monitoring it during all growth phases through vegetation phase of leek crop (AGOSTINI *et al.* 2010). Mathematical analysis could also allow modeling the effect of light interception and nitrogen on dry matter production and yield of leek crop (RAHN *et al.*2010). It means that there is a considerable interest in investigations of leaf area development, light interception and canopy expansion. Highly intensive research could focus on the relationship between absorption of photosynthetic active radiation and leaf area development. Results of BOOIJ *et al.* (1996) showed an exponential increment of absorbed photosynthetic active radiation with the increase in leaf area index. Traditionally, the calculations of the optimum of crop nitrogen fertilization have been based on the determination of nitrogen content in crop, or in the soil. However, according to BOOIJ and MEURS (2002) the system based on measurement of parameters of photosynthetic active radiation is equally reliable as a system based on determining only available nitrogen in soil. Furthermore, MANDAL and SINHA (2004) asserted that the system based on photosynthetic active radiation measurements and calculation of light interception was easier for application and, therefore, they recommended it.

Table 2. Statistical interpretation of evaluated parameters in experimental model for 91st day after planting

Evaluated parameters	Unifactorial ANOVA (p values)	Students t test (p values)		
		250+0/125+125	250+0/0+250	125+125/0+250
W (t/ha) Dry matter	0.099	*0.031*	0.435	0.162
Nu (kgN/ha) Nitrogen uptake	*0.002*	*0.003*	0.444	*0.009*
Nc (%) nitrogen critical concentration in dry matter	0.465	0.301	0.466	0.510
ND (kgN/ha) Nitrogen demand	*0.045*	*0.015*	0.269	0.165
Nt (%) Total nitrogen concentration in dry matter	*0.011*	*0.001*	0.691	*0.013*

CONCLUSION

Obtained results on leek hybrid genotype yield expression represented possibility to take them in account for modeling of productivity and growth through determination of light interception at open field, under nitrogen nutrition. It was shown that variant of mineral nutrition did not correlate with dry matter parameter significantly. But, comparison between two different nutrition variants showed that variant 125+125 resemble to be significantly more effective than 250+0 variant. Present study put special attention to a role of a genotype and nitrogen parameters dynamics in dry matter of leek crop and light interception of the canopy, which could provide information about optimal nitrogen mineral nutrition of leeks, as well as monitoring it during all growth phases through vegetation phase of leek crop. Obtained results indicated that correlation of nitrogen and light interception could be used as criteria in plant breeding.

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GENETIČKI POTENCIJAL HIBRIDA PRAZILUKA I ZAVISNOST ADAPTACIJE NA INTERCEPCIJU SVETLOSTI I PRIHRANJIVANJE AZOTOM

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Dobijeni rezultati u ispitivanjima hibrida praziluka na genotipsko ispoljavanje prinosa, pomoću utvrđivanja intercepcije svetlosti lisnog pokrivača praziluka gajenog na otvorenom polju u uslovima dodatne mineralne ishrane azotom. Pokazano je da uticaj varijante đubrenja nije značajno statistički povezano sa produktivnošću useva, ali srednje odstupanje pokazuje da je za ostale ispitivane parametre varijanta 125 +125 efikasnija od varijante 250+0 prilikom berbe 91. dana od dana rasađivanja. U navedenim ispitivanjima posebna pažnja je posvećena ulozi genotipa i dinamici parametara azota u suvoj materiji useva praziluka kroz intercepciju svetlosti, koja može da pruži informacije o optimalnoj ishrani azotom u različitim fazama rastenja i razvića biljaka praziluka tokom vegetacionog perioda.

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