THE POSSIBILITIES OF USE OF NITROGEN HARVEST INDEX IN WHEAT BREEDING IN TERM OF ECOLOGICAL AGRICULTURE

Olivera NIKOLIC[1], Milanko PAVLOVIC[1], Miodrag JELIC[2]

[1]EDUCONS University, Sremska Kamenica, Vojvode Putnika 87, Serbia
[2]Faculty of Agriculture, Lesak, Kopaonicka bb, Serbia
(Corresponding author: nikolicolivera69@yahoo.com)

Abstract

The topic of nitrogen wheat nutrition was becoming very actually during last decades of last century because of many reasons: fertilizers price, energetic crises, environmental protection, ecological agriculture. Despite the detrimental impacts, the use of fertilizers (N in particular) in agriculture, together with an improvement in cropping systems, mainly in developed countries, have provided a food supply sufficient for both animal and human consumption. Therefore, the challenge for the next decades, with an expanding world population, will be to develop a highly productive agriculture, whilst at the same time preserving the quality of the environment. A multidisciplinary approach to breeding winter wheat and include physiological indicators of nitrogen nutrition efficiency could help in achieving this goal. Consequently, this paper deals with physiological indicator as nitrogen harvest index, its connection with grain yield, heritability and variance and evaluation of Serbian winter wheat genotypes in term of this indicator. The best values of nitrogen harvest index were registered at KG 165/2, Pobeda and Bujna. Emphasized genotypes, selected as superior in term of this indicator, could be considered as carriers of de desirable traits in terms of wheat breeding theory, improvement of production efficiency, environmental protection and development of ecological agriculture.
Key words: breeding, ecological agriculture, nitrogen harvest index, wheat.

Introduction

Despite the detrimental impacts, including pollution of soil and water and deterioration of food safety, the use of fertilizers (N in particular) in agriculture, together with an improvement in cropping systems, mainly in developed countries, have provided a food supply sufficient for both animal and human consumption. Therefore, the challenge for the next decades, with an expanding world population, will be to develop a highly productive agriculture, whilst at the same time preserving the quality of the environment (Hirel et al., 2001; Patel et al., 2004; Shrawat et al., 2008; Weinkauf, 2008). One way to enhance productivity and maintain efficient production and minimize environmental impact is to develop specific cropping strategies and select productive genotypes that can grow under low N conditions (Delmer, 2005). A multidisciplinary approach to breeding winter wheat and include physiological indicators of nitrogen nutrition efficiency could help in achieving this goal (van Ginkee et al., 2001; Baker et al., 2004; Flowers et al., 2004; Zivanovic et al., 2006; Pathak et al., 2008).
The concept of the nitrogen nutrition efficiency of a crop should be considered a function of root activity, soil texture, climate conditions, interactions between soil and bacterial processes, the nature of organic or inorganic N sources and genetics specificity (Walley et al., 2002; Burger & Jackson 2004; Lopez - Bellido et al., 2005; Haberle et al., 2006). The direct evaluation of root system activity as a measure of plant absorption efficiency is difficult under

field conditions indirect measurements are possible. The relationship between indicators of absorption efficiency as well as nitrogen utilization ones and desirable traits such as grain yield in this case is an important question. Many authors (Anderson et al., 2004; Gallais & Coque, 2005) have defined parameters that affect grain yield positively.

Nitrogen harvest index (the ratio of nitrogen content in grain and in the whole plant) is a measure of the efficiency of nitrogen translocation from vegetative organs to the grains.Nitrogen harvest index reflects the grain protein content and thus the grain nutrition quality (Hirel et al., 2007) and, for wheat, usually ranges from 0.70 to 0.80 (Brancourt - Hummel et al., 2003).

The objective of this study was to investigate phenotypic variability of nitrogen harvest index and its relationship with grain yield in thirty bread wheat genotypes, grown under different environmental conditios during three year, at sub – optimal nitrogen soil provided.

Material and method

The study was carried out on the property of the Small Grains Research Center in Kragujevac city (186 m.a.s.l.) in Serbia, during the three consecutive seasons (2001/02, 2002/03 and 2003/04). The soil type was smonitza in degradation (Vertisol).

The average temperatures and monthly rainfall during the wheat vegetation period (October-June) for the three seasons and the 30 years mean (1970-2000) are shown in table 1. In all three years, the mean temperature was higher than the 30 yr average. There was considerable variability in rainfall amounts and distribution from year to year. The amount of rainfall was most suitable for plant growth in the third season. Rainfall (74.5mm), received during the germination period (October - November) in the first season was less than in other two (97.00mm and 111.8mm) and long-term average (94.73 mm). Rainfall distribution during the rest of the vegetative period in the first season was auspicious but the total amounts of rainfall were less than long – term means.

Table 1. Weather conditions during the three test growing season and long-term (30-yr) mean for (LTM) winter wheat

Month	Average monthly temperatures (C)				Monthly amounts of rainfall (l)			
	2001/02	2002/03	2003/04	LTM	2001/02	2002/03	2003/04	LTM
X	13.8	12.2	10.6	11.40	10.4	65.5	83.2	47.53
XI	4.6	9.7	8.9	5.90	64.1	31.5	28.6	47.20
XII	- 2.4	1.1	2.2	2.13	27.6	39.4	37.2	44.33
I	- 0.1	0.7	- 0.9	0.73	17.2	59.0	86.4	36.70
II	7.0	- 2.4	3.0	2.42	20.1	19.7	59.5	35.77
III	8.9	5.8	7.1	6.43	26.0	2.8	21.3	41.57
IV	10.8	10.8	12.8	11.22	63.7	37.2	52.3	50.77
V	18.4	19.9	14.5	16.24	38.6	42.3	50.3	65.43
VI	21.6	23.3	19.8	19.40	57.2	47.7	61.4	81.27
Season average					Total			
9.18	9.01	8.67	8.43		324.9	345.1	483.2	624.43

The experiment included 30 wheat cultivars and experimental lines, originating from the Serbia: Small Grains Research Center, Kragujevac and Institute of Field and Vegetable Crops, Novi Sad. The basic processing and pre – sowing preparation of the soil was done using

standard procedures. The randomized complete block experimental design was used with five replicates in rows 1.5m on, with spacing between rows of 0.20m. Sowing (200 grains per row) was done by hand (one genotype per row), during the optimal planting period for central Serbian conditions, for winter wheat (29. 10. 2001, 15. 11. 2002 and 06.11. 2003). NPK fertilizer, formulated 8:24:16, was applied at the rate of 300 kg ha^{-1} before sowing each season. Eight grams row[-1] of nitrogen (260 kg KAN ha^{-1}) was added at the tillering stage of growth development each season.

Plant samples of each genotype were taken at maturity (five plants per replication). The samples were air – dried and grain yield (GY, g m^{-2}), weight of straw at maturity (DMstraw, g m^{-2}) and total above – ground biomass at maturity (BY, g m^{-2}) were measured. All dry vegetative samples and grain were first ground and then plant N concentration was determined by the standard macro- Kjeldahl procedure. Nitrogen content (at grain, straw and total at maturity) was calculated by multiplying the N concentration by dry weight (gN m[-2]). Moreover, the nitrogen harvest index (NHI) was calculated according to Arduini et al. (2006) as follows:

NHI = Ngrain / N content of aboveground parts at maturity (Ntotal) (%)

The components of variability, broader - sense heritability, standard errors and coefficients of variability of these parameters, as correlation coefficients, their standard errors and test of significance were determined according to Chaudhary et al. (1999).

Results and discussion

Analysis of variance (ANOVA) revealed highly significant (P<0.01) differences among genotypes and years as well as highly significant year x genotype interaction NHI. Three-year average of all investigated genotypes was 75% (Table 2). Genotype means for NHI varied from 67% (KG 10) to 79% (KG 165/2).

The N harvest index, defined as N in grain to total N uptake, is an important consideration in cereals. NHI reflects the grain protein content and thus the grain nutritional quality (Hirel et al., 2007). It can be recommended as a selection criterion for nitrogen use efficiency improvement, while improving NUE is one of possibilities for developing new high-yielding quality wheat cultivars (Gorjanovic et al., 2011).

The fact that increasing doses of nitrogen did not lead to increased NHI is very important in terms of ecological agriculture, saving nitrogen fertilizer and minimizing their possible harmful effect on environment. Moreover, the majority of genotypes had the highest value on the control and low N variants (Le Gouis et al., 2000; Chen et al., 2011).

Nitrogen harvest index for wheat usually ranges from 0.70 to 0.80 (Brancourt-Hummel et al., 2003). More than half of studied genotypes had NHI over 75%, which is desirable from a wheat breeding point of view.

Table 2. Average values of nitrogen harvest index (NHI) in three – years investigation

NHI Genotype	$\overline{X}$ (%)	S	Cv
Morava	74	1.17	3.64
Lepenica	75	1.63	5.18
Studenica	76	0.75	2.16
Takovcanka	72	0.58	1.82
Toplica	75	1.05	3.05

Srbijanka	71	0.93	2.86
KG – 100	72	0.86	2.76
Lazarica	73	0.86	2.70
Bujna	77	0.51	1.49
Matica	77	0.37	1.10
Vizija	72	0.95	3.26
Pobeda	78	0.73	2.14
Ran 5	76	1.11	3.52
Evropa 90	77	6.22	19/09
Renesansa	77	2.77	8.77
Tiha	74	0.97	3.04
Mina	71	0.71	2.33
Prima	77	1.69	5.00
Kremna	75	1.03	3.37
Rusija	74	0.93	2.98
Pesma	76	1.98	6.41
KG 200/31	74	0.81	2.78
KG 253/4-1	76	0.75	2.41
KG 115/4	77	0.73	2.13
KG 165/2	79	0.73	2.17
KG 56/1	77	0.58	1.78
KG 100/97	76	0.32	1.02
Perla	76	0.93	2.94
KG 224/98	74	0.55	1.70
KG 10	67	1.46	4.97
$\overline{X}$	75		
Factor	A**	B**	A x B**
$LSD_{0.05}$	0.75	2.36	4.09
$LSD_{0.01}$	0.98	3.11	5.38

From a practical point of selection is not desirable that the total variation (phenotypic variation Vp) has a greater share of environmental variance (Ve) compared to genetic (Vg) (Zivanovic, 1997). Significantly larger share of the total variation of genetic variance to the environment means less influence of environmental factors on the realized variation of these traits, which in terms of selection and breeding is considered a very favorable ratio. The obtained results about relation Ve : Vg = 7.92 : 25.58 (Table 3) confirm possibility of use NHI as selection criterion.

Table 3. Components of variability, coefficients of variation and broad – sense heritability of NHI

Trait	year	Vp	Ve	Vg	Relative share of Vp (%)		CVp	CVg	H^2
					Ve	Vg			
NHI	1	22,63	12,19	10,44			6,63	4,51	0,46
	2	52,10	2,70	22,40			9,19	6,03	0,43
	3	25,76	8,87	16,89	24	76	6,81	5,52	0,66
$\overline{X}$		33,50	7,92	16,58			-	-	0.52

The correlation coefficients for NHI and GY (0.65**, 0.49**) and NHI and BY (0.37**, 0.33**) were significant in the second and third year. The relation between NHI and indicators of DM accumulation, utilization and distribution vary depending on the year (Nikolic et al., 2011). NHI is very reliable indicator of nitrogen utilization efficiency for protein synthesis and its correlation with GY depends on the intensity of that process. These results indicate the ability of these genotypes to use nitrogen for protein synthesis more efficiently than for grain filling. This feature may change depending on growing conditions.

Table 4: The simple genotypic and phenotypic correlation coefficients between nitrogen harvest index and grain and biological yield

Indicator	Year	GY	BY
genotypic correlation coefficients			
NHI	1	0,06	- 0.13
	2	0,41**	0.19
	3	0,06	0.07
phenotypic correlation coefficients			
NHI	1	0,10	0.06
	2	0,65**	0.37**
	3	0,49**	0.33**

Conclusion

Considering obtained results, it can be concluded that investigated materials represents a desirable variability source and has beneficial relationship between variability components and broader – sense heritability. Therefore, it can be considered as important material for future breeding programs of wheat.

Judging by obtained results, NHI, as physiological indicator, could meet requirements to the wheat selection and breeding in terms of improvement productivity in specific circumstances, characteristic, above all, as appropriate safe food production and ecosystem protection.

The strong and statistically high significant interrelationships between grain and biological yield and wheat nitrogen harvest index were registered. The results could be helpful in wheat breeding and for production efficiency while reducing the adverse impacts on the ecosystem Therefore, the nitrogen harvest index as parameter of wheat nitrogen nutrition efficiency, depending on the circumstances, could be successfully used for the evaluation and selection genotypes, adapted to the low – input systems, ecological and organic agriculture.

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