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Olivera NIKOLIĆ, Ljubinko JOVANOVIĆ,
Miodrag JELIĆ, Milivoje MILOVANOVIĆ, Milanko PAVLOVIĆ [1]

VARIABILITY OF SERBIAN WINTER WHEAT GENOTYPES AND THEIR EVALUATION IN TERMS OF SUSTAINABLE AGRICULTURE

SUMMARY

The topic of nitrogen for wheat nutrition has become quite important over the last few decades for many reasons. The most important are the energy crises and the escalation of the price of fertiliser, causing a decrease in profitability of small grains production and an adverse impact from the excessive use of nitrogen (N) fertiliser on the ecosystem and the production healthy safe food. Despite the detrimental impacts, the use of chemical fertilisers, especially N in agriculture, together with an improvement in cropping systems (mainly in developed countries), has provided a food supply sufficient for both animal and human consumption. Therefore, the challenge for the next few decades, considering the expanding world population, will be to develop highly productive agriculture, whilst at the same time preserving the quality of the environment. A selection approach to this issue is to identify winter wheat genotypes efficient in absorption and utilisation of soil nitrogen, which would be desirable for both practical production and breeding programs. Consequently, this paper deals with an evaluation of Serbian winter wheat genotypes in terms of some indicators of their nitrogen absorption and utilisation efficiency. Genotypes KG 10, Evropa 90, and Morava were the most efficient at nitrogen accumulation in the aboveground part of plant during the phases of anthesis, grain, straw, and total nitrogen accumulation at maturity. The best nitrogen partitioning between grain and straw was registered in the genotypes KG 165/2, Pobeda and Bujna. Prima, Lepenica and Studenica had the most efficient reutilization of nitrogen, which accumulated in the plant until anthesis, while the genotypes KG 200/31, KG 253/4-1 and KG 10 expressed the greatest ability to continue nitrogen assimilation during the reproductive period. Genotypes, selected as superior in absorption and utilization of nitrogen, are considered the carriers of desirable traits in terms of wheat breeding theory, improvement of production efficiency, environmental protection, and the development of sustainable agriculture.

Keywords: ecosystem, efficiency, genotypes, nitrogen, wheat

INTRODUCTION

In terms of ecological agriculture and ecosystem protection, it is important to search for species or genotypes that are able to absorb and accumulate high concentrations of Nitrogen (N). Although it is well known that there is some

[1] Olivera NIKOLIĆ (corresponding author: nikolicolivera69@yahoo.com), Ljubinko JOVANOVIĆ, Milanko PAVLOVIĆ, EDUCONS University, Sremska Kamenica, Miodrag JELIĆ, Faculty of Agriculture, Leshak, Milivoje MILOVANOVIĆ, Small Grains Research Center, Kragujevac, Serbia

genetic variability in maximum N uptake in wheat (Le Gouis et al 2000), the physiological and genetic basis for such variability has never been thoroughly investigated. As described in the review articles of Lemaire et al (2004) and Hirel and Lemaire (2005), it is possible to develop a framework for analysing the genotypic variability of a crop's N uptake capacity across a wide range of genotypes, thus allowing the selection of those with the greatest capacity to accumulate an excess of N.

It is therefore of major importance to identify the critical steps controlling plant N use efficiency (NUE). Moll et al (1982) defined NUE as being the yield of grain per unit of available N in the soil (including the residual N present in the soil and the fertiliser). This NUE can be divided into two processes: uptake efficiency (NupE; the ability of the plant to remove N from the soil) and utilization efficiency (NutE; the ability to use N to produce grain yield). This challenge is particularly relevant to cereals for which large amounts of N fertilisers are necessary to attain maximum yield and for which NUE is estimated to be far less than 50% (Zhu, 2000). In addition to the improvement of N fertilisation, soil management, and irrigation practices (Alam et al 2004), there is still a significant margin to gap to improve NUE in cereals by selecting new hybrids or cultivars from the available ancient and modern germplasm collections in both developed and developing countries. There are several indicators; we can come to conclusions about nitrogen utilisation efficiency on the basis of these, particularly an understanding of the nitrogen harvest index and the physiological efficiency of nitrogen. Many researchers have pointed out the correlation of these understandings with wheat grain yield, emphasising their importance in selecting genotypes for practical production as well as wheat breeding programs (van Ginkel et al 2001; Pathak et al 2008).

The aim of this study is to evaluate wheat genotypes on the basis of nitrogen nutrition efficiency indicators.

MATERIAL AND METHODS

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

Table 1. Chemical characterization of soil (0-20 cm) before establishing experiments (Summer, 2001)

Chemical characteristics	Summer 2001
Water pH	6.23
KCl pH	5.15
Total N	0.25%
Available K (K_2O)	28.8 mg $100g^{-1}$
Available P (P_2O_5)	13.8 mg $100g^{-1}$
Organic matter	2.65%

The soil type was smonitza in degradation (Vertisol). The chemical analyses were carried out in the Agrochemical Laboratory of the Centre, where a moderate level of soil fertility and acidity (Tab. 1) was indicated.

Table 2. Weather conditions during the three test growing seasons and the long-term (30-yr) mean (LTM) for winter wheat

month	Average monthly temperatures (^oC)				Monthly amounts of rainfall (l)			
	2001/ 2002	2002/ 2003	2003/ 2004	LTM	2001/ 2002	2002/ 2003	2003/ 2004	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 average temperatures and monthly rainfall during the wheat vegetation period (October-June) for the three seasons and the 30 year mean (1970-2000) are shown in Table 2. In all three years, the mean temperature was higher than the 30 year average. There was considerable variability in rainfall amounts and distribution from year to year.

The experiment included 30 wheat cultivars and experimental lines, all originating from the Serbia Small Grains Research Centre, in Kragujevac and the Institute of Field and Vegetable Crops, in Novi Sad: Morava, Lepenica, Studenica, Takovcanka, Toplica, Srbijanka, KG 100, Lazarica, Bujna, Matica, Vizija, Pobeda, Rana 5, Evropa 90, Renesansa, Tiha, Mina, Prima, Kremna, Rusija, Pesma, KG – 200/31, KG – 253/4 – 1, KG – 115/4, KG – 165/2, KG – 56/1, KG – 100/97, Perla, KG - 224/98 and KG – 10. The experiment was set up as a randomized complete block system design, with five replications. The sowing was done manually, with a genotype per row. The sowing rate was 200 grains per row. The row length was 1.5m and the distance between rows 0.20m. NPK fertiliser (8:24:16) was used for basic fertilization (300kg ha^{-1}) and KAN in the tilling stage (7.5 – 8 g per row i.e. 250 – 260 kg ha^{-1}).

Plant samples of each genotype were taken at anthesis (10 plants per replication) and maturity (five plants). The samples were air-dried. The above-ground weight of the plants at anthesis (DManthesis, g m^{-2}), the grain yield (GY, g m^{-2}), the weight of the straw at maturity (DMstraw, g m^{-2}) and the total above-ground biomass at maturity (BY, g m^{-2}) were measured. All dry vegetative samples and grain were first ground, and then the plant N concentration was determined by the standard macro-Kjeldahl procedure. Nitrogen content (at anthesis, grain, straw and total at maturity) was calculated by multiplying the N concentration by the dry weight (gN m^{-2}). Moreover, the following parameters, related to N accumulation and translocation within the wheat plant during grain filling, were calculated according to Arduini et al 2006 and Masoni et al. (2007), as follows:

1. Nitrogen harvest index (NHI) = Ngrain / N content of aboveground parts at maturity (Ntotal) (%)

2. Nitrogen reutilisation (NreU) = Nanthesis – Nstraw (g m^{-2})

3. Nitrogen lost (–) or gained (Npost - anthesis) = N content at maturity – N content at anthesis (g m^{-2})

The data collected were statistically analysed through the method of two-factorial analysis of variance. The least significant differences (LSD) are reported at the 5% (*$P < 0.05$) and 1% level of confidence (**$P < 0.01$).

RESULTS AND DISCUSSION

Over three years the average value of the N content in plants at anthesis, grain, straw, and whole maturated plant of all investigated genotypes was 8.65g m^{-2}, 8.06g m^{-2}, 2.88g m^{-2} and 10.93 g m^{-2}, respectively (Table 1). The average value of NHI was 75%. The efficiency of N reutilisation and the efficiency of post-anthesis N assimilation of tested genotypes were, on average, 5.70g m^{-2} and 2.44g m^{-2}, respectively. The average N content in a plant at anthesis varied, among investigated material, from 4.64g m^{-2} (KG 200/31) to 13.03g m^{-2} (KG 10). The same genotypes had the lowest (4.90g m^{-2}, KG 200/31) and the highest (12.92g m^{-2}, KG 10) values of N content. In grain, Prima was the genotype with the lowest efficiency of N accumulation in straw (1.60g m^{-2}), while KG 10 expressed the highest value of this parameter (5.39g m^{-2}). Total N content in a matured plant varied from 7.13g m^{-2} (KG 200/31) up to 18.31g m^{-2} (KG 10). The best distribution of nitrogen between grain and straw (NHI 79%) was registered in KG 165/2, but the worst (NHI 67%) in KG 10.

Reutilisation of N was carried out most efficiently in KG 10 (7.77g m^{-2}), but the least efficient was in KG 200/31 (2.79g m^{-2}). Nitrogen lost during the post-anthesis period was observed in Lazarica (-0.52 g m^{-2}), but the highest N increase during that period was observed in KG 10 (5.75g m^{-2}).

Looking at the presented results, we can mark off several genotypes with very high and satisfactory values for parameters that indicate the capacity for soil nitrogen accumulation, as KG 10, Evropa, KG 100, Morava, Lazarica, Matica, Vizija, Mina, KG 56/1 etc. The mentioned genotypes are, mainly, very efficient in terms of reutilisation of the nitrogen reserves stored in the vegetative parts of the plant, and nitrogen assimilation during the reproductive period. They can be considered a source of desirable traits in the wheat breeding process and substantial support in the planning of a sustainable crop production. Identification of such genotypes is very important because strong relationships have been reported between indicators of nitrogen accumulation efficiency and grain yield in wheat. Statistically significant and strong interrelation of grain yield and N content in the plant at anthesis is very important for bringing wheat breeding to grain yield.

Table 3. The three years' average values of some nitrogen nutrition efficiency indicators for the investigated genotypes

Indicator / Genotype	N-anthesis	N-grain	N-straw	N-total	NHI (%)	NreU	N-post-anthesis
Morava	10.42	11.84	4.19	16.02	74	7.09	4.20
Lepenica	7.92	6.41	2.04	8.44	75	5.83	0.50
Studenica	8.91	7.94	3.02	10.96	76	5.80	2.45
Takovčanka	8.41	7.46	3.14	10.59	72	5.17	2.09
Toplica	8.14	7.30	2.82	10.12	75	5.12	2.25
Srbijanka	8.74	7.20	3.12	10.32	71	4.90	2.47
KG – 100	10.51	9.05	4.07	13.12	72	6.72	2.41
Lazarica	9.73	6.37	2.38	8.75	73	6.79	-0.52
Bujna	7.83	7.28	2.38	9.66	77	5.25	2.35
Matica	9.31	9.34	2.89	12.23	77	6.36	3.11
Vizija	8.38	8.27	3.75	11.89	72	4.90	3.40
Pobeda	7.62	7.65	2.07	9.72	78	5.54	2.51
Rana 5	7.46	7.83	2.47	10.27	76	4.94	2.69
Evropa 90	11.49	11.93	3.64	15.22	77	7.11	4.79
Renesansa	6.77	6.85	2.36	9.21	77	4.45	2.61
Tiha	7.91	7.88	2.70	10.64	74	5.15	2.90
Mina	9.21	8.48	3.31	11.79	71	5.98	2.33
Prima	7.17	5.63	1.60	7.28	77	5.26	0.70
Kremna	8.71	7.79	3.07	10.93	75	5.44	2.15
Rusija	8.45	7.79	2.86	10.65	74	5.85	2.13
Pesma	7.19	6.01	1.87	7.88	76	5.18	0.93
KG 200/31	4.64	4.90	2.23	7.13	74	2.79	2.20
KG 253/4-1	8.40	9.79	3.59	13.38	76	4.55	5.11
KG 115/4	9.56	8.09	2.70	10.80	77	6.61	1.68
KG 165/2	8.77	8.19	2.45	10.63	79	6.19	2.13
KG 56/1	9.65	8.55	2.75	11.27	77	6.93	1.53
KG 100/97	9.08	8.29	2.40	10.68	76	6.51	2.05
Perla	9.19	8.99	3.06	12.05	76	6.08	2.87
KG 224/98	6.99	5.69	2.19	7.81	74	4.87	1.48
KG 10	13.03	12.92	5.39	18.31	67	7.77	5.75
$\overline{X}$	8.65	8.06	2.88	10.93	75	5.70	2.44

It has been deduced in previous investigations (Bebyakin and Kairgaliev, 2004; Barbottin et al 2005; Nikolic et al 2011) that excess N at maturity can be accumulated in the period before flowering, often the total N, subject to environmental conditions and genotypes traits. It means, essentially, the estimation and selection of progeny can be carried out precisely and certainly during earlier plants' growing and developing phases.

It is clear that KG 10 was the most efficient genotype in nitrogen accumulation during the period including anthesis and up to maturation. KG 10 expressed the best ability to use N, accumulated in the plant during the vegetative period, and the best ability to continue N assimilation during the reproductive period. The ability to use the N stored in the plant during the vegetative period is a very important trait, especially taking into consideration the unfavourable weather conditions during the reproductive period which limit N assimilation (Barbottin et al 2005). Very often, even 90% of grain nitrogen comes from reutilised nitrogen. The effectiveness of a genotype in continuing nitrogen assimilation during the reproductive period, regardless of environmental conditions, is its value. It is interesting that KG 10, as a superior genotype, had the lowest value of NHI.

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 2001). It can be recommended as a selection criterion for nitrogen use efficiency improvement, while improving NUE is one possibility for developing new high-yielding wheat cultivars (Gorjanovic et al 2011).

CONCLUSIONS

Tested Serbian wheat genotypes represent an important source of many desirable traits in terms of contemporary agriculture and breeding. According to the parameters of the study, they showed remarkable effectiveness in nitrogen accumulation and utilisation. In this sense, there can be distinguished genotypes: KG 10, Evropa, KG 100, Morava, Lazarica, Matica, Vizija, Mina and KG 56/1, as the most efficient genotypes in nitrogen accumulation genotypes: KG 165/2, Pobeda, Bujna, Renesansa, Prima and KG 115/4, separated as the most efficient in nitrogen distribution and utilisation, can be added to the previous group with desirable traits. Prima, Lepenica and Studenica had the most efficient reutilisation of nitrogen, accumulated in the plant until anthesis, while genotypes KG 200/31, KG 253/4 – 1 and KG 10 expressed the greatest ability to continue nitrogen assimilation during the reproductive period.

There is no doubt that these genotypes, generally, can answer the demands of sustainable agriculture. Further investigations are necessary to examine, in details, the possibility of their application in wheat breeding to increased yield in contemporary farming systems conditions.

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Olivera NIKOLIĆ, Ljubinko JOVANOVIĆ,
Miodrag JELIĆ, Milivoje MILOVANOVIĆ, Milanko PAVLOVIĆ

VARIJABILNOST SRPSKIH GENOTIPOVA OZIME PŠENICE I NJIHOVA OCENA SA ASPEKTA ODRZIVE POLJOPRIVREDE

SAŽETAK

Pitanje ishrane pšenice azotom postaje veoma aktuelno poslednjih decenija prošlog veka, iz mnogo razloga. Najvažniji su energetska kriza i rast cena đubriva, što je prouzrokovalo smanjenje profitabilnosti proizvodnje strnih žita. Prekomerna upotreba azotnih đubriva ima niz neželjenih efekata na ekosistem i proizvodnju zdravstveno bezbedne hrane. Uprkos tim neželjenim efektima, primena azotnih đubriva, zajedno sa unapređenjem sistema gajenja, posebno u zemljama u razvoju, jedino može da obezbedi dovoljne količine hrane za ljudsku i animlanu ishranu. Stoga je izazov u sledećim dekadama, u uslovima širenja ljudske populacije, omogućiti razvoj visoko produktivne poljoprivrede, uz istovremeno očuvanje i zaštitu ekosistema. Selekcioni pristup ovom pitanju podrazumeva identifikaciju genotipova ozime pšenice, efikasnih u usvajanju i iskorišćavanju zemljišnog azota, koji su poželjni i sa aspekta praktične proizvodnje i sa aspekta oplemenjivanja pšenice. Shodno tome, u radu se ocenjuju genotipovi ozime pšenice, selekcionisani u Srbiji, na osnovu pokazatelja efikasnosti usvajanja i iskorišćavanja azota. Genotipovi KG 10, Evropa 90 i Morava su bili najefikasniji u akumulaciji azota u nadzemnom delu biljaka, u periodu do cvetanja, u zrnu, slami i ukupnoj akumulaciji azota u zreloj biljci. Najbolja raspodela azota između zrna i slame zabeležena je kod genotipova KG 165/2, Pobeda i Bujna. Prima, Lepenica i Studenica imale su najefikasniju reutilizaciju azota, dok su genotipovi KG 200/31, KG 253/4 – 1 i KG 10 ispoljili najveću sposobnost da nastave asimilaciju azota i tokom reproduktivnog perioda. Genotipovi, koji su izdvojeni kao superiorni u usvajanju i iskorišćavanju azota, mogu se smatrati nosiocima poželjnih osobina sa aspekta oplemenjivanja pšenice, poboljšanja produktivnosti proizvodnje, zaštite životne sredine i razvoja održive poljoprivrede.

Ključne riječi: ekosistem, efikasnost, genotip, azot, pšenica