Bulgarian Journal of Agricultural Science, 21 (No 3) 2015, 599-604
Agricultural Academy

NITROGEN FERTILIZATION OF DURUM WHEAT VARIETIES

G. PANAYOTOVA[1*] and Sv. KOSTADINOVA[2]
[1]*Trakia University, Faculty of Agriculture, Student Campus, BG - 6000 Stara Zagora, Bulgaria*
[2]*Agricultural University, Faculty of Agronomy, BG - 4000 Plovdiv, Bulgaria*

Abstract

PANAYOTOVA, G. and Sv. KOSTADINOVA, 2015. Nitrogen fertilization of durum wheat varieties. *Bulg. J. Agric. Sci.*, 21: 599–604

The response of durum wheat to nitrogen (0; 80; 120 and 160 kg N.ha^{-1}) was studied in a long-term fertilizing experiment in crops rotation cotton – durum wheat for the period 1998 – 2010 in Institute of field crops – Chirpan, Bulgaria. The experimental design consisted of split-plots design with four replications. Assessment of durum wheat response to nitrogen was studied by means of main nitrogen use efficiency indicators Partial factor productivity (PFP) and Agronomic efficiency (AE). It was found that durum wheat varieties positively responded to nitrogen fertilization. Average of thirteen years, relative grain yield increased with 25-29% at a rate of N_{80}; by 40-43% at a moderate rate of N_{120}, and by 45-46% at the rate N_{160}. The yield variation was highest at no fertilized control for both varieties. Throughout the thirteen years period PFP for nitrogen changed in the range from 15.6 to 77.1 kg.kg^{-1} and depended on the yield level, respectively on the climate conditions. Variety Progress showed higher PFP at N_{80} compared to variety Vazhod and the difference was 11.2 kg.kg^{-1}. AE for nitrogen varied from 0 to 26.7 kg.kg^{-1}. In average, AE slightly changed in dependence of nitrogen rate and variety and was in the range 9.6 -12 kg.kg^{-1}.

Key words: nitrogen, durum wheat, partial factor productivity, agronomic efficiency

Abbreviations: PFP - Partial factor productivity; PFPN - Partial factor productivity of applied nitrogen;
AE - Agronomic efficiency

Introduction

Human demands for food, fiber, and biofuel production are rising with the world's population. Use of mineral fertilizers sustains the world's growing population and sparing millions of hectares of natural and ecologically-sensitive systems that otherwise would have been converted to agriculture (Cassman, 1999). Today, economic and environmental challenges are driving increased interest in nitrogen use efficiency. Higher prices for both crops and fertilizers have focused interest in efficiency-improving technologies and practices that also improve productivity (Ladha et al., 2005). Risks of increased environmental N losses via leaching, runoff, volatilization and denitrification, which may be associated with increased global N use and that harm air and water quality can be reduced by improving use efficiencies of nutrients (Kuzmanov and Tomov, 2000; Voicu and Soare, 2012). Since fertilizers are made from non-renewable resources, pressure to increase their use efficiencies will continue and at the same time, efforts should increase to enhance fertilizer use effectiveness for improved productivity and profitability of cropping systems (Horhota, 2012; Koteva and Marcheva, 2012b). Nitrogen fertilization is expected to increase to satisfy these growing human needs. Future fertilizer N management decisions must be increasingly based on economic, social, and environmental goals. On-farm N use efficiency and effectiveness can be improved, through better management of N sources, rates, timing, and placement (Koteva and Marcheva, 2012a). A goal of improving N use efficiency by 25% from current levels is considered achievable in the United States and may also be within the reach of many developing countries (Dobermann and Cassman, 2002).

According to Dobermann and Cassman (2005) 66% of fertilizer N was used to fertilize cereal crops, mainly corn and wheat. By raising N use efficiency and effectiveness through better cropping system and fertilizer N management, societal food fiber and biofuel demands may be met while

* E-mail: galia_panayotova@abv.bg

also protecting air, water, and soil resources for current and future generations.

Partial Factor Productivity (PFP) of nutrients due to factor fertilization answers the question what is the productivity of the system compared to nutrient inputs. This index is the simplest form for the yield efficiency and is calculated in units of crop yields per unit nutrient element. It is used as long-term indicator of trends (Fixen, 2009). Higher levels indicate of higher imported amount of nutrients, while lower - limiting productivity deficit. Typical values of the nitrogen partial productivity were about 40-80 $kg.kg^{-1}$. The higher rates than 60 $kg.kg^{-1}$ were in very efficiently managed systems, or at low nitrogen rates and low soil nitrogen supply.

Partial factor productivity of nitrogen (PFPN) (often simply called nitrogen use efficiency or NUE) was changed from a high value at low N fertilization to lower values by increasing the nitrogen levels. PFPN for cereals in world declined from 245 kg grain.kg N imported in 1961-1965 to 52 $kg.kg^{-1}$ in 1981-1985 and in recent years was an average of about 44 kg per kg N (Snyder and Bruulsema, 2007). The increase in yields with increasing nitrogen fertilization was the reason for the decline. In many developed countries the yields of cereals continued to rise over the past 20 years without significant changes in fertilization. PNP sustainable was increased in Western Europe, North America, and Japan since the mid 80s of last century (Dobermann and Cassman, 2005). At present time, the average cereals yield in these regions are 60 to 100% higher than those at nitrogen rates higher only with 30 to 60% of the world (Dobermann and Cassman, 2005). High yield and high PNP rates were the result of fertile soil, favorable weather conditions and excellent agrotechnics. Giller et al. (2004) also reported that significant increases in nitrogen use efficiency are often achieved through reductions in N fertilizer use by 10 to 30%, while increases in yield tend to be small.

Since 1960, improved nitrogen efficiency leads to a sharp decline in the PNP on average 1-2% per year in developing countries (Dobermann and Cassman, 2005). Too high values of this parameter in Africa (122 $kg.kg^{-1}$ imported N), in Eastern Europe and Central Asia (84 $kg.kg^{-1}$) are indicators of unsustainable use of soil due to the low nitrogen requirements.

The partial productivity of the imported element is the most important indicator for grain farmers because it integrates the use efficiency of soil elements and the efficiency of applied fertilizers (Doberman, 2007; Hawkesford, 2012; Snyder and Bruulsema, 2007).

Agronomic efficiency (AE) of applied nutrient answers the question what is the increase in yield resulting from the nutrients. AE is used as a short term indicator of the nutrient impact on the productivity (Moll et al., 1982). Average values of AE of nitrogen for the wheat was approximately 10-30 kg grain yield increase per kg N applied. Lower levels suggest that changes in management can increase productivity. Values higher than 25 kg grain per kg N are obtained in systems with best practices, low levels of nitrogen or low supply of soil nitrogen. AE is the result of the return of the applied fertilizer and the efficiency with which the plant uses each additional unit of the nutrient (Hawkesford, 2012; Snyder and Bruulsema, 2007). AE characterizes the plants ability to increase production in response to nitrogen or other fertilizers (Novoa and Loomis, 1981; Craswell and Gowdin, 1984) and for wheat depends to a large extent of nitrogen fertilization and the climatic conditions (Delogua et al., 1998). AE is often used for economic assessment of fertilization and generally decreased with increasing fertilizer rates (Kostadinova and Velkov, 2003; Kostadinova and Tomov, 2003; Panayotova and Kostadinova, 2004; Kostadinova et al., 2010; Moll et. al., 1982; Kostadinova, 2003).

The partial productivity of nutrient is calculated easily for each farm that observes the holdings and income. To determine the AE is required plot without fertilization.

The objective of this study was to examine the response of durum wheat to nitrogen fertilizing based on main indicators of nitrogen effectiveness – partial factor productivity and agronomic efficiency.

Materials and Methods

The response of durum wheat varieties Progres and Vazhod to nitrogen fertilization was studied in a long-term fertilizing experiment in Institute of field crops – Chirpan, Bulgaria. These two varieties are Bulgarian standards for yield and quality. The investigation was established in two field crops rotation (cotton – durum wheat) under rain conditions for the period of thirteen vegetations including years 1998 – 2010. The experimental design consisted of split-plots design with four replications. The harvested size of the plots was 10 m^2. The treatments were as follows: 0; 80; 120 and 160 kg $N.ha^{-1}$. Nitrogen fertilization in the form of NH_4NO_3 was applied before sowing (1/3 of the rate) and at early spring (2/3 of the rate). The phosphorus fertilization (P_{80}) was done before sowing in the form of triple superphosphate. The precursor crop was cotton fertilized by N_{80}.

The soil type of experimental field was *Pellic vertisols* (FAO) and generally refers to the so called Mediterranean chernozems. The soil type is one of the most generous and widely spread and significant in Bulgaria. It is suitable for growing most of the field crops and has a potential for high yield. The main parent materials are pliozen clay deposits. It has a high-powered humus horizon (70–80 cm), with a compact zone of the profile (united horizon). By humus content it belongs to the mean humus soils. It characterizes with high humidity capacity, caused by the high percentage of clay minerals, with clay soil texture, small water-permeability, bulk density of the arable soil layer 1.2-1.3 g.cm^{-3}, with specific gravity 2.4-2.6 and low total porosity, neutral soil reaction and high cation exchange capacity (CEC) - 35-46 meq per 100 g soil, with high degree of bases saturation (93.4-100.0%), with total N in the arable layer 0.095-0.14% and low content of total phosphorus (0.05-0.11%), poor to medium supplied with hydrolyzed nitrogen, poorly supplied with available phosphorus and well-supplied with available potassium.

Hydro-thermal conditions during the vegetation period of wheat were different: three of the harvested years were very favorable, three of the years were unfavorable, and the temperature and precipitations of the rest seven years were close to the long-term average norm for the region.

The main nitrogen use efficiency indicators Partial factor productivity and Agronomic efficiency were used for assessment of durum wheat response to nitrogen (Dobermann, 2007). AE were calculated as increased yield per unit imported nutrient and clearly reflects the influence of the applied fertilizer. Partial factor productivity (PFP) and Agronomic efficiency (AE) were calculated on dry weight basis using the following formulas: PFP = Y/F (kg.kg^{-1}), and AE = (Y-Y_0)/F (kg.kg^{-1}); where Y and Y_0 were grain yields from fertilized treatments and unfertilized control, respectively, and F - amount of N fertilizer applied (kg.ha^{-1}).

The data were statistically analyzed with the ANOVA procedure within the SPSS statistical program and Duncan's multiple range test (P = 0.05) to find significant differences among means.

Results and Discussion

Durum wheat varieties positively responded to nitrogen fertilization (Table 1). Average of thirteen years, relative grain yield increased of 25-29% at a rate of N_{80}; by 40-43% at a moderate rate of N_{120}, and by 45-46% at a higher rate N_{160}. The yield variation was highest at no fertilized control treatment for both varieties.

PFP represents the kg of product harvested (Y) per kg of N fertilizer applied. It can be used as an index of total economic outputs relative to the use of all N sources (soil N and applied fertilizer). Typical levels of PFP for cereals crops are 40-80 units (Dobermann, 2007). The obtained values of the PFP reduced with increasing of the applied nitrogen amount at the two varieties of wheat (Table 2 and Figure 1).

Table 1
Durum wheat grain yields response to nitrogen fertilization, average for the period 1998-2010 (kg.ha^{-1})

Variety	Fertilization	Yield	Min	Max	Relative yield, %
Progress	N_0	3317 ± 1183	1970	5860	100
	N_{80}	4273 ± 832	3140	6170	129
	N_{120}	4735 ± 785	3020	5850	143
	N_{160}	4849 ± 953	2500	6260	146
Vazhod	N_0	3377 ± 1158	2020	5820	100
	N_{80}	4218 ± 939	2780	6260	125
	N_{120}	4738 ± 975	2750	6000	140
	N_{160}	4896 ± 1006	2330	6290	145

Table 2
Nitrogen use efficiency indicators PFP and AE, average for the period 1998-2010 (kg.kg^{-1})

Variety	Fertilization	PFP*	Min	Max	AE	Min	Max
Progress	N_{80}	53.4^a ± 10.4	39.3	77.1	12.0^{ns} ± 7.36	2.3	23.6
	N_{120}	39.5^b ± 6.5	25.2	48.7	11.8 ± 7.28	0.0	23.8
	N_{160}	30.3^c ± 5.9	15.6	39.1	9.7 ± 7.01	0.0	19.4
Vazhod	N_{80}	42.2^a ± 14.5	25.3	72.8	10.5^{ns} ± 7.02	1.3	26.4
	N_{120}	35.1^{ab} ± 7.8	23.2	52.2	11.4 ± 7.98	0.0	26.7
	N_{160}	29.6^b ± 6.1	17.2	37.5	9.6 ± 7.00	0.0	20.1

*Mean values in the column (separately for Progress and Vazhod) followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test

Throughout the thirteen years period PFP changed in the range from 15.6 to 77.1 kg.kg^{-1} and depended on the yield level, respectively climate conditions. The minimum estimated values of PFP were obtained in 2007 with apply of N_{160} and maximum (72.8 - 77.1) in 2001 at a rate N_{160}. At cultivar Progress, average for the period, differences were mathematically proven for the three used nitrogen rates, while at cultivar Vazhod proven differences were found between the low rate N_{80} and the double higher rate N_{160}. Variety Progress showed higher PFP at N_{80} compared to variety Vazhod and the difference was 11.2 kg.kg^{-1}.

Agronomic efficiency for nitrogen represents the kg of yield increase per kg of N fertilizer applied and typical levels for cereals crops are 10-30 kg.kg^{-1}. Our results demonstrated that agronomic efficiency for nitrogen varied from 0 to 26.7 kg.kg^{-1} (Table 2 and Figure 2). Very low values indicate inefficient use of the fertilizer nitrogen. In average, AE slightly changed in dependence of nitrogen rate and variety and it was varied between 9.6 and 12.0 units. Cultivar Progress was more effective compared to cultivar Vazhod at applying 80 kg N.ha^{-1} - it had by 26.5% higher average value of PFP and by 14.3% higher average AE. The differences in efficiency indexes of nitrogen were eliminated with increasing of the amount of applied nitrogen. The two varieties had very similar values of PFP and AE at a rate of N_{160} average for thirteen years period. Over the years, characterized by the most favorable conditions for the development of durum wheat have a higher additional grain yield per unit of nitrogen fertilizer, which is why the agronomic efficiency is highest.

Conclusions

The main Bulgarian durum wheat cultivars Progress and Vazhod positively responded to applied nitrogen. Average for thirteen years period relative grain yields increased by 25-

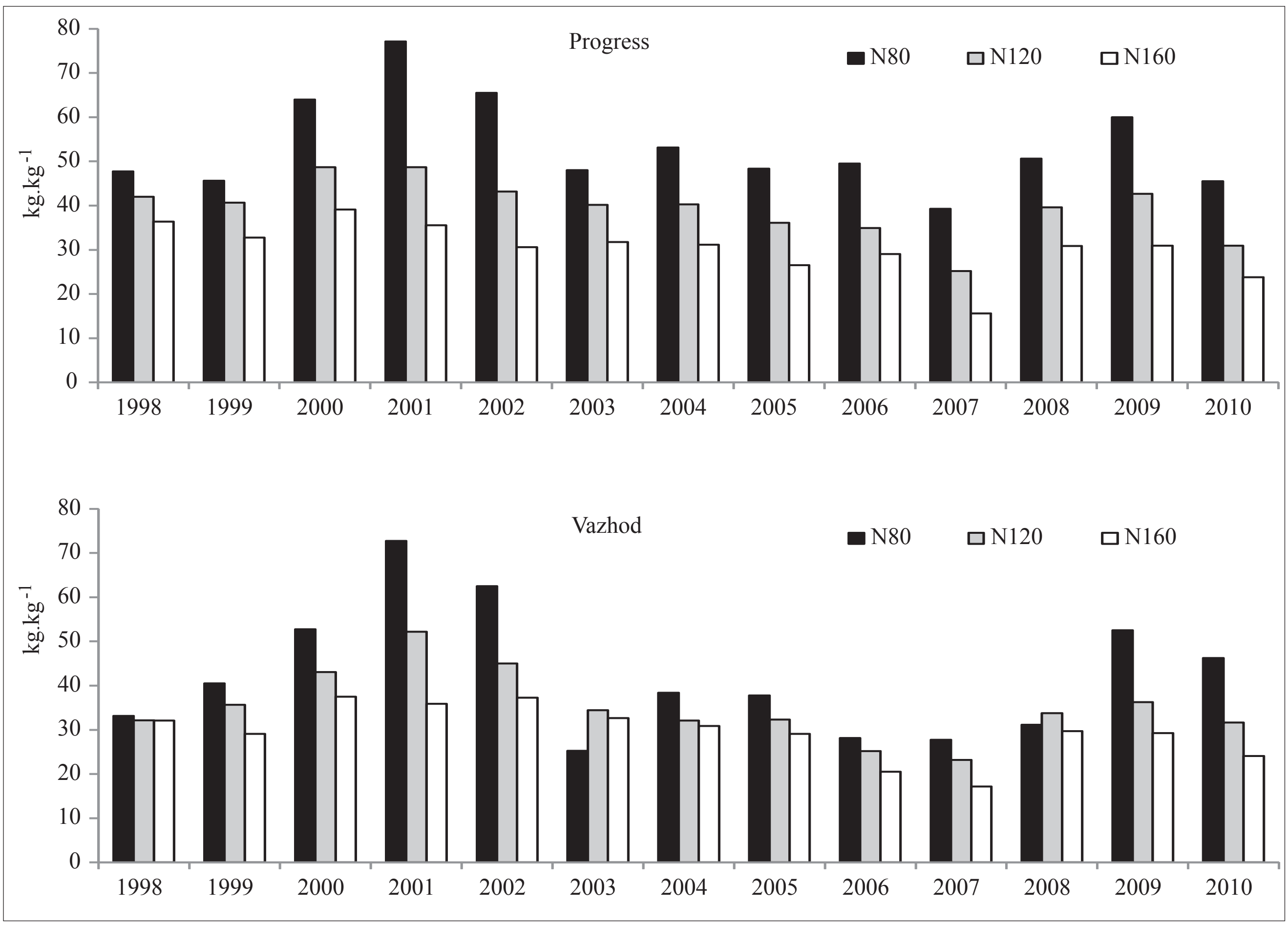

Fig. 1. Partial factor productivity for nitrogen at durum wheat cultivars Progress and Vazhod

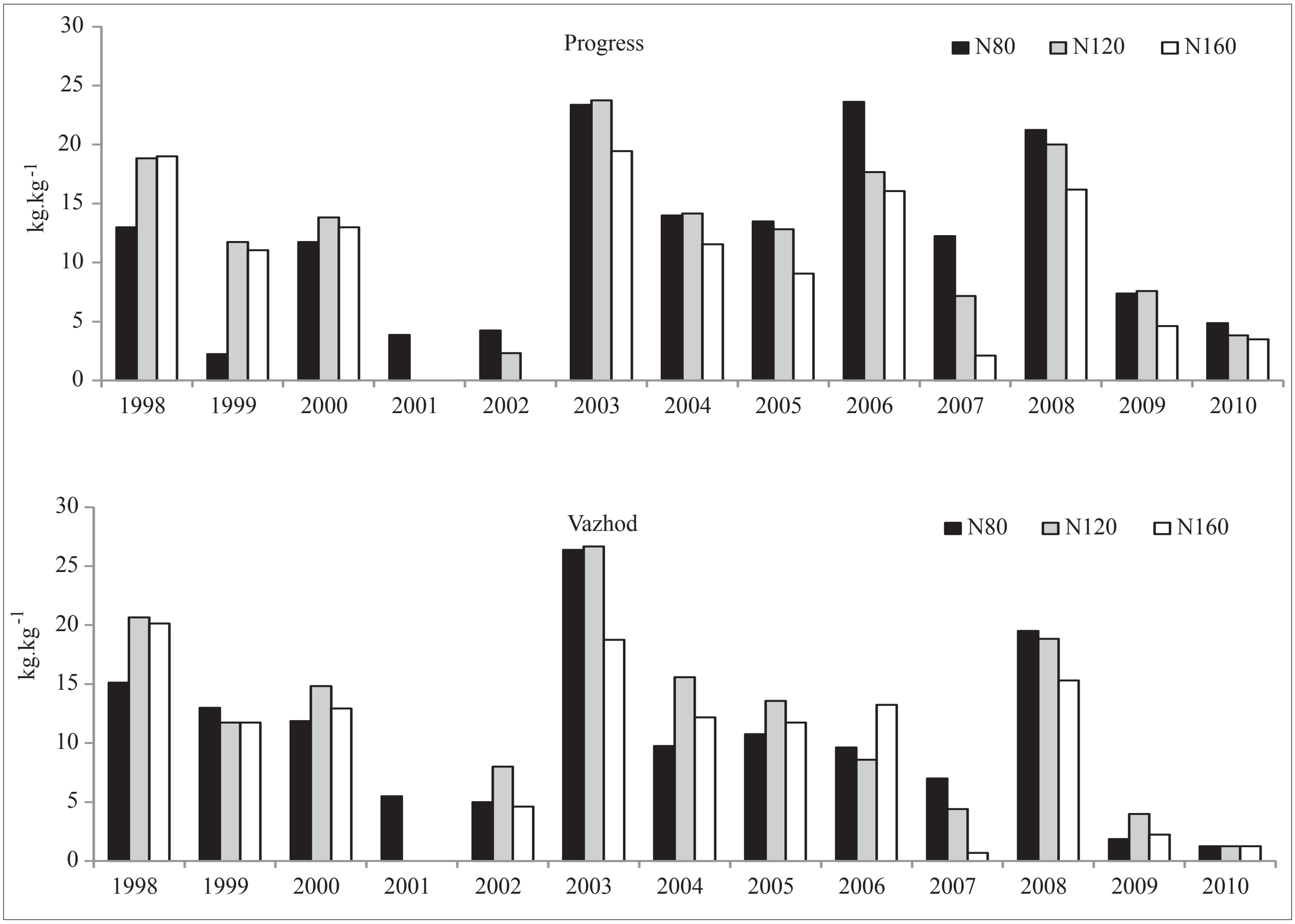

Fig. 2. Agronomic efficiency for nitrogen at durum wheat cultivars Progress and Vazhod

29% at a rate of N_{80}; by 40-43% at a moderate rate of N_{120}, and by 45-46% at a higher rate N_{160}. The yield variation was highest at no fertilized control for both varieties.

Throughout the experimental period Partial factor productivity for nitrogen changed in the range from 15.6 to 77.1 kg.kg^{-1} and PFP depended on the yield level, respectively on the climate conditions. Variety Progress showed higher Partial factor productivity at N_{80} compared to variety Vazhod and the difference was 11.2 kg.kg^{-1}.

Agronomic efficiency for nitrogen varied from 0 to 26.7 kg.kg^{-1}. In average, Agronomic efficiency slightly changed in dependence of nitrogen rate and variety and its values were in the range 9.6 -12 kg.kg^{-1}.

References

Cassman, K., 1999. Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture. *Proceedings of the National Academy of Science of the United States of America*, **96** (11) 5952-5959.

Craswell, A. and P. Godwin, 1984. The efficiency of N fertilizers applied to cereals in different climates, *Advances in Plant Nutrition*, **1**: 1-55.

Dobermann, A., 2007. Nutrient use efficiency - measurement and management. Workshop on Fertilizer Best Management Practices (Proceedings of *International Fertilizer Industry Association* (IFA), Brussels, Belgium, March 2007), pp. 22-27.

Dobermann, A. and K. Cassman, 2002. Plant nutrient management for enhanced productivity in intensive grain production systems of the United States and Asia. *Plant Soil,* **247**: 153-175.

Delogua, G., L. Cattivellia, N. Pecchionia, D. De Falcis et al., 1998. Uptake and agronomic efficiency of nitrogen in winter barley and winter wheat, *European Journal of Agronomy*, **9** (1): 11-20.

Dobermann, A., 2007. Nutrient use efficiency – measurement and management. In: A. Krauss, K. Isherwood and P. Heffer (Eds). IFA International Workshop on Fertilizer Best Management Practices (Proceedings: 7–9 March 2007, Brussels, Belgium, Paris, France) *International Fertilizer Industry Association*, pp. 1-28.

Dobermann, A. and K. Cassman, 2005. Cereal area, yield and nitrogen use efficiency are drivers for future nitrogen fertilizer consumption. *Science in China,* **48**: 745-758.

Fixen, P., 2009. Nutrient use efficiency in the context of sustainable agriculture. In J. Espinosa and F. García (Eds.) Nutrient Use Efficiency. *International Plant Nutrition Institute* (IPNI), USA: pp. 1-10.

Giller, K., P. Chalk, A. Dobermann, L. Hammond, P. Heffer, J. Ladha, P. Nyamudeza, L. Maene, H. Ssali and J. Frene, 2004. Emerging technologies to increase the efficiency of use of fertilizer nitrogen. In A. R. Mosier et al. (Eds.) Agriculture and the Nitrogen Cycle: Assessing the Impacts of Fertilizer Use on Food Production and the Environment. SCOPE 65, *Island Press*, Washington, p. 35-52.

Hawkesford, M., 2012. The diversity of nitrogen use efficiency for wheat varieties and the potential for crop improvement, *Better Crops,* **96** (3): 10-15.

Horhota, L., 2012. Economic efficiency and environmental protection in agriculture. *J. of Environmental Protection and Ecology*, **13** (2): 811.

Kostadinova, S., 2003. Nitrogen fertilization and agronomic efficiency at winter wheat, *Ecology and Future,* **2** (1)**:** 33-36.

Kostadinova, S. and N. Velkov, 2003. Nitrogen fertilizing and efficiency of nitrogen and phosphorus of wheat variety Pobeda. *Ecology and Future*, **2** (1) part II: 64-70.

Kostadinova, S. and T. Tomov, 2003. Fertilizing systems and efficiency of wheat variety Prelom. *Ecology and Future,* **2** (1), part II: 71-76.

Kostadinova, S., N. Yordanova and G. Rachovski, 2010. Fertilization and agronomic efficiency at barley variety Kamenica. *Field Crops Studies*, **6 – 1**: 85-90.

Novoa, R. and R. Loomis, 1981. Nitrogen and plant production, *Plant and Soil*, **58** (1-3): 177-204.

Koteva, V. and M. Marcheva, 2012a. Productivity of common wheat variety Mirjana grown with reduced mineral fertilizing. *Soil Science, Agrochemistry and Ecology*, **3**: 55-62 (Bg).

Koteva, V. and M. Marcheva, 2012b. Productivity of barley variety Veslec grown with reduced mineral fertilizing. *Agricultural Sciences*, **4** (11): 7-13.

Kuzmanov, N. and A. Tomov, 2000. Seasonal monitoring of flowing and non-moving water sources in Parvomaj region in Bulgaria. *J. of Environmental Protection and Ecology*, **1** (3): 324.

Ladha, J., H. Pathak, T. Krupnik, J. Six and C. Van Kessel, 2005. Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. *Advances in Agronomy.* **87**: 85-176.

Moll, R., E. Kamprath and W. Jackson, 1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. *Agronomy Journal*, **74**: 562-564.

Panayotova, G. and Sv. Kostadinova, 2004**.** Economic and energy efficiency of nitrogen fertilization in durum wheat cultivar progress. *Plant Science,* **41** (3): 283-287.

Snyder, C. and T. Bruulsema, 2007. Nutrient Use Efficiency and Effectiveness in North America: Indices of Agronomic and Environmental Benefit. *International Plant Nutrition Institute,* Norcross. GA: pp. 3-15.

Voicu, Gh. and A. Soare, 2012. Protection of waters against pollution by nitrites and nitrates from agricultural sources. *J. of Environmental Protection and Ecology*, **13** (1): 69.

Received April, 20, 2014; accepted for printing January, 20, 2015.