UDC 575:633.11
DOI: 10.2298/GENSR1101091N
Original scientific paper

INTERRELATIONSHIP BETWEEN GRAIN YIELD AND PHYSIOLOGICAL PARAMETERS OF WINTER WHEAT NITROGEN NUTRITION EFFICIENCY

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Nikolić O., T.Živanović, M.Kraljević-Balalić, and M.Milovanović (2011): *Interrelationship between grain yield and physiological parameters of winter wheat nitrogen nutrition efficiency*-Genetika, Vol 43, No. 1, 91 - 100.

This paper deals with interrelationship between grain yield and some physiological parameters of wheat plant nitrogen nutrition efficiency as well as interrelationships between these parameters and some yield related traits (biological yield, grain harvest index). The aim of such investigation is to affirm possibilities of using physiological parameters of wheat plant nitrogen nutrition efficiency as criterions in breeding on its grain yield. The investigation, conducted as three years field trials, included 30 wheat cultivars and perspective lines. There were studied: nitrogen

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content in the above – ground part of plant at anthesis, in grain, in straw and total nitrogen content at maturity, nitrogen harvest index, nitrogen reutilization, post – anthesis nitrogen accumulation and physiological efficiency of nitrogen. The positive and statistically high significant relationships between nitrogen content in the above – ground part of plant at anthesis, in grain and in straw, total nitrogen content at maturity, nitrogen reutilization and post – anthesis accumulation as physiological parameters and grain yield were registered in investigated material. Most of listed parameters, important by grain yield aspect, can be studied easily and measured before wheat vegetative period ends. The investigated parameters can be recommended as criterions for selecting of parental pairs and evaluating progeny in breeding of wheat on grain yield, considering to their determined interrelationships and their measurability.

Key words: breeding, efficiency, nitrogen nutrition, parameters, wheat, grain yield.

INTRODUCTION

Wheat grain yield increasing for two to three times during last half of past century is great result of directed wheat selection and breeding. The grain yield increasing has been, however, followed by grain protein content decreasing up to 10%, even less, at the same time (OURY and GODIN, 2007). Considering that grain protein content is very important trait and indicator of grain quality, too, it is necessary do something to slow up and stop further grain protein dilution as well as retains and increase grain yield of wheat. Contemporary wheat selection and breeding, in the goal to achieve that task and to obtain satisfactory results in increasing productive and quality potential of new genotypes, need involving of new criterions and different scientific knowledge as base (van GINKEL *et al.,* 2001; BRANCOURT-HULMEL *et al*., 2005).

The problem of plant physiology including in selection and wheat breeding programs is actual in investigations for a long time. Obstacles are results of sensitivity of physiological traits towards environmental conditions, complexity of physiological interactions and non existence of adequate methods (ASSENG and MILROY 2006; VÁŇOVÁ *et al.,* 2006; ESTRADA-CAMPUZANO *et al.,* 2008). According to ABELEDO *et al*., (2003), some physiological traits can be used as breeding criterions if its genetic variability and control, relationship with desirable traits (grain yield, mainly) and measurability can be defined and formulated. The importance of some physiological traits in wheat breeding under various environmental conditions analysed: van GINKEL *et al.* (2001); BAKER *et al.* (2004); FLOWERS *et al.* (2004), PATHAK *et al.* (2008); KANDIĆ *et al.* (2009).

Considering very important role of nitrogen in plant life cycle, there is suppose that parameters of plant nitrogen nutrition efficiency present group of traits suitable to contemporary wheat breeding aims. The investigations of BERTIN and GALLAIS (2001); WHITE and BROADLEY (2004); VREUGDENHIL *et al*. (2005); ŽIVANOVIĆ *et al*. (2006); KASTORI *et al*. (2008) represent the base of genetic

investigations in area of mineral and nitrogen nutrition and new aspects in physiology, agrochemistry and genetic and breeding of plant.

The mineral fertilizers using and efficiency of small grains plant nitrogen nutrition is topical subject nowadays, especially because of world energetic crises and fertilizers market, as well as requests for agriculture to be more effective and ecosystem protection appeal at the same time (MALESEVIĆ *et al*., 2010). There is the opinion that by increasing efficiency of wheat plant nitrogen nutrition might be solved many of these problems and found the way to pass negative correlations between grain yield and quality (GORJANOVIĆ *et al*., 2010). The wheat plant nitrogen nutrition is very complex process and its explanation need following and appreciation a lot of physiological traits and reactions. It can be divided into two parts, roughly: absorption of nitrogen from applied fertilizers and soil reserves and its utilization in plant for grain filling and protein synthesis. Basically, the entire process depends on root system activity, mass and absorption capacity, kinds of fertilizers and time of their application, seasonal trends, physiological and genetic factors (LOPEZ – BELLIDO *et al.,* 2005; VUČKOVIĆ *et al*., 2005; BOZHKOV *et al*., 2007). The direct evaluation of root system activity, as trait which works highly on plant absorption efficiency, is hardly deducible in the field conditions. So, there are some certain parameters, suitable to do it indirectly, like: nitrogen content in plant at anthesis or maturity as well as physiological efficiency of nitrogen and nitrogen harvest index as indicators of efficiency of plant nitrogen utilization. By wheat selection and breeding aspects, existance of dependence between these parameters and desirable traits, in other words grain yield in this case, is one of very important questions. Many authors (ANDERSSON *et al.,* 2004; GALLAIS and COQUE, 2005) defined that some of these parameters affect grain yield positively.

On the basis of above mentioned, the aim of this investigation is to determine interrelationship between wheat grain yield and several physiological indicators of plant nitrogen nutrition efficiency, in the group of Serbian genotypes, with further aim to point out possibilities of their using in wheat selection and breeding programs.

MATERIALS AND METHODS

The investigation was carried out in Small Grains Research Center in Kragujevac. Thirty wheat cultivars and perspective lines were included: 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 arranged as field trial, sowing "genotype by row", with five replications, during three years. It is important to accent that genotypes were grown at the same soil conditions, by minimum limit of nitrogen, adding 8,5 g NPK (8: 24: 16) pre – sowing and 7,5 g KAN in tillering, per row.

The plant samples were taken at anthesis and full maturation stages. There were measured the weight (g) of: above – ground part of plant in flowering, grain

and straw per mature plant as well as the nitrogen concentration (%). The weight of grain per plant was computed, using the number of plants per row, and expressed as grain yield (GY) by g m^{2-1}. The biological yield (BY) was calculated as sum of grain yield and the weight of straw, computed at the same way like grain yield. The grain harvest index (GHI) was calculated as ratio between GY and BY and expressed by % (STOJANOVIĆ *et al*., 2004). On the basis of some of that dates, the physiological parameters were calculated using forms by MOLL *et al.,* (1982) and modified forms by DJOKIĆ (1996). So, nitrogen content in the above – ground part of plant at anthesis, grain and straw were calculated multiplying their weight per plant and N concentration in it and expressed by g m^{2-1}. Total nitrogen content at maturity was calculated summing up nitrogen content in the grain and straw, expressed by g m^{2-1}. Nitrogen harvest index (NHI) was calculated dividing nitrogen content in grain and total nitrogen content at maturity, expressed by %, Nitrogen reutilization was determined taking nitrogen content in straw from nitrogen content in the plant at anthesis, expressed by g m^{2-1} while post – anthesis nitrogen accumulation taking nitrogen content in the plant at anthesis from total nitrogen content at maturity, expressed by g m^{2-1}, too. Physiological efficiency of nitrogen (PEN) was computed as ratio between grain yield and total nitrogen content at maturity, expressed by g gN^{-1}.

Genotypic and phenotypic correlations between all pairs of variables were determined according to CHAUDHARY *et al.,* (1977).

RESULTS AND DISCUSSION

The genotypic and phenotypic correlation coefficients for studied traits are shown in Tables 1 and 2. As it can be seen from the Tables, all traits were positively and significantly, at least in one year, correlated with grain yield. Negative, but significant, genotypic correlation coefficiets were expressed only between GHI and N content in the plant at anthesis (-0,30**) and GHI and N reutilization (- 0,29*) in the second year of investigation. Other negative correlation coefficients were non - significant.

Obtained results confirm strong dependence between N metabolism and dry matter accumulation and distribution. The N content in the grain and entire N content in matured plant have the highest genotypic correlation with grain yield during three years of investigation: 0,97**, 0,73**, 0,94** and 0,98**, 0,73**, 0,93**, respectively. The same remark refers to the phenotypic correlations, which values are: 0,98**, 0,79**, 0,95** and 0,98**, 0,78**, 0,94**, respectively. The correlation coefficients between grain yield and N content in the straw and post – anthesis N accumulation were high and significant, too, but their values varied in the years of investigation from moderate to high (genotypic 0,34** – 0,85** and phenotypic 0,33** – 0,92**; genotypic 0,35** – 0,76** and phenotypic 0,40** – 0,86**, respectively). Overall, such correlation coefficients, obtained in this investigation, are in accordance with previous results (KASTORI *et al*., 2006; MARINCIU *et al.,* 2008) and suggest possibility of using parameters of plant N state as selection and breeding criterions.

Table 1. The simple genotypic correlation coefficients between grain yield and related traits and studied physiological parameters of nitrogen nutrition efficiency

Parameter	year	N content in the plant, anthesis	N content in the grain	N content in the straw	Total N content	NHI	N reutilization	Post – anthesis N accumulation	PEN
				genotypic correlation coefficients					
	1	0,80**	0,97**	0,85**	0,98**	-0,16	0,66**	0,62**	0,01
GY	2	0,20	0,73**	0,34**	0,73**	0,41**	0,01	0,35**	0,38**
	3	0,61**	0,94**	0,66**	0,93**	0,06	0,29*	0,76**	0,27*
	1	0,86**	0,95**	0,91**	0,97**	-0,13	0,70**	0,59**	0,02
BY	2	0,48**	0,67**	0,32*	0,70**	0,19	0,30*	0,20	0,36**
	3	0,65**	0,90**	0,68**	0,94**	- 0,07	0,27*	0,73**	0,07
	1	0,02	0,16	- 0,01	0,13	0,06	-0,05	0,25*	-0,01
GHI	2	-0,30**	0,47**	0,06	0,42**	0,40**	-0,29*	0,29**	-0,03
	3	0,01	0,27*	- 0,13	0,16	0,22*	0,15	0,13	0,03

t – test of significance level: * P<0,05, ** P<0,01

GY – grain yield; BY- biological yield; GHI – grain harvest index;
NHI – nitrogen harvest index; PEN – physiological efficiency of nitrogen

Observing the investigation years, also we can see that relation between grain yield and some parameters varied from non - significant to high significant, as, for example NHI, N reutilization and PEN. Mainly, their correlation coefficiets are weak or moderate. Nitrogen harvest index is indicator of nitrogen using for protein synthesis and filling grain concurrently. BARRACLOUGH *et al.,* (2010) set down GHI and NHI are in direct and strong relation with grain yield, emphasizing it is more expressed at increasing nitrogen doses. Such relation could not be confirmed in this investigation completely, whereas relation NHI and grain yield varied during it. We can explain that declination, providing this investigation was carried out in the low input conditions. At once, it can be supposed that studied genotypes are more efficient in using nitrogen for protein synthesis.

AKMAN and KARA (2003) determined that physiological efficiency of nitrogen depends on N plant supply and doesn't affect grain yield always significantly.

The variation of statistical significance of interrelation, as well as its power is noticed in the case of grain yield and N content in the plant at anthesis, too. Declination is noticed only in second year (0,20 and 0,28**), while all other coefficients are significant and high.

Statistically significant and strong interrelation of grain yield and N content in the plant at anthesis is very considerable for wheat breeding to grain yield in practice. It is deduced, in previous investigations (BEBYAKIN and KAIRGALIEV, 2004;

BARBOTTIN *et al*., 2005), that excess of the N amount at maturity can be accumulated in period before flowering, often the total N, subject to environmental conditions and genotypes traits. It means, essentially, estimation and selection of progeny can be carried out precisely and certainly at earlier plants growing and developing phases.

Nearly the same effects of parameters of nitrogen nutrition efficiency on biological yield are registered, too. It was recorded (NIKOLIĆ, 2009) extremely high correlation coefficient (genetic and phenotypic) between biological yield and grain yield, while path analysis demonstrated that BY has high direct and indirect effect on grain yield, too, via accumulated dry matter in the plant at anthesis. Biological yield is, then, important postulate for high yielding of genotype, whence studying that relationships is necessary for completely investigation with stated aim.

Table 2. The simple phenotypic correlation coefficients between grain yield and related traits and studied physiological parameters of nitrogen nutrition efficiency

Parameter	year	N content in the plant, anthesis	N content in the grain	N content in the straw	Total N content	NHI	N reutilization	Post – anthesis N accumulation	PEN
				phenotypic correlation coefficients					
GY	1	0,90**	0,98**	0,92**	0,98**	0,10	0,72**	0,67**	0,16
	2	0,28**	0,79**	0,33**	0,78**	0,65**	0,13	0,40**	0,31**
	3	0,71**	0,95**	0,67**	0,94**	0,09	0,41**	0,86**	0,22*
BY	1	0,92**	0,97**	0,91**	0,97**	-0,06	0,75**	0,61**	0,03
	2	0,52**	0,80**	0,38**	0,78**	0,37**	0,34**	0,21*	0,55**
	3	0,68**	0,94**	0,75**	0,93**	0,04	0,40**	0,85**	0,24*
GHI	1	-0,02	0,22*	0,06	0,16	0,49**	0,04	0,36**	0,38**
	2	0,06	0,56**	0,12	0,50**	0,50**	0,07	0,52**	0,17
	3	0,69**	0,51**	0,31**	0,40**	0,52**	0,52**	0,36**	0,42**

t – test of significance level: * P<0,05, ** P<0,01

GY – grain yield; BY- biological yield; GHI – grain harvest index;

NHI – nitrogen harvest index; PEN – physiological efficiency of nitrogen

Previous investigations (KRALJEVIĆ – BALALIĆ *et al.,* 2001; PETROVIĆ *et al.*, 2001; RICHARDS, 2002) suggested dependence of grain yield on GHI and possibilities of increasing grain yield by its increasing. The influence of parameters of nitrogen nutrition efficiency on this trait, which is close by yield, in this investigation is very variable. According to investigations of STOJKOVIĆ, (2001), WHITE and WILSON, (2006), NIKOLIĆ, (2009), GHI is commendable indicator of genotype productivity in any circumstances, while NHI is more proper and stable one. The presence of significant and mainly moderate correlation between NHI and GHI (genetic coefficient 0,40** and phenotypic coefficients 0,49** - 0,52**)

confirms either grain yield forming is almost impossible without nitrogen or protein synthesis without non - nitrogen substances (BARRACLOUGH *et al.,* 2010). If we give attention to N content in the plant in the flowering, we can distinguish that its effect varied from significant, moderate and negative (-0,30**) to extremely low, non - significant and positive (0,01). The difference is more obvious in the case of phenotypic coefficients (-0,02 – 0,69**).

Generally, this investigation confirms genetic nature of parameters of nitrogen nutrition efficiency and their significant correlation with grain yield and relateed traits. Because of that, these parameters can be considered to be effective as selection criteria to grain yield improving in winter wheat genotypes.

CONCLUSION

According to presented results, the plus-hybrid effect differed over observed hybrids, but it was not significant. Considering that each plus-hybrid combination of the first hybrid was better than its fertile variant, it can be concluded that the genotype of a sterile female hybrid in the combination is crucial in the expression of the plus-hybrid combination. Furthermore, for the time being, it can be claimed that the genetic distance is related to this effect. Although the grain yield increase is not significant, all the same, both hybrids, at least in some combinations, positively responded to the combined effect of cms and xenia. The study will be continued for another two years, and results of the molecular marker analysis will be considered. According to this, the best combination, in order to finally confirm the possibly obtained plus-hybrid effect, could be set in the strip trials.

ACKNOWLEDGMENTS

This work was supported by Ministry of Sciency and Technological Development (Republic of Serbia), project TR 31054.

Received, June 16th2010
Accepted, February 22th 2011

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MEĐUZAVISNOST PRINOSA ZRNA I FIZIOLOŠKIH PARAMETARA EFIKASNOSTI ISHRANE PŠENICE AZOTOM

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I z v o d

U radu je razmatrana mogućnost korišćenja fizioloških parametara, koji se odnose na efikasnost ishrane pšenice azotom, kao kriterijuma u oplemenjivanju na prinos zrna, na osnovu njihove međuzavisnosti i uticaja na neke osobine povezane sa prinosom zrna pšenice (biološki prinos, žetveni indeks zrna). Istraživanje je izvedeno kao trogodišnji poljski ogled i uključivalo je 30 sorti i perspektivnih linija pšenice. Od fizioloških parametara proučavani su: sadržaj azota u nadzemnom delu biljke u cvetanju, sadržaj azota u zrnu i slami, ukupni sadržaj azota u zreloj biljci, žetveni indeks azota, reutilizacija i prirast azota i fiziološka efikasnost azota. Utvrđena je pozitivna i statistički visoko značajna korelacija između prinosa zrna i skoro svih ispitivanih fizioloških parametara: sadržaja azota u biljci, u cvetanju, zrnu, slami, ukupnog sadržaja azota u zreloj biljci, reutilizacije i prirasta azota. Imajući to u vidu, kao i njihovu merljivost i jednostavnost u izračunavanju, navedeni fiziološki parametri mogu se preporučiti kao kriterijumi za odabir roditeljskih parova i ocenu potomstava u oplemenjivanju pšenice na prinos zrna

Primljeno 16. VI. 2010.
Odobreno 22. II. 2011.