Economics of agriculture
SI – 2
UDK: 631.84:633.15

EFFECTS OF NITROGEN FERTILIZING ON THE 1000-GRAIN WEIGHT OF MAIZE INBRED LINES

Hojka Zdravko[1]

Abstract

In this study the influences of three N fertilizers (urea = 46% N; calcium ammonium nitrate or CAN; ammonium sulphate) and their distribution (N-autumn; N-spring; N-50% autumn + 50% spring; N-33% autumn + 67% spring; N-100% spring based on N-$_{min}$ method test) on 1000-grain weight of two maize inbred lines (IL1 and IL2) were tested under conditions of Zemun Polje calcaric chernozem for three growing seasons (2001, 2002 and 2003) with aim of N fertilization optimization for seed-maize growing. The use of the N-$_{min}$ method test (N ranging from 17 to 35 kg ha^{-1}, in dependence on the soil mineral nitrogen content), especially in years with lower precipitation sums, resulted in the highest increase in 1000–grain weight (3.2%) of observed maize inbred lines in relation to the control. The application of different forms of nitrogen did not result in statistically significant differences in 1000–grain weight of observed maize inbred lines.

Key words: *Time of nitrogen application, Nitrogen form, Maize inbred lines, 1000-grain weight.*

Introduction

Nitrogen is one of the most important nutritive elements, and it is used worldwide to enhance and sustain the production of agricultural crops. During the Green Revolution, nitrogen fertilisers contributed to the increase and sustainability of yields within different agroecological systems. Nitrogen was also a key of economic variability of the agricultural production all over the word, and by it of world population food. On the other hand, anthropogenic factors (combustion of fossil fuels) contribute to a greater release of gases (carbon dioxide and nitrogen oxides) that affect global warming of our planet (*IPCC, 1994*). The application of organic and mineral nitrogen

1 Phd. Zdravko Hojka , Faculty of Biofarming, Megatrend University Belgrade , Maršala Tita 39 Bačka Topola; e-mail: z.hojka@yahoo.com

fertilisers can result in losses of nitrogen in gaseous forms, as well as, in nitrite leaching. Therefore, as stated by *Newbould (1989)*, drinking water contamination with nitrates has been becoming a serious problem all over the world. These are principal reasons for continuation of the development of new technologies and methods of nitrogen applications that can increase efficiency of its utilisation. Procedures such as: band fertilisation, nitrogen application during the growing season, testing of new varieties with a greater efficiency of the nitrogen utilisation, crop rotation and alternation of crops, irrigation by the drop by drop system, determination of the nitrogen content in the soil with the aim to calculate necessary rates of fertilisers - are globally used as a conventional method of the agricultural production. New technologies of nitrogen fertilisers application and cropping, such as: precise technique of the plant production, fast *in situ* tests for the analysis of the nitrate nitrogen concentration in plant tissues, fast tests for the chlorophyll determination, use of the computer simulation models to improve planning and organisation of the production - can affect the increase of the average efficiency of the nitrogen utilisation within different agroecosystems by more than 50%. Moreover, the application of nitrification inhibitors and slow-release nitrogen fertilisers significantly affect a higher crop use of both, nutrient and water, and the reduction of nitrogen losses from the soil by approximately 50% (*Delgado and Mosier, 1996; Detrick, 1996; Engelsjord et al., 1997*).

The maize seed production is mainly performed on higher quality soils. Soil quality is a capability of the soil to satisfy requirements of crops (and therefore of animals), to provide transport and regulation of water and other compounds present in the soil or added to the soil (*Doran and Parkin, 1994; Karlen et al., 1998*).

Since there are usually no sufficient amounts of nitrogen in the soil available to plants, for obtaining high yields of good quality, soil fertilisation is necessary. The application of N fertilisers in the maize seed production represents an important cropping practice as it significantly affects the yield level and certain seed traits.

Materials and methods

The field experiment

The field experiment was conducted for three growing seasons (the factor A: 2001, 2002 and 2003) with two maize inbred lines (the factor B: IL1 and IL2), six fertilization (the factor C–Table 1) and three N–fertilizers appliations (the factor D–Table 1) on the constant P and K fertilization (kg ha^{-1}: 60 P_2O_5 + 60 K_2O as superphosphate and KCl) was conducted on chernozem soil (Maize Research Institute in Zemun Polje).

The experiment was conducted in the randomized block design in four replicates. Gross of the basic plot was 28 m^2. Maize was sown by pneumatic sowing maschine in the terms as follows: May 8, April 24 and April 15, for 2001, 2002 and 2003, respectively (crop rotation after winter wheat). Weed control was made by incorporation of Eradicane (6.0 l ha^{-1}) by presowing soil tillage and pre–emergence application of Atrazin + Prometrin + Monosan (l ha^{-1} = 1.0 +1.5+1.5) as well.

Table 1. Forms and distributions of N by fertilization

N Fertilizer (the factor C)	Distribution of N in kg ha^{-1} (the factor D)						
	Period	D1	D2	D3	D4	D5	D6**
C1 = urea (46% N: 100% NH_2-N)	Autumn	0	100		50	34	
C2 = CAN* (50% NH_4-N + 50% NO_3-N)	Spring	0		100	50	33	$N-_{min}$
C3 = $(NH_4)_2SO_4$ (100% NH_4-N)	Dressing	0				33	
		0	D2-D6 (kg ha^{-1}): 60 P_2O_5 + 60 K_2O				

* Calcium ammonium nitrate (26% N); ** $N–_{min}$ to 120 cm of depth + fertilization = 100 kg N ha^{-1} (kg N ha^{-1} = 35, 31 and 17, for 2001, 2002 and 2003, respectively).

Plant number reduction to the level of 60,000 plants ha^{-1} was performed in early growth stage. The harvest was done on October 5th, 2001; September 10th, 2002; September 5th, 2003 at the moment of physiological maturity of maize grain inbred lines. Harvested ears were dried at the seed drying and processing plant at the Maize Research Institute, Zemun Polje. Statistical analyses (LSD–test) were performed according to Mead et al., 1996.

Harvested by hand 4-5. October 2001, 10 September 2002. and 5 September 2003. in physiological maturity, grain and maize inbred lines were evaluated in yield that is at the 14% humidity. Statistical analysis (LSD test) were made according to Mead et al. (1996)

Weather conditions

Precipitation for the 6–month period (April–September2002), being the growing season, was within range of 30–year average (LTM), while in years 2001 and 2003 they were 46% higher and 30% lower than LTM, respectively. Temperature regime for maize growth was more favorable in 2001, compared to the other two years (Table 2).

Table 2. Weather characteristics (Zemun Polje Weather Bureau: 44°49'N, 20°27'E)

	Weather characteristics (LTM = long–term means: 1961-1990)							
Month	Precipitation (mm)			Mean air–temp. (°C)			LTM	
	2001	2002	2003	2001	2002	2003	mm	°C
April (IV)	148.8	54.8	14.6	11.0	11.6	11.2	48.3	11.2
May (V)	46.2	29.4	36.4	17.6	19.5	20.5	61.2	16.9
June (VI)	168	65.0	19.0	14.1	22.0	24.0	79.4	19.3
July (VII)	41.8	34.8	105.4	22.4	23.4	22.5	63.5	20.3
August (VIII)	35.0	105.2	26.4	23.6	21.6	24.3	52.3	22.1
Sept. (IX)	70.8	55.4	41.2	15.9	16.5	17.2	44.7	17.2
IV-IX: Total	510.6	344.6	243.0				349.4	
IV-IX: Mean				17.4	19.1	19.9		17.8

In general, low yield of maize is connected with drougt stress, especially during July and August (Shaw 1988.; Josipovic et al., 2005.)

Results and discussion

Forms and timing of nitrogen (N) application are important factors of plants growth and development, especially for maize inbred lines, which are used as parents in maize seed production (Binder et al., 2000; Vetsch and Randall., 2004).

Kling and Okoruwa (1994) and Okoruwa (1997) refer to several biological seed traits, while Miric and Brkic (2002) describe several dozens of different seed traits affecting sowing and having the importance for seed drying, transport, storing, packing and conservation. However, Miric et al. (2000) conclude that germination and 1000-grain weight are traits among a dozen of the most important sowing-technical and production-economical traits, because they specify both quantity and quality. The variety, soil tillage, crop density and uniformity, irrigation regime and fertilisation have greatest impact on 1000-grain weight. The effects of weather conditions, except during pollination and maturity are less important, while the fractioning has a crucial effect on 1000-grain weight.

In these investigations thousand-grain weight significantly varied over investigation years and genotypes (Table 3). Fertilization based on the N_{min} method resulted in significantly greater 1000-grain weight compared with other fertilization variants performed, on the average for three years and all three forms of nitrogen. Applied nitrogen in the form of fertilizer did not differ in 1000-grain weight.

According to the fertilization date x nitrogen form interaction it can be concluded that significant differences occurred within certain fertilization variants. The inbred lines fertilization based on the N_{min} method and distribution of N fertilizers in autumn and spring (D5: 34% + 66%) by the application of the amidic nitrogen (urea), resulted in significantly higher grain weight compared with using of CAN. On the other hand, 1000-grain weight was very significantly higher in the fertilizing variants D2 (single application of N fertilizers in autumn) and D4 (application of N fertilizers in autumn and spring: 50% + 50%) with CAN in relation to the urea. Grain weights did not differ over D3 variant (single application of N fertilizers in spring).

Observed maize inbred lines responded differently to nitrogen application dates. The inbred line IL1 had significantly lower seed weight in treatment with single application of fertilizers in autumn compared with other treatments. The highest 1000-grain weight in the inbred IL2 was obtained by the application of the N_{min} method.

Table 3. 1000-grain weight (g) of maize inbred lines

Factor	Year 2001 (A1)			Year 2002 (A2)			Year 2003 (A3)			
	Genotype (B)		Mean	Genotype (B)		Mean	Genotype (B)		Mean	Mean
	IL-1	IL-2		IL-1	IL-2		IL-1	IL-2		
	Influences of A, B C and interactions AB, AC and ABC									
Year (A)	**264.0**			**297.9**			**242.1**			
Genotype (B)	3-year means:			**277.2**	**258.7**					
Interaction AB	**297.9**	**230.1**	Y2001	**318.9**	**276.4**	Y2002	**214.5**	**269.6**	Y2003	
Interaction BC	**277.2**	**258.2**	NH_2-N	**275.9**	**259.3**	CAN	**278.7**	**258.6**	NH_4-N	
Fertilizer (C)	ABC		**AC**	ABC		**AC**	ABC		**AC**	**C**
NH_2-N	299.1	228.6	**263.9**	316.6	277.8	**297.2**	215.8	268.1	**242.0**	**267.7**
CAN	294.8	232.9	**263.9**	322.8	274.9	**298.9**	210.0	270.2	**240.1**	**267.6**
NH_4-N	299.6	228.9	**264.3**	318.9	276.5	**297.7**	217.5	270.5	**244.0**	**268.7**
	Influences D and interactions AD, BD and ABD									
Distribution (D)	ABD		**AD**	ABD		**AD**	ABD		**AD**	**D**
N-0	297.6	231.7	**264.7**	325.5	276.2	**300.9**	210.4	266.6	**238.5**	**268.0**
N-100 autumn	306.9	211.9	**259.4**	327.8	270.6	**299.2**	213.5	267.0	**240.3**	**266.3**
N-100 spring	284.2	241.5	**262.9**	312.2	267.5	**289.9**	226.6	257.0	**241.8**	**397.3**
N 50a+50spr	282.4	234.6	**258.5**	316.0	278.5	**297.3**	219.9	268.1	**244.0**	**266.6**
N 34a+66spr	309.5	229.2	**269.4**	312.9	264.3	**288.6**	216.4	261.0	**238.7**	**265.6**
N-min spring	306.6	232.0	**269.3**	322.1	301.2	**311.7**	200.0	297.8	**248.9**	**276.6**

	Interactions ACD and CD (a= NH_2-N; b=CAN; c= NH_4-N)											
	Year 2001 (A1)			Year 2002 (A2)			Year 2003 (A3)			3-year means		
	a	b	c	a	b	c	a	b	c	a	b	c
	ACD			ACD			ACD			CD		
N-0	265	265	265	301	301	301	238	238	238	268	268	268
N-100 autumn	262	258	258	289	313	300	224	256	241	259	276	264
N-100 spring	257	265	267	293	295	282	244	245	236	264	268	262
N 50a+50spr	242	270	264	293	301	297	238	249	244	258	274	268
N 34a+66spr	275	265	268	296	265	304	244	218	254	272	249	275
N-min spring	283	261	264	311	318	307	263	233	250	285	271	274

	Analyses of variance (LSD-test to levels 5% and 1%)											
	A	B	C	D	AB	AC	AD	BC	CD	ABC	ABD	ACD
LSD 5%	3.3	20.1	3.3	4.7	4.7	5.8	8.2	4.7	8.2	5.2	6.3	7.1
LSD 1%	4.4	26.5	4.4	6.3	6.3	7.7	10.8	6.3	10.8	7.0	8.7	9.3

These data differ from the results obtained by other study (Jovin and Vesković, 1997) which showed that the highest 1000-grain weight had been obtained by the application of the greatest fertilizer rate (N-150 $kgha^{-1}$, P_2O_5 -120 $kgha^{-1}$ and K_2O-80 $kgha^{-1}$).

Similar investigations were made by others (Gotlin et al., 1981; Ćirović, 1985; Cirilo and Andrade, 1994; Uhart and Andrade, 1995; Maksimović, 1997; Purcino et al., 2000). For example, by testing 1000-grain weight of maize inbred lines and hybrids by fertilization for 3-year period, increase of soil moisture and application of N fertilizers affected the increase of 1000-grain weight. The use of N fertilizers showed considerable influences on maize 1000-grain weight and resulted in 30-40% higher yield in comparison with the unfertilized plot. 1000-grain weight depended on application of N fertilizers and these effects were different for individual maize hybrids.

Conclusions

According to the statistical analysis of effects of fertilisation dates and nitrogen forms on the 1000-grain weight of maize inbred lines, very significant differences were obtained over different investigation years and genotypes. It can be concluded that each inbred has its own potential for magnitude and range of variations for the observed trait.

Fertilizing on the basis of the N_{min} method resulted in very significantly higher 1000-grain weight compared with other fertilization variants, on the average for all years, genotypes and all three nitrogen forms used. The use of the N-$_{min}$ method test (N ranging from 17 to 35 kg ha^{-1}, in dependence on the soil mineral nitrogen content), especially in years with lower precipitation, resulted in the highest increase in 1000–grain weight (3.2%) in all maize inbred lines tested, compared with the control. The application of different forms of nitrogen did not result in statistically significant differences in 1000–grain weight of maize inbred lines tested.

Thousand-grain weight is an important sowing-technical trait mainly conditioned by inheritance, but partially subjected to certain cropping practices. It is considered that 1000-grain weight close to a mean for a given hybrid is desirable. Namely, the overweight means a small number of grain per a unit of the harvested area, as it is case with the inbred lines. This trial shows variations of this trait within a population, which is a result of inheritance.

References

1. Binder, D.L., Sander, D.H. Walters, D.T. 2000. Maize response to time of nitrogen application as affected by level of nitrogen deficiency. *Agron. J.,* 92, 1228-1236.
2. Cirilo. A.G., Andrade, E.H. 1994. Sowing date and maize productivity: II Kernel number detrmination. *Crop Sci*. 34, 1044-1046.
3. Cirovic, M. 1985. Proučavanje bioloških osobina samooplodnih linija kukuruza pri različitim gustinama i optimalnim uslovima gajenja sa i bez navodnjavanja. *Doktorska disertacija*. Poljoprivredni fakultet, Novi Sad.
4. Delgado, J.A., Moiser, A.R. (1996): Mitigation Alternatives to Decrease Nitrous Oxide Emissions and Urea-Nitrogen Loss and Their Effect on Methane Flux. Journal of Environmental Quality, 25, 1105-1111.
5. Detrick, J. (1996): RCL Membrane Encapsulated Fertilizer Technology Can Deliver High Value Benefits for Agriculture. Proceedings, Great Plains Soil Fertility

Conference, Denver, CO, March 4-6, 330-340.

6. Doran, J.W., Parkin, T.B. (1994): Defining and assessing soil quality. In Doran et al. (ed.) Defining soil quality for a sustainable environment. SSSA Spec. Publ. 35. SSSA and ASA, Madison, WI.
7. Engelsjord, M.E., Fostad, O., Singh, B.R. (1997): Effects of Temperature on Nutrient Release From Slow-Release Ferilizers. Nutrient Cycling in Agroecosystems, 46, 179-187.
8. Gotlin, J., Pucaric, A., Varga, B. 1981. Utjecaj gnojidbe dušikom na prinos i komponente prinosa hibrida kukuruza raznih vegetacijskih grupa. Zbornik radova sa naučnog skupa: "Ekosistemi i mogućnosti njihovog racionalnog korišćenja", *Matica Srpska*, Novi Sad, 389-400.
9. Intergornmental Panel on Climate Change (IPCC) (1994): Radiative Forcing of Climate Change. The 1994 Report to the Scientific Assessment Working Group of IPCC, Summary for Policymakers.
10. Josipovic M., Kovacevic V., Petosic D., Sostaric Jasna 2005. Wheat and maize yield variations in the Brod-Posavina area. *Cereal Research Communications* 33 (1):229-233.
11. Jovin, P., Vesković, M. (1997): Uticaj gustine setve i doza mineralnih đubriva na prinos i broj zrna u semenskom kukuruzu. Selekcija i semenarstvo, Vol. 4, 3-4, 93-97, Novi Sad.
12. Karlen, D.L., Gardner, J.C., Rosek, M.J. (1998): A soil quality framework for evaluating the impact of CRP. J. Prod. Agric., 11, 56-60.
13. Kling, J.G., A.E. Okoruwa 1994. Influence of variety and environment on maize grain quality for food uses in Africa. p. 119. *In Agronomy abstracts. ASA, Madison, W.I.*
14. Maksimovic, L. 1997. Uticaj predzalivne vlažnosti zemljišta i đubrenja na prinos i neka morfološka svojstva kukuruza. *Uređenje, korišćenje i očuvanje zemljišta. Jugoslovensko društvo za proučavanje zemljišta*, Novi Sad, 651-656.
15. Mead, R., Curnow, R. N., Hasted, A. M. 1996. Statistical methods in agriculturae and experimental biology. *Chapman & Hal*l, London.
16. Miric, M., Selakovic D., Trifunovic V. B., Vidojkovic Z., Maja Marinkovic 2000. Seme preduslov za ispoljavanje visokog potencijala ZP hibrida kukuruza. *Prvo savetovanje "Nauka, praksa i promet u agraru - znanje u hibridu"*, Vrnjačka Banja, 100– 104.
17. Miric, M., Brkic, M. 2002. Dorada semena. *Društvo selekcionera i semenara Srbije*, 22-67.
18. Newbould, P. (1989): The Use of Nitrogen Fertilizer in Agriculture: Where Do We Go Practically and Ecologically? Plant Soil, 115, 297-311.
19. Okoruwa, A.E. 1997. Enhancing maize processing and utilization in West and Central Africa.p. 108-119. In B. Badu-Apraku et al. (ed.). Contributing to food

self-suficiency: maize resaearch and development in West and Central Africa. *Proc. Regional Maize Workshop*. IITA.Cotonou, Benin Republic. 29 May – 2 June 1995. WECAMAN/IITA, Nigeria.

20. Purcino, A.A.C., Silva, M.R., Andrade, S.R.M., Belele, C.I., Parentoni, S.N., dos Santos, M.X. 2000. Grain filling in maize: The effect of nitrogen nutrition on the activities of nitrogen assimilating enzymes in the Pedicel-placento-chalaza region. *Maydica* 45, 95-103.
21. Shaw R. H. 1988. Climatic requirement. pp. 609-638. In: G. F. Sprague (Ed.). Corn and corn improvement, *Agronomy Monograph* No 18 ASA-CSSA-SSSA, Madison, Wisconsin, USA.
22. Uhart, S.A., Andrade F.H. 1995. Nitriogen deficiency in maize:I. Effects on crop growth, development, dry matter partitioning and kernel set. *Crop Sci*., 35,1376-1383.
23. Vetsch, J.A., Randall, G.W. 2004. Corn production as affected by nitrogen application timing and tillage. *Agronomy J.*, 96, 2, 502-509.