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NITROGEN EFFICIENCY IN EGGPLANTS (*SOLANUM MELONGENA* L.) DEPENDING ON FERTILIZING

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Abstract

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A field fertilizer test was carried out on the experimental field of the Department of Horticulture at the Agricultural University in Plovdiv with the *Patladzhan 12* eggplant cultivar grown on mollic fluvisols (FAO, 2006) as a mid-early field production over the three-year period of 2004 – 2006. The separate effects of two levels of soil fertilization ($N_{120}P_{60}K_{60} = T_1$ and $N_{240}P_{120}K_{120} = T_2$) were studied, as well as their combination with four foliar sprays (*Fitona, Hortigrow Universal, Agroleaf Total and Kristalon Special*), applying the following scheme: 1. T_0; 2. T_1; 3. T_1+Fitona; 4. T_1+Hortigrow; 5. T_1+ Agroleaf; 6. T_1+ Kristalon; 7. T_2; 8. T_2+Fitona; 9. T_2+Hortigrow; 10. T_2+Agroleaf; 11. T_2+Kristalon. The experiment was done with four replications. The agronomic N efficiency as a result of the foliar feeding with Fitona 1, Hortigrow, Agroleaf and Kristalon decreased with the increase of the level of soil fertilization of $N_{120}P_{60}K_{60}$ на $N_{240}P_{120}K_{120}$ and was insignificantly dependent on the type of foliar fertilizer. The obtained results showed that the tested foliar sprays compared with the two levels of soil fertilization increased the NREC compared with the unaided soil fertilization on the average for the period. Both the fresh and dry yields were significantly and positively related to the nitrogen harvest index and the N export during maturity. A considerable negative relation was established between the fresh fruit yield of the eggplants and the physiological nitrogen efficiency. The agronomic efficiency of nitrogen was strongly and positively related to the physiological and recovery efficiency as well as to the nitrogen harvest index.

Key words: eggplant; foliar spray

Abbreviations: PFP - partial factor productivity; NUEa - agronomical NUE; NUEp - physiological NUE; NREC - apparent N recovery efficiency

Introduction

At certain stages of development, including vegetables and eggplant are particularly needed nutrients - typically stages of rapid growth, accumulation of vegetative mass and formation of generative organs. Feeding of the plants at this time of development leads to a higher yield.

Foliar spray with fertilizers is necessary to further activity in the whole system of optimal mineral nutrition of plants. It may be supplemented and amended mineral nutrition. In Foliar spray plants not only uptake part of their development necessary nutrients through the leaves, but increases and physiological activity of the root system. Eggplant is one of the crops with low absorbability of the root system. With this change in the activity of the root system could explain the large effect on productivity through the cast leaves relatively small amounts of macro - and micronutrients. Foliar spray provides a more economical water regime of plants and allows overcoming the physiological disturbances caused by adverse soil conditions that hamper mobility and absorption nutrients.

In recent years, displays extensive research to study the effectiveness of the new Bulgarian and foreign suspension and liquid fertilizers on the growth, productivity and quality of products in a variety of vegetable crops. Foliar spray is seen as a necessary adjunct to fertilization of vegetable crops to increase yields, possibility of adjusting fertilizing rate of NPK, while reducing the risk of further contamination of soil and production. Increasing the photosynthetic activity of plants and reduce the negative impact of adverse environmental factors (Lopez-Cantarero-I et al., 1997; Janas et al., 2002).

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Fertilization is one of the most important measures for increasing the yield of eggplant. The effect of four N-fertilization rates (N_0, N_{100}, N_{200}, and N_{300}) on yield, growth, N uptake, and N use efficiency of processing tomato in a silty-clay soil under Mediterranean conditions was studied (Elia and Conversa, 2012). The respective maximum values 4.6, 1.16 g MJ^{-1}, 13.4 Mg ha^{-1}, and 383 kg ha^{-1} were detected with N_{300}. Maximum total and marketable yield were obtained with the N_{200} rate and were respectively 155 and 119 Mg ha^{-1} in 2005 and 135 and 104 Mg ha^{-1} in 2006 season. N supply decreased the agronomical (NUEa) and physiological (NUEp) N use efficiency, these indices reaching a maximum with the N_{200} rate (NUEa = 11.8 kg kg^{-1}, NUEp = 15.1 kg kg^{-1}).

The agronomic and physiological responses of eggplant to nitrogen input were insufficiently studied. The aim of the present research was to study the N-efficiency indices in eggplants in relation to fertilization.

Materials and Methods

A field fertilizer test was carried out on the experimental field of the Department of Horticulture at the Agricultural University in Plovdiv with eggplant variety *Patladzhan 12* cultivar grown on mollic fluvisols (FAO, 2006) as a mid-early field production over the three-year period of 2004 – 2006. The separately effects of two levels of soil fertilization ($N_{12}P_6K_6 = T_1$ and $N_{24}P_{12}K_{12} = T_2$) were studied, as well as their combination with four foliar sprays (*Fitona, Hortigrow Universal, Agroleaf Total and Kristalon Special*), applying the following scheme: 1. T_0; 2. T_1; 3. T_1+Fitona; 4. T_1+Hortigrow; 5. T_1+ Agroleaf; 6. T_1+ Kristalon; 7. T_2; 8. T_2+Fitona; 9. T_2+Hortigrow; 10. T_2+Agroleaf; 11. T_2+Kristalon. The experiment was done with four replications.

Fitonal ($N_{6.6}P_{4.0}K_{5.1}Fe_{0.01}B_{0.15}$) is a Bulgarian specialised liquid foliar fertilizer; *Hortigrow Universal* ($N_{20}P_{20}K_{20}$) comes in powder form and is 1 000 g.kg^{-1} water-soluble; *Agroleaf Total* ($N_{20}P_{20}K_{20}$) is a Dutch foliar fertilizer of pure, highly concentrated substances in powder form; *Kristalon Special* ($N_{18}P_{18}K_{18}Mg_3$) is a powder product of the chemical concern *Norsk Hydro* of a universal formula.

The phosphorus and potassium fertilization were done with triple superphosphate and potassium sulphate respectively, as basic feeding. Nitrogen, in the form of ammonium nitrate, was incorporated prior to planting. The foliar sprays were applied twice – at the beginning of flowering and about 20 days later. *Kristalon* and *Agroleaf* were used at a rate of 3 kg.ha^{-1}, *Fitona* – at 0.0025 m^3.ha^{-1}, and Hortigrow – at 3 g.ha^{-1} concentration. The foliar application was done late in the afternoon with a backpack sprayer using 0.8 m^3.ha^{-1} of active solution and some adhesive adjuvant added.

During the mass fruit bearing the content of the overall N was determined by the *Kjeldahl* (Walinga, et al., 1995**.**) distillation method and the overall N-export and the N-export through the fruits were calculated.

Nitrogen use efficiency indexes (expressed on dry weight basis) were calculated according to *Pandey et al.* (2001) using the following formulas:

1). Partial factor productivity (PFP): PFP=Yf/NA (kg.kg^{-1}) which represents the kg of product harvested (Y) per kg of N fertilizer applied.

2). Agronomical NUE (NUEa): NUEa = (FWf-FWc)/NA (kg. kg^{-1}) which represents the kg of yield increase per kg of N fertilizer applied.

3). Physiological NUE (NUEp): NUEp=(FWf-FWc)/(TNf-TNc) (kg. kg^{-1}) which represents the kg of yield increase per kg increase in N uptake from fertilizer.

4). Apparent N recovery efficiency (NREC): REC = (TNf –TNc)/ NA (kg. kg^{-1}) which represents the kg increase in N uptake by the crop per kg of N applied, where in the formulas FWf is the fruit dry weight (kg.ha^{-1}) obtained with the application of a determinate N fertilizer (NA) rate (kg ha^{-1}); FWc is the fruit dry weight (kg ha^{-1}) obtained without application of N-fertilizer; TNf is the N content of above-ground biomass at harvest (kg ha^{-1}) when an amount NA is applied, and TNc is the corresponding N-content in the above-ground biomass at harvest (kg ha^{-1}) when no N-fertilizer is applied.

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

Results and Discussion

Out of the three years of research, 2004 was characterized by lower than the mean rainfall values for the region, while 2005 was extremely wet and 2006 meteorological data close to the mean multi-year values for the region. As a result, the average fruit yield was higher in 2005 (46.470 kg ha^{-1}) as compared to those in 2004 (40.241 kg ha^{-1}) and 2006 (39.680 kg ha^{-1}). Applying of foliar sprays was increase the yield at the two levels of soil fertilization (Figure 1).

The partial factor productivity (PFP) represents the kg of product harvested 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). N productivity proves to be the simplest index for N efficiency and is most important for the producers, since it represents the efficiency at which the applied fertilizing nitrogen turns into an economic yield (Dobermann, 2005). The figures usually decrease as the imported N quantities increase (Hirel and Lemaire, 2005).

The obtained results corresponded to the above understanding during the three experimental years (Table 1). The N productivity fell averagely for the period from 19.6 kg.kg^{-1} at a rate of N_{120} to 13.8 kg.kg^{-1} at a rate of N_{240}, in other words – 296 g.kg^{-1} less basic yield was produced per unit of incorporated nitrogen above the N_{120} rate. In a research carried out with tomatoes it has been established that N productivity decreases by about 400 g.kg^{-1} at rates well above 100 kg N.ha^{-1} (Elia and Conversa, 2012). The productivity per unit of fertilizing nitrogen at the rate of T_1 showed similar values over the three experimental years. At T_2 when the rates of nitrogen, phosphorus and potassium were doubled, a higher N productivity was discerned during the wet 2005. The climatic conditions during the vegetative period of the eggplants differentiated the effect of the tested foliar sprays as well. During the drier 2004 the N productivity was determined mainly by the level of soil fertilizing and depended insignificantly on its combination with a foliar fertilizer. During the wetter 2005 and under weather conditions close to the mean multi-year values for the region in 2006, the use of foliar sprays evidentially increased the N productivity compared with the two levels of soil fertilization. At T_1, the average N productivity increase, as a result of foliar fertilizer application, was by 697 g.kg^{-1} and 302 g.kg^{-1} for 2005 and 2006 respectively. The effect of foliar feeding at T_2 was weaker – by 78 g.kg^{-1} and 179 g.kg^{-1} for 2005 and 2006 respectively. Considering the two levels of soil fertilization, no proven differences were observed in N productivity as a result of the use of the four foliar sprays.

Table 1
Partial factor productivity of nitrogen PFP_N (kg kg^{-1}) in eggplant

Fertilizing	2004	2005	2006	Mean 2004-2006
T_1	19.9 a	19.3 b	19.5 b	19.6 ab
T_1+Fitona	21.7 a	31.8 a	26.1 a	26.5 a
T_1+Hortigrow	20.8 a	32.6 a	24.8 a	26.1 a
T_1+Agroleaf	20.3 a	32.6 a	25.1 a	26.0 a
T_1+Kristalon	20.2 a	32.7 a	25.5 a	26.1 a
T_2	12.5 b	16.7 c	12.3 d	13.8 b
T_2+Fitona	11.1 b	17.5 bc	14.0 c	14.2 b
T_2+Hortigrow	9.7 b	17.9 b	14.2 c	13.9 b
T_2+Agroleaf	11.3 b	18.1 b	14.5 c	14.7 b
T_2+Kristalon	9.6 b	18.5 b	15.1 c	14.4 b

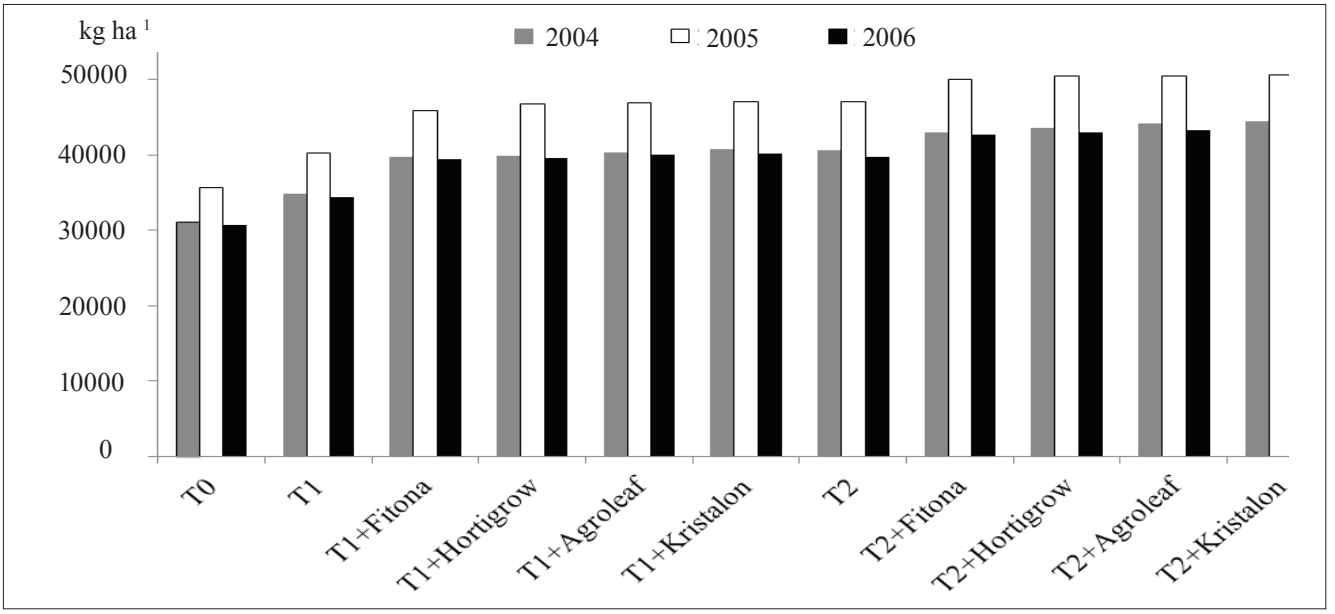

Fig. 1. Fruit yields of eggplant depending of fertilizing

The agronomic efficiency represents the increase of yield kg per kg of a fertilizer element. The N agronomic efficiency was strongly dependent on the weather conditions during the eggplant vegetation stage and differed over the three experimental years (Table 2). During the less wet 2004, the yield increase of dry fruit for every kilogram of soil-incorporated nitrogen changed within relatively narrow boundaries – from 1.2 to 4.8 kg.kg^{-1} and no particular effect of the application of foliar sprays was observed for both levels of soil fertilization. During the wet 2005 the variations in the figures of the agronomic efficiency were significant – from 2.6 to 15.9 kg.kg^{-1}. The four foliar sprays, which were tested evidentially contributed to the increase of the dry weight of the eggplant fruit for a unit of fertilizer nitrogen compared with the T_1 ($N_{120}P_{60}K_{60}$) soil fertilization averagely 6.1-fold during the second year and 2.3-fold during the third year of the experiment as compared with the figures of the variant when only soil fertilization was applied. The agronomic N efficiency as a result of the foliar feeding with Fitona 1, Hortigrow, Agroleaf and Kristalon decreased with the increase of the level of soil fertilization of $N_{120}P_{60}K_{60}$ на $N_{240}P_{120}K_{120}$ and was insignificantly dependent on the type of foliar fertilizer.

The physiological nitrogen use efficiency accounts for the kg of increased yield per kg of enhanced uptake as a result of the fertilization. It represents the efficiency with which the plants utilize the absorbed nutrients for the formation of dry fruit mass yield. The combination of soil fertilization and the application of foliar sprays led to, averagely for the period, a trend to a lower physiological N efficiency compared with the variants of unaided soil fertilization (Table 3), the reason for that being that compared with the soil fertilization, the tested foliar sprays increased the uptake of nitrogen with the aboveground biomass (Figure 2).

The nitrogen harvest index accounts for the share of the nitrogen partitioned to the fruit as part of the overall nitrogen in the aboveground biomass. The present research detected a trend of a lower nitrogen harvest index when the eggplants were grown without fertilizing. The fertilized variants surpassed the distribution of the absorbed nitrogen to the fruit during maturity averagely by 407 g.kg^{-1} compared with the non-fertilized ones (Table 3). In all fertilized variants, the values of the fruit-allocated nitrogen as part of the overall absorbed N in the aboveground biomass were close and were insignificantly dependent on the tested variants of soil and foliar spray.

The nitrogen recovery efficiency reveals the ability of the crop to absorb nitrogen from the soil, which is a crucial process in the management of N fertilizing. The obtained results showed that the tested foliar sprays compared with the two levels of soil fertilization increased the NREC compared with the unaided soil fertilization on the average for the period (Table 3).

Both the fresh and dry yields were significantly and positively related to the nitrogen harvest index and the N export

Table 3
Physiological nitrogen use efficiency NUEp (kg kg^{-1}), apparent nitrogen recovery efficiency NREC (kg/kg) and nitrogen harvest index in eggplant (average for 3 years)

Fertilizing	NUEp	NREC	NHI
T_1	25.4 ns	0.13 f	0.22 ns
T_1+Fitona	28.4	0.37 cde	0.29
T_1+Hortigrow	23.7	0.43 abcd	0.39
T_1+Agroleaf	21.6	0.46 ab	0.38
T_1+Kristalon	19.9	0.50 a	0.38
T_2	28.6	0.20 f	0.39
T_2+Fitona	20.7	0.29 e	0.37
T_2+Hortigrow	17.1	0.35 de	0.39
T_2+Agroleaf	16.9	0.39 bcd	0.37
T_2+Kristalon	14.3	0.45 abc	0.38

Table 2
Agronomical nitrogen use efficiency NUEa (kg kg^{-1}) in eggplant

Fertilizing	2004	2005	2006	Mean 2004-2006
T_1	3.0 ab	2.6 c	4.5 c	3.3 ns
T_1+Fitona	4.8 a	15.1 a	11.1 a	10.3
T_1+Hortigrow	3.8 a	15.9 a	9.8 a	9.8
T_1+Agroleaf	3.4 a	15.8 a	10.1 a	9.8
T_1+Kristalon	3.2 a	15.9 a	10.5 a	9.9
T_2	4.0 a	8.3 b	4.8 c	5.7
T_2+Fitona	2.6 b	9.1 b	6.5 bc	6.1
T_2+Hortigrow	1.3 b	9.5 b	6.7 b	5.8
T_2+Agroleaf	2.8 b	9.8 b	7.0 b	6.5
T_2+Kristalon	1.2 b	10.1 b	7.6 b	6.3

during maturity (Table 4). A considerable negative relation was established between the fresh fruit yield of the eggplants and the physiological nitrogen efficiency. The agronomic efficiency of nitrogen was strongly and positively related to the physiological and recovery efficiency as well as to the nitrogen harvest index.

Conclusions

The N productivity averagely for the period is the highest at a rate of N_{120} – 19.6 kg.kg^{-1}. The foliar fertilizing increases the nitrogen productivity against the background of the two levels of soil fertilization in both wetter and close to long term average values for the regional weather conditions.

The agronomic efficiency of nitrogen strongly depended on climate conditions. The highest value (15.9 kg.kg^{-1}) was registered in wet 2005 in the variants fertilized with *T1 + Hortigrow* and *T1 + Kristalon*.

Applying soil fertilization $N_{24}P_{12}K_{12}$ let to higher physiological efficiency of nitrogen 28.6 kg.kg^{-1}. Combined soil ($N_{24}P_{12}K_{12}$) plus foliar fertilizing decreased the physiological efficiency of nitrogen. The lowest value was obtained at rates $N_{24}P_{12}K_{12}$ and spraying with Kristalon – 14.3 kg.kg^{-1}.

The tested foliar fertilizers promote the apparent nitrogen recovery efficiency at the two levels of soil fertilization and the highest value of the latter is achieved by applying $N_{12}P_6K_6$+*Kristalon* – 0.50 kg.kg^{-1}.

Table 4
Correlation coefficients between the fresh and dry fruit yields. nitrogen harvest index. nitrogen uptake. and efficiency indexes

	FY	DY	NHI	N uptake	PFP	NUEa	NUEp
DY	0.978 **						
NHI	0.892 **	0.933 **					
N uptake	0.944 **	0.887 **	0.741 **				
PFP	-0.488	-0.402	0.135	-0.504			
NUEa	0.089	0.220	0.687 *	-0.015	0.803 **		
NUEp	-0.705 *	-0.467	-0.234	-0.852	0.385	0.134	
NREC	0.509	0.480	0.722 *	0.538	0.443	0.768 **	-0.519

* r is significant at 0.05 level
** r is significant at 0.01 level

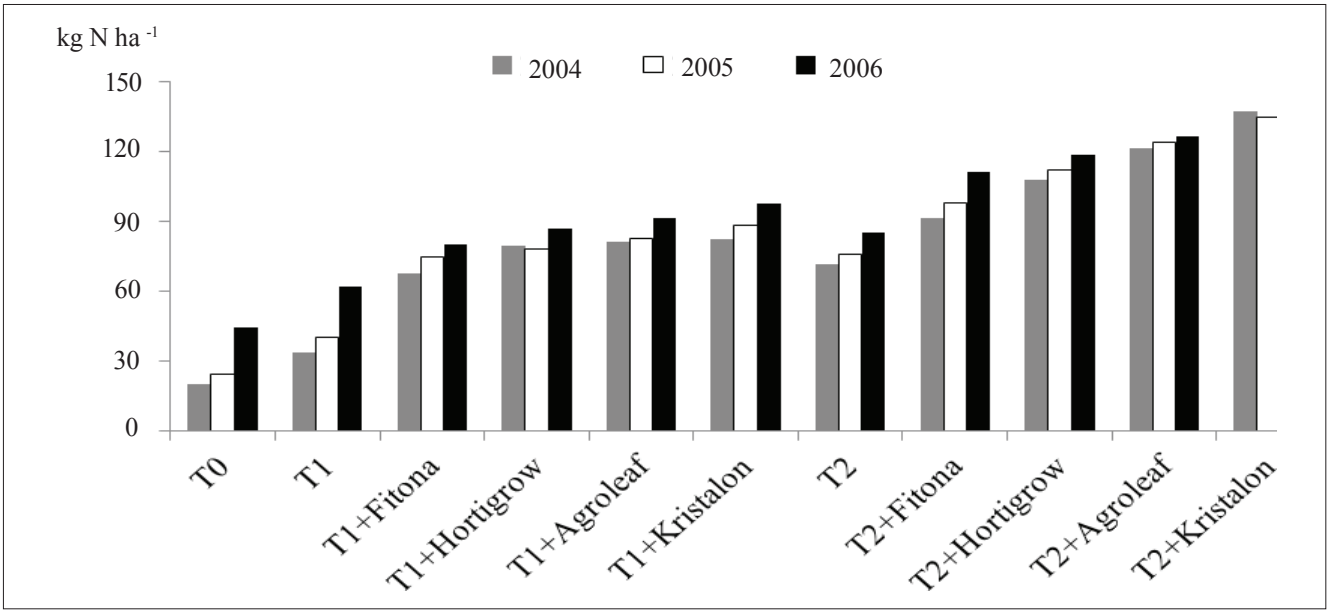

Fig. 2. Nitrogen uptake of eggplant depending of fertilizing

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