Economic cost-effectiveness of different nitrogen rates application in the production of corn hybrids of different fao maturity groups on brown forest soil (E*uteric Cambiosol*)

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Abstract

The goal of this paper is to analyse optimal nitrogen rate in corn production that will produce maximal profitability. Main objective of corn production is high and stabile yield and consequently generating maximum return for the producer. In order to achieve this, an adequate set of agro-technical measures has to be applied in the production process. Application of optimal quantity of nitrogen is important in order to increase profitability from corn production, and second, to avoid environmental pollution. During period 2005- 2007 a research was conducted to determine influence of nitrogen application rate (control – without fertilisation, PKN_{fon}, PKN_{60}, PKN_{120} and PKN_{180}) and different FAO group hybrids (ZP-SC 434, ZP-SC 578 and ZP-SC 677) on production profitability. Increase of nitrogen fertilizer tended to raise grain yield. In a dry year of 2005, high additional return of 257.04 $/ ha was with nitrogen fertilization rate of 120 kg/ha. The highest return in 2006 and 2007, was with moderate nitrogen rate of 60 kg/ha. Despite yield increase, excessive use of nitrogen can result in decrease of gross return due to rise in fertilization costs, which happened in 2007 where use of 180 kg/ha resulted in a loss of 210 $/ha.

Key words: corn profitability, nitrogen application, brown forest soil.

1. Introduction

The primary objective of corn production is high and stable yield, both quantitatively and qualitatively, and therefore the maximum profit for the producer in this way largely depends on the implementation of the complex agro-technical measures in the production process. Given that there are no universal agro-technical solutions for all areas of production of corn, production technology should be adapted to the climate conditions and land type (Živanović, 2013).

To achieve high, quality, stable, and economically viable yields of corn, timely and rational use of fertilizers is necessary. Fertilization with phosphorus and potassium fertilizers, with regard to the origin, behaviour and cycling of these two biogenic elements in the soil, to a large extent, science has responded (Bogdanović et al., 2005). However, the behaviour of nitrogen in the soil is very different from other biogenic elements and therefore the quantity, and the time and method of application has to be further studied. Literature data pertaining to the issue of fertilizing corn are very numerous, but very often different, which is understandable considering that the results of experiments with fertilization affected by many factors (Schlegel and Havlín, 1995).

Since the greatest impact on the dynamics and yield formation is influenced by the nitrogen, most research in the area of corn fertilization is dedicated to nitrogen (Stevens et al., 2003). Experiments with different application of nitrogen show that the yield of maize, as well as its need for nitrogen vary between the production fields (Bundy and Andraski, 1995), such as within the soil types (Blackmer and White, 1998), due to differences in the requirements of plants, supply of land and availability of water in different places within the same field (Baxter et al., 2003).

Yield variation depends on the type of soil, relief, physical and chemical characteristics of soil and the accessibility of nutrients (Penney et al., 1996). In most cases the variation of grain yield depends on the amount of nitrogen applied in different locations (Schmidt et al., 2002).

Minimum amount of nitrogen necessary for the high yield ranged from 52 kg/ha to 182 kg/ha, depending on the test fields.

Natural fertility and soil mineralization capacity significantly affect the efficiency of applied fertilizers. As a rule, the effect of the applied fertilizers is higher on the land less fertile and vice versa (Latković et al., 2005). Corn yield depends on the nitrate content in the are available to corn, and mineralization and nitrification in the early vegetation period (Bundy and Malone, 1988). Some studies show that 21 mg NO3 - NKG-1 of the first layer of soil is sufficient to reach optimal yield (Blackmer et al., 1989).

Specificity of mineral nutrition with different corn hybrids is studied with the intention to establish mutual differences between genotypes in the content of certain ions. Many authors have tried to determine the amounts, and the mineral nutrients, which are optimal in the production of certain genotypes (Spasojević, 1972; Sarić and Krstić, 1978; Sarić and Kovačević, 1980). Using stationary field trials with increasing doses of nitrogen (Starčević et al., 2000) examined the reaction of the hybrids to different levels of nitrogen in the soil with the aim to identify the specificity of hybrids in the utilization of nitrogen. In addition to grain yield, examined the above ground biomass yield as a whole, calculate harvest and nitrogen harvest index, determine the nitrogen content in the grain and crop residues, removal of N calculate grain and nitrogen utilization efficiency. Newer hybrids, in addition to higher grain yield, achieved higher yields of aboveground biomass compared to the older generation hybrids, NSSC 70 and NSSC 606. The nitrogen utilization efficiency was also higher in the newer hybrids.

The degree of nitrogen exploitation depends on genotype ability to generate high yields with a lower content of nitrogen in the soil (Sattelmacher et al., 1994). Experiments performed in the US (Balko and Russell, 1980), in the tropic climate (Lafitte and Edmeades, 1994; Bänziger et al., 1997), in Europe (Bertin and Gallais, 2000) show different degree of utilization of nitrogen can vary significantly in between genotypes.

For these reasons, there is a need to further develop genotypes of maize that can efficiently acquire existing nitrogen from the soil, as well as to more efficiently exploit adopted nitrogen (Andrea et al., 2006).

Efficiencies of use of nitrogen in nitrate form depend on the interaction of several factors, such as adoption, reduction, translocation, the energy state of the plant and others. Creating corn hybrids more efficiently acquire nitrogen fertilization and alignment with the needs of the plants will be one of the directions in the development of the maize growing technology (Raun and Johnson, 1999).

Environmental aspect of reducing the excessive use of nitrogen fertilizer is also important in relation to environmental protection.

2. Methodology and Experiment Model

Survey is conducted on the influence of nitrogen application on profitability of production of different FAO group hybrids. Experiment was located in Rača Kragujevac (Central Serbia) in the period 2005-2007.

Two factors were combined in this research:

a) Nitrogen quantity (Q)

Q_1 – Control trial (without fertilizers applied)

Q_2 – P_{90} K_{60} $N_{\mathbf{60}}$ kg/ha

Q_3 – P_{90} K_{60} $N_{\mathbf{120}}$ kg/ha

Q_4 – P_{90} K_{60} $N_{\mathbf{180}}$ kg/ha

b) FAO type (H)

H_1 – ZP-SC 434

H_2 – ZP-SC 578

H_3 – ZP-SC 677

In experiment standard agricultural technology is applied. Winter wheat was the preceding crop in all three observed years. Applied is 300 kg/ha of 10:30:20 NPK in autumn. With the depth on 25 cm, tillage was performed during autumn. In the spring, additional application of nitrogen is added with 27 %, (active ingredient NH_4NO_3) in quantities of 30, 90 and 150 kg/ha).

During the second half of April, manual sowing was done. According the sowing plan, it was used the space 0,7m between rows, planting of 2 seeds per hole. Plants density for ZP-SC 434 was 64,935 plants/ha, ZP-SC 578 57,143 per/ha and ZP-SC 677 51,020 per/ha.

Herbicides applied before emergence were Acetochlor 2 l/ha + Atrazine 1 l/ha. During the vegetation were applied: Motivell 1 l/ha + Cambio 2 l/ha.

Harvesting is done manually and grain yield with moisture content of 14 % was calculated by next formula:

$$Y = R \times (100 - U)/100 - US$$

Where: Y – quantity with moisture content 14 %; R – quantity of raw grains; U – Grain moisture content at harvest; US – Calculated grain with moisture content (14 %).

After statistical analysis of gained results, they were presented by tables and graphs.

2.1. Climate characteristics

Territory of Rača Kragujevačka covers basin of namesake river, that lies down between the basins of River Jasenica, at the north, and River Lepenica, at the south. Described territory belongs to the area of Low Šumadija.

Table 1: Rača Kragujevačka precipitation in milimeters for the period 2005-2007 at the experimental location

Year	Month						Average
	April	May	Jun	July	August	September	
2005	69.0	71.0	52.0	86.0	118.0	112.0	508.0
2006	85.0	30.0	84.0	23.0	143.0	59.0	424.0
2007	3.0	119.0	26.0	11.0	83.0	52.0	294.0

Source: RHSS, 2011.

Table 2: Temperature in Rača Kragujevačka in Celsius degrees for the period 2005-2007 at the experimental location

Year	Month						Average
	April	May	Jun	July	August	September	
2005	12.1	16.5	19.1	22.0	20.5	18.1	18.1
2006	12.9	16.4	19.7	22.4	21.1	18.2	18.5
2007	12.8	18.3	22.5	24.1	23.4	16.3	19.6
Average (1995 - 2004)	11.8	17.2	20.7	22.5	22.6	17.0	18.6

Source: RHSS, 2011.

Climate of Rača Kragujevačka is temperate continental, with translational character, as well as under the strong influence of the northern (polar), eastern and south-eastern air flows, that are facing in mentioned area, determining the local weather conditions (hydrology, temperature, etc.). From the morphological aspect, Rača Kragujevačka is an integral part of the Low Šumadija relief. Field micro-experiment was conducted at an altitude of 193 m.

2.2. Soil characteristics

Mineral forest soils include a large group of related soils formed in temperate climate. Beside climate, the second major factor in formation of these soils is leaf wood. Natural vegetation on brown forest soil is mostly cut down in the process of soil production. There are various brown forest soil substrates. They influence soil formation rate, mechanical composition, certain physical and chemical properties, and consequently soil fertility.

The most important sediments in brown soils substrates are: tertiary lake sediments, loess, alluvion and diluvial deposits. They can also be found on certain igneous and metamorphic rocks, but those substrates are less significant than afore mentioned sediments. Relief is also important factor that affects brown earth formation indirectly, through vegetation and microclimate.

As a climate generated soil, brown forest soil can be formed on all relief elements: plains, loess plains, river valleys and Šumadia hills. Brown earth can be found on altitudes up to 500m. It is formed on terrains with deep groundwater. Other factors relevant for brown forest soil formation are length of pedogenesis (length of brown earth forming process) and human impact.

The most important morphological characteristic of brown forest soil is its reddish-brown colour which is especially distinctive in underlying (B) horizon. The reddish-brown colour comes from $Fe(OH)_3$ iron hydroxide. In the upper portion of the soil profile this colour is dark brown, covered by humus and, while the clearest colour is in (B) horizon below 30-50 cm. Specific quality of mineral forest soils is that they are arable land with little humus. They have relatively thin humus horizon.

Structure of these soils is granular or prismatic with various structural aggregate sizes. Calcium carbonate is completely washed out from brown earth and lime can be found only in surface layer of a parent rock. Although calcium carbonate was washed out, brown earth has high base saturation, so it reacts neutral or slightly acidic. Clay washing out is reduced to the minimum but it's still present.

Table 3: Nitrogen before corn sowing (mg/kg)

Period	Soil layer in cm	Brown forest soil		
		NH_4^+	NO_3^-	Sum
2005	0 – 30	7.7	7.7	15.4
	30 – 60	6.8	7.8	14.6
	60 – 90	5.3	6.8	12.1
	0 – 90	19.8	22.3	42.1
	%	47.0	53.0	100.0
2006	0 – 30	8.7	10.7	19.4
	30 – 60	8.5	8.2	16.7
	60 – 90	8.0	7.4	15.4
	0 – 90	25.2	26.3	51.5
	%	48.9	51.1	100.0
2007	0 – 30	7.0	14.7	21.7
	30 - 60	6.5	7.4	13.9
	60 - 90	4.0	6.3	10.3
	0 - 90	17.5	28.4	45.9
	%	38.1	61.9	100.0
Annual average		13.7	7.0	14.7

Source: Živanović, 2013.

3. Results and Discussion

Of great importance is to optimal use off fertilizers for increase in profitability. Optimal use of inputs is important for environmental protection (Živanović et al., 2015).

Nitrogen use in rate of 60 kg/ha prove to be most profitable. For nitrogen rate application is used following calculation:

$P = (Y – Y_0) \times Pc - F$

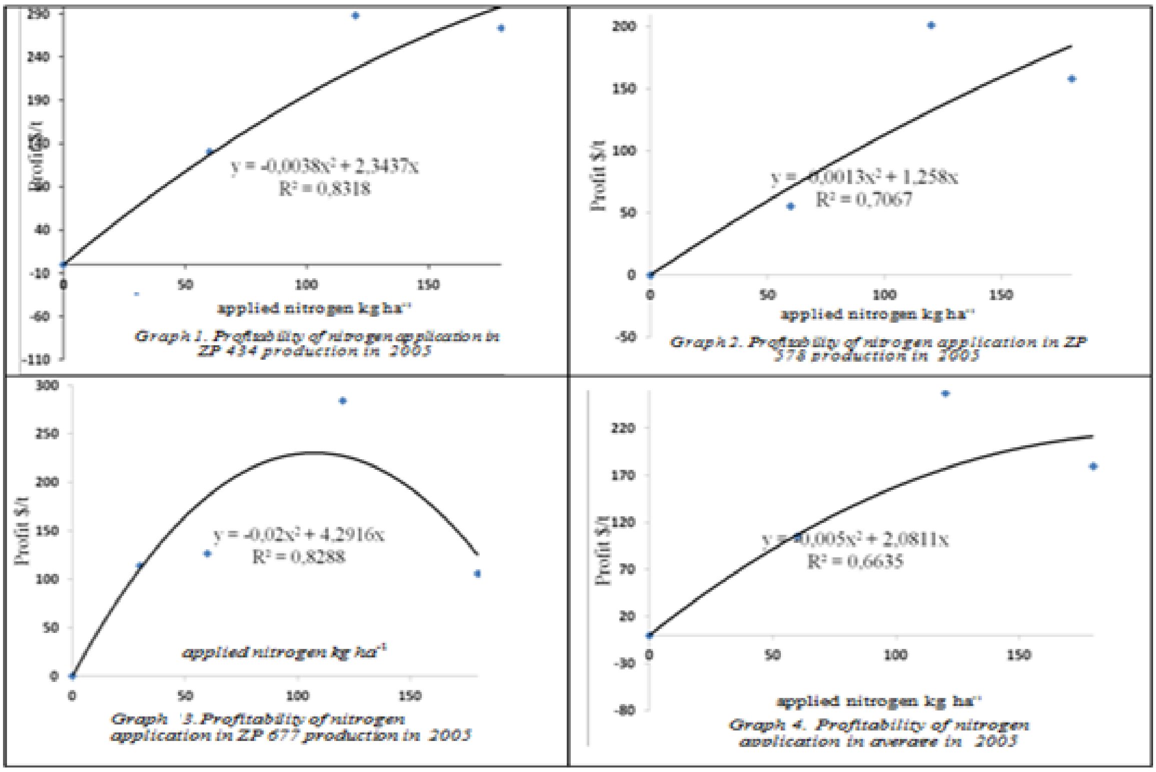
Where: P – profitability of applied nitrogen rate; Y – yield in trials with different nitrogen rate application; Y_0 –yield in test trial without nitrogen applied: Pc - Price of corn 192.7 $/t; F - price of nitrogen fertilizers: F (PKN_{fon}) - 195 $/ha; F ($PKN_{60}$) - 239.61 $/ha; F ($PKN_{120}$) - 328.77 $/ha; F ($PKN_{180}$) - 418.13 $/ha.

Table 4: Effects of nitrogen rate and corn FAO group on yield and profitability (in 2005.)

N quantity	Hybrids						Y Average t/ha	P Average (all FAO groups) $/ha
	Y FAO 400 t/h	P FAO 400 $/ha	Y FAO 500 t/h	P FAO 500 $/ha	Y FAO 600 t/h	P FAO 600 $/ha		
Control	8.86		9.61		9.90		9.46	
PKN_{fon}	9.68	-36.99	10.37	-48.55	10.32	114.07	10.12	9.51
PKN_{60}	10.78	130.37	11.14	55.21	11.83	126.52	11.25	105.32
PKN_{120}	12.06	287.87	12.36	201.15	13.08	284.10	12.50	257.04
PKN_{180}	12.45	273.66	12.60	158.04	12.62	106.01	12.56	179.25

Source: Authors calculation.

Weather conditions were optimal in 2005, when the additional nitrogen application for all hybrids resulted in increased profitability. Nitrogen application in the rate of 120 kg/ha provided remarkable profitability increase of 257.04 $/t. Effects of nitrogen rates on profitability in 2005. are presented on the Graphs 1., 2., 3. and 4.



Graph 1. Profitability of nitrogen application in ZP 434 production in 2005

Graph 2. Profitability of nitrogen application in ZP 578 production in 2005

Graph 3. Profitability of nitrogen application in ZP 677 production in 2005

Graph 4. Profitability of nitrogen application in average in 2005

From Graph 1 can be concluded that FAO 400 group had the best profitability with nitrogen rate at 120 kg/ha and 180 kg/ha.

Results from Graph 2. showed that FAO 500 has significant profitability at use of 60, 120 and 180 kg/ha. The highest profit is 201.15 $/ha achieved with 120 kg/ha. For FAO 600, highest production profit is at 120 kg/ha of nitrogen application.

Highest average profitability of 284.1 $/t, for all three FAO hybrid groups, is presented at Graph 4., achieved with nitrogen dose of 120 kg/ha.

Value of R-square analyse ranging from 0.6635 to 0.8288 showing significant correlation between nitrogen application and profitability.

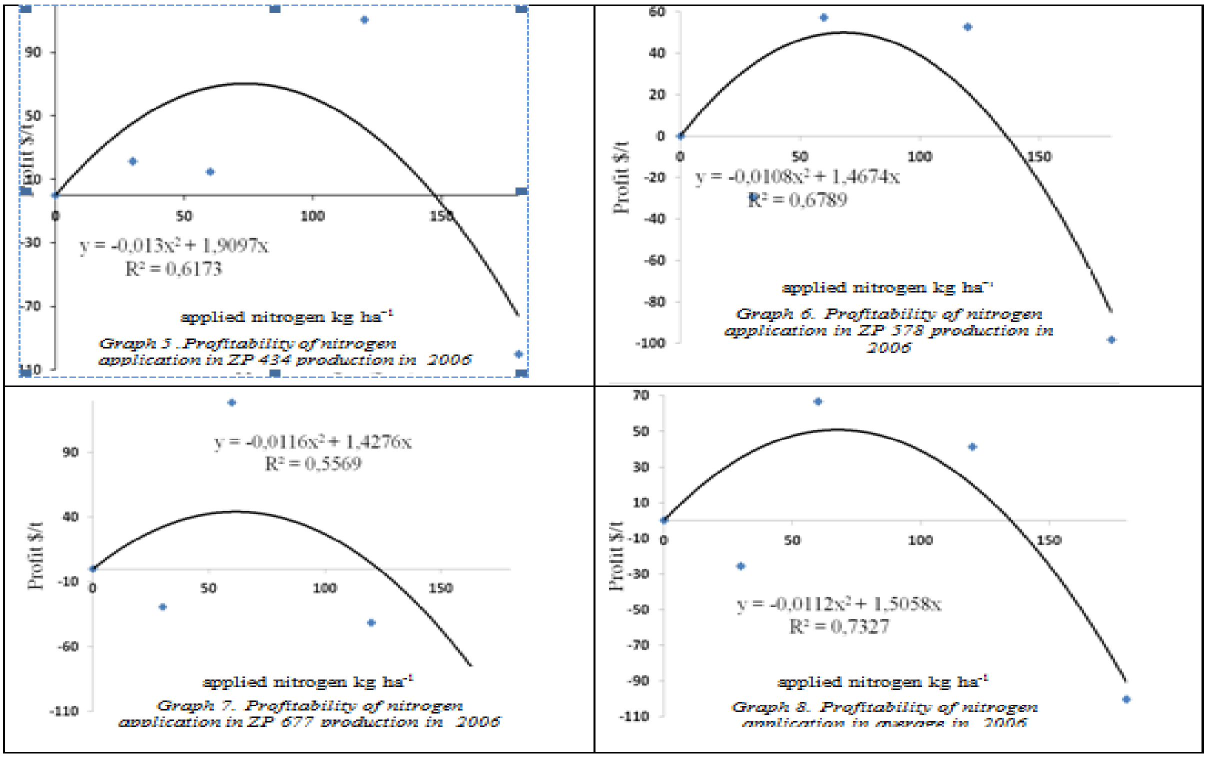
Table 5: Effects of nitrogen rate and corn FAO group on yield and profitability (in 2006.)

N quantity	**Hybrids**						Y Average t/ha	P (all FAO groups) average $/ha
	Y FAO 400 t/h	P FAO 400 $/ha	Y FAO 500 t/h	P FAO 500 $/ha	Y FAO 600 t/h	P FAO 600 $/ha		
Control	6.99		7.56		7.54		7.36	
PKN_{fon}	7.89	21.57	8.42	-29.28	8.40	-29.28	8.24	-25.42
PKN_{60}	8.31	14.75	9.10	57.15	9.45	128.45	8.95	66.78
PKN_{120}	9.27	110.59	9.54	52.78	9.03	-41.65	9.28	41.21
PKN_{180}	8.64	-100.17	9.22	-98.25	9.16	-105.96	9.01	-100.17

Source: Authors calculation

The 2006 was with unfavourable weather conditions. Unlike previous year, there was little effect of the additional nitrogen rate on yield, or it even resulted in a loss.

Regression correlation analyses on effect of nitrogen application on corn production profitability (experimental year 2006.) are graphically presented on Graphs 5., 6., 7. and 8.



For FAO 400 corn group the best nitrogen dose was 120 kg/ha, gaining extra profit of 110.59 $/ha. From Graph 6. can be concluded that for FAO 600 group nitrogen application of 60 and 120 kg/ha was the optimal dose. The highest profit was scored in amount of 50 $/ha, applying 60 kg/ha.

In FAO group 600, highest profitability of 128.45 $/ha is accomplished with dose of 60 kg/ha.

Additional profit in average was low in 2006. with application of 60 and 120 kg/ha.

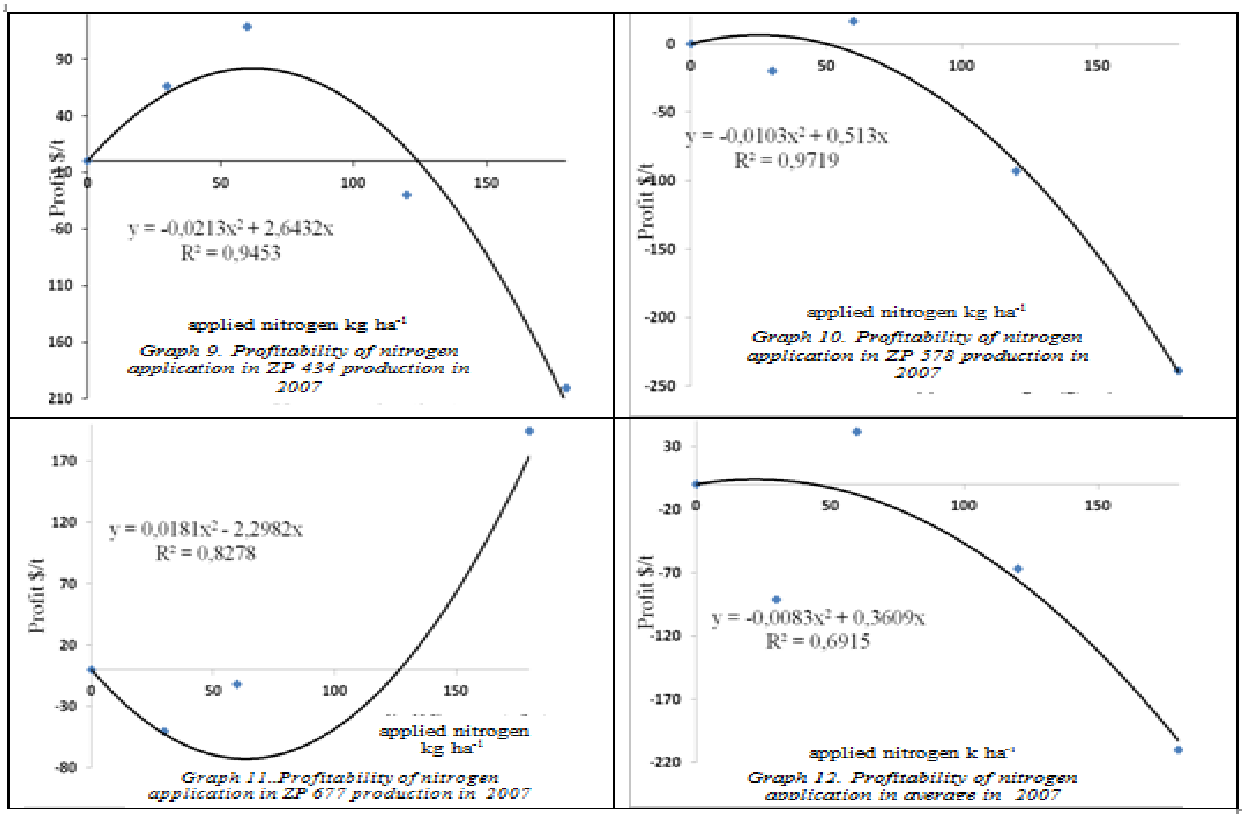
Applied quantity of nitrogen effecting profitability measure by R-square between 0.5569 and 0.7327.

Table 6: Effects of nitrogen rate and corn FAO group on yield and profitability (in 2007.)

N quantity	Hybrids						Y Average t/ha	P (all FAO groups) average $/ha
	Y FAO 400 t/h	P FAO 400 $/ha	Y FAO 500 t/h	P FAO 500 $/h	Y FAO 600 $/ha	P FAO 500 t/h		
Control	5.02		5.66		6.04		5.57	
PKN_{fon}	6.38	66.12	6.57	-19.64	6.79	-50.47	6.58	-1.33
PKN_{60}	6.88	118.81	6.99	16.68	7.22	-12.24	7.03	41.73
PKN_{120}	6.57	-30.08	6.88	-92.9	7.35	-76.33	6.93	-66.7
PKN_{180}	6.15	-200.38	6.59	-238.92	7.20	194.60	6.65	-81.76

Source: Authors calculation

Regression correlation analyses on effect of nitrogen application on corn production profitability (experimental year 2006.) are graphically presented on Graphs 9., 10., 11. and 12.



Graph 9. Profitability of nitrogen application in ZP 434 production in 2007

Graph 10. Profitability of nitrogen application in ZP 578 production in 2007

Graph 11..Profitability of nitrogen application in ZP 677 production in 2007

Graph 12. Profitability of nitrogen application in average in 2007

Results in experimental year 2007. shows for FAO 400 group that optimal nitrogen dose was 60 kg/ha, gaining additional profit of 118.81 $/ha.

For the same year FAO group 500 had the highest profitability with dose of 60 kg/ha.

In the 2007. for FAO group 600 optimal nitrogen quantity was 180 kg/ha, adding the highest additional profit.

Table 7: Effects of nitrogen rate and corn FAO group on yield and profitability - average 2005 to 2007

Nitrogen application rate (A)	Hybrids						Y Average (all FAO groups) t/ha	P (all FAO groups) average $/ha
	Y FAO 400 t/h	P FAO 400 $/ha	Y FAO 500 t/h	P FAO 500 t/h	Y FAO 600 $/ha	P FAO 500 t/h		
Control	6.96		7.61		7.83		7.47	
PKN_{fon}	7.98	1.55	8.45	-33.13	8.50	-65.89	8.31	-33.13
PKN_{60}	8.66	87.98	9.08	45.50	9.50	82.2	9.08	70.64
PKN_{120}	9.30	122.15	9.59	52.78	9.82	54.7	9.57	75.9
PKN_{180}	9.08	-9.06	9.47	-59.70	9.66	65.49	9.40	-46.22

Source: Authors calculation

In all three experimental years in average most effect on profitability increase is nitrogen doses of 60 and 120 kg/ha. Application of high nitrogen rates were proven to lead to high yields but with negative effect on profitability.

4. Conclusion

Experimental results shows that corn yield is correlated with nitrogen nutrition, where nitrogen application increased grain yield by 0.77 to 1.26 t/ha, or by 9.3 to 15.2%. Also corn hybrids with longer vegetation periods have higher yields. Climate conditions were the important part of the corn yields in 2005.

According to experimental results effects of nitrogen rate application on yield and profitability are complex and highly correlated with climate conditions. If the rainfalls and temperatures are optimal such as in 2005., optimal nitrogen rate is higher. While in 2006. as results of uneven precipitation yield was lower by 23,3 %, while in 2007. as a result of draught yield was lower by 41.4% compared with 2005. Within the years with poor climate conditions, such as 2006. and 2007., application of higher quantity of nitrogen is not recommendable.

Experiment showed that nitrogen application has positive effect on yield which corresponded with significant square regression. But highest nitrogen rate is not always most profitable.

In the modern conditions of market production, optimal nitrogen application results in increased profitability and environment protection.

The highest profitability in brown forest soil was achieved in the year with favourable amount and distribution of precipitation, as the result of good nitrogen absorption by the plants. Therefore it can be concluded that if irrigation or enough precipitation is provided, higher nitrogen rate should be applied. In years with less precipitation lower nitrogen rates should be applied considering the fact that in dry conditions fertilizer decomposition is reduced and plants are not able to adequately absorb mineral fertilizer.

Considering the high correlation between nitrogen absorption and amount and distribution of precipitation during the growing period of corn, it would be significant to conduct further research with irrigation systems as one of the factors.

Within the survey the highest profitability in average was at nitrogen rate at 60 kg/ha to 120 kg/ha. Study results highlight the importance of analyses and application of nitrogen in quantity which will bear maximal profit in corn production. Beside the profitability controlled nitrogen application will have positive impact on environmental protection.

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