DOI: 10.17707/AgricultForest.65.1.16

Dmytro ONOPRIIENKO, Mykola KHARYTONOV [1]

THE EFFECTS OF IRRIGATION AND NITROGEN APPLICATION RATES ON YIELD AND QUALITY OF CORN IN THE STEPPE ZONE OF UKRAINE

SUMMARY

The given experimental data testifies that nitrogen fertilizers can be effectively introduced with irrigation water (fertigation). The advantages of fertigation in comparison with the traditional technology of introduction of mineral fertilizers of brushwood are shown for production of corn grain in conditions of the northern part of Ukraine's Steppe zone Nitrates migrate from the root layer and is gradually impoverished when nitrogen fertilizer introduced in the autumn. By the period of intense need for N (10-12 leaves), nitrates in the soil were less than in the phase of 5-6 leaves, 15.3%, and in the phase of milk ripeness of grain their content was 50.3%. It is advisable to add N fertilizers to irrigated water in the following proportions: 40% of the overall dose during the period of 10-12 leaves, 40% - in the phase of pinnacle ejection and 20% in the phase of milky ripeness of grain. The corn grain yield of was increased up to 10.3 t/ha when the trial of N fertilizer application include 3 times of fertigation. The protein content of the grain increased with fertigation.

It is advisable to add N fertilizers to irrigated water in the following proportions: 40% of the overall dose during the period of 10-12 leaves, 40% - in the phase of pinnacle ejection and 20% in the phase of milky ripeness of grain.

Keywords: Irrigation, fertigation, corn, grain yield, mineral fertilizers.

INTRODUCTION

Application of fertilizers through an efficient irrigation system was called fertigation (Bussi et al, 1991; Hebbar et al., 2004). The combination in one technological process of fertilization and irrigation determines the phenomenon of synergy. Two of the most effective factors in the production of maize are irrigation and fertilizers mutually reinforce each other, with an additional factor - their interaction. It is one of the effective ways to intensify irrigated land, to provide more accurate and timely crop nutrition (Ardell, 2006), water use efficiency under different cropping situation (Tiwari et al., 2002). The introduction of mineral fertilizers with irrigation water fully complies with the idea of multipurpose use of irrigation systems and sprinkler technology, increases

[1]Dmitro Onopriienko, Dnipro State Agrarian and Economic University, 49600, Dnipro, UKRAINE; Mykola Kharytonov, (corresponding author: kharytonov.m.m@dsau.dp.ua), Dnipro State Agrarian and Economic University, 49600, Dnipro, UKRAINE.
Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

the efficiency of water and fertilizers, contributes to maintain the structure of the soil, improves the environmental conditions in the cultivation of crops.

Drip fertigation with water-soluble fertilizer improved the root system by inducing new secondary roots which are succulent and actively involved in physiological responses (Fanish et al., 2013).

Fertigation promotes the production of intensely branched roots that facilitates nutrient acquisition and foraging capacity. Fertigation allows the implementation of complex mechanization and automation of technological processes, ensuring, with the observance of the recommended agrotechnology. Higher grain yields of 7.5 t/ha were recorded under drip fertigation of 100 per cent recommended dose of fertilizer (RDF) with 50 per cent P and K as water soluble fertilizer (Fanish, 2013). Considering the high cost of water soluble fertilizers, drip fertigation of 150 per cent RDF with radish as intercrop could be an alternative option to realize a reasonably good yield and income in maize containing intercropping system. Similar results were obtained by Zwart and Bastiaansen (2004), who reported values of 1.1-2.7 kg/m^3 for the water productivity of maize. These finding indicate that it is essential to employ appropriate methods for determining the amount of irrigation water and the period of applying the fertilizer through the irrigation water under the drip irrigation system.

The increase in water use efficiency in all drip irrigated treatments over surface irrigation was mainly due to considerable saving of irrigation water, greater increase in yield of crops and higher nutrient use efficiency (Fanish et al., 2011). This was in agreement with Ardell (2006) reported that application of N and P fertilizer increases crop yields, thereby increasing crop water use efficiency. In order to maximize maize yields and the productivity of the irrigation water under the drip irrigation system in the sandy soil, it is recommended to irrigate maize crops using a water amount at 1.2 of crop evapotranspiration every 3 days and applying the recommended fertilizer dose in 80% of the irrigation time (Ibrahim et al., 2016). Application of fertilizers with irrigation water radically solves the problem of uniform distribution of fertilizers in the active layer of soil to the level of uniform distribution of irrigation water (Mmolawa and Or, 2000).

The traditional technology of fertilizer spreading across the field is imperfect because it is dominated by man-made factors instead of biological ones. Fertilizers that are cultivated in soil for almost six months before their intensive use by maize, are losing a lot of nutrients due to mineralization, evaporation into the air and washing into deep layers of the soil, contaminating the environment (Harold and Reetz, 2016). The technological capabilities of existing scatterers are very low. The uneven distribution of fertilizers in the field, especially in the case of large doses, reaches 50-75%. Under these conditions, even the negative effect of fertilizers on plants and soil is observed. In addition, fertilizers are unevenly fed into farms, and those purchased during vegetation of corn are practically not used. Consequently, there was a need for new approaches to the rational use of mineral fertilizers, which involves introducing them mainly with irrigation water, as well as locally. The retail introduction of N fertilizers along with irrigation water ensures more even assimilation during the growing season than the one-time introduction at sowing (Nilahyane et al., 2018).

Rates of fertilizer should be established depending on the biological characteristics of the crops, soil conditions, and closely aligned with the irrigation schedule. Corn (Zea mays L.) harvested for silage is the most important feed crop worldwide. In semi-arid regions, scarcity of water supply reduces the potential of sustainable corn production (Bannayan et al, 2011). Efficient irrigation systems and adequate fertilization strategies could improve nutrients and water uptake and productivity (Kim et al., 2008). These strategies must be supported with research-based information addressing key issues that may decrease yield (Mansouri- Far et al., 2010). These include the negative effects of water stress on plant growth and leaf area (Stone et al., 2001; Pandey et al., 2000).

The main aim was to investigate the effects of sprinkler irrigation and N application rates on soil nitrate-N (NO_3^--N) accumulation, corn grain yield and quality.

MATERIAL AND METHODS

The research was conducted during 3 years (from 1999-2001) growing seasons in the educational - research farm "Samara" of the Dnipro State Agrarian University. Agrochemical analyzes of soil samples were carried out follow accepted approaches (Dokuchaev Soil Institute, 1965). Groundwaters lie at a depth of more than 15 m.

Weather conditions during the growing seasons were generally favorable for growing corn in irrigation by the method of sprinkling. During the vegetation period (May-September), 1999, 128 mm of precipitation was felled, in 2000 was 216 mm, and in 2001 was 192 mm.

The seeds of the medium-sized hybrid of corn Pioneer 3978 was sown in the field experiments. The rates of mineral fertilizers were calculated for the expected grain yield of 8 and 10 t/ha. There was also an option without fertilizers. Corn cultivation technology was commonly used for this crop in the northern part of the steppe zone of Ukraine. Sprinkler irrigation was performed with unit DDA-100MA. Urea (carbamide) was dosed in irrigation water with a special hydro-fluid in accordance with the program of research for cultivation and irrigation water. The irrigation mode provided for the maintenance of soil moisture in the active layer of not less than 70-80% minimum water capacity (MWC). Irrigation rate norm was 1800-2100 m^3/ha.

Rates of N fertilizers were calculated by the balance method, taking into account the content of the main nutrients in the arable soil layer. Introducing various options of urea fertilizer with irrigation water was developed in order to study this technology efficiency in comparison with the traditional spreading method and studying the optimal parameters of fertigation.

Technological schemes for the introduction of N fertilizers are as follows:

A – no fertigation;

B – fertigation under the cultivation with a full norm;

C – fractionally fertigation: 40% of the norm of sprouts for cultivation, and with irrigation water 40% in the phase of 10-12 leaves and 20% in the phase of pinnacle ejection;

D - full N norm with irrigation water (fractionally fertigation in doses, 40% in the period after sowing to the phase of 10-12 leaves, 40% in the phase of pinnacle ejection and 20% in the phase of milky ripeness of grain).

Sowing area of the experimental fields 630 m², and accounting 150 m², repetition - fourfold. Yields data were processed by the method of dispersion analysis. Grain quality was estimated on several parameters including crude protein, starch, fat and gluten using infrared analyzer “Infrapyd 61” (Hungary).

RESULTS AND DISCUSSION

The data on N-NO_3 content in the topsoil layer depending on the methods of nitrogen fertilizers introducing (average for 3 years) to reach the yield of 8 t/ha, mg/kg of soil (Table 1).

Table 1. The content of N-NO_3 in the topsoil layer depending on the methods of introducing nitrogen fertilizers at the programming of the yield of 8 ton/ha (average for 3 years), mg/kg

Trial	Vegetation stage		
	5-6 leaves	10-12 leaves	milky ripeness of grain
B	30.8	26.1	15.3
D	20.5	25.0	18.8

It was shown that N content plays an important role in plant productivity under irrigation conditions, depending on the method and time of fertilizer application. Nitrates migrate from the root layer and is gradually impoverished when nitrogen fertilizer introduced in the autumn. By the period of intense need for N (10-12 leaves), nitrates in the soil was less than in the phase of 5-6 leaves, 15.3%, and in the phase of milk ripeness of grain their content was 50.3%.

The three years corn yields data of field experiment on urea using with irrigation water are shown in the table 2. The corn grain yield of was increased up to 10.3 t/ha when the trial of N fertilizer application include 3 times of fertigation.

There were established sometimes a deterioration in the quality of grain during irrigation together with an increase in yield (Wang et al, 2012). The increased demand of limited water sources presents a constraint in crop production with deteriorating quality as result of increased consumption (Ma et al., 2005). Zhang et al. (1996) found that fertilizers are applied at double or even triple the rates required for agricultural production.

Table 2. The yield of maize hybrid Pioneer 3978, depending on the dose and method of mineral fertilizers application, t/ha

For yield. t/ha	Trials	Year			Average	± to control	
		1st	2nd	3rd		t/ha	%
	A	5.16	5.96	5.48	5.53	-	-
8.0	B	7.86	7.75	8.01	7.87	-	-
	C	8.14	8.46	8.54	8.38	0.51	6.6
	D	8.28	8.65	8.58	8.51	0.63	8.1
	Average	8.09	8.28	8.37	8.25	-	-
10.0	B	9.28	9.34	9.46	9.6	-	-
	C	9.87	10.20	10.06	10.04	0.62	6.7
	D	10.14	10.32	10.42	10.29	0.93	10.0
	Average	9.76	9.95	9.98	9.89	-	-
HIP_{05} t/ha for trial		0.03	0.47	0.21			
HIP_{05} t/ha for rate		0.24	0.32	0.13			

Meantime our experiments showed that there was a tendency to increase the content of protein with increasing calculated rates of urea (Table3).

Table 3. The grain quality of maize hybrid Pioneer 3978, depending on the methods and timing for the introduction of urea (the average for 3 years).

Expected yield, t/ha	Trials	Content in grain,%			
		Crude protein	Fat	Starch	Cluten
	A	8.9	4.9	61.8	2.9
8.0	B	9.1	4.9	62.2	3.1
	C	9.5	4.8	64.3	2.9
	D	9.4	5.0	63.1	3.0
	Average	9.3	4.9	63.2	3.0
10.0	B	9.4	4.9	62.9	2.9
	C	9.4	5.0	63.1	3.0
	D	9.6	5.0	61.8	3.0
	Average	9.4	4.9	62.6	3.0

The method of introducing nitrogen fertilizers also has an effect on the protein content of the grain. The protein content of the grain increased with fertigation. Two rates of urea introducing with fertigation way did not significantly affect the content of starch, fat and gluten in the grain.

Many factors affect grain crops yield and NO_3-N accumulation in soil. These include crop N uptake dynamics, N fertilizer management, rainfall, irrigation, soil texture, and N transformation in the soil (Wang et al, 2012). However, N fertilizer and irrigation are two major factors influencing grain crops yield and NO_3-N accumulation but these can be controlled by the grower (Ottman and Pope, 2000; Yin et al., 2007). In our research during repeated application of N fertilizers with irrigation water, the volatility of nitrates in the soil in this period was lower. Moreover, their content in soil was bigger in the milk grazing phase.

It is necessary to take into account that N fertilization increases crop yield when the soil N supply is low (Fredrick et al., 1995a: 1995b; Sexton et al., 1996). N fertilizer applied at rates higher than the optimum requirement for crop production may cause an increase in NO_3-N accumulation below the root zone and pose a risk of NO_3-N leaching (Zhu et al., 2003; Fang et al., 2006). It was shown also that the amount of NO_3-N, decreases with the black soil depth in the DSAEU educational - research farm "Samara" (Kharytonov et al, 2016). The greatest energy of nitrification (27.1 mg/ kg) was in the stratum 0- 30 cm. The impact of nitrogen fertilization at silking was higher at the smallest rate of N during the plant vegetative development. Enhancements in grain yield with late N side - dressing resulted from increases in grain weight. Two nitrogen fertilizer rates calculation to get grain yield 8 and 10 ton/ha in our research was based for N content in soil in medium level. Obviously that 20% of N in the phase of milky ripeness enhance grain yield as well.

CONCLUSIONS

It is advisable to add N fertilizers to irrigated water in the following proportions: 40% of the overall dose during the period of 10-12 leaves, 40% - in the phase of pinnacle ejection and 20% in the phase of milky ripeness of grain.
The results of research indicate that combination of irrigation with the introduction of mineral fertilizers (fertigation) is an effective way of saving energy and material resources, increasing the yield and quality of corn grain yield, and protecting the soil from degradation.

ACKNOWLEDGEMENTS

This study was supported by the Ukrainian Ministry of Agrarian Policy.

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