International Journal of Waste Resources

Paschalidis X, et al., Int J Waste Resources 2015, 5:1
http://dx.doi.org/10.4303/2252-5211.1000173

Research Article Open Access

Effect of Fertilization and Irrigation on Plant Mass Accumulation and Maize Production (*Zea mays*)

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Received date: January 16, 2015, **Accepted date:** February 05, 2015, **Published date:** February 10, 2015

Abstract

The efficiency levels of nitrogen fertilization on growth and yield of maize (*Zea mays*) at two different levels of irrigation were examined. The experimental work was carried out at the farm of the Technological Educational Institute of Kalamata. The soil characteristics include: sandy clay soil texture, 11.07% $CaCO_3$, slightly acidic to neutral pH, non- saline, sufficient organic matter, adequate nitrogen, phosphorus, potassium and magnesium concentrations. Plot dimensions were equal to 3.0x4.0 m with four rows of plants per 0.75 cm in each plot of which the two inner rows represent the experimental surface. The experimental design was a Randomized Block Design. The experiment consisted of six treatments in three replications, with two levels of soil water capacity (70 and 40% respectively). N levels were 0, 160, 240 kg/ha, while the P and K levels were kept constant at 100 kg/ha. The amounts of P, K and 30% of N were added to the basic fertilization before sowing. The remaining N amount separated to two doses, at different growth stages of maize and incorporated through the irrigation system. The type of fertilizers was ammonium sulfate, ammonium nitrate, superphosphate and potassium sulfate. Based on the experimental data, it was found that the fed conditions greatly influence the nature and direction of the processes involved in developing plant, the addition of nutrients, regardless of treatment combination and their dosages, affected positively the plant growth, the fresh plant mass accumulation and the weight of 1000 grains compared to plants cultivated in soil without nitrogen. The total plant weight increase was equal to 59.13% compared to plants cultivated in soil with lack of nitrogen maintaining N, P, K levels to 240, 100, 100 kg/ha and soil water capacity to 70%. High seed yields were observed with the addition of 160 and 240 kg/ha N, constant levels of P and K, and 70% of soil water capacity. Low seed yields were observed when the level of irrigation was 40% of soil water capacity regardless the added amount of N, P and K. This can be interpreted that fertilizers have a high impact on crop yield, when combined with the appropriate level of irrigation.

Keywords: *Zea mays*; Irrigation levels; Sandy clay soils; Fertilizers

Introduction

In Greece, maize is cultivated mainly in Macedonia, Thrace, Central Greece and Peloponnese. The annual output reaches around 1.5 million tons. Historically maize is one of the major Greek crops. It was grown mainly for grain and biomass production due to its higher yield compared to other cereals. Maize seed is used in animal husbandry, in the human diet and in the production of by-products for the industrial sector. The biomass intended for silage, fresh or dried fodder, and for paper, ethanol and biofuel production. Among all the nutrients, nitrogen has the greatest effect on maize yield, particularly in light textured soils [1]. According to literature [2], the production of 1000 kg grain/ha require 19.4 kg of nitrogen, 2.7 kg of phosphorus, 13.8 kg of potassium, 1.4 kg of magnesium, 2.7 kg of calcium and small amounts of trace elements. In Messinia region (South Peloponnese), maize cultivation realized from light to medium texture soils, slightly acidic environment, where nitrogen leached from the surface layer, mainly due to the high rainfall and large annual irrigation doses. The excessive use of nitrogen fertilizers resulted to high nitrate concentrations in groundwater especially during the period of major nutrient requirements. Maize is very demanding in water, lack of which decrease its yield. The composition of 1 kg of dry maize matter requires the adsorption of 350-400 kg of water [3,4].

Studies have shown the efficiency of soil amendments such as zeolite, bentonite and zeolite – bentonite regarding the retention of nitrate ions, from maize (*Zea mays).* Two doses of nitrogen were used (400 and 800 kg N ha^{-1}) in the form of NH_4NO_3. According to the statistical analysis of the greenhouse experimental data, nitrogen fertilizers influenced strongly the development of maize, bentonite and zeolite – bentonite as soil amendments increased the height of the plants in the dose of 800 kg N ha^{-1}. Moreover, all the used soil amendments reduced the concentration of nitrate nitrogen in soil and plants [5].

The aim of the present study is the examination of the efficiency levels of nitrogen fertilization on growth and yield of maize (*Zea mays*) at two different levels of irrigation (40 and 70%, respectively). Moreover, the accumulation of maize organic dry biomass was also examined. The experimental design was a Randomized Block Design which consisted of six treatments in three replications, with two levels

of soil water capacity. Fertilizers that were used, were ammonium sulfate, ammonium nitrate, superphosphate and potassium sulfate.

Materials and Methods

Maize was cultivated in the farm of the Technological Educational Institute (TEI) of Kalamata. The soil of the farm is a typical light textured sandy clay soil of the Messinia region in South Peloponnese. Other soil characteristics include: 11.07% of $CaCO_3$, pH equal to 6.39, non- saline soil. Plot dimensions were equal to 3.0x4.0 m with four rows of plants per 0.75 cm in each plot of which the two inner rows represent the experimental surface. The experimental design was a Randomized Block Design. The completely randomized experimental design consisted of six treatments in three replications, with two levels of soil water capacity (70 and 40% respectively). N levels were 0, 160, 240 kg/ha, while the P and K levels were kept constant at 100 kg/ha. The whole amounts of P, K and 30% of N were added to the basic fertilization before sowing. The remaining N amount separated to two doses, at different growth stages of maize and incorporated through the irrigation system. The type of fertilizers was ammonium sulfate (21-0-0), ammonium nitrate (34.5-0-0), superphosphate (0-20-0) and potassium sulfate (0-0-45). The simple hybrid maize used was "Aris". Seeding took place by hand at April 23rd, 2008. Crop irrigation was through the artificial rain and soil moisture was maintained at the levels of 70 % and 40 % of soil water capacity during cultivation. The appropriate cultivation treatments were applied to all experimental plots uniformly.

Measurements were taken for plant growth in two stages, the first is the development of corn two months after sowing and the second is at the end of its biological cycle. The measurements were made on each block separately and then the average plant growth per treatment was also determined. Plant tissue samples obtained at ripeness corn. The processing of the experimental data was performed by ANOVA analysis. The comparison of the averages by Dunkan test at a significance level of 0.05 was also examined.

Results and Discussion

During the experiment, morphological characteristics concerning the color appearance of leaves during the life-cycle of maize were observed. Comparing maize crops, where fertilizers were applied, with crops, which were grown in fertilized plots with no nitrogen (N0-P10-K10), color differences appeared in the 5th-6th normal leaves. The plants, which fertilized with nitrogen, have intensely green color in leaves compared to those which developed to soil with lack of nitrogen.

Plant growth measurements were taken in two stages, the first one represents the development of maize two months after sowing (June 26th) and the second one the development of maize at the end of its biological cycle (September 11th). The measurements were made on each block separately and then the average plant height per treatment was determined.

According to Table 1, the addition of phosphorus and potassium (N0-P10-K10) has a positive effect on plant height.All treatments had a constant level of potassium and phosphorus equal to 100 kg/ha.The average plant height with 70% soil water capacity ranged to 157.0 cm without the addition of nitrogen, to 247.33 cm with the addition of 160 kg N/ha and to 257.17 cm with the addition of 240 kg N/ha.

Treatments with 40% soil water capacity had an average plant height close to 227.0 cm without the addition of nitrogen, to 224.0 cm with the dose of 160 kg N/ha and to 218.50 cm with the dose of 240 kg N/ha.

Treatments			Plant height (cm)	
a/a	Fertilizers	Soil water capacity	June 24th	September 11th
A1	N0-P10-K10	70%	148.33	157
A2	N16-P10-K10	70%	188.83	247.33
A3	N24-P10-K10	70%	200.67	257.17
B1	N0-P10-K10	40%	162.83	227
B2	N16-P10-K10	40%	152.83	224
B3	N24-P10-K10	40%	159.83	226.5

Table 1: Effect of nitrogen levels and soil water capacity on the plant height of maize.

The addition of nitrogen (N16-P10-K10 & N24-P10-K10) influences significantly the plant heights when it was combined with 70% soil water capacity. Low soil water capacity around 40% did not increase the plant height regardless the addition amount of nitrogen in plants.

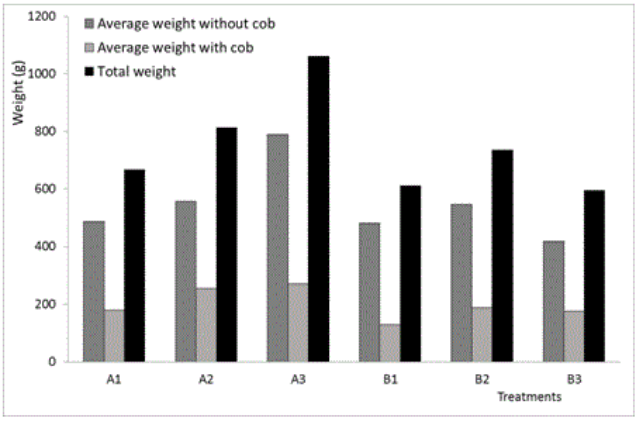

Figure 1: Effect of nitrogen levels and soil water capacity on the total maize weight (g/plant).

The effect of fertilizers and soil water capacity on seed fresh weight and on the fresh weight of 1000 grains is presented in Table 2. There was an increasing trend of weight in treatments with high soil moisture (70%) in contrary to the treatments with low soil moisture (40%). The increase of nitrogen level, e.g. N16-P10-K10 and N24-P10-K10 with 40% of soil water capacity maintained constant the seed fresh weight and the fresh weight of 1000 grains.

Maintaining the level of potassium and phosphorus constant and increasing the amount of nitrogen and soil water capacity, the seed fresh weight and the fresh weight of 1000 grains increased. According to literature the application of 100 kg N/ha increased biomass by 25-42% while irrigation increased grain yield by 59% [6].

Treatments	Average weight of fresh seeds (g/plant)	Fresh weight of 1000 grains (g)
A1	147.52	240.32
A2	211.98	293.85
A3	227.25	322.73
B1	101.81	234.68
B2	157.28	260.42
B3	141.68	258

Table 2: Effect of nitrogen levels and soil water capacity on seed fresh weight (g/plant) and on the fresh weight of 1000 grains (g).

Table 3 presents the data regarding the average yield of maize fertilization and irrigation levels. The lowest average maize yield (8110.0 kg/ha) was presented in treatment without nitrogen and irrigation at 40% of the soil water capacity. The highest average maize yield (19630.0 kg/ha), was presented in treatment with nitrogen level around 240 kg/ha and irrigation at 70% of the soil water capacity. Treatments had a constant level of potassium and phosphorus equal to 100 kg/ha.

Treatments	Maize Yield Replicates (kg/ha)			Average yield(kg/ha)
	1st	2nd	3rd	
A1	11730	8860.6	10460.6	10350cd*
A2	15330.3	22330.3	14660.6	17440ab*
A3	17290.3	19860.6	21730.3	19630a*
B1	9930.3	7330.3	7060.6	8110d*
B2	17130.3	14400	12730.3	14760bc*
B3	12200	14660.6	12530.3	13130bc*

Table 3: Effect of nitrogen levels and soil water capacity on average maize yield.*Means in the same column followed by the same letter(s) are not significantly different according to Duncan Multiple Range Test at 0.05 level of significance.

Treatments with nitrogen levels equal to 160 and 240 kg/ha, respectively, and 70 % of the soil water capacity, have shown a significant increase of yield. Thus, in these treatments yield ranges from 17440.4 to 19630.0 kg/ha maize.

In treatments where irrigation was 40 % of the soil water capacity by adding nitrogen dose gave a small increase of yield as it happened in seed fresh weight and on the fresh weight of 1000 grains (Table 2).

According to Duncan multiple range test at 0.05 significance level, it seems that the treatments B2 and B3 were not significantly different, i.e. treatments at 40% of soil water capacity with either the addition of 160 kg N/ha (B2) or 240 kg N/ha (B3). All the other treatments were significantly different to each other. According to literature [7], the maximum leaf area index, number of grains per cob, grain yield and harvest index were achieved with the addition of 250 kg N/ha and eight irrigations while the highest biological yield was reported by the addition of 300 kg N/ha and eight irrigations.

Figure 2 presents the data regarding the yield percentage of maize fertilization and irrigation levels. The effect of nitrogen in maize is important to the total production. The addition of nitrogen, i.e. 160 and 240 kg/ha, with 70% of soil water capacity led to an increase in yield percentage around 65% and 86% respectively compared to soil with lack of nitrogen (N0-P10-K10).

Note that maize yield, as it seems to the previous measurements, affects the rate and soil moisture. This can be interpreted that fertilizers have a greater impact on crop yield, when they are combined with the appropriate level of irrigation. Similar results were also referred in literature [8-11].

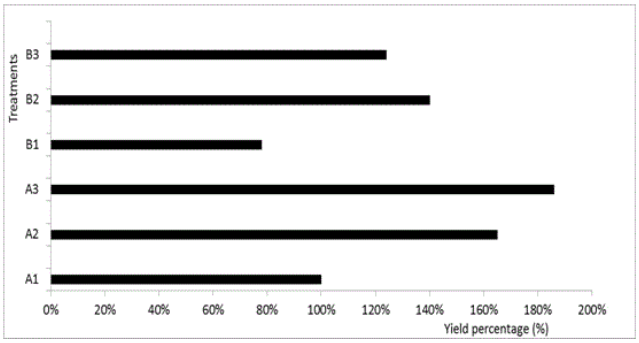

Figure 2: Effect of nitrogen levels and soil water capacity on maize yield percentage.

Conclusions

The nutritional conditions greatly influenced the nature and direction of the processes involved in developing plant. The addition of nutrients, regardless of the combination of each treatment and their dosage, positively affected plant growth and accumulation of fresh plant mass relative to soil with lack of nitrogen.

A high yield was observed with the addition of nitrogen in proportion equal to 160 and 240 kg/ha. Nitrogen was the main factor which increased maize yields maintaining the level of irrigation at 70 % of soil water capacity.

Comparing the high dose of nitrogen, i.e. 240 kg/ha and the different irrigation levels, it seems that the yield percentage increased (186%) with the increase of soil water capacity (70%). This can be interpreted that fertilizers have a greater impact on maize yield, when they are combined with the appropriate level of irrigation.

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