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Assessing the efficiency of different fertilizer type and levels on maize yield

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Abstract

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Many commercial compounds exist that promise the increasing efficiency of urea fertilizers by inhibiting urease activity in soils. Such a compound gaining in commercial importance in the last decades is N-(n-butyl) thiophosphorictriamide, broadly known with its registered trade name of "Agrotain". In this study, the effect of nitrogen fertilizer dressings using Agrotain versus conventional (urea) fertilizers was studied under field conditions. In particular, the effect of three different nitrogen dressings using conventional N-fertilizers and Agrotain was investigated on the growth and final yield of maize cultivation at 2 different sites (Palamas and Velestino) and two years (2014 and 2015) in central Greece. Urease inhibitor ensures crops N-nutrition for longer period compared to conventional fertilizers. This results in better utilization of supplied nitrogen, achieving ultimately higher yields. It was demonstrated that crop fertilized with Agrotain obtained greater chlorophyll contents and reached significantly higher biomass and grain yields comparing to the treatments receiving traditional nitrogen fertilization, due to the more effective nitrogen release and uptake by the crops. The differences between the examined fertilizers are possibly due to smoother and stable N-nutrition and the higher photosynthesis rates. Therefore, application of urease inhibitor fertilizers, such as Agrotain, might reduce nitrogen application dressings, reduce N-losses and nitrification, and their introduction to existing crop rotations is highly advisable.

Keywords: maize; nitrogen; agrotain; yield; chlorophyll

Introduction

There is a prediction for an increase on food global demand while it has been reported that this increase may rich the double by 2050 (Godfray et al., 2010; Tilman et al., 2011).On the other hand, it is reported that yields of important crops are stagnating (Cassman et al., 2003; Brisson et al., 2010; Ray et al., 2012), and for this reason, it is critical to understand the yield differences between potential and actual yield (e.g.harvested yield) (Cassman, 1999; Lobell et al., 2009). The knowledge about yield potential and actual yield will help to guide to a sustainable intensification of agriculture (Ittersum et al., 2013).

Yield potential is the yield of a cultivar when grown in environments to which it is adapted, with nutrients and water (resources)non-limiting and with pests, diseases, and other stresses effectively controlled (Fischer, 2015; Grassini et al., 2011). Due to limiting factors, potential yield varies with location.

One of the world's major cereal crops is maize (*Zea mays* L.), ranking third in importance after wheat and rice (Lashkari et al., 2011), and demand is expected to increase by up to 50% in the coming century (Rosegrant et al., 2009).Most of the maize produced worldwide is used for animal feed, although it is also part of the basic diet in human nutrition, as it is a good source of starch, proteins, lipids, polyphenols, carotenoids, vitamins and dietary fiber (Nuss & Tanumihardjo, 2010; Blandino et al., 2017).

Maize is a crop of high input requirements in irrigation and fertilization especially in nitrogen requirements. Nitrogen is an essential plant nutrient and the key to maintaining higher yield production and worldwide economic viability of agricultural systems. Nitrogen fertilizer is essential for the high rate of food production delivered by modern agriculture. It contributes 20–80 billion of profit per year for EU farmers (Sutton et al., 2011).

Farmers apply different N fertilizers such as urea, ammonium nitrate, ammonium sulphate and potassium nitrate to increase yields. However, this increase in N use, with N response efficiency reported to be between 33 and 50%, is contributing to higher worldwide N losses via NH_3 volatilization and NO_3^-leaching that impact air and water quality (Raun & Johnson, 1999; Howarth et al., 2002; Nosengo, 2003).

Such a low N response efficiency shows that a large percentage of the applied fertilizer Nis not being used for productive purposes and is lost to air, water, having negative impact tothe quality recipient ecosystems (Harrison & Webb, 2001; Howarth & Marino, 2006; Turner et al., 2010), while increases production costs (Van der Stelt et al., 2005).

In the crowd of the different types of N fertilizer that exist, urea has become the predominant source of inorganic N used throughout the world (Harrison & Webb, 2001), meeting almost half of the world's N requirement. Continued growth is expected in the use of urea fertilizer owing to its high N-content and ease of application in a dry granular form or as an aqueous solution. Nevertheless, there is a need to improve the efficiency of urea-based fertilizers through new technologies and management approaches.

One of the most promising approaches is to apply urea in combination with the urease inhibitor (N-(n-butyl) thiophosphorictriamide, nBTPT or NBPT) at low concentrations ranging from0.01 to 0.5% (NBPT, w/w) (Watson and Miller, 1996; Rawluk et al., 2001; Sanz-Cobena et al., 2008). Urease inhibitor (NBPT) is commercially available under the trade name of Agrotain. Agrotain refers to a liquid product containing 25% NBPT as the active ingredient. Granular urea applications with NBPT have been reported by a number of researchers to be effective in delaying urea hydrolysis as well as increasing productivity under a range of cropping and pasture systems (Chen et al., 2008; Martin et al., 2008).

Urease inhibitor (NBPT) is commercially available under the trade name of Agrotain. Urease inhibitors inhibit the enzyme urease, decrease the urease activity and block the hydrolysis of urea to NH_3 (Varel, 1997). Urea can damage the seedlings after it hydrolyses by the enzyme urease, where the produced ammonia (NH_3) and ammonium (NH4+) can cause ammonia toxicity and osmotic damage (Bremner, 1995). Urea toxicity can be reduced by applying urease inhibitor to the fertilizer granule (Grant & Bailey, 1999; Malhi et al., 2003, Karamanos et al.,2004).

Finally, this study was designed to evaluate the effect of different fertilizers containing urease inhibitor on the yield of the major cereal crop (maize) in the main agricultural plain (Thessaly) in Greece.

Materials and Methods

For the purposes of the project, field experiments were established at two sites in East Thessaly (Velestino, Volos) and West Thessaly (Palamas, Karditsa), to assess the impact of a new fertilizer type and different nitrogen dressings onmaizewhich is a crop of high requirements in N-fertilization and one of the most prevalent arable crops in Greece.

Soil characteristics

Velestino soil is a clay loam (sand 19-21%; clay 39-41%, silt 38-42%) calcareous (pH = 8.1-8.3) rich in organic matter (2.3-2.7% in soil profile of40cm), while Palamas soil is a deep, sandy loam to loamy (37-45% sand, clay51-43%, silt 12%), calcareous (pH = 8.3), poor (organic matter content 0.9% in soil profile of40cm). Furthermore, Palamas area is characterized by a shallow underground aquiferand is classified as Aquic Xerofluvent, while Velestino soil as Calcixerollic Xerochrept according to USDA (1975).

Cultivation practices

The experimental plots were demarcated byfixed points both on the outer perimeter and the sub-plots of each replication (block), as to beable to remain stable the treatments for the following year of the conducting experiments.

Maize was sown using a pneumatic precision seeder machine at row distances of 75 cm and 15 cm on each row at the end of March, while the hybrid "PR32P26" of Pioneer Hi-Bred was used.

In both regions was performed pre- and post-emergence herbicide application, as well as manual control of weeds. Basic fertilization took place one-two days before sowing using a dispenser and then the fertilizer was incorporates using a rotary cultivator. Finally, the irrigation dose for the emergence applied using a sprinkler system and then a drip irrigation system was established.

Experimental design

Three different levels of N-fertilization was applied for basic fertilization(120, 240 and 360 kg ha^{-1}), using two conventional (20-10-0 and 27-7-5M+0.5 Zn) and two with Agrotain (30-15-0 and 24-8-8M+0.5 Zn) fertilizers. The top dressing applied using two conventional fertilizers: the ammonium nitrate (34.5-0-0) and the urea (46-0-0), while in the case of Agrotain were used: the 40-0-0 and 46-0- 0. Ofcourse in each block there was a plot of zero fertilization (control).

Yield measurements and data analysis

To calculate the yield a destructive sampling in both sites of 3.75m^2 took place by hand in each plot for both years and thereafter the samples were transported to the laboratory for further analysis. All data were analyzed using the GenStat 7th Edition statistical package.

Meteorological data

Meteorological data were recorded in Velestino from the established meteorological station of University ofThessaly, while the meteorological data in Palamas from the meteorological station of NAGREF in Karditsa.

Results

Meteorological

In Figure 1 are illustrated the average temperature and precipitation in both cultivating years 2014 and 2015 for maize growth at Velestino and Palamas, respectively.

On 2014 the germination period at Velestino and Palamas was helped by the low precipitation occurred in early April (10mm at Velestino and 40mm at Palamas) gaining satisfactory germination in both regions. Although there was occurred some rainfall during the summer, crop required significant addition of water through irrigation for satisfactory crop development. Finally, the rainfall in September especially at Velestino delayed the harvest.

The same was also recorded on 2015, where couple a days after corn sowing, there was recorded satisfactory rainfall (≈ 20 mm) that contributed to a satisfactory ger-

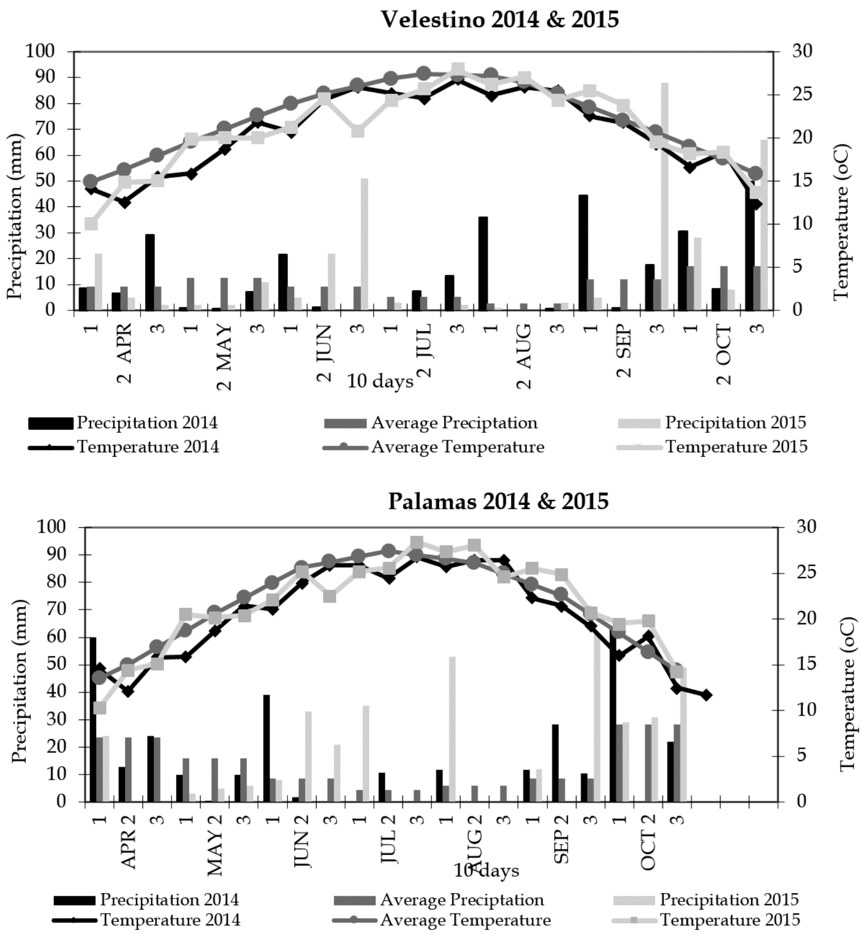

Fig. 1. Average ten days air temperature – precipitation of the study sites in 2014-2015 and average air temperature – precipitation of the last 30 years (upper graph Velestino, bottom graph Palamas)

mination. There after there was required significant addition of irrigation for the satisfactory crop development, although low precipitation was recorded during summer period. Finally, the rainfall occurred after September 20 postponed crop harvest.

Yield and growth characteristics

Plant height was not shown statistically significant differences between different nitrogen levels, nor among the different fertilizer combinations (Table 1). Combinations of fertilizer with urease inhibitor seem to produce taller plants

Table 1. Agronomic characteristics of maize at harvested stage at Velestino for both cultivating years 2014 and 2015

Factor	Characteristic	Height (cm)	Chlorophyll	Seed Yield (kg/ha)	Height (cm)	Chlorophyll	Seed Yield (kg/ha)
		2014			2015		
N – LEVEL (kg/ha)	0	196	14.0	7320	155	15.2	6300
	120	231	46.7	11210	201	31.6	12660
	240	238	55.2	13720	203	44.2	15510
	360	236	61.8	15190	205	49.1	16460
$L.S.D_{0.05}$		ns	4.18	2999.2	ns	3.10	999.1
FERTILIZER TYPE	20-10-0 & 34.5-0-0	234	52.4	12350	198	38.0	14260
	30-15-0 & 40-0-0 Nutr	237	57.5	14220	200	44.5	15490
	26-7-5 & 34.5-0-0	237	50.0	12790	201	39.3	13980
	24-8-8 & 40-0-0 Nutr	237	55.8	13850	206	41.0	15250
	20-10-0 & 46-0-0	228	52.4	13010	202	42.5	14480
	30-15-0 & 46-0-0 Nutr	234	57.1	13910	204	44.3	14980
	26-7-5 & 46-0-0	234	53.3	12960	203	40.1	14960
	24-8-8 & 46-0-0 Nutr	239	58.2	13890	208	42.3	15620
$L.S.D_{0.05}$		ns	ns	ns	ns	ns	ns
N-LEVEL * FERTILIZER TYPE	120 * 20-10-0 & 34.5-0-0	223	44.3	10400	195	26.6	12550
	120 * 30-15-0 & 40-0-0 Nutr	231	51.1	12310	201	32.2	13180
	120 * 26-7-5 & 34.5-0-0	235	41.8	10780	198	34.6	11790
	120 * 24-8-8 & 40-0-0 Nutr	237	48.3	11780	198	34.2	12230
	120 * 20-10-0 & 46-0-0	224	41.2	11090	195	30.1	11520
	120 * 30-15-0 & 46-0-0 Nutr	231	48.2	11790	210	31.7	13310
	120 * 26-7-5 & 46-0-0	228	47.3	10520	203	30.3	12700
	120 * 24-8-8 & 46-0-0 Nutr	237	51.1	11000	200	32.9	14010
	240 * 20-10-0 & 34.5-0-0	241	53.5	12610	197	43.5	14730
	240 * 30-15-0 & 40-0-0 Nutr	243	59.6	15080	200	44.9	16370
	240 * 26-7-5 & 34.5-0-0	234	50.6	12390	202	48.9	14840
	240 * 24-8-8 & 40-0-0 Nutr	237	57.0	13740	203	45.1	15300
	240 * 20-10-0 & 46-0-0	227	54.0	13630	203	40.4	15360
	240 * 30-15-0 & 46-0-0 Nutr	244	56.0	14760	197	42.2	15500
	240 * 26-7-5 & 46-0-0	236	52.7	13440	207	43.9	15870
	240 * 24-8-8 & 46-0-0 Nutr	242	58.0	14100	217	44.5	16100
	360 * 20-10-0 & 34.5-0-0	237	59.3	14040	203	44.1	15510
	360 * 30-15-0 & 40-0-0 Nutr	237	61.7	15250	200	50.6	16920
	360 * 26-7-5 & 34.5-0-0	241	57.5	15190	202	50.2	15300
	360 * 24-8-8 & 40-0-0 Nutr	238	62.0	16030	215	53.5	18220
	360 * 20-10-0 & 46-0-0	234	62.0	14320	207	47.5	16560
	360 * 30-15-0 & 46-0-0 Nutr	229	67.0	15160	204	48.0	16140
	360 * 26-7-5 & 46-0-0	238	59.7	14930	199	48.8	16320
	360 * 24-8-8 & 46-0-0 Nutr	236	65.4	16580	208	49.7	16740
$L.S.D_{0.05}$		ns	ns	ns	ns	ns	ns
CV (%)		4.4	11.0	18.0	6.8	12.8	11.6

in some cases, but without significant difference.

In case of chlorophyll measures, although fertilizers with urease inhibitor showed higher chlorophyll levels over conventional, the differences were not statistically significant.

Finally, the grain yield, which is the economic product, reached higher yields but not statistically significant in the case of agrotain fertilizers. Specifically, in the case of the three N-fertilization levels it was found that the supply of 120 kg N ha^{-1}to maize produced a higher seed yield compared to control (average seed yield for both years 6810 kg

Table 2. Agronomic characteristics of maize at harvested stage at Palamas for both cultivating years 2014 and 2015

Factor	Characteristic	Height (cm)	Chlorophyll	Seed Yield (kg/ha)	Height (cm)	Chlorophyll	Seed Yield (kg/ha)
		2014			2015		
N – LEVEL (kg/ha)	0	213	18.3	9610	184	17.6	7700
	120	236	51.1	13760	218	35.6	13040
	240	244	57.8	16260	224	48.4	15910
	360	245	63.5	17040	225	52.5	16280
L.S.D $_{0.05}$		3.3	6.30	694.0	ns	3.08	912.1
FERTILIZER TYPE	20-10-0 & 34.5-0-0	238	55.8	14820	218	42.3	13900
	30-15-0 & 40-0-0 Nutr	243	59.7	16370	222	48.6	15920
	26-7-5 & 34.5-0-0	244	54.9	14640	223	43.3	14520
	24-8-8 & 40-0-0 Nutr	248	60.3	16340	227	42.3	15700
	20-10-0 & 46-0-0	236	55.1	15160	219	48.0	14260
	30-15-0 & 46-0-0 Nutr	241	59.0	16690	222	48.3	15550
	26-7-5 & 46-0-0	243	56.3	15260	223	44.1	15450
	24-8-8 & 46-0-0 Nutr	241	58.7	16240	225	46.6	15290
L.S.D $_{0.05}$		ns	ns	ns	ns	ns	ns
N-LEVEL * FERTILIZER TYPE	120 * 20-10-0 & 34.5-0-0	223	47.3	12930	209	30.6	12330
	120 * 30-15-0 & 40-0-0 Nutr	234	55.1	13390	217	38.6	13390
	120 * 26-7-5 & 34.5-0-0	232	46.4	13200	215	34.1	12140
	120 * 24-8-8 & 40-0-0 Nutr	250	54.4	15110	224	34.3	13560
	120 * 20-10-0 & 46-0-0	232	47.0	13500	214	36.2	11990
	120 * 30-15-0 & 46-0-0 Nutr	234	54.6	14410	222	38.2	13790
	120 * 26-7-5 & 46-0-0	246	49.4	13070	225	35.7	13200
	120 * 24-8-8 & 46-0-0 Nutr	237	54.2	14510	218	36.9	13930
	240 * 20-10-0 & 34.5-0-0	249	57.1	15100	223	47.5	14320
	240 * 30-15-0 & 40-0-0 Nutr	251	57.4	17280	225	52.9	17200
	240 * 26-7-5 & 34.5-0-0	249	56.4	14840	226	44.4	15580
	240 * 24-8-8 & 40-0-0 Nutr	245	58.8	16880	224	43.2	16250
	240 * 20-10-0 & 46-0-0	237	57.9	15410	220	53.2	15230
	240 * 30-15-0 & 46-0-0 Nutr	239	58.6	17860	218	49.1	16590
	240 * 26-7-5 & 46-0-0	245	57.5	16190	226	47.9	16730
	240 * 24-8-8 & 46-0-0 Nutr	238	58.6	16540	228	49.3	15370
	360 * 20-10-0 & 34.5-0-0	240	63.0	16440	222	48.8	15050
	360 * 30-15-0 & 40-0-0 Nutr	244	66.5	18450	222	54.2	17180
	360 * 26-7-5 & 34.5-0-0	251	61.9	15870	227	51.5	15850
	360 * 24-8-8 & 40-0-0 Nutr	251	67.7	17010	233	50.8	17280
	360 * 20-10-0 & 46-0-0	238	60.3	16570	223	54.6	15560
	360 * 30-15-0 & 46-0-0 Nutr	249	63.8	17800	227	57.5	16290
	360 * 26-7-5 & 46-0-0	238	61.8	16510	218	48.7	16420
	360 * 24-8-8 & 46-0-0 Nutr	247	63.4	17680	228	53.7	16580
L.S.D $_{0.05}$		ns	ns	ns	ns	ns	ns
CV (%)		5.4	10.7	12.2	4.5	11.6	10.4

ha^{-1}) of 5000 kg ha^{-1}, the level of240 kg N ha^{-1}had a further increase up to7800 kg ha^{-1}(compared to control), while the final level of 360 kg N ha^{-1}increased almost 9000 kg ha^{-1}compared to control (Table1). Even if the seed yield is increasing by increasing the fertilization level it is clearly shown that the more N-fertilization is applied the smaller is the degree of performance.

At Palamas site maize height had the same trend as at Velestino (Table 2). Among the different fertilization levels it was found significantly difference of the lower level (120 kg ha^{-1}) compared to the others. The combination of fertilizers with urease inhibitor against the simple shown plants of higher height in the three of the four cases, but there was not found significant differences.

In case of chlorophyll the three nitrogen levels statistically differ with the highest level having higher measures which means greenest plants.

Finally, there was found a statistically significant difference between nitrogen levels and superiority of fertilizers with urease inhibitor against conventional on seed yield. Specifically, in the case of the three N-fertilization levels it was found that the supply of 120 kg N ha^{-1}to maize produced a higher seed yield compared to control (average seed yield for both years 8655 kg ha^{-1}) of 4800 kg ha^{-1}, the level of240 kg N ha^{-1}had a further increase up to7400 kg ha^{-1} (compared to control), while the final level of 360 kg N ha^{-1}increased almost 8000 kg ha^{-1}compared to control (Table 2).

Plotting the seed yield versus the nitrogen supply results in the Yield – N-supply relation illustrated in Figure 2. The results of both experimental years shown that at Palamas site the control treatment produced higher yield compared to Velestino (Figure 2), indicating the higher soil fertility due to the almost same weather conditions (Figure 1).

It can be seen that a linear relationship apply that might explain 90% of the existing variation (R^2: 0.90), largely independent offer tilization type and environmental conditions (soils, weather condition).

The results of the experimental years showed a response to the supplied nitrogen doses. Seed yield under four N-dressings for the two fertilizer types (conventional and agrotain) are presented in Figure 3 for both years and sites. In both cases (Velestino and Palamas), N-dressing had a positive effect on seed yield while agrotain fertilizers produced even higher yields.

As it is illustrated in Figure 2, the N-dressing of 120 kg ha^{-1} had higher response to the yield. Specifically in Velestino case and for the conventional fertilizers the N-dressing of 120 kg ha^{-1} increased the seed yield for 38.4 kg for each

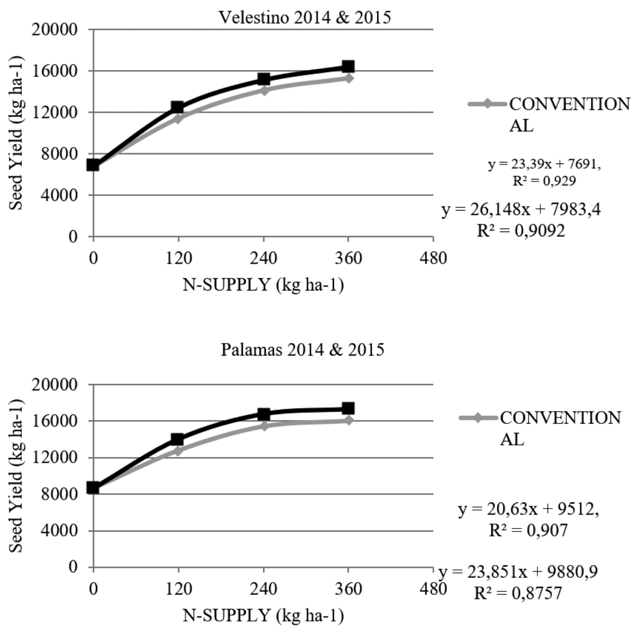

Fig. 2. Average seed yield as affected by 4 N-fertilization levels (0, 120, 240 and 360 kg N ha^{-1}) and 2 different fertilizer types (conventional and agrotain) during 2 growing periods (2014 and 2015; upper graph Velestino, bottom graph Palamas)

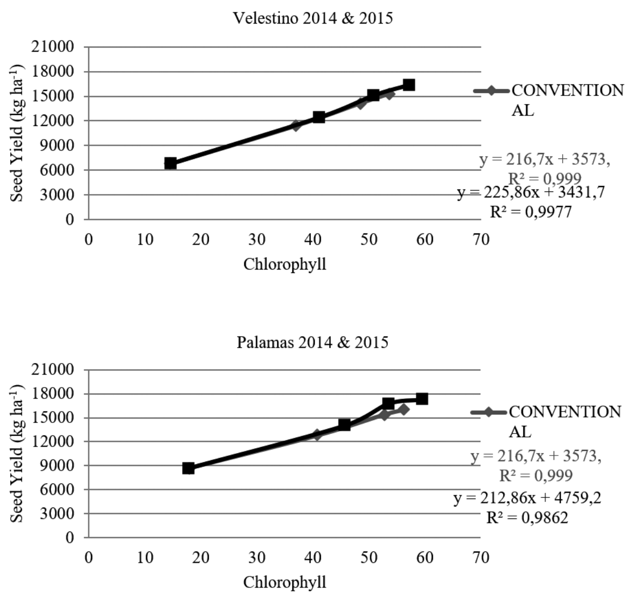

Fig. 3. Average seed yield according to different chlorophyll content as affected by 4 N-fertilization levels (0, 120, 240 and 360 kg N ha^{-1}) and 2 different fertilizer types (conventional and agrotain) during 2 growing periods (2014 and 2015; upper graph Velestino, bottom graph Palamas)

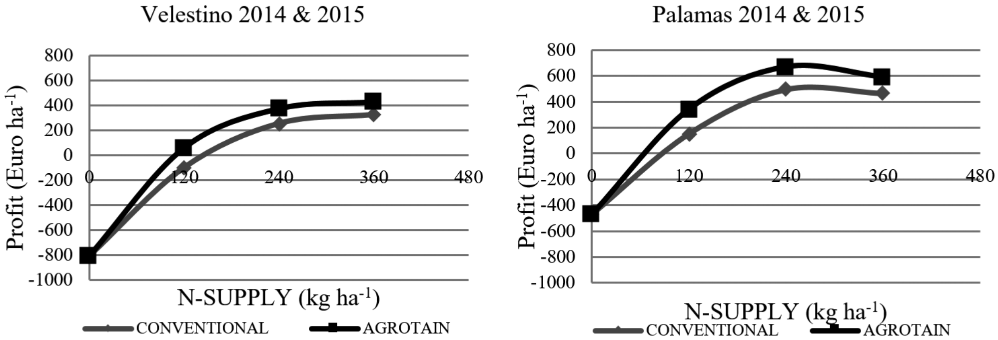

Fig. 4. Average profit as affected by 4 N-fertilization levels (0, 120, 240 and 360 kg N ha^{-1}) and 2 different fertilizer types (conventional and agrotain) during 2 growing periods (2014 and 2015; upper graph Velestino, bottom graph Palamas)

supplied nitrogen kg. Increasing the N-dressing leaded to a lower increase of seed yield and therefore the 240 and 360 kg N ha^{-1} increased the seed yield for 30.4 and 23.5 kg for each supplied nitrogen kg, respectively. In case of agrotain fertilizers, the N-dressing of 120 kg ha^{-1} increased seed yield for 47 kg for each supplied nitrogen kg, while the N-dressing of 240 and 360 kg N ha^{-1} increased the seed yield about 34.6 and 26.6 kg for each supplied nitrogen kg, respectively.

At Palamas site the results were the same. In case of conventional fertilizers the N-dressing of 120 kg ha^{-1}had an increase to the seed yield of 34.5 kg for each supplied nitrogen kg. The higher N-dressings (240 and 360 kg N ha^{-1}) had lower increase for each supplied nitrogen kg (28.2 and 20.5 respectively). In case of agrotain fertilizers, once again the N-dressing of 120 kg ha^{-1} increased seed yield for 44.6 kg for each supplied nitrogen kg, while the N-dressing of 240 and 360 kg N ha^{-1} increased the seed yield about 33.7 and 24.0 kg for each supplied nitrogen kg, respectively. Moreover, in figure 2 it is shown that seed yield almost reached potential yield.

Therefore, it could be concluded that the N-fertilization level of 240 kg ha^{-1} using fertilizers with urease inhibitor lead to the same yield with the fertilization of 360 kg ha^{-1} using simple fertilizers, which means probably less nitrogen losses from leaching and evaporation, and less production costs, while the increase to seed yield by increasing the N-dressing it is clearly shown that the more is applied the lower, is the degree of performance.

Seed Yield – Chlorophyll relation

Plotting seed yield versus chlorophyll content results to a linear relationship apply that might explain 99% of the existing variation (R^2: 0.99), depended on N-fertilization level (Table 1 and Table 2), and largely independent of fertilization type and environmental conditions (soils, weather condition), as it is illustrated in Figure 3.Moreover, in Figure3 in Palamas case it is clearly shown that when chlorophyll content is over 55 then the rate of increase of seed yield production decreasing with a tendency to get stable and reach the potential yield.

Nitrogen – yield cost relation

Current average market prices for nitrogen in Greece is 1.20 € per kg in case of conventional fertilizers and 1.49 per kg for the agrotain fertilizers, while the market price for maize is 185 € per ton of seeds. In Table 3 are presented the average cultivation costs of maize in central Greece for

Table 3. Cultivations costs of maize production using average costs of studied sites

	Cultivation costs (€ ha^{-1})	
Weed & Pest management	150	150
Plowing	90	90
Cheeler	40	40
Harrowing	60	60
Sowing	30	30
Seeds	250	250
Irrigation	600	600
Fertilizer Type	Conventional	Agrotain
Fertilization (control)	0	0
Fertilization (120 kg ha^{-1})	144	178.8
Fertilization (240 kg ha^{-1})	288	357.6
Fertilization (360 kg ha^{-1})	432	536.4
Land Rent	700	700
Harvest Cost	150	150

the different fertilization. In case of zero fertilization there is a negative income which demonstrates the necessity of nitrogen fertilization, especially in such soil. The required nitrogen dressing to balance cultivation costs with revenue, with the current prices and results, is 80-100 kg ha^{-1} and 45-60 kg ha^{-1}, for conventional and agrotain fertilizers, respectively. Moreover, in figure 4 is illustrated that agrotain fertilizers in all cases resulting to higher profit with the N-dressing of 240 kg ha^{-1}being the scenario of highest profit even of the N-dressing of 360 kg ha^{-1} using conventional fertilizers.

Discussion

As it has been already mentioned, maize is a crop of high input requirements especially in nitrogen fertilization Effective management of nitrogen fertilization is a leading challenge for enhancing maize productivity, and environmental sustainability (Ma et al., 2006). Nitrogen is a major nutrient for crop production as it directly affects the dry matter production by influencing the leaf area and photosynthetic efficiency; hence an optimum rate of application of nitrogen is necessary to prevent retardation of plant growth and yield (Tafteh & Sepaskhah, 2012), which is also in agree with the results of the current study especially in the case of chlorophyll content and seed yield.

Plant growth parameters of maize were significantly influenced by nitrogen dressings for both years and sites which is supported by results from other studies also (Azeez et al., 2006; Barbieri et al., 2008; Jinet al., 2012;Abbasi et al., 2013; Chen et al., 2015; Hammad et al., 2016; Kiani et al., 2016). Treatments of lower N-fertilization levels showed significantly lower plant height and seed yield in comparison to treatments with higher N-dressings.

In the reported study, it was found that an increase in nitrogen level increases the seed yield significantly. In literature (Ma et al., 2006; Qian et al., 2016) is reported that nitrogen fertilization significantly increased the grain yield per plant and per unit area. In contrast, Jin et al. (2012) reported that with an increase in fertilizer application there was no increase in maize yields beyond certain limit of fertilization.

It was found that higher amount of N fertilization increases the yield to some extent, but it can also cause serious environmental problems (Zhu et al., 2016). Thus, the reduction of N fertilizer input and improved N use efficiency are crucial for sustainable production especially in maize case which is crop of high input requirements in irrigation and fertilization especially in nitrogen requirements.

Moreover, higher rate of nitrogen combined with low nitrogen use efficiency will have adverse effect on the environment such as, soil acidification, environmental pollution and decreased soil microbial activity (Chen et al., 2014; Zhu et al., 2016), which is in agree with the findings of the current study where N-fertilization level of 240 kg ha^{-1} using fertilizers with urease inhibitor lead to the same yield with the fertilization of 360 kg ha^{-1} using conventional fertilizers, which means probably less nitrogen losses from leaching and evaporation, and less production costs, while the increase to seed yield by increasing the N-dressing itis clearly shown that the more is applied the lower, is the degree of performance. Hence, the reduction of N fertilizer inputs and improved N use efficiency are essential for the sustainable production of maize. Thus, a balance between crop nitrogen and yield efficiency needs to be taken care of. Therefore, for sustainability of agroecosystem, both the crop yield, and nitrogen use efficiency need to be balanced (Jin et al., 2012).

Nitrogen (N) fertilizer plays a vital role in optimizing the trade-off between grain yield and profit (Jin et al., 2012).The cost for nitrogen fertilization, which is the key to maintaining higher yield production and worldwide economic viability of agricultural systems, is almost 400 € ha^{-1} and it was found that it is the responsible key for farmers' profit and thus also agree with the findings of Sutton and his colleagues (2011) who found that nitrogen fertilizer is essential for the high rate of food production and contributes 20–80 billion of profit per year for EU farmers.

Conclusions

The study indicated that variation in nitrogen fertilization levels affect the crop growth characteristics. The fertilized plots with fertilizers using urease inhibitor showed higher chlorophyll levels and therefore higher rates of photosynthesis and thus to increased biomass production perhaps due to smoother and stable nitrogen nutrition. The use of fertilizers with urease inhibitor resulted in increased yield in proportion of 3.5 to 9.1% with an average of 6.4%.

Increased nitrogen fertilization reduced the agronomic N efficiency. N-dressing of 120 kg ha^{-1} had higher response to the yield. Specifically, for the conventional fertilizers the N-dressing of 120 kg ha^{-1} increased the seed yield for 34-39 kg for each supplied nitrogen kg. Increasing the N-dressing was found a lower increase of seed yield and therefore the 240 and 360 kg N ha^{-1} increased the seed yield for 28-30 and 20-24 kg for each supplied nitrogen kg, respectively. In case of agrotain fertilizers, the N-dressing of 120 kg ha^{-1} increased seed yield for 45-47 kg for each supplied nitrogen kg, while the N-dressing of 240 and 360 kg N ha^{-1} increased the seed yield about 33-34 and 24-26 kg for each supplied nitrogen kg, respectively.

Agrotain fertilizers are more expensive but can lead to higher profit because N-fertilization level of 240 kg ha^{-1} using fertilizers with urease inhibitor lead to the same yield with the fertilization of 360 kg ha^{-1} using conventional fertilizers, which also leads to less nitrogen losses from leaching and evaporation.

Finally as general conclusions is that fertilizers with urease inhibitor give constant voltage supremacy against conventional fertilizers in almost all the studied characteristics. The second N-fertilization level using fertilizers with urease inhibitor gained greater than or equal odds with the high N-fertilization level with simple fertilizers, demonstrating the superiority of these types of fertilizers. The second N-fertilization level was the most effective. Therefore, the more is applied the lower, is the degree of performance, while the reduction of N fertilizer inputs and improved N use efficiency are essential for the sustainable production of maize. Thus, a balance between crop nitrogen and yield efficiency needs to be taken care of.

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