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Does fertilization practices increase residual nitrate nitrogen in soil irrigated with treated wastewater? An experimental trial on maize

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***Abstract*—** *Treated wastewater has significantly improved DM yield compared to ground water. The form of nitrogen provided by the water was determinant in drawing yields. Irrigation with ground water (where nitrogen is as nitrate) induces a faster migration of nitrogen at depth. In contrast, using treated wastewater (where nitrogen is as ammonium), resulting in a relative distribution of the remaining nitric smaller in the lower profile and therefore higher in the surface, especially after the second year (2010). In addition, the relative distribution of nitrates in the soil surface is even more important in the presence of organic manure. All happens as if a certain amount of ammonium provided by treated wastewater is retained in the organic compounds of manure. Yields were significantly lower in irrigation with treated wastewater in the second year and especially when fertilization was given in additional. If the soil can be used for storage of the nitrogen supplied by the treated wastewater during the first year of irrigation (24 kg N-NO3/ha before irrigation to 115 kg N-NO3/ha after irrigation), to the second year the capacity drops (to 64 N-NO3/ha) and a significant increase in nitrate leaching occurs. Therefore, unlike the contribution of manure that seems enrich the topsoil nitrate nitrogen, at least during the first campaign, mineral fertilization unreasoning causes faster migration of nitrogen at depth.*

Keywords*—*Treated wastewater, Fertilizer, Nitrate leaching, Dry matter.

I. INTRODUCTION

In arid and semi-arid region, water has become increasingly rare source which by its lack alters the socio economic development. To preserve their fields and keep constant production of their crops to continue living, farmers are willing to use all types of water such as treated wastewater (TWW). In Tunisia, this method is an old (since 1960) and popular practice in agriculture. Despite of this long experience, a great effort remains to spend to convince farmers about fertilizers and economic potential of this water and to raise farmers' awareness of the drawbacks of poor use of these waters. Irrigation with TWW has been used for three purposes: (i) complementary treatment method for wastewater (Bouwer and Chaney, 1974); (ii) use of marginal water as an available water source for agriculture (Bouwer and Idelovitch, 1987; Al-Jaloud et al., 1995; Tanji, 1997) – a sector demanding ~ 83% of the consumptive water use in Tunisia (iii) use of TWW as nutrient source (Bouwer and Chaney, 1974**;** Vazquez-Montiel et al., 1996**;** Khelil et al., 2011) associated with mineral fertilizer savings and high crop yields (Smith and Peterson, 1982; Feigin et al., 1991; Khelil et al., 2005).

In many studies worldwide the use of TWW as water and nutrient sources in agricultural have been introduced as a viable alternative for TWW destination in the environment. However, various studies have revealed that the nutrient supply only by TWW irrigation was not sufficient to meet plant nutrient requirements resulting in yield decreases. The problem could be solved by an adapted effluent/fertilizer management (khelil et al., 2012; da Fonseca et al., 2007a). Due to the often observed accumulation of nitrogen losses (leaching, volatilization and denitrification) after TWW irrigation, the monitoring of these components is of crucial importance for a sustainable use. According to Rafael Marques Pereira Leal and al. (2009), throughout the irrigation period, high NO_3-N concentrations (up to 388 mg/ l with treatment receiving 200% of crop water demand) was measured in soil solution below the root zone, indicating the potential of groundwater contamination. Nitrogen (N) cycling in agro-systems can also be altered by TWW irrigation, mainly in the long-term (da Fonseca et al., 2007a). Several studies have shown increased total carbon (TC) and total nitrogen (TN) contents in the soil due to C and N input by TWW irrigation (Friedel et al., 2000; Ramirez-Fuentes et al., 2002). Other studies have found decreased contents of soil TC and TN (Speir et al., 1999; Snow et al., 1999), mainly attributed to enhanced mineralization

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and nitrification processes under effluent irrigation (da Fonseca et al., 2007b). Of greater concern, increasing concentrations of nitrate (NO_3-N) in soil solution due to TWW irrigation have often been reported (Polglase et al., 1995; Smith and Bond, 1999; Gwenzi and Munondo, 2008), representing one of the main challenges for the sustainable land application of effluents (Bond, 1998; da Fonseca et al., 2007a).

Otherwise, the soil-plant system, if adequately managed, encourages retention of TWW components mainly due to the incorporation of elements in the dry matter (DM) of plants (Bouwer and Chaney, 1974; Vaisman et al., 1981), leading to decreasing element concentrations in ground and surface waters (Feigin et al., 1978). Harvest and removal of plant material withdraw the accumulated elements, which further contribute to prevent leaching of elements, mainly nitrogen (N) and enrichments in the subsoil solution and the groundwater concentrations (Quin and Forsythe, 1978; Hook, 1981). Although irrigation with TWW may mitigate the damage and utilization of natural water resources and enables the diversion of nutrients from TWW and save the conventional inorganic and organic fertilizers including nitrogen fertilizers, it may result in risks that need to be considered in more detail, especially since farmers do not conceive reducing their fertilizer supply. With this in mind, a study of experimental was conducted at the Agricultural Experimentation Unit – Nabeul-Tunisia to study the impact of the different fertilizations practices adopted by farmers on maize yield and on nitrate status of the ground after harvest and to serve as farmer's awareness to convince them to reduce their contribution in terms of fertilizers, including irrigation with treated wastewater.

II. MATERIALS AND METHODS

This field study was conducted during the summer in 2009 and 2010, as part of a larger study in bilateral collaboration between the Agronomic research Center, (CRAg) Gembloux ABT(ULg) from Belgium and the Rural, Water and forest research Institute "INRGREF" of Tunisia. The field had been for maize in summer and vegetables in winter for three years prior 2009. Some physical and chemical properties of the experimental soil determined before sowing are presented in Table 1.

Table.1: Physicochemical and moisture characteristics of the soil

Paramètres			**Soil depth (Cm)**		
	0 /20	**20/40**	**40/60**	**60/80**	**80/ 100**
%					
Coarse silt	5	5	5	-	
Fine sand	29	24	30	-	
Coarse sand	64	68	64	-	-
Conductivity $ds.m^{-1}$ 25° C	2.01	1.87	1.98	-	-
% Organic matter	0.4	0.3	0.2	-	-
% Total nitrogen	0.087	0.066	0.045	-	-
% Carbon	0.3	0.2	0.1	-	-
C/N	3.4	3.0	2.2	-	-
Humidity at pF 4.2	2.88	1.97	1.28	1.10	1.10
Humidity at pF 2.7	8.68	6.76	4.43	2.77	2.72
weight Density (da)	1.35	1.35	1.35	1.35	1.35
Ru (mm)	15.66	12.93	8.50	4.51	4.37

pF 4.2 corresponds to moisture at the point of wilting. 2.7 pF corresponds to moisture at field capacity. da, bulk density. Ru, reserves calculated in mm per layer (20 cm x 2 = da (Humidity in pF2.7 - humidity at pF 4.2)

These analyzes show that the soil is sandy type of low organic matter, with a C/N ratio, lower than 10. Moisture content expressed as% at pF 2.7 and pF 4.2 by 20 cm layer to a depth of 100 cm, were used to calculate the usable water reserves (Ru) for the soil (Table 1). From Table above, the Ru soil decreases with depth for both pF, indicating a low water-holding capacity of about 45mm on 1m soil depth. The use of a sheet of water over Ru, leads to a loss of water and solute by the system and automatically contributes to groundwater pollution.

The experimental protocol was designed to use fertilization practices used by farmers. The treatment comprised: (i) two irrigation water qualities, treated wastewater (TWW) and well water (WW), and (ii) four practices fertilization taken as treatments for each kind of water : (1) treatment without fertilizer (0N), (2) treatment with application of 120kgN/ha as ammonium nitrate, brought in two equivalent fractions, at raising and at elongation stage, (3) a treatment that corresponds to the application of 20t/ha of cow manure and (4) a treatment which represents the joint application of manure and

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mineral fertilizer (120kg N/ha + 20t/ha of manure). The experiment was organized in a randomized complete block design with four replications. Each treatment block was 2.25m by 4.2 m. TWW used in this study come from the wastewater treatment plant SE4 and WW used was a mixture of shallow wells on the experimental station. Water samples were collected ones a week in wells and outlet valves distribution of wastewater. The main characteristics of the two types of water are shown in the following table (Table 2).

Table.2: Characteristics of irrigation water

Parameters	Well water (WW)	Treated wastewater (TWW)
	mg/l	
NO3-	129 (±19.2)	< 5
N-NH4	2.36 (±0.26)	36 (±07.68)
HCO3-	219 (± 25.6)	344,94 (±37.24)
SO4--	487 (± 131.5)	426,51 (±148.6)
Cl-	729.2 (± 50)	548,57 (±55.14)
Ca++	238.8 (±13.6)	126,79 (±17.12)
Mg++	90 (± 6)	90,00 (±07.45)
P	-	5.37 (±01.99)
K+	60.45 (± 13.6)	31,64 (±03.40)
Na+	579.4 (± 40.7)	408,94 (±176.4)
pH	7.29 (± 0.14)	7,15 (±0.14)
Sels dissous (g/l)	2.86 (± 0.21)	2,17 (±0.26)
SAR	8.10 (± 0.66)	8,00 (±0.94)
Cd	-	0,009 (±0.01)
Co	-	-
Cr	-	-
Cu	-	-
Fe	-	0,005 (±0.02)
Mn	-	0,003 (±0.01)
Ni	-	0,006 (±0.005)
Pb	-	0,030 (±0.014)
Zn	-	0,009 (±0.005)

The TWW is rich in potassium and in nitrogen and poor in phosphor and nitrate and have salinity comparable to that of the WW. The concentration of heavy metals in TWW is below Tunisian standard (NT 106.03) on the use of TWW in agriculture. The N composition of TWW ranged from 28 to 51 mg N-NH_4/l, with an average of 36 mg N-NH_4/l and contained less than 2 mg/l of NO_3^-. However, WW were loaded with nitrate with an average of 25 mg N-NO_3^- and accounted less than 2 mg/l of nitrogen as ammonium. Mineral composition of manure is comparable in 2009 and 2010 but with a lower phosphorus content in 2010 (Table 3).

Table.3: Chemical characteristics of manure

Parameters		**Manure 2009**	(%)	**Manure 2010**
Total nitrogen		0.707		0.779
Ammoniacal nitrogen		0.004		0.001
Organic nitrogen		0.703		0.778
Dry matter		53.25		32.18
Carbon		55.34		55.26
P		0.741		0.375
K		1.782		1.900
Ca		5.086		4.248
Mg		0.505		0.419
C/N		78.15		70.93

N composition was in the order of 0.7% which corresponds to a contribution of 140 kg N/ha. Manure is rich in calcium but low in magnesium with a C/N ratio of about 75.

Due to the sandy nature of the soil, a pre-irrigation was performed in order to fix the soil and to ensure optimum germination and emergence. Feed maize (zea mays) was planted on monthly statement on Mai in 0.65 m row spacing and with a spacing of 0.2 m within the row, with two seeds per hill. Plant was thinned before fertilization to keep one foot per hill shortly after emergence. Each repetition consisted of four lines representing 80 feet of Maize. Manure was spread and incorporated into the soil two weeks before planting, while nitrogen fertilizer was applied online at equal fraction at 3-leaf stage and at elongating stage.

Water irrigation levels were designed to approximate the seasonal evapotranspiration (ETP) minus precipitation deficit, according to the following formula "Water requirement = Kc x ETP – effective rainfall – R**"**, where R is the stock of the soil moisture at planting time, assumed equal to zero. Water requirement was calculated on the basis of the average climatic parameters of the experimental station (ETP), calculated by the Penman-Monteith formula on 12-year period (1997/2008) and on the bases of crop coefficients (Kc) at various vegetative stages of maize, mentioned in Richard et al (1998)**.** The crop ETP requirement was 750mm from mid Mai to mid September under local conditions. According to Rebour and Deloye (1971), water use efficiency was estimated at 95% for drip irrigation, so that an additional of 5% (equal to 27 mm) excess water was applied to meet 100% water use efficiency. A total of 19 irrigations were made in

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2009 and 2010. Overall, the crop received a total amount of about 544 mm (5440 m^3/ha) for each year and for each kind of water (Table 4).

Table.4: Water requirement of maize and irrigation scheduling

Parameter		Months from May to September					Total (mm)
		M	J	J	A	S	
ETP (mm /Mois)		134	155	182	163	116	**750**
Kc		0.5	0.65	1.08	0.9	0.6	-
Besoin/Mois (mm)		67	100	197	147	70	**581**
number of irrigation		1	4	7	6	1	**19**
Rate/irrigation		24	27.4	31.4	27.4	25	-
Rate/month (mm)		**24**	**110**	**220**	**165**	**25**	**544**

Before sowing, a characterization of the content of nitric nitrogen in soil was performed. Then, after each campaign a soil sample is taken to determine the residual nitrate nitrogen. Only one plant sampling was carried out at pasty milky stage in 2009. While in 2010, to follow the dilution of nitrogen in the dry matter "DM" (N% DM), four sampling during the vegetative cycle were performed. The fourth sampling coincided with the pasty milky stage. All samples were made on the above ground part of ten corn feet taken on a surface of 1m². All plant portions were dried at 70°C, and weights were recorded. Soil sampling concerned a profile probed by 80 cm layer of 20 cm. Three carrots repetition were performed. For each depth, the three samples were mixed and an average sample depth was analyzed. Analyzes are concerned mainly nitrogen, either in the soil or in the plant. Mineral nitrogen in the soil was determined on the filtrate after extraction with KCl (0.5 M) with a dilution of 1/5, the nitrate analysis was performed at CRA-W by colorimetry using a continuous flow system. The principle is to reduce the nitrate by hydrogen sulphate then to cause the Griess reaction on the nitrite formed to give a purple compound. The plant tissue was ground and analyzed for total N using kjeldhal digestion method according to Bremner and Mulvaney (1982).

III. RESULTS AND DISCUSSION

3.1 Dry matter yield production

Irrigation with treated wastewater has greatly improved the production of DM especially in 2009 despite the significant amount of nitrate nitrogen provided by WW (Fig 1).

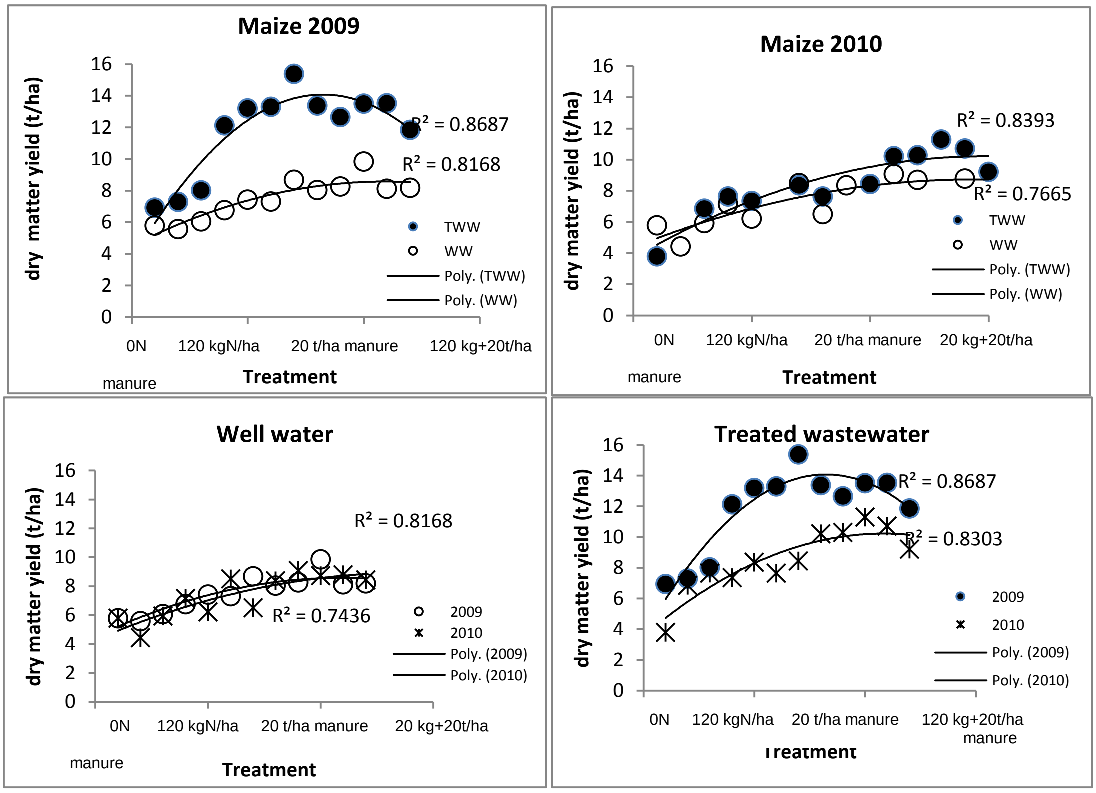

Fig.1: Effect of the kind of water and of fertilizer practices on the DM yield of feed maize.

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This improvement would explained either by the wealth of treated wastewater with other nutrients such as P, Ca, Mg, or also by the low efficiency of the nitrate nitrogen provided by TW throughout the vegetative cycle and even at times when the plant absorbs less. The nitrate nitrogen is also exposed to leaching, especially at the beginning and at the end the vegetative cycle. Vazquez-Montiel (1996) on maize, noted an increase in yield and N content (% N) and phosphorus (P%) in irrigation with TWW compared to WW. Moreover, the comparison between the two years shows that the yield response to different fertilization practices was more significant in 2009 than in 2010. It seems that the memory effect of previous contributions (in 2009 and even before planting) is produced on corn in 2010. In the WW treatment, the DM production was similar for both years. Whereas, we note a decrease in DM production in 2010 when TWW was used for irrigation, notably when a supplemental fertilization was added.

3.2 Effect of the treatments on the dilution of N in aboveground biomass during maize growth

The dilution curves of N in the aboveground biomass during maize growth in 2010 (Fig 2), were compared to the reference curve used for non-limiting nitrogen nutrition for grasses (Lemaire and Salette, 1984).

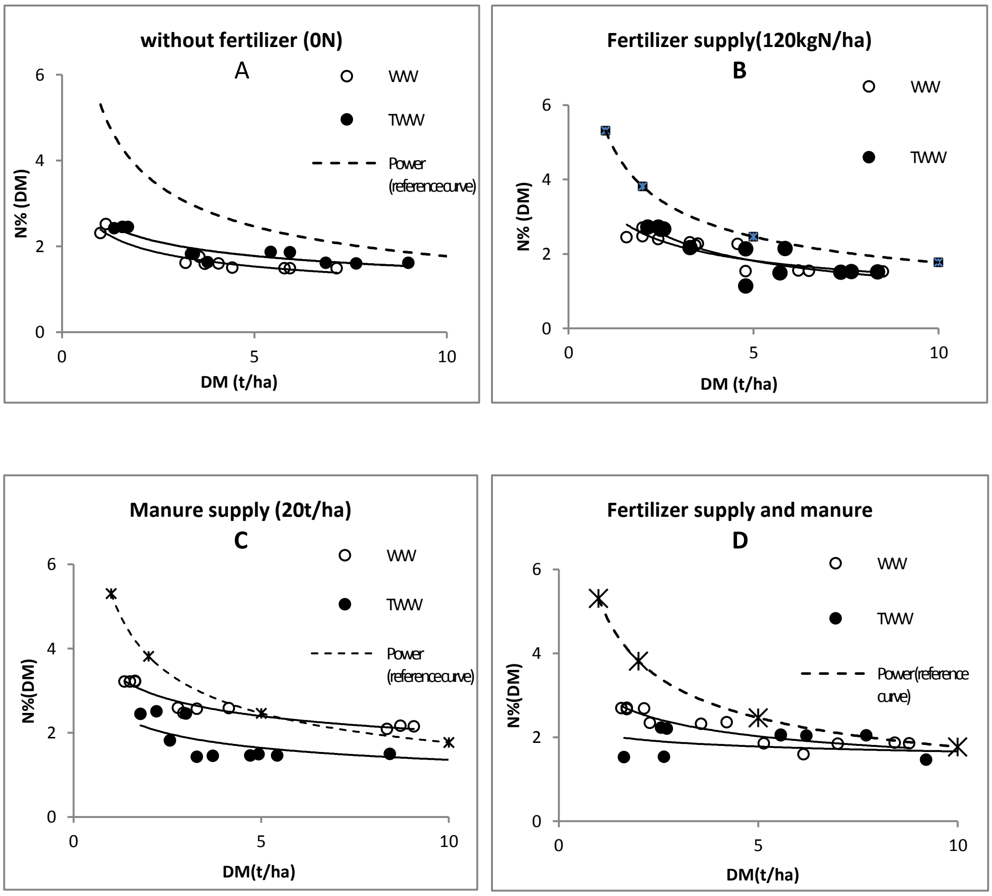

Fig.2: Dilution curve of nitrogen (N%) in the dry matter production (DM) depending on water qualities and fertilization practices

Regardless of treatment, nitrogen dilution in the DM during the growth cycle decrease with increasing dry matter production. The following mathematical relationship has been applied to our results:

$$\alpha = N\% (DM)^{-\beta} \qquad 1$$

In the absence of fertilizer, the dilution curve is below the reference curve and shows that nitrogen nutrition was significantly better with TWW compared to WW treatment (Fig 2A). By cons, when nitrogen fertilizer was added, N nutrition is rather better with WW irrigation. (Fig 2B), it even exceeds the reference curve in WW irrigation when manure (20 t/ha) was spread (Fig 2C), indicating a good nitrogen nutrition notably at final harvest. The difference between the two treatments WW and TWW is probably due to growth retardation observed on TWW plots. Independent on water irrigation quality, mineral fertilization improves nitrogen nutrition even in the presence of manure. However, improved nitrogen nutrition of maize was not followed by a significant increase in the DM production due to the luxury

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consumption of nitrogen especially on the plots irrigated with TWW. We assume therefore that irrigation with TWW with higher N content in addition to fertilizer input, leads to promote a situation of excess nitrogen resulting in a depressive effect on nitrogen nutrition and on DM production. All these observations support the thesis already advanced by Salette and Lemaire (1981) on the existence of a more or less closely relationship between the accumulation of nitrogen in shoots and their dry matter growth.

3.3 Effect of treatments on the relationship between dry matter produced and nitrogen uptake

The relationship between DM and N exported has been demonstrated for stands of grasses by Salette and Lemaire (1981). It can result in the following mathematical relationship:

$$\text{N uptake} = 10\,\alpha\,(\text{DM})^{1-\beta} \qquad 2$$

This is in fact an allometric relationship between nitrogen uptake and DM production. The coefficient (1 - β) is the ratio of the relative rates of N uptake and relative growth rates, the coefficient 10α represents the amount of nitrogen absorbed for the production of the first tone of DM. However, although this relationship is much talking in terms of agronomic, since it describes the relationship between growth and nitrogen uptake. The comparison of the different relationships between them arises under Lemaire et al. (1985) a statistical problem not satisfactorily solved theoretically. In our work, we used the method Dagnelie (1969), cited by Lemaire et al. (1985), which is based on the determination of the confidence interval of the orthogonal regression coefficient. We have used this method to compare the values of the allometric coefficient (1 - β) and the coefficient values 10α. Though, the values used to calculate the regressions curves are the average of four samples which were used for determining the DM yield and N content.

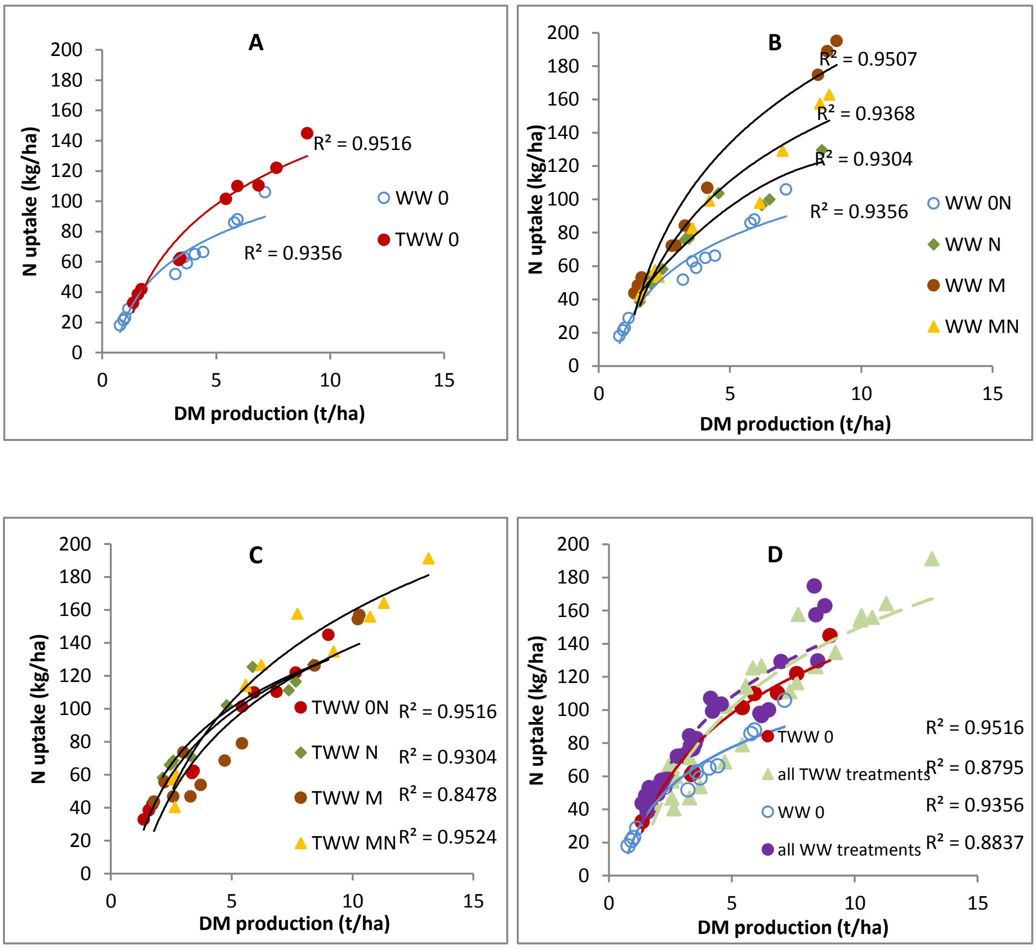

Fig.3: Relationship between allometric growth of DM and nitrogen uptake in maize (2010)

For our work, the values were between 0.3 and 0.4% N for the WW and between 0.1 and 0.3% N for TWW. This precision corresponds to a variation of the coefficient 10α of about 3 to 4 kgN/ha and 1 to 3 kgN/ha for the well and the treated wastewater, respectively. In the absence of fertilization, irrigation with treated wastewater significantly increases the nitrogen and the DM production. However, when well water is used for irrigation we note a deflection of the allometric relationship reflecting a slowing of nitrogen uptake followed by DM production stagnation despite continuing input of N by these waters. This slowdown is probably linked to the nitric form of nitrogen supplied by well water that is relatively labile and more exposed to leaching than ammonium provided by TWW. Otherwise, in TWW irrigation, no effect of fertilizer used on the relationship between the dry matter produced / nitrogen input was observed (Fig 3). However, when manure and nitrogen fertilizer was applied together, we note a slight improvement in the absorption of N at the end of growth, represented by an accumulation of 15 kgN without being translated into DM. This excess nitrogen consumption at the end of culture could be the result of the mineralization of nitrogen from manure or also from soil under the action of microbial biomass. Unlike irrigation by TWW; a significant effect of fertilizing practices on nitrogen absorption and on the production of DM was recorded when WW was used for irrigation (Fig 3). This significant effect is all the more important as the total dose of N added is significant. Comparing the coefficients 10α and (1-β) at the same level of growth, shows that the lowest nitrogen uptake was recorded with WW0 treatment (Table 5) with the absorption of 23 kgN/ha for the production of the first ton of MS against 26-39 kg N/ha for the rest of the treatments. This difference is dependent on the treatment and is related to the amount of available nitrogen in the soil with treated wastewater irrigation.

Comparing the value of 10α we note that in irrigation with TWW, the value of 10α is the highest for the treatment with mineral fertilizer input split. Whereas, 10α value is significantly lower with manure. This could be explained by the organization of a certain amount of ammonia nitrogen supplied by TWW rendered inaccessible to the plant, especially since the value of the manure C/N ratio is well over 20. However, in irrigation with WW, the difference between the values of 10α for all treatments with fertilization does not exceed 4 kg/ha. It should also be noted that, at the end of growth, and particularly with treatments with an addition of 120 kg N/ha, a curve decline reflects a more marked slowdown in nitrogen withdrawals at the end of growth, which is explained by a more low coefficient value (1-β) (Table 5).

This slowing of the absorption of N at the end of growth coincides with the depletion of the nitrogen reserves in the soil just after a phase of acceleration of N absorption following the applications of mineral fertilizer (ammonitrate). For the rest of the treatments, including control treatments, the value of (1-β) is similar, indicating a consistency in the nitrogen absorption during the vegetative cycle and also a constant supply of N by the environment.

Table.5: Comparison of the coefficients 10 α and 1-β of the relation $N_{exp} = 10\alpha\ (DM)^{1-\beta}$

Traitements	**10 α**	**1-β**	**R²**	confidence interval of **(1-β) P = 5%**
TWW-0N	27	0.76	0.990	0.03
TWW-120N	39	0.53	0.689	0.02
TWW-20t Fumier/ha	26	0.73	0.870	0.12
TWW-120N+20t Fumier/ha	25	0.81	0.915	0.16
WW-0N	23	0.75	0.992	0.03
WW-120N	33	0.63	0.909	0.08
WW-20t Fumier/ha	35	0.77	0.976	0.01
WW-120N+20t Fumier/ha	31	0.74	0.994	0.02

The highest allometry coefficient (0.81) corresponds to the treatment receiving the highest total dose of N (450 kgN/ha), shows that the N content in the plant decreases little during growth, from 1.99 at the beginning growth at 1.46 at the end of growth. This coefficient would be a sign of luxury consumption of N and probably of growth retardation.

3.4 Effect of treatments on nitrate nitrogen in the soil

The profile before sowing was poor with nitrate nitrogen content of 15kgN-NO_3/ha at surface and practically nothing beyond 40cm depth (Fig 4). Only irrigation, without any addition of fertilizer, modifies and in the same way as well with the TWW and WW the nitric profile. About 40 kgN-NO_3/ha was found on the soil

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surface but also at depth after harvest (Fig 4), highlighting a deep migration of nitrate. Hence the lack of effect of the nitrogen form (NO^-_3 vs NH^+_4) provided by the two types of water on the nitric profile in the soil. It is often reported in the literature that ammonium ions contributed by the TWW is rapidly oxidized to nitrate after irrigation (Speir et al, 1999**)**. This conversion is actually favored by the sandy nature of our soil, the irrigation technique that prevents water logging of the soil and also by climatic conditions, ie high temperature, 30-35 ° C (Marot-Gaudry ., 1997). This rapid conversion of ammonium to nitrate, often leads to an accumulation of nitrate ions in the soil (Page et al, 1998). Similarly, Vazquez-Montiel et al. (1996) reported that the concentration of ammonium in soils irrigated with treated wastewater is generally low. Berdai et al. (1998) find that the maximum levels of ammonia nitrogen are achieved at 48 hours after irrigation. After 48 hours, the nitric and ammonia nitrogen content decreases due to losses through gaseous channels, leaching and absorption by the plan

The addition of 120kgN/ha results in an enrichment of the soil profile with nitrate more important on the surface of the soil and with the TWW irrigation. This enrichment is, on the one hand, the result of an intense microbial activity in the rhizosphere and, on the other hand, the product of an acceleration of the nitrification of the organic nitrogen in the soil under the effect of nitrogen fertilizer. Recently, Belligno et al. (2000), by incubating soil in the presence of treated wastewater and clear water plus the same amount of N, find that the amount of nitric nitrogen in the soil is higher in irrigation with treated wastewater.

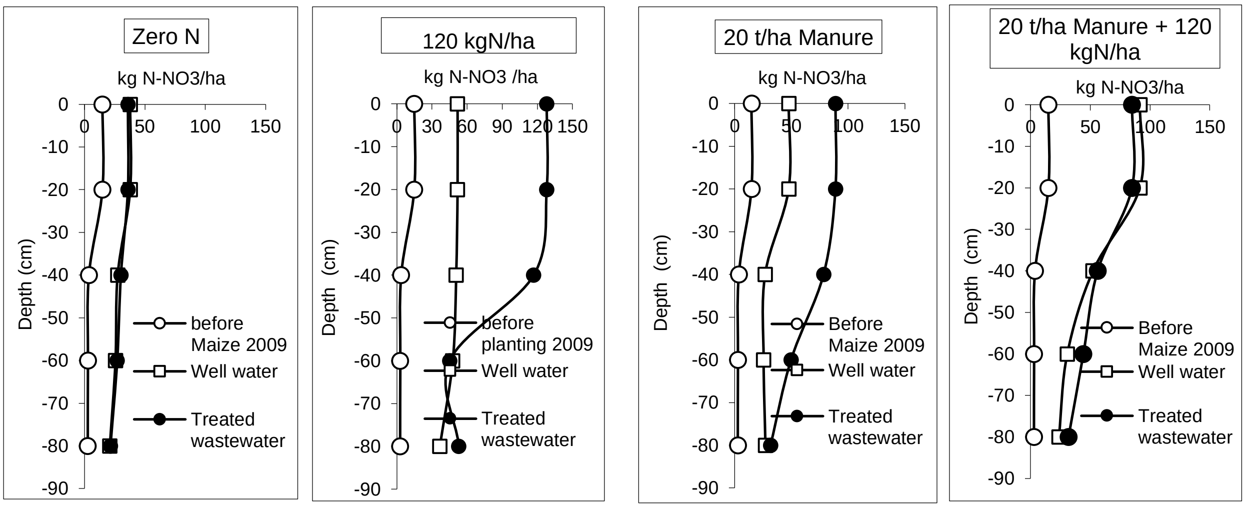

Fig.4: Nitrate remaining in the soil after the first harvest in 2009

The same authors suggest that the addition of nitrogen fertilizer in irrigation with treated wastewater accelerates nitrification in the soil. Papadopoulos and Styliano (1988), using a treated wastewater with 30 mg N/l and receiving 60 mg N/l as ammonium nitrate fertilizer and a well water with the same total amount of N (90 mg/l), find that nitrate migration below the root zone is higher in the treatment with treated wastewater. Nashikkar (1993) showed that the organic matter load explained by the high value of the BOD can also accelerate the conversion of NH_4 to NO_3 due to the anoxic conditions that it favors. The retention of nitrate nitrogen in the upper zone of the soil when TWW is used for irrigation reflects the intensity of microbial activity in this part of the ground. However, in the absence of uptake by crops, this nitrogen will migrate into the water table with the first autumn rainfall.

In irrigation with well water the addition of 120 N slightly increases the amount of nitrate in the soil profile compared to the control "WW-0N" while keeping the same aspect of the profile. This flat profile indicates that a large amount of N is lost only by nitrate leaching. This loss in fact explains the absence of the response of the DM yields to nitrogenous fertilizers.

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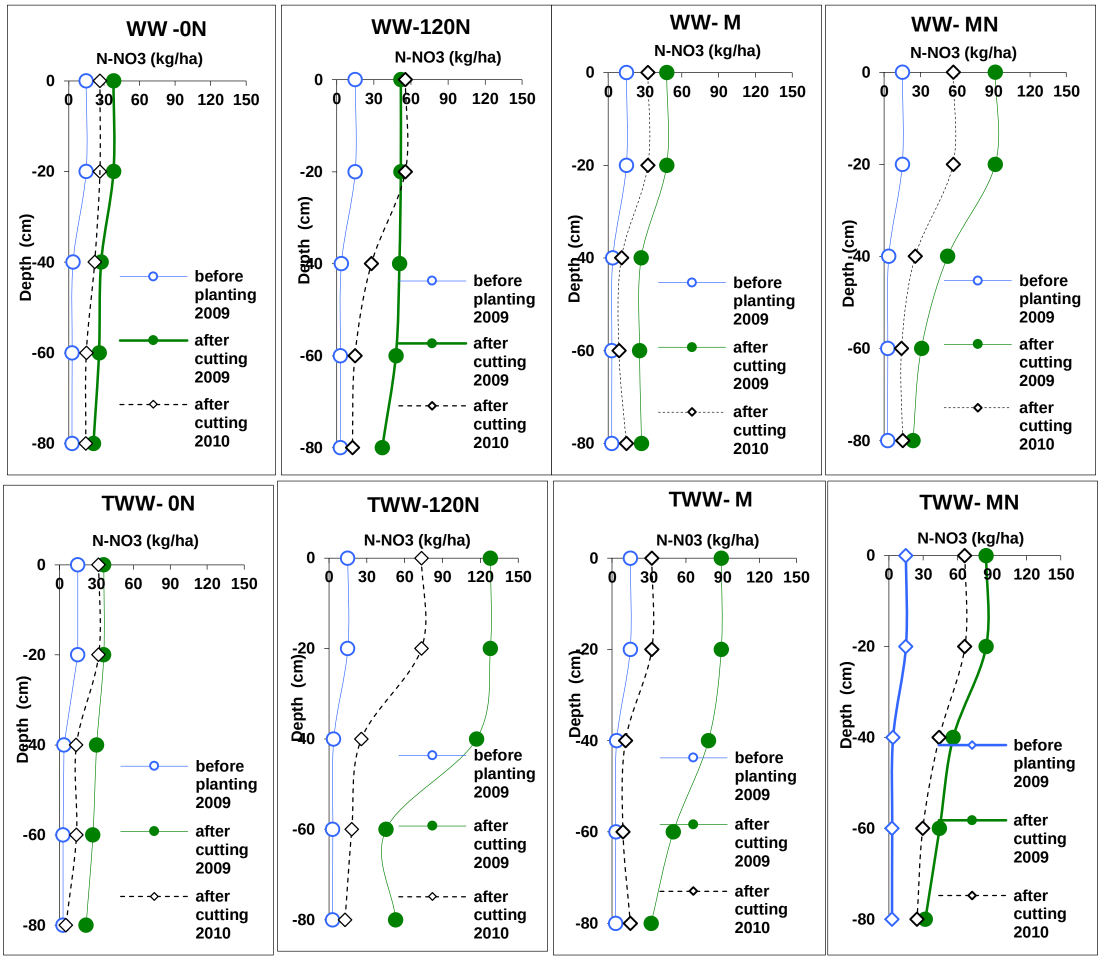

Fig.5: comparison of residual nitrate nitrogen in the soil after harvest in 2009 and 2010

Moreover, in the presence of manure we note an accumulation of nitrates in the upper part of the soil. This nitrogen has two origins, depending on the type of water used. In WW irrigation, these nitrates certainly come from irrigation water. Thus, in this case, the manure has to help to retain this nitrogen and prevent it from going to the water table, at least temporarily before covering the soil with a nitrate trap crop (NTC). However, in TWW irrigation, the residual nitrogen was greater than in WW irrigation, this may be the result of significant mineralization of manure organic matter due to high microbial activity sustained by the supply of a carbonaceous substrate by the treated wastewater (HCO_3 = 345 mg/l). The comparison of the nitrate profile between control and manure treatments supports this hypothesis. In fact, in irrigation with WW the nitric profile is similar for the control and the treatment with manure. While in TWW irrigation, the nitric profile is more enriched in the presence of manure. Only in the presence of fertilizer and manure that an enrichment of the nitric nitrogen profile has been noticed especially on the soil surface in WW irrigation,. This significant increase in nitrate nitrogen at the soil surface is probably the result of active mineralization of the organic matter of the manure under the effect of the mineral fertilizer. By cons, On the other hand, in irrigation with TWW, the nitric profile is generally more enriched in nitric nitrogen than in irrigation with WW. The comparison of the nitric profile between the two years shows that, in general, the shape of the nitric profiles was practically similar between the two campaigns (fig 5). However, the profile appears to be less loaded with nitric nitrogen after the second season (2010). It is therefore assumed that the nitrogen retention and its storage in the soil are achieved with the high total nitrogen dose brought in 2009, especially in TWW irrigation with manure and fertilizer. Jordan et al. (1997) reported that if the soil can be used for storage of nitrogen contributed by TWW during the first year of irrigation (of 1-46 micromol/l before irrigation to 30-71 mmol/l after irrigation), in the second year retention capacity decreases and a significant increase in nitrate leaching occurs. This leaching can be minimized by using plant species that could effectively remove nitrogen from the soil as forage crops (Gant et al, 1982; FAO, 2003). In irrigation with WW loaded with nitrate, the situation is different. Residual nitric nitrogen at the end of cultivation is practically low and does not vary between the two years especially for the treatment zero N but it increases with the total N added. This in turn increases leaching losses of nitrates, especially in the presence of manure and nitrogen fertilizer. Hook and Burton (1979) suggest using crops that can undergo several cuts to reduce leaching.

IV. CONCLUSION

Irrigation with treated wastewater has significantly improved the DM production and maize grain yield compared to well water despite the richness of well water by nitrate nitrogen. We believe that the form of nitrogen contributed by water played a decisive role in the development of yields. In contrast to ammonium provided by treated wastewater, that can be fixed on the clay-humus complex of the soil and it's released slowly according to culture needs; the nitrates are mobile enough and because they are provided throughout the vegetative cycle by the well water, are rather exposed to losses by leaching. The observation of nitric profile end of the culture supports this hypothesis. Irrigation with WW, where nitrogen is mainly nitric form, causes a rapid migration of nitrogen to the soil depth. However, irrigation with TWW, where nitrogen is mainly ammoniacal, results in a lower nitrate distribution in the soil depth and greater in the soil surface, notably in 2010. These yield differences between the two types of water are probably the result of the higher fertilizer value (P, K, Ca, Mg and S) in the treated wastewater.

If the yields were stable in the two years in irrigation with WW, a drop in yields with TWW irrigation and especially with supplementary fertilization was noticed. Indeed, the TWW and fertilizer contributions seem to favor a situation of excess N which has led to a depressing effect on yields. However, according to other studies (Khelil et al., 2005), a reasoned starter fertilizer taking into account the N content in water and soil could be recommended. This fertilizer should't exceeds 30% of the dose usually given.

In addition, additional mineral or even organic fertilization enriches the soil profile with nitric nitrogen. These nitric reserves may be very different for similar yields. In 2009, the profile was more loaded with nitric nitrogen than in 2010 and especially in the TWW treatment with fertilization. So, if the soil can be used as storage for the nitrogen contained in TWW in the first growing season from 24 kg N-NO_3/ha before irrigation to 115 kg N-NO_3/ha after irrigation. At the end of the second growing season, storage capacity dropped to 64 kg N-NO_3/ha, which suggests that a considerable increase in nitrate leaching occurred. Therefore, in contrast to manure, which seems to enrich the upper part of the soil with nitrogen, at least during the first year of growth, unreasoned mineral fertilization leads to a more rapid migration of nitrogen at depth.

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