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Alfalfa production irrigated with treated effluent in Canary Islands

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Summary - The aim of this work was to study agronomic effects of wastewater on the soil and on forage yields when irrigated using secondary effluent. We present the results obtained in 1998/99, although the experiment started in 1995. The experimental field was located in northeast Gran Canaria island, Spain. Climate has 243 mm/year of precipitation and an annual temperature average of 19.5° C). Soil has 3 dS/m of total dissolved salts and 13.7 of Sodium Adsorption Ratio (SAR). We tested four alfalfa varieties (Gilboa, Giulia, Hunterfield and a Spaniard ecotype: Aragón). The experimental field was divided in two zones, respectively irrigated with reclaimed water (T1) and fresh water (T2). Each zone was subdivided in two blocks with all the varieties seeded randomly three times per block, each one with a 10 m^2 surface. There were no fertilization programs and the harvest is handmade. Surface irrigations were applied. The irrigation frequency depended on the climatic conditions, varying from 15 to 21 days. We collected vegetal samples depending on their growth, soil was sampled every six months and water was sampled over each irrigation. Although no significant, Hunterfield was the higher-yielding variety at experimental field. Giulia had high-yielding with low plant number/m^2 values, showing good performance.There are possibilities to obtain 9 cuts/year with an estimated yield around 150.000 kg of green forage/ha·year when irrigated using a secondary effluent, in close-to-shored areas of Canary Islands nowadays usually abandoned.

Key-words: forage crops, wastewater, *Medicago sativa*, alfalfa, water quality

Résumé - *L'objectif de ce travail a été d'étudier les effets agronomiques de l'eau dépurée sur le sol et sur les champs de fourage quand ceux-ci ont été irrigués en utilisant un effluent secondaire. Nous présentons les résultats obtenus en 1998/1999, bien que les expériences aient commencé en 1995. Le champ expérimental était localisé au nord est de l'île de Grande Canarie, Espagne. Le climat dans cette région présente des précipitations de l'ordre de 243 mm/an, des températures annuelles moyennes de 19,5°C et le terrain présente 3 dS/m de sels totaux dissous et 13,7 de taux d'adsorbtion de sodium. Nous avons testé quatre variétés d'alfalfa (Gilboa, Giulia, Hunterfield et Aragon). Le champ expérimental était divisé en deux zones, irriguées respectivement avec de l'eau dépurée et de l'eau de puit. Chacune des zones à leur tour était divisée en deux blocs, toutes les variétés d'alfalfa ayant été plantées trois fois par bloc. La fréquence d'irrigation varia de 15 à 21 jours. Les échantillons de végétaux furent prélevés selon leur croissance, le sol fut échantillonné chaque six mois, et l'eau à chaque irrigation.Bien que de manière non significative, Hunterfield apparut comme étant la variété la plus productive sur le champ expérimental. Giulia présenta un haut rendement uni à peu de plantes par mètre carré, cela démontrant une meilleure performance du point de vue nutrititif. Ces résultats démontrent qu'il existe la possibilité d'obtenir neuf coupes par an avec un rendement d'environ 150.000 kg de fourage vert/ha par an quand irrigué avec un effluent secondaire dans les régions près des côtes des îles Canaries, régions qui sont aujourd'hui normalement inutilisées.*

Mots-clès: *fourage, eau dépurée,* Medicago sativa, *alfalfa*

Introduction

Water is a critical factor to regional development. One of the more extended worries in the arid and semi-arid regions is to have enough available water with a suitable quality. Gran Canaria Island (Canary Island, Spain), has a typical hydrological unbalance between water consumption and renewable water availability. Thus, water consumption (130 hm^3/year), is 51 hm^3/yr greater than real availability (11 hm^3/year rainfall, 47 hm^3/year from renewable ground water and 21 hm^3/yr from desalination plants) and is extracted from non-renewable ground water resources. (Palacios, 1996). This fact degrades water quality, compromising the sustainability of agriculture. Reclaimed water (almost 17 hm^3/year in Gran Canaria Island) can partially avoid this situation. In fact, it is starting to be a reality in the whole archipielago.

Agriculture represents the 58% on the total consume (about 75 hm^3) and has to compete with other uses, like tourism, which is the basic economical income. Tourist sector is the most prevalent in the islands, so it is necessary to provide non-conventional water resources with a competitive price and suitable sanitary conditions to promote agriculture in the island.

Agriculture is the most important potential user of reclaimed water (RW). It is necessary to make a previous agronomic study on qualitative and quantitative estimation of the different nutrients contained in reclaimed waters and on the effects on the physical and chemical soil properties, and residues on the crops must be investigated. Finally an appropriate choice of the commercial varieties is needed to guarantee the proper use of reclaimed waters.

Forage production is the most suitable choice to reuse RW resources, due to its lower quality exigency and the lack of the fresh forage crops to feed livestock caused by the high water price. Canary ruminant livestock has 21, 820 cattle, 246,563 goats and 37,370 sheep. Livestock feed is mainly produced *in situ*, with addition of corn, alfalfa and compound mixed feed. Difficulty to obtain enough forage quantity is the main limiting factor for the livestock development.

Materials and Methods

Climatic and soil characteristics: The experimental field was sited on a cliff in the Gran Canaria's northeaster coast. Climate has low rainfall (243 mm/year) and mild temperatures (annual average of 19.5°C). Soils are salty (3 dS/m) and sodic (SAR: 13.7).

The crop: Alfalfa (*Medicago sativa*) has been seeded in March 1998 using 2 gr/m^2 per experimental unit (with a 10 m^2 surface). Four varieties were used: Gilboa, Giulia, Hunterfield and the ecotype Aragón. After the seeding surface irrigation was applied using low salinity water in order to guarantee the germination. No fertilization program was used in wastewater plots. Irrigation frequency depended on the climatic conditions, varying from 15 to 21 days. Harvest was handmade and begun when 10% of the crop was flowering.

Water characteristics: Main water characteristics (obtained during the period 1998/99) are presented in tables 1 and 2, using mean and standard deviation. Macroelements as Na, K, Ca, Mg, Cl, HCO_3^-, NH_4^+, P and SO_4^2 and sodium adsorption ratio (SAR), electrical conductivity (EC) and pH have been measured. Reclaimed water and Fresh water samples have been obtained simultaneously. in every irrigation day.

Table 1 Analytical Results for: Sodium Adsortion Ratio (SAR), Electrical Conductivity (EC), pH, Na, K, Ca and Mg obtained during 1998/99 and using mean and standard deviation Values with different letters are significantly different.

Type of water	SAR	EC (dS/m)	pH	Na(meq·L^{-1})	K (meq·L^{-1})	Ca meq·L^{-1})	Mg (meq·L^{-1})
Reclaimed water (T1)	7.47±0.57 ^{b}	1.96±0.20 ^{b}	7.63±0.07 ^{a}	291.46±37.83^b	39.77±3.09 ^{b}	46.25±4.67 ^{a}	25.30±5.63 ^{a}
Fresh water (T2)	3.87±0.56 ^{a}	1.20±0.20 ^{a}	7.64±0.07 ^{a}	177.92±37.10^a	24.72±3.03 ^{a}	40.45±4.58 ^{a}	32.83±5.52 ^{a}

Table 2 Analytical Results for: Ca, Mg, Cl, HCO_3^-, NH_4^+ , NO_3^-, P and SO_4^{2-}obtained during 1998/99 and using mean and standard deviation. Values with different letters are significantly different.

Type of water	Cl (meq·L^{-1})	HCO(meq·L^{-1})	NH4$^+$(meq·L^{-1})	NO3-(meq·L^{-1})	P (meq·L^{-1})	SO4(meq·L^{-1})
Reclaimed water (T1)	304.27±61.63 ^{a}	520.42±40.8 ^{b}	48.08±9.35 ^{a}	7.90±3.79 ^{a}	57.96±1.63 ^{b}	113.30±14.75 ^{b}
Fresh water (T2)	257.16±60.43 ^{a}	248.38±40.01 ^{a}		1.71±3.59 ^{a}	47.52±1.87 ^{a}	69.06±15.37 ^{a}

Statistical design: Experimental field was divided in two zones respectively irrigated using reclaimed water (T1) and fresh water (T2). Each zone was subdivided in two blocks, related to the sea proximity due to its influence in soil salinity: farest (B1) and nearest (B2), with all the varieties seeded randomly three times per block.

Samples collect: Soil samples were collected at the seeding time, to carry out chemical analysis (macro and micro nutrients) and texture determination in the laboratory. After the seeding and cut time an estimation of the germination and shooting was done using a 30 cm diameter ring, thrown three times in every experimental unit.

Coinciding with the irrigation frequency, vegetal samples were collected from the 16 experimental units. Vegetal samples were weighed green and dried, the plant number was counted and nutrient contents were submitted to the laboratory. Using irrigation frequency, water T1 and T2 samples have been collected and submitted to the laboratory.

Results and discussion

Significant differences between T1 and T2 have been observed by SAR, EC, Na, K, HCO_3, P and SO_4^{2-} as previously mentioned (Zekri, 1994). No significant differences between T1 and T2 have been observed by pH, Ca, Mg, chlorides and nitrates. Same trend is followed by SAR, EC, Na, Ca and Mg, as showed in figures1 and 2 (EC and SAR). As showed in figure 3, there were occasional contamination water events by nitrates in T1.

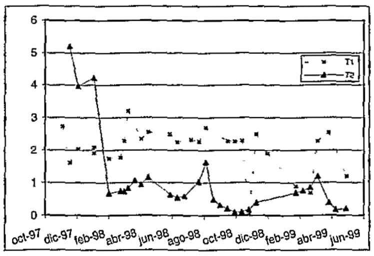

Figure 1: Electrical Conductivity (EC) variations for T1(Reclaimed water) and T2 (Fresh water).

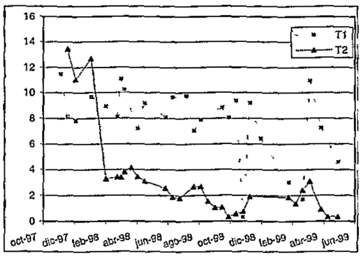

Figure 2: SAR variations for T1 (Reclaimed water) and T2 (Fresh water).

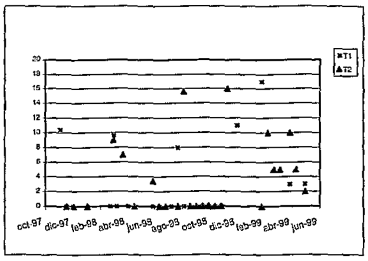

Figure 3: NO_3 variations for T1 (Reclaimed water) and T2 (Fresh water).

No effects have been observed by fresh production using reclaimed water. There were not any significant differences between T1 and T2 by this factor as mentioned by Neilsen (1989). Hunterfield (HF) variety had no significant differences with Gilboa (G) and Giulia (J) varieties, but HF showed significantly higher production than Aragón (Ar). Thus, at experimental field, HF was the most productive and Ar was the lowest one, as showed in figures 4 and 5. Significantly higher dry matter contents were observed in T1 (29,40%) from T2 (20,40%).

Although no significantly, HF dry matter contents (35%) were higher than G, J and Ar. There were no significant differences among varieties, but HF tended slightly to have higher dry matter contents than the others, as obtained by Overman (1995).

There were not any significant differences between T1 and T2 in plant number/m^2 (PN) measures. However significantly different plant number/m^2 by varieties were observed among Ar, J and G, as showed in figures 4 and 5. G presented significantly lowest plant number/m^2 values, and Ar offered the highest ones.

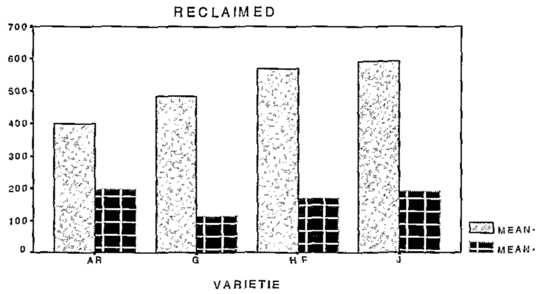

Fig 4: Comparison among Alfalfa varieties (Aragón, Gilboa, Giulia and Hunter field) for Production and Plant Number/m^2 (PN) irrigated with Reclaimed water (T1).

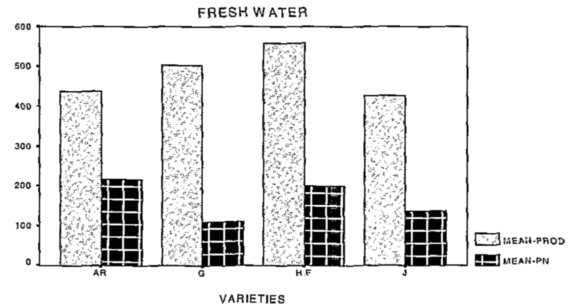

Fig 5: Comparison among Alfalfa varieties (Aragón, Gilboa, Giulia and Hunter field) for Production and Plant Number/m^2 (PN) irrigated with Fresh water (T2).

One productive cycle (from regrowth after cutting to the following flowering period) were represented in figures 6, 7, 8 and 9 for the 4 varieties. As showed in figure 9, there was high stems winter mortality, with special incidence in Gilboa variety. When reclaimed water irrigation was used, alfalfa emergency was affected. As time pass this problem disappeared, coinciding with the results obtained by Shalhevet (1994).

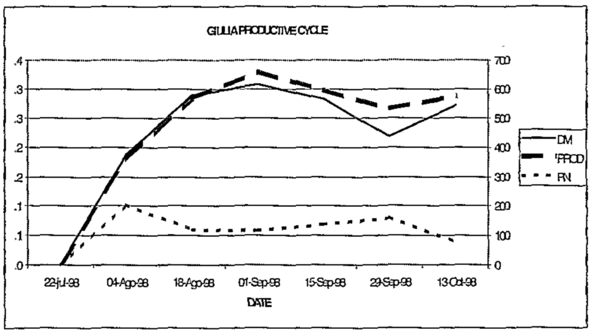

Figure 6 Giulia productive cycle.

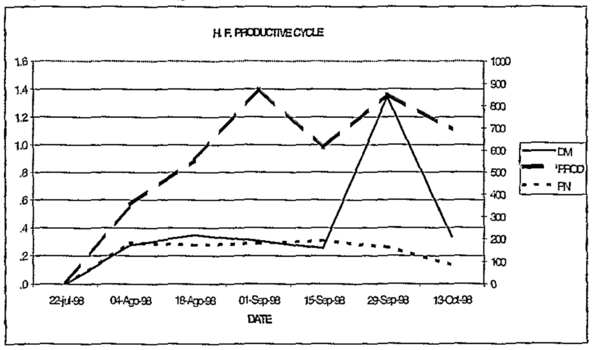

Figure 7 Hunter Field productive cycle.

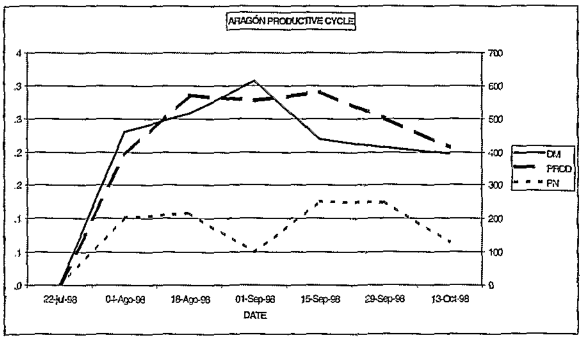

Figure 8 Aragón productive cycle.

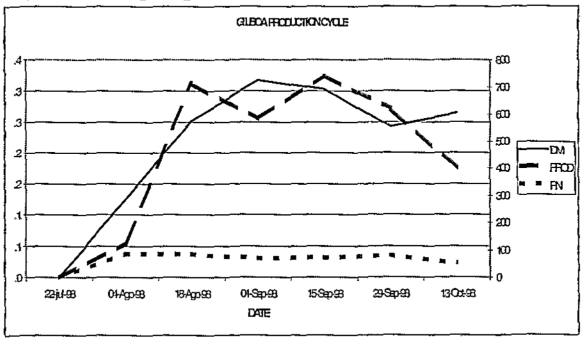

Figure 9 Gilboa productive cycle.

Conclusions

Although there were not any significant differences in production and plant number/m^2 between T1 and T2, values tended to be slightly higher in T1 than T2. These results demonstrated that there was no water effect on crop. Thus, wastewater irrigation could be used to irrigate fodder crops in order to produce bulk feed for livestock (Palacios, 1996) and it would be interesting to do digestibility tests to check it. When reclaimed water irrigation was used, alfalfa emergency was affected by water quality. As time passed, this problem disappeared.There was high winter stems mortality, specially occurred in Gilboa variety, greater when reclaimed water was used.

Aragon had the highest plant number/m^2 values, but its productivity values are the lowest among the four varieties tested. Thus, its leaves/stem ratio had to be low.

Although no significant, Hunterfield was the higher-yielding variety at experimental field. Giulia had high-yielding too. In spite of Giulia's low plant number/m^2 values, this variety showed high-yielding. Thus it could be expected that Giulia would have the best performance to feed livestock in Canary condition.

There are possibilities to obtain 9 cuts/year with an estimated yield around 150.000 kg of green forage/ha·year in near-shored zones of Canary Islands, nowadays usually abandoned.

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