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EFFICIENCY OF FURROW IRRIGATION ON SANDY SOIL AMENDED WITH BENTONITE IN ARID AND SEMI ARID REGION

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SUMMARY - Great extents of sandy soils in Algeria are occurring on the Mediterranean coast and in the Sahara. Their properties are unfavourable for agricultural production because of their low clay and organic matter content, water holding capacity and their poor retention capacity of nutriments for plant growth.
It has been shown that strong correlations exist between water holding capacity and particle size distribution of the soils, especially their clay and fine silt contents. The addition of bentonite to a sandy soil increases water holding capacity and crop yield. Several works showed that a 10% dose of bentonite increased the water holding capacity in the average to 170 % compared to non amended reference soils.
Furrow irrigation is the most used technique to irrigate sandy soils related to their high permeability insuring water transfer in soils horizontally as well as vertically. This technique concerns most usual practice of irrigation in Algeria.
In this work, we have studied the performance parameters of this type of irrigation on a sandy soil of the plateau of Mostaganem (West-north of Algeria) amended by 5% and 15% of bentonite in between the optimal dose of 10% on an experimental site. The results are discussed in the light of experimental data obtained in the laboratory.
This study showed that the percolation losses on water decreased with an increasing dose of bentonite and so the efficiency of water was improved. General considerations are deduced to improve control of furrow irrigation in sandy soils amended with bentonite.

Key words: furrow irrigation, bentonite, hydraulic field, infiltrated volume, irrigation efficiency, economic use water, arid and semi arid region.

RESUME *- En Algérie, il existe de grandes étendues de sols sableux sur le littoral et au Sahara. Leurs propriétés sont défavorables à la production agricole à cause de leur faible teneur en argile, humus et capacité de rétention en eau et en éléments minéraux.*
De fortes corrélations existent entre la réserve hydrique du sol et sa composition en argile et en limons fins. L'addition donc, de bentonite à sol sableux, engendre une augmentation de sa capacité à retenir l'eau et à produire. Plusieurs travaux montrent que l'apport de 10% de bentonite, augmente la réserve hydrique d'un sol sableux de 170 % en moyenne par rapport au témoin.
L'irrigation à la raie est la plus utilisée dans les sols sableux vue leur grande perméabilité qui assure une bonne mobilité de l'eau aussi bien horizontalement que verticalement. Cette technique couvre l'essentiel des pratiques d'irrigation en Algérie.
Dans ce travail, nous avons étudié les paramètres de performance de ce type d'irrigation sur le site d'un sol sableux du plateau de Mostaganem (Nord ouest d'Algérie) amendé par 5% et 15% de bentonite ajoutées à la dose optimale de 10%. Ces résultats sont discutés à la lumière d'autres données expérimentales obtenues au laboratoire.
Cette étude a permis de constater que les pertes d'eau par percolation ont diminué suite à l'augmentation de la dose d'argile et l'efficience de l'irrigation est améliorée. Nous déduisons, globalement, que ce type d'amendement pour des sols sableux procure un meilleur contrôle des paramètres de performance de l'irrigation à la raie.

Mots-clés*: irrigation à la raie, bentonite, rendement hydraulique, volume infiltré, efficience de l'irrigation, économie d'eau, régions arides et semi-arides.*

INTRODUCTION

General data show that 64% of arid zones and 97% of more arid zones in the world are concentrated in Africa and Asia (Greenland *et al*, 1994). In Algeria, arid and semi arid areas cover approximately 95% of the country (Halitim, 1984). Soils of this region mainly differ from those of humid regions by their sandy character and thus by significant properties associated with an insufficient of water supply (Haseltine, 2005). Low content of organic matter (< 1%), CEC (< 1 meq.100 g^{-1} of soil), and a small holding capacity as well as energy retention of water, and mineral nutrients are some of the properties that limit agriculture in those regions.

There over, the global availability of water in the world is constantly decreasing where as the needs of water for agriculture are constantly growing. This situation underlies an extreme challenge for many countries and especially affects those of North Africa (Wolff, 1996; Azeem El Kadi, 1997; Shannon *et* al., 1999). It is therefore fundamental to discuss, improve or change water management practices in the light of its use and to consider water as a very precious and fragile resource, especially to limit its waste and optimise its efficiency, as well its access.

The use of clay to improve the physical - chemical characteristics and specifically the water retention properties of sandy soils have been studied for decades (Engelthaler, 1977; Lhotsky, 1979; El Sherif, 1987; Benkhelifa, 1997; Halilat, 1998). It is known that according to the type and amount of added clay, the cation exchange capacity (CEC) of sandy soils may increase from 8 to 100 meq.100 g-1 (Haseltine, 2005). Water holding capacity records report increases on average up to 170% as compared to the reference (Benkhelifa, 1997). The literature reports that the optimum amount of clay amendment to improve soil properties is on average about 10% of the dry soil weight (Benkhelifa, 1997; Halilat, 1998). In this case the agricultural outputs showed an increase in crop production from 10 to 40% according to the crop (Engelthaler, 1985; El Sherif, 1987; Benkhelifa, 1997).

Furrow irrigation is in general greatly utilized in the sandy environments of the large permeability of the soils that insures good water transfers horizontally as well as vertically. In Algeria, this technique covers the essential of the irrigation practices (Chabaca, 2004).

In order to light the economic aspect of water use, we studied in this work performance parameters of furrow irrigation on a sandy soil of the plateau of Mostaganem amended with a bentonite doses of 5, 10 and 15%.

MATERIALS AND METHODS OF STUDY

Material of study

Soil

The experimental study was conducted at the farm of the University of Mostaganem (Algeria). The experimental side was chosen because of the sand texture representative character (*Table 1*). The plot was drawn with a cover crop and disk draw machinery up to 30 cm depth. Note that the content in coarse sand (200-2000 μms) is important and exceed 55%.

Table 1. Granulometric characteristics of experimental parcel (%)

Profil	Clay	Fine silt	Coarse silt	Silt	Fine sand	Coarse sand	Sand
I	1.70	1.80	2.70	4.50	34.60	55.10	89.70
II	2.20	1.70	2.40	4.10	30.90	59.50	90.40
III	3.10	1.20	2.70	3.90	31.30	57.90	89.20

Bentonite

The selected bentonite deposit was located at Mostaganem on the northwest of Algeria (Table 2). Initially, the material contains 77% of sodium on its cationic exchange capacity.

The clay was spread on the experimental plots 18 months before the essay. Clay spread and mixture were done by hand. Experiments were conducted on clay-sands mixtures to determine parameter that govern soil properties (Benkhelifa *et* al., 2006, under press).

Table 2. Physical and chemical characteristics of Mostaganem bentonite (Halilat *et al.*, 2006)

Clay (%)	Silt (%)	Sand (%)	CEC ($cmol^+.kg^{-1}$)	Na.CE C^{-1} (%)	Specific surface ($m^2.g^{-1}$)
63	20	17	49	77	347

The quantities of applied bentonite (*Table 3*), for each rate are determined in function of the soil bulk density in state that is in average of 1.50.

Table 3. Quantities of applied bentonite

Rate of bentonite (%)	5	10	15
Per experimental stripe (Kg)	72	144	216
Per hectare (tonne)	225	450	675

Experimental stripe

The tests have been done on twelve stripes with open downstream extremities of 4m length and 0.8m width.

Methods of study

Experimental device

The slope of the stripes was designed in order to limit erosion caused by runoff. As a rule, it should be lower or equal to 1%, but can reach 3% in some cases (Berthome, 1984). We chose slopes of 1%, 2% and 2.5%. The stripes were designed according to three complete blocks including each four treatments (0, 5, 10 and 15% of bentonite) and three random distributed slopes. Every experimental stripe was placed between two guard stripes. A passageway of 3m separates the different blocks in order to facilitate their access. The stripes have trapezoidal section. The total surface of every block is 28.8 m².

Irrigation

On the designed stripes, we determined humidity at field capacity (HFC) for an average depth of 15 cm (*Table 4*). Drying curves were (Fig. 1) in order to determine the watering frequencies, i.e.:

- 4 days for reference stripes,
- 7 days for stripes with 5% of bentonite,
- 9 days for stripes with 10% of bentonite,
- 11 days for stripes with 15% of bentonite.

The irrigation time was determined by considering potential evapotranspiration (ETP), i.e. between 5 and 6 mm.jour-1 during our experiment (Bourenane, 1995). For a hydraulic yield of 50%, the gross dose should be equal to 34 mm that corresponds to 110 litres of water for a surface area of 3.2 m². In order to insure a flow of 0.6 $l.s^{-1}$, the irrigation time must be 3 minutes. Because the hydraulic yields are weak in practice for this type of irrigation (Mailhol, 1992), the irrigation time (set time) was increased to 6 and 9 minutes.

Table 4. Humidity at field capacity as a function of rate of bentonite added.

Dose of Clay, %	0	5	10	15
	4,81	4,87	7,98	10,22
HFC, %	4,13	5,69	8,75	9,78
	4,80	5,43	8,89	10,60
Average	4,58	5,33	8,54	10,20
Standard Deviation	0,32	0,34	0,40	0,34

The watering flow that was used in practice varied between 0.3 to 1 $l.s^{-1}$. We adopted for this work an average value of 0.6 $l.s^{-1}$ a lot more for convenience reasons known that the operating debit is going to be the object of a stationary parameter. After having installed the operating debit at 0.6 $l.s^{-1}$, the water alimentation is begun and the advancement time is noted. Water infiltrates during the whole set time. At the end, the alimentation been stopped and the dripping volumes are noted.

Three irrigations have been done for every experimental stripe and the measure of the initial humidity was taken before the watering.

The operating debit of water was fixed with a reservoir of 70 l and a chronometer. The principle rests on the fact that for every water level in the container corresponds so a certain debit. The water level is maintained constant through the intermediary of an opening of overflow. The position of this last is chosen according to the debit.

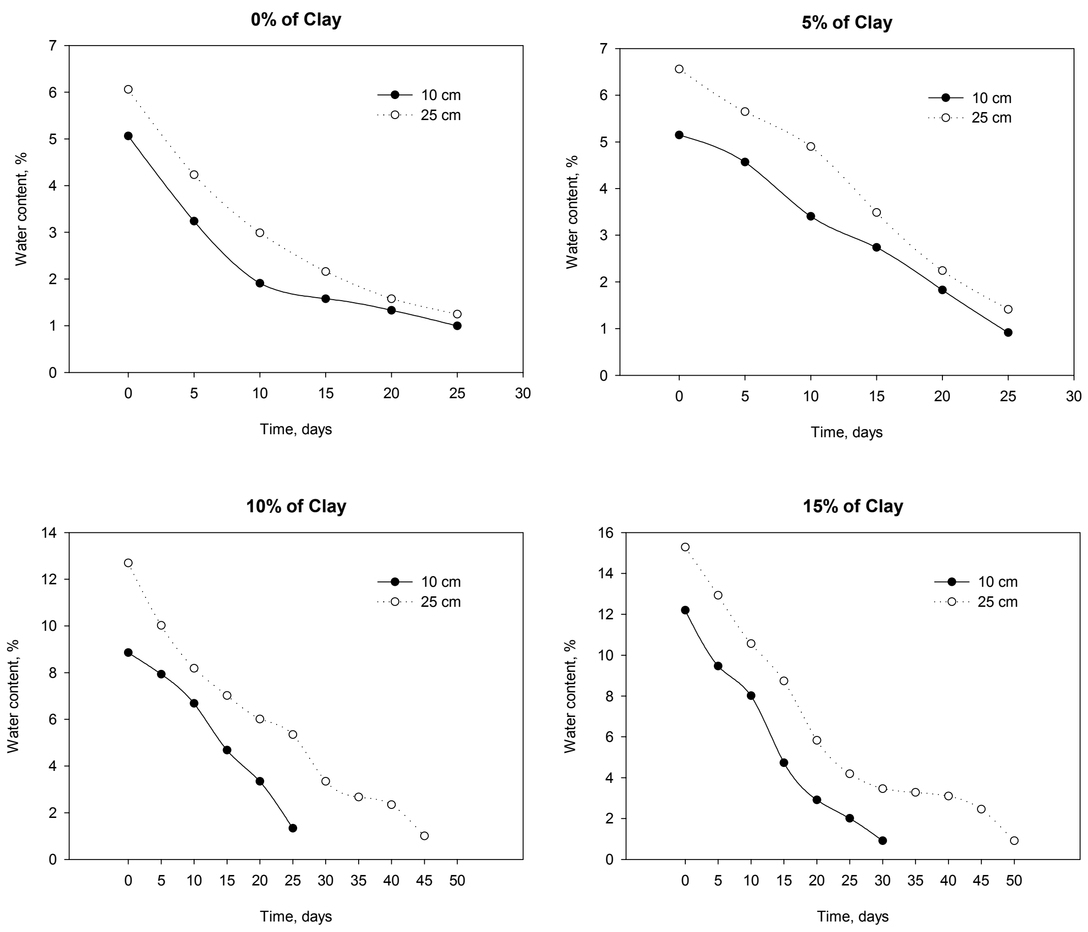

Fig. 1. Evolution of humidity of field capacity in function on bentonite rate.

Analytical methods

Field humidity

By difference of weight of the sample just after its sampling and after its passage in heating oven at 105° C during 24 hours.

Humidity at field capacity

48 hours after saturation of soil, sampling for determination of soil humidity.

Hydraulic yield

To determine the hydraulic yield (R_h), it is necessary to calculate the infiltrated volume (V_i), the net dose (d_n) and the gross dose (d_b) of irrigation.

The infiltrated volume is estimated on the basis of the relation of the model of the volume balance defined by the expression:

$$V_i(t) = V_e - V_c - V_s \quad \text{(Hanks } et\ al., \text{ 1980)} \tag{1}$$

Where:

V_e: entered volume (mm).
V_i: infiltrated volume for a time t (mm).
V_c: dripping volume by collator (mm).
V_s: stocked volume (mm).

In our case, looking at the limited length of the applied stripes, the stocked volume in the stripe is negligible (BERTHOME, 1984). The infiltrated volume becomes therefore: $V_i(t) = V_e - V_c$. The net dose is deducted with the help of the following formula:

$$d_n = da \times Z \times (HFC - H_i) \quad \text{(Hanks } et\ al., \text{ 1980)} \tag{2}$$

Where:

D_n: net dose (mm).
da: bulk density.
Z: soil depth (mm).
H_i: initial humidity (%).
HFC: humidity at field capacity (%).

The percolation losses are estimated by the following expression:

$$P_p = d_b - d_n - P_c. \quad \text{(Hanks } et\ al., \text{ 1980)} \tag{3}$$

Where:

P_p: percolation losses (mm).
P_c: filtration losses (mm).
d_b: gross dose (mm).
d_n: net dose (mm).

The hydraulic yield is estimated by two manners depending on whether the net dose is attained or not attained (Hanks *et al.*, 1980):

1^{er} *case*: net dose attained

$$R_h = \frac{d_n}{d_b} x100 \qquad (4)$$

R_h: hydraulic yield (%)
d_b: gross dose (mm)

2^{eme} *case*: net dose not attained

$$R_h = \frac{d_{inf}}{d_b} x100 \qquad (5)$$

d_n: net dose (mm)
d_{inf} : infiltrated dose (mm)

RESULTS AND DISCUSSIONS

Performance parameters

Infiltrated volume

The values of the infiltrated volume (Vi) according to the doses of bentonite and for the three set times (Fig. 2), show that the quantity of water infiltrated decrease with the increase of the clay dose. It is bound to the infiltration rate of water in the mixture that decreases when its colloidal fraction is bigger.

For stationary values of the bentonite dose and in the set time, the infiltrated volume decreases when the slope of the stripe increases (Fig. 2). This is appears obvious when we note that the speed of water dripping at the surfaces of one soil is especially big that its slope is raised more. Indeed, more the slope is raised more the infiltration is weak because the contact time between water and soil becomes more reduced.

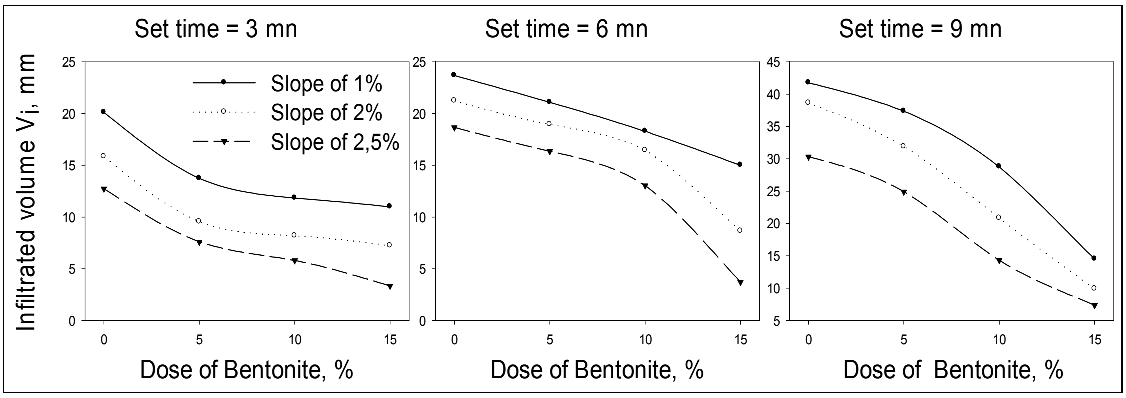

Fig. 2. Volume of infiltrated water in function of dose of bentonite and slope of stripe for thethree set times: 3, 6 and 9 minutes

It appears therefore that the variations of the infiltrated volume don't depend solely on the dose of clay, but also of the slope of the stripe. The statistical analysis (*Table 5*) shows that the influence of the bentonite doses is predominant on the global variations of the infiltrated volume of water in comparison with those assigned to the effect of slope sprite. This predominance of the clay dose is valued to 60, 18 and 85% respectively for the three set times of 3, 6 and 9 minutes. These results agree with those returned by El Sherif (1986) that found that the increase of the bentonite dose added to a sandy soil, decrease the volume of infiltrated water by unit of surface when soil is not saturated.

Otherwise, the presence of bentonite in the sandy soil draws a increase of its micro porosity (Benkhelifa, 1997), what increases its resistance to the water circulation and is translated therefore by an increase of its useful available water (Mailhol, 1992).

For stationary values of the dose of clay and the slope of the stripe, the infiltration continues in the time. It follows that the risks of losses by percolation should increase.

Table 5. Part of different factors in the global variations.

Variation source	Variation (%)			Signification		
	3min.	6min.	9min.	3 min.	6min.	9min.
Dose	64.58	51.77	85,65	$p<0.01$	$p<0.01$	$p<0.01$
slope	25.68	42.26	13,20	$p<0.05$	$p<0.01$	$p<0.01$
Residual	9.74	5.97	1,15			
Coefficient of variation (%)	11.00	7.30	10,30			

Water losses

The results of water losses by percolation are presented in the *Table 6.*

The data of the *Table 5* indicate that for one set time of 3 min, the estimated percolation losses are absent for all treatments et all slopes of the stripes since the net doses are not attained and the soil reserve is not completely filled. The set time of 3mn is therefore insufficient to fill the net dose.

Table 6. Percolation losses according to the dose of clay and slope of stripe, mm.

Set time	3 minutes			6 minutes			9 minutes		
Slope (%)	1	2	2.5	1	2	2.5	1	2	2.5
Clay dose (%)	Percolation losses, mm								
0	0.36	-3.92	-7.02	4.17	2.71	-1.86	30.78	28.52	20.55
5	-6.02	-10.22	-8.15	3.78	-2.56	1.84	27.62	20.68	18.66
10	-8.77	-11.57	-13.96	2.21	1.93	-1.47	21.43	15.74	11.03
15	-7.92	-11.77	-16.41	0.43	-5.86	-10.78	11.18	3.88	-4.28

For the set time of 6mn, the percolation losses are weak and the net doses are attained for the slope of 1%.

For one set time of 9mn, the percolation losses are important and decrease on the one part with the increase of the bentonite dose and the stripe slope on the other part. These results agree with those of the infiltrated volumes and can be explained by the phenomenon of infiltration rate and by the effect of the stripes slope.

A deeper exam of these results (Fig. 3), show that the cumulated losses by percolation for the three set times decrease following the increase of the bentonite dose and the stripes slope.

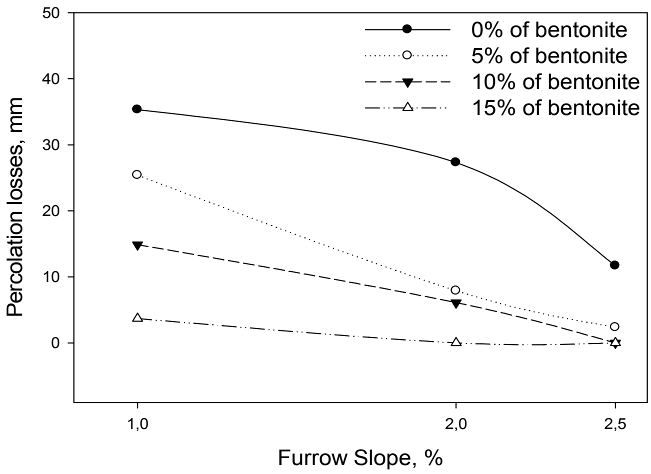

Fig. 3. Percolation losses versus bentonite content and furrow slope

The statistical analysis of the results of the cumulated losses by percolation (*Table 7*), reveal a predominant effect of the bentonite dose on the global variations in relation to those link to the stripes slope. These results reflect the determining role that should play the addition of bentonite concerning economy of water. Indeed, the humidified volume of the rhizospher should be more important if we refers to analyzes it done by Yonts Dean *et al.*, 2005, on the role of the clay

Table 7. Part of different factors on the global variations of cumulated losses by percolation

Variation source	Variation (%)	Signification
Dose	56.82	$p<0.05$
Slope	29.45	$p<0.05$
Residual	13.73	
Coefficient of Variation = 5.1%		

On the performance parameters of the furrow irrigation. It means, that the clay while limiting the infiltration, encourage a lateral movement of water permitting to plants to disposed more easily of water (Fig. 4).

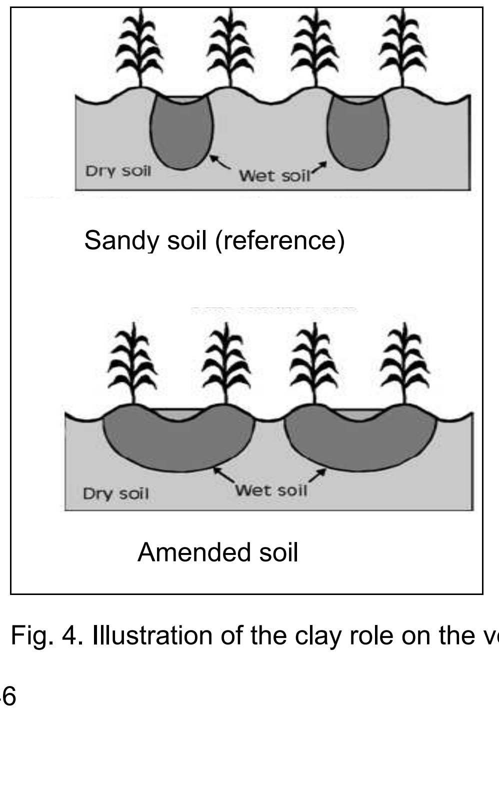

Fig. 4. Illustration of the clay role on the volume of humid rhizospher (Yonts *et al.*, 2005)

To debate the economy of water linked to the use of the bentonite in the sandy soil bonus, there is an important data, according to the bibliography, that indicates that the migration of the bentonite is slow in soil, this permitting not to renew the amendment that after 7 to 10 years (Engelthaler, 1985; El Sherif, 1987).

Otherwise, the results of the present study show that for one set time of 6 minutes and a slope of 1%, soil treated with 10% of bentonite drags a reduction of the percolation water losses of 47% in relation to the witness. In these conditions, the economic evaluation should confront the related to costs of bentonite addition to the gains which it should be generated by economy of water and agricultural production to (Table 8). We did our calculations on the basis of a cost of 66 Algerians Dinars of the water m^3 (Diouf *et* al., 2005), that is to say the equivalent of 0,75 Euros.

We notice, that according to the considered cultures, the gains in economy of water and crop yield can approach the costs of amendment, to see even to pass them. Nevertheless, it is important to note that this approach remains coarse since it is established on the basis of evaluations of the very variable costs of the organic amendment. Besides, the gain achieved on the outputs of the cultures is him self linked to the cultivated species, its needs in water and its economic importance. For the potato and the onion, water only represents 4% of the production costs, whereas for the watermelon, it would represent 30% of them (CNES, 2000). A more precise assessment of the economic impact of the amendment of clay requires taking in account all factors of productions, of the conditions of harvest and even the merchandising.

Table 8. Economic approach of bentonite addition to sandy soil at a depth of 20 cm

Loads bound to bentonite amendment per hectare	Operation nature	Acquisition	Transport	Spread	Total
	Observation	120 AD.Quintal^{-1} (AD: Algerian Dinar)	Deposit at 37 Km	Can be Manual	
	Estimated cost (Algerian Dinar, AD)	360000 DA	10000*	8000*	378000
Gain generated by bentonite amendment per hectare	Factor bind to	Water economy	Organic matter	Yield	Total
	Observation	47% percolation losses in relatition to the reference	7 to 10 times organic amendment on matter for one year	Increase 10 to 40 % in various cultures regarding reference	
	Estimated cost (Algerian Dinar, AD)	Gross dose = 67,5 mm 47% = 6500 AD	12700* AD per year: 89000 to 127000	260000* to 380000*	355500 to 513500

* Approximate average evaluation

Hydraulic yield

The results of the hydraulic yield for the different doses of bentonite and stripes slopes for the set time of 3 minutes are reported Fig. 5. The hydraulic yield decreases following the increase of the dose of bentonite and the stripe of the slope. This evolution is due to the fact that the set time of 3 minutes is insufficient to permit to the net dose of water to infiltrate through the amended stripes this even when the rate of bentonite is raised. Of another side, biggest values of the hydraulic yield is gotten for the slope of 1%, what is in conformity with what has been returned by Berthome (1984), that recommends to decrease the slopes of the stripes to raise the efficiency of the furrow irrigation.

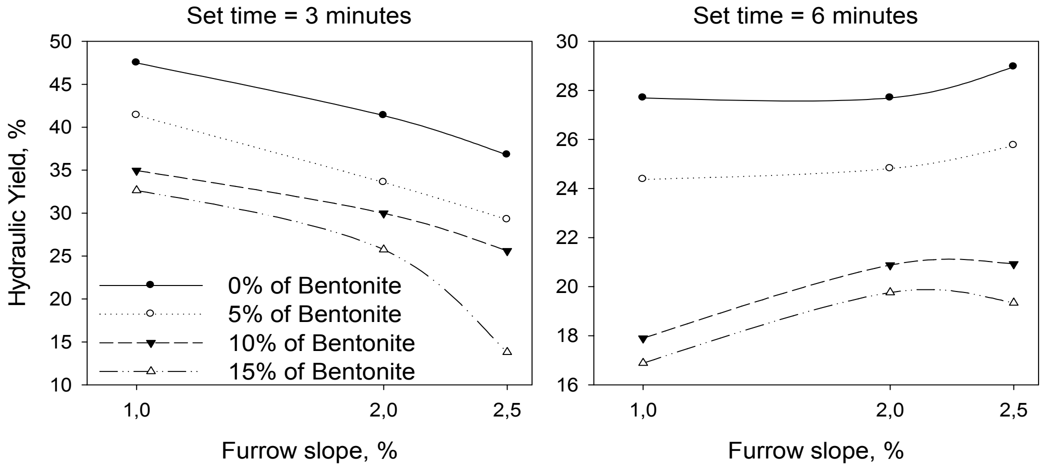

Fig. 5. Hydraulic yield in function of doses of bentonite and stripe slope

For the set time of 6 minutes, the hydraulic yield decreases with the increase of the bentonite dose. The same remark of insufficiency can make itself with regard to the necessary time to the infiltration of the net dose of irrigation. In this case the effect of the slope on the variations of this parameter is not significant (*Table 9*). Indeed it is the effect of the bentonite dose that predominates on the variations of the hydraulic yield for the two set times of 3 and 6 minutes. Thus, the clay content would entail a reduction of the hydraulic yield, while increasing the power of soil retention. Indeed, the infiltration rate becomes slower but has for consequence to encourage the losses of water with infiltration, which are drag the strong chutes the hydraulic yield.

For the set time of 9minutes, the statistical treatment (*Table 10*), reveal that the variations of the hydraulic yield don't depend on the dose of bentonite or the slope of the stripes.

Table 9. Part of different factors in the global variations of hydraulic yield.

	Variation (%)		Signification	
Variation source	3 min.	6 min.	3 min.	6 min.
Dose	54.14	71.96	$p<0.05$	$p<0.05$
Slope	33.24	0.74	$p<0.05$	(NS)*
Residual	12.62	27.30		
Coefficient of Variation (%)	12.7	13		

* No significant

It can be explained by the fact that the set time is so important that it records very strong losses whose average value is the order of 88% of the gross dose of irrigation. That is why the effect of the doses and slopes doesn't appear. As one could note it during the exam of the results of the water volume infiltrated, the optimal set time must be lower to 9 minutes.

Table 10. Analyse of the variance of results of Hydraulic yield R_H (set time = 9mn).

					Theoretical F	
Source variation	SCE	dl	Variance	Calculated F	p(0.05)	p(0.01)
Total	40.67	11				
Dose	7.77	3	2.59	1.21	4.76	9.78 (NS)
Slope	20.12	2	10.06	4.72	5.14	10.9 (NS)
Residual	12.78	6	2.13			
Coefficient of Variation (%)	12.0					

Evolution analysis at medium and long term of clay-sand mixture properties under irrigation

The physical properties of bentonite-sand mixture have been studied by Halilat *et al*., (2006) and Benkhelifa *et al*., (2006). The first important data that comes out again from it, is the granulometric distribution of the sand. Compared to the sand used by Halilat *et al*., (2006) the sand in the present study is coarse (*Table 1*). To put in evidence this difference, we recall that the humidity of the field capacity (HFC) for 10% of clay is of 10% for this survey whereas it was of near 35% for 12% of the same clay at Halilat et *al*., (2006). For very near values of doses of the same material, it is obvious that the difference in HFC remains essentially linked to the texture of the sand. It is why, the data of the infiltration can be analysed therefore in light of these results. Indeed, these studies show that the mixture of 5% of clay doesn't fill the porosity completely, the one of 10% fills it and the one of 15% infiltrates. These three situations remain partially tributaries of the granulometric distribution of the sand size. It reinforces that bentonite attenuates a lot of water losses especially when it is about coarse sand.

It is just as important, to note that the clay added in the present survey is a Na-bentonite (rate of saturation by Na in the CEC = 77%, *Table 2*). It appears that at medium and long term, the properties of the mixture risks to deteriorate by filling (warping), when we knows that the irrigation waters in the plateau of Mostaganem record a content in salts on average of 4 to 5 $g.l^{-1}$ (Harrache *et al*., 1997). Factual, the salinity and sodicity constitute the principal constraints encounter in the arid and semi arid regions where the dominant texture is sandy (Halitim, 1984). It is therefore important to take in account the effect of the initial nature of the bentonite and the sand. In this setting we refer to the works of Benkhelifa *et al*. (2006) that shows that the initial state of the clay is very determinant on its hydratation properties as well with regard to the phenomenon of infiltration that the aspects linked to the constraints of salinity and sodicity. Indeed, if the origin clay is sodic, it can aggravate the effects of the salinity and sodicity. On the other hand if it has a calcic origin, as the one of Maghnia used by Benkhelifa *et al*., (2006) and that is characterized by a strong natural content in calcium (15% of $CaCO_3$), it will have an favourable role by attenuating effects of these two abiotic constrains, related to the sodium state on the physical properties of the mixtures. As a consequence, it is a lot more discriminating to use calcic clay for the sandy soil bonus in the arid and semi arid regions to predict some effects linked to these abiotics constraints. This aspect becomes an asset and especially reinforces the interest of the bentonisation on the water economy of furrow irrigation, on the increase of crop yield and on the prevention of the salinity and the sodicity particularly in irrigation conditions with charged waters (Daoud *et al*., 1994).

CONCLUSION

At the term of this work it is possible to put in inscription the following points:

Furrow irrigation requires taking in account the related parameters to the nature of soils. Indeed, the management of water must be function of infiltration features that depend on the dose of bentonite applied to the sandy soil. We confirm that the coarse sandy soils are more suitable for the irrigation that fine sandy soils with a more spread granulometric distribution.

The management of the irrigation must take into account the topography and notably the slope of the stripe that may reduce the infiltration speed. On this point, our statistical treatments demonstrate the importance of the effect linked to the clay quantity added to a sandy soil in relation to this one linked to the slope of the stripe.

We note that a relation of cause to effect exists between the water holding capacity of one soil amended by bentonite and the extent of its losses by percolation. These losses are also in narrow relationship with the set time. One common problem in furrow irrigation is the application of water in excess, especially during the first irrigation. Proper furrow irrigation practices can minimize water application, irrigation costs and chemical leaching and than result in higher crop yields. It means that the management of water implies to master the set time of water provision. This aspect is not generally taken in consideration in the system of irrigation in Algeria.

The addition of clay permits to reduce considerably the losses in water due to the deep infiltration. It also permits to improve the hydrous properties of soil, to knowledge on the water holding capacity and the energy of water retention. So with 10% of clay, one may increase to 170% the useful water reserve.

It appears important to manage better the devices of furrow irrigation by limiting the course of water and notably by restricting the runoff in extremity of stripe. The use of stripes with closed downstream extremities would presumably succeed more elevated hydraulic yield because of the elimination of the filtration losses.

The cost of the amendment remained a suspense question and the study of the feasibility of this technique remains to do for regions where the constraint linked to the nature of the substrate to irrigate and the type of clay can raise problems. However for all causes, the sandy soil improvement by the bentonite remains also a technical to local use for sandy lands where the water factor is strongly limiting or for arboriculture in order to improve the soil to the scale of the tree. In this case, another technique prevails, to knowledge the incorporation of a bentonite layer like physical barrier to the infiltration water and that plays the role of reservoir where concentrates the root system.

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