A LOCAL MACHINE FOR CONSTRUCTION GRAVEL-FILLING MOLES TO ENHANCE RECLAMATION PROCESSES OF SALT-AFFECTED SOILS

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ABSTRACT

Heavy clay slat-affected soils due to their dense nature and bad physical and chemical properties have very low rates of solute and water movement. Thus these soils required long periods of time and high costs for reclamation. In a trying to enhance leaching efficiency through improving internal drainage of these soils; a local machine has been developed to construct gravel-filling mole drains. The machine performance was evaluated in a field study conducted in a clay saline sodic soil, during summer season 2009, at the Experimental Farm of the High Institute of Efficient Productivity, Zagazig Univ. The specific objectives were to: (1) evaluate the construction and gravel-filling performance of moles at three different depths of 30, 45 and 60 cm, three construction spacing 2, 3,and 4m under four machine forward speed 4, 4.5, 5, and 6 Km.h^{-1}, and (2) ameliorating role of moling in terms of their beneficial effects on soil infiltration rate (IR), and soil salinity and sodicity expressed as total soluble salts (EC$_e$), and sodium adsorption ratio (SAR), respectively.

The obtained data showed that at mole depth about 60 cm and 2m mole space, the machine actual field capacity and the percentage of tractor wheel slip were increased by about 28%and 120% respectively when the machine forward speed change from 4 to 6 km.h^{-1}. While the energy requirements and mole filling efficiency were decreased (about 22%, and 5% resp.).

Increasing the mole construction depth from 30 to 60 cm caused significant decrease in AFC by about 5%, non significant increase in operation costs, and highly significant increase of energy requirements by about 158%. Also, the mole filling efficiency,

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and tractor wheel slip percentage by about 6% and 65% respectively at machine speed 4.5 km.h^{-1} and 2 m mole space.

The IR significantly increased by about 43% when the mole space decreasing from 4 to 2 m, and in turn caused highly significant improving in both soil salinity and its sodicity. The EC and SAR were decreased by about 57 and 60%, respectively. On the other side, IR was highly significant decreased (about 47%) when the moling depth increased from 30 cm to 60 cm and high significantly increased in both soil salinity (EC) and its sodicity (SAR) by about 27% and 49 % respectively.

INTRODUCTION

The Nile Delta and the Nile valley of Egypt, is one of the oldest agricultural areas in the world, having been under continuous cultivation for at least 5000 years. The arid climate of Egypt, characterized by high evaporation rates (1500 - 2400 mm/ year), and little rainfall (5-200 mm/year), are considered the main factors for soil salinization. Most lands in the Nile Delta are considered problem soils due to composite controversial factors: (i) they are salt affected soils, (ii) the presence of a saline groundwater constitutes source and permanent threat for soil salinization, (iii) they are heavy clay soils salt removal is difficult, (iv) they are assumed to lie in the zone of upward movement of water flow and (v) groundwater is shallow and highly saline. These are huge areas (more than 60 % in Egypt) which representing clay salt-affected soils of poor productivity (Moukhtar et al 2010). Heavy clay soils posses a high inherent fertility that gives them excellent potential for agricultural production (Brady and Weil, 2001). Clayey soils with shallow and highly saline ground water lying in the zone of upward movement, are subject to severe salinity problems. For these reasons, water table depth plays an important role in soil properties and crop productivity. Unfortunately, in many semi arid and arid areas under irrigation, poor internal drainage in similar soils has led to salt accumulation that resulting insignificantly reduced yields and/or abandonment of the land (Moustafa et al, 1990).Also, he added that the

difficulty of desalinization in clay soils might arise from the preferential type of water flow. Since leaching water may pass only through macrospores and not within clay peds. Consequently improving leaching efficiency through artificial reconstruction would be a possible solution.

The rapid swelling of the soil matrix on wetting causes closure of cracks and macro-pores, rendering the clay soil virtually impermeable. In this state the high intensity of land drains needed for effective leaching of salts make reclamation projects economically unviable (Tanton et al, 2000).

So, the prime requirement in these soils is the water to flow fast and drainage channel. Mole drainage subsurface system is considered as an efficient, economic and successful drainage method (Abou El Soud et al 1996), and it improve the physical and hydrological properties of the soil (Abdel-Dayem 1986). Drainage installation for leaching purposes will only be fully successful if they permit the uniform leaching of soluble salts from the whole soil profile (Boers and Someren, 1998).

Spoor *et al*., (2004), and Scheifer (2005), reported that the broken stone or clean gravel back filled moles at depth more than 40 cm and about 180 cm distance between moles are favored to increase the efficiency of tile drainage in heavy clay soil. Sommerfeldt and Chang (2001) reported that the heavy soils of low hydraulic conductivity (less than 0.01 m/day) often require very closely spaced drainage systems (2-4 m spacing) for satisfactory water control. Mole drains are unlined circular soil channels which function like pipe drains. Their major advantage is their low cost, and hence they can be installed economically at very close spacings. Their disadvantage is their restricted life, but, providing benefit cost ratios are favorable, a short life can be acceptable (Godwin *et al*., 1998). Currently, mole drainage systems are most commonly used for surface water control in perched water table situations.

The optimum mole forward speed is 2 to 6 km/hr, and generally moles are pulled at 400 to 700 mm depth.(Dierickx,2003). Torpedo diameter is 65 to 100 mm is recommended, and the channel diameter will be slightly less immediately after moling. Moles less than 400 mm deep are liable to be damaged by tractors and animals during or immediately after rain. The use of mole plow need draft about 10.32kN per subsoiler shank was at

operation depth about 46 cm (Thomas *et al*., 1981). This data was confirmed with Bowers(1995).

Therefore the specific Objectives of this study were:

1- To evaluate the performance of a simple manufactured local machine in constructing moles at different depths, spacing, and machine forward speed and fill mole by fine gravel (3- 5mm diameter).

2- To determine the beneficial effects of moling on enhancing some soil properties such as infiltration rate (IR), soil salinity (EC) and soil sodicity (SAR) and sequence improving the soil condition.

MATERIALS AND METHODS

**Specifications of the manufactured machine:-**

A simple unit machine was locally manufactured shown in (Fig.1). It comprises : (1) Steel frame has three points used to hanged with tractor, (2) Steel shank has a rectangular cross sectional area with long of about 90 cm, ended with steel share, followed by(3) Square cross sectional area torpedo (10 cm diameter). (4) Pyramid funnel has size of about 0.3 m^3 (about 0.5 ton), and (5) Steel pipe with diameter of about 10 cm attach with funnel, supported behind shank has a gate to control the flow of gravel. The shank and expander makes the subsurface drain channel and the steel pipe generates a slot with associated soil fissures which extend from the surface down into the channel. The used gravel was adjusted at diameter of about 3-5 mm.

Statistical analysis: Analysis of variance and combined analysis of the obtained data were carried out using SPSS program.

To evaluate the performance of this machine an experiment with a split plot designed with three replicates was achieved. The experiment consists all combinations of the following treatments: three mole construction spacing (2, 3 and 4 m), three mole construction depth (30, 45 and 60 cm), and four machine speed (designed 4,4.5, 5, and 6km. h^{-1}). The study was conducted in heavy clay saline- sodic soil located at Experimental farm of the High Institute of Efficient Productivity, Zagazig Univ. during summer 2009. Some chemical and physical properties of the experimental soil area are presented in table (1).
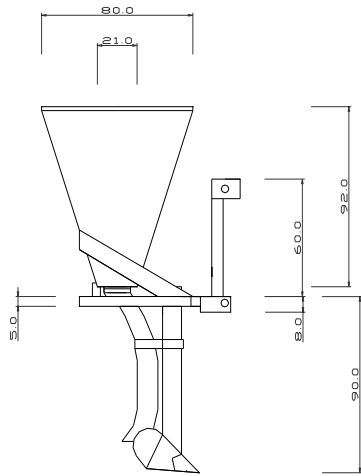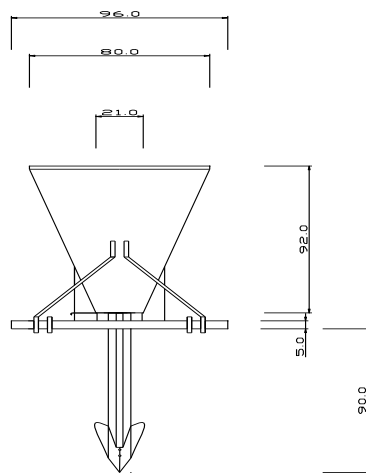
a-: Side view of manufactured machine
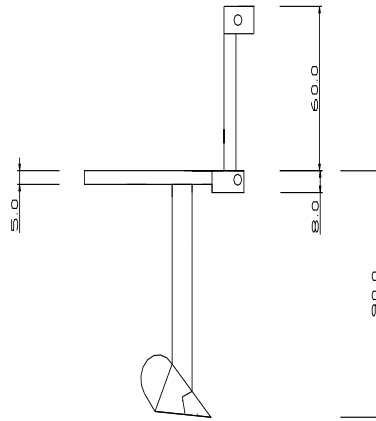
b- Frame, shank, and torpedo
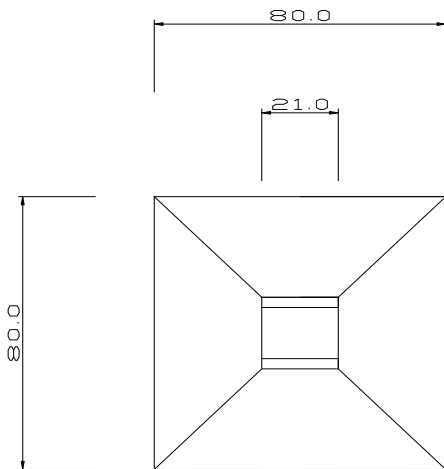
c- Plan for machine funnel (tank)

d- Front view of machine

(All dimensions in cm)

Fig. (1): Some views of manufactured machine

Table1: Some chemical and physical properties of the studied soil

Chemical properties			Physical properties		
pH (1: 2.5 soil water suspension)		8.15		Sand %	17
Total dissolved salts	EC^* (dSm^{-1})	10.9		Silt %	20
	(gm.100gm^{-1})	1.01			
Organic matter %		1.7	Particle size distribution	Clay %	63
Calcium carbonate(CaCO$_3$)		2.2		Texture class	clayey
Soluble cations (mmol$_c$/l)	Ca^{2+}	33.6			
	Mg^{2+}	12.9			
	Na$^+$	56.9	Bulk density (gm.cm^{-3})		1.24
	K$^+$	1.15	Real density (gm.cm^{-3})		2.65
Exchangeable cations (cmol$_c$/kg)	Ca^{2+}	18.8	Soil resistance (Kg.cm^{-2})		
	Mg^{2+}	10.5	Basic infiltration rate (cm.hr^{-1})		0.099
	Na$^+$	9.9	Saturation %		88.4
	K$^+$	1.43	Field capacity %		36.7
CEC (meq / 100 g)		40.63	Permanent welting point		19.11
ESP		24.4	Void ratio %		53.21

* Measured in soil paste extract.

Measurements:

A hydraulic dynamometer used to measure draft for moling machine, and the actual speed was measured. The actual field capacity (A.F.C.), energy requirements, tractor wheel slip, and the operation costs were calculated as followed.

$$A.F.C.(fad. h^{-1}) = \frac{1}{actual\ time\ consumed\ per\ 1\ faddan\ (hr. fad^{-1})}$$

$$Tractor\ wheel\ slip\ \% = \frac{Distance\ without\ load - Distance\ with\ load}{Distance\ without\ load} \times 100$$

$$Operation\ cost\ (LE. fad.^{-1}) = \frac{Total\ machine\ costs\ (LE.. hr^{-1})}{AFC.(fad.hr^{-1})}$$

$$Energy\ requirements\ (kW.h.fad^{-1}) = \frac{Machine\ power\ (kW)}{AFC.(fad.hr^{-1})}$$

Double ring infiltrometer was used to determine the soil infiltration rate according to Garcia (1978). Electrical conductivity (EC), and sodium adsorption ratio (SAR) were measured according to the methods described by Jackson (1958)

The mole filling efficiency was measured as follow:

$$Actual\ gravel\ cross\ sectional\ area\ (m^2) = \frac{Volume\ of\ gravel\ in\ pyramid\ funnel\ (m^3)}{Length\ of\ molling\ line\ (m)}$$

$$Mole\ filling\ efficiency\ (\%) = \frac{Actual\ gravel\ cross\ sectional\ area}{Theoretical\ (Design)\ mole\ cross\ sectional\ area} \times 100$$

RESULTS AND DISCUSSION

The performance of the manufactured machine was evaluated in terms of the effects of machine forward speed and mole construction depth on the machine productivity (A.F.C.), field efficiency, energy requirements, mole filling efficiency and operational costs. Also the effects of mole spacing and depth on infiltration rate (IR), soil salinity (EC), and its sodicity (SAR) were discussed .

Effect of machine forward speed

Machine forward speed affected some operational parameters such as the actual field capacity (productivity), tractor wheel slip percent, energy requirements and the mole filling efficiency (Table 2).The machine actual field capacity (A.F.C.), and the percentage of tractor wheel slip were increased with increasing the machine forward speed, while the field efficiency decreased slightly. With increasing A.F.C. the energy requirements was decreased. On the other side, the mole filling efficiency decreased with increasing machine forward speed. This may be due to that increasing the machine speed was associated with a shorter time that it is needed for gravel downward movement to complete filling of the entire mole shape (Figs. 2&3).
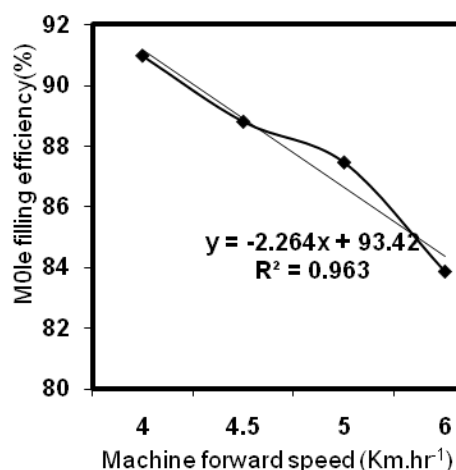
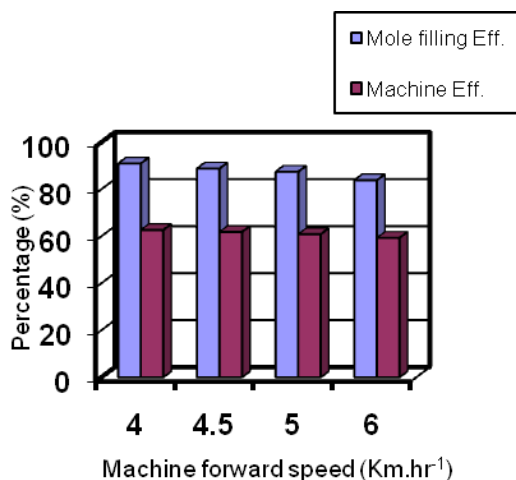**Fig. (2): Effect of machine forward speed on mole filling efficiency**

Fig. (3): The relationship between machine forward speed and both of mole filling efficiency & machine field efficiency

Effect of mole construction depth

Data presented in Table 3 showed that consumed power, A.F.C., tractor wheel slip percent, and mole filling efficiency were greatly influenced by mole construction depth. With increasing mole construction depth the tractor wheel slip percentage, draft for moling machine and consequently consumed

power was increased. This is logically attributed to that power requirements being increased to overcome the high soil resistance. On the other hand, there are two reasons cause increasing energy requirements: (1) the decreasing in

Table 2: Effect of machine speed on mole fill efficiency, machine actual field capacity, slip % and energy requirements under moles construction at 2 m and 60 cm depth

Machine speed, $Km. hr^{-1}$	Mole filling efficiency, %	A.F.C., $fad.hr^{-1}$	Machine efficiency, %	Tractor wheel slip, %	Energy requirements, $kW.hr. fad^{-1}$
4	90.96	1.19	62.66	6.8	23.19
4.5	88.79	1.28	61.84	9.32	21.56
5	87.45	1.37	60.87	11.18	20.14
6	83.86	1.52	59.32	15.0	18.15

Table 3: Some machine performance parameters as influenced by construction of filled gravel moles at different depths under forward speed 4.5 km.[h-1] and mole spacing 2 m

Mole construction depth, cm	Draft, Kg	Tractor wheel slip, %	Actual field capacity, fad.hr⁻¹	Power , kW	Energy requirements, kW.hr. fad⁻¹	Mole filling efficiency, %
Designed 30	913.5	5.87	1.39	11.37	8.17	83.42
Designed 45	1474.5	8.04	1.37	18.34	13.38	86.46
Designed 60	2220	9.67	1.32	27.61	20.92	88.79

A.F.C. and (2) the increasing in power required. Increasing the tractor wheel slip caused decreasing in the forward speed slightly and the injected gravel take enough time to make a complete designed mole form, and moreover it improve the mole filling efficiency (Fig. 4).
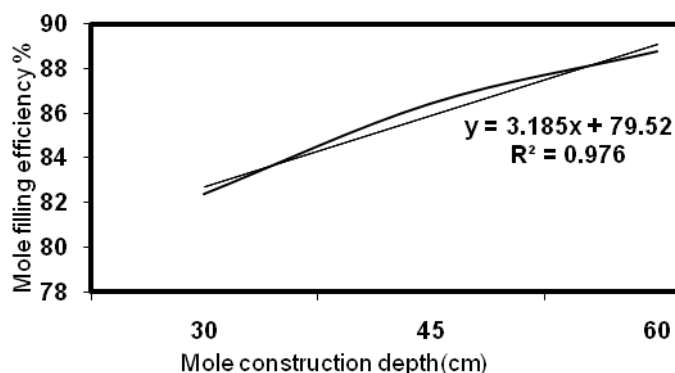

The plotted data shows the equation $y = 3.185x + 79.52$ with $R^2 = 0.976$

Fig.(4): The effect of mole constructing depth on mole filling efficiency

Effect of mole space, depth and their interactions

The mole space has significant effects on the studied machine operation parameters (AFC, operation costs, and energy requirements) and also on the studied soil properties (IR, EC, and SAR). Increasing of mole space has a positive effects on operation parameters, it decreased the energy requirement and operation costs, due to increasing of AFC. In contrast, decreasing the mole space from 4 to 2 m improved the studied soil properties. It is evident obviously from table (4) that the (IR)

significantly increased (by about 43%), and in turn caused highly significant improving in both soil salinity and its sodicity. The EC and SAR were decreased by about 56.6 and 59.5%, respectively (Figs. 5, 6 &7).The improving in these soil properties are mainly attributed to the enhancing in the downward movement of water through the soil mass and thus induced high leaching efficiency of the salt across drain mole. These results are in agreements of those obtained by (Moukhtar et al 2010).

Increasing the mole construction depth from 30 to 60 cm caused significant decrease in AFC by about 5%, non significant increase in total costs, and highly significant increase of energy requirements by about 158%. This may be due to the increase in pulling force which increased with depth, and also the decreasing in AFC. Concerning studied soil properties, the IR was highly significant decreased (about 47%) when the depth increased from 30 cm to 60 cm. Although, increasing the IR improves the efficiency of salt leaching as EC high significantly decreased, it caused non significant decrease in SAR (Table 4 and Figs. 8 &9).
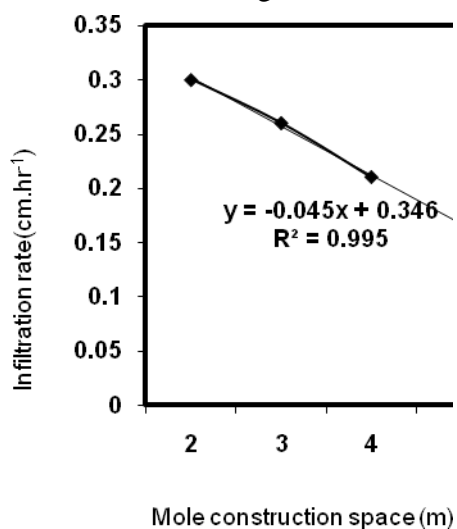

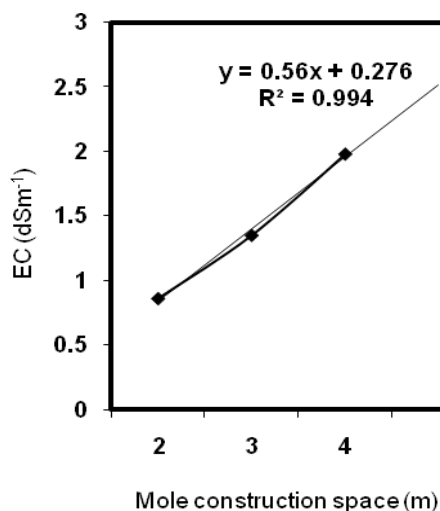**Fig. (5):Effect of mole construction space on IR.**

Fig. (6):Effect of mole construction space on EC.

Table4: Effect of mole space, depth and their interactions on some machine operation parameters and Soil properties.

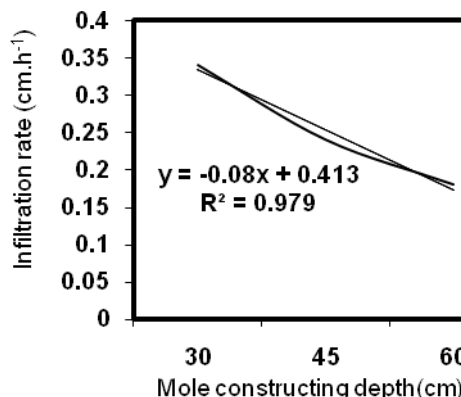| Mole space (m)	Mole construction depth (cm)	Machine operation parameters			Some soil properties		
		A.F.C. (fad.h^{-1})	Operation costs (LE.fad.$^{-1}$)	Energy requirements (kW.h.fad^{-1})	Infiltration rate (cm.h^{-1})	EC (dSm^{-1})	SAR (meq.lit.$^{-1}$)
2	30	1.39± 0.04	19.95± 0.47	8.3± 0.32	0.41± 0.04	0.8± 0.15	1.14± 0.71
	45	1.36± 0.04	20.34± 0.47	13.3± 0.32	0.28± 0.04	0.88± 0.15	1.46 ± 0.71
	60	1.32± 0.04	20.95± 0.47	21.00± 0.32	0.2± 0.04	0.91± 0.15	2.1± 0.71
3	30	2.02± 0.04	13.69± 0.47	5.67± 0.32	0.34± 0.04	1.21± 0.15	2.27± 0.71
	45	1.98± 0.04	13.94± 0.47	9.33± 0.32	0.25± 0.04	1.27± 0.15	3.09± 0.71
	60	1.92± 0.04	14.38± 0.47	14.33± 0.32	0.19± 0.04	1.58± 0.15	3.79± 0.71
4	30	2.69± 0.04	10.27± 0.47	4.00± 0.32	0.26± 0.04	1.76± 0.15	3.46± 0.71
	45	2.66± 0.04	10.37± 0.47	7.00± 0.32	0.2± 0.04	1.86± 0.15	3.85± 0.71
	60	2.56± 0.04	10.78± 0.47	11.00± 0.32	0.16± 0.04	2.32± 0.15	4.34± 0.71
Significance		NS	NS	**	NS	NS	NS
Effect of space:-							
2 (m)		1.36±0.03c	20.41±0.36a	14.2±1.86a	0.3±0.04a	0.86±0.07c	1.57±0.15b
3 (m)		1.97±0.03b	14.0±0.02b	9.78±1.27b	0.26±0.03ab	1.35±0.09b	3.05±0.62a
4 (m)		2.64±0.03a	10.47±0.12c	7.33±0.95c	0.21±0.02b	1.98±0.11a	3.88±0.21a
Significance		**	**	**	*	**	**
Effect of depth:-							
30 (cm)		2.03±0.19a	14.64±1.43	5.99±0.59c	0.34±0.03a	1.26±0.16b	2.29±0.39
45 (cm)		2.0±0.19ab	14.88±1.48	9.88±0.98b	0.24±0.02b	1.34±0.15b	2.8±0.42
60 (cm)		1.93±0.18b	15.37±1.5	15.44±1.5a	0.18±0.02b	1.6±0.22a	3.41±0.63
Significance		*	NS	**	**	**	NS
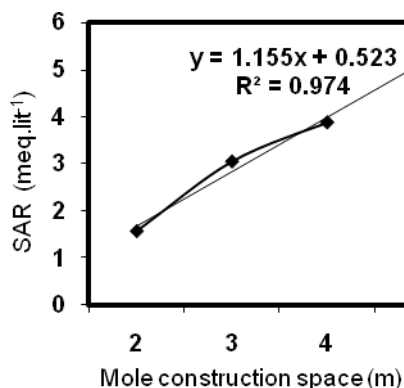
Fig. (7):Effect of mole construction space on SAR

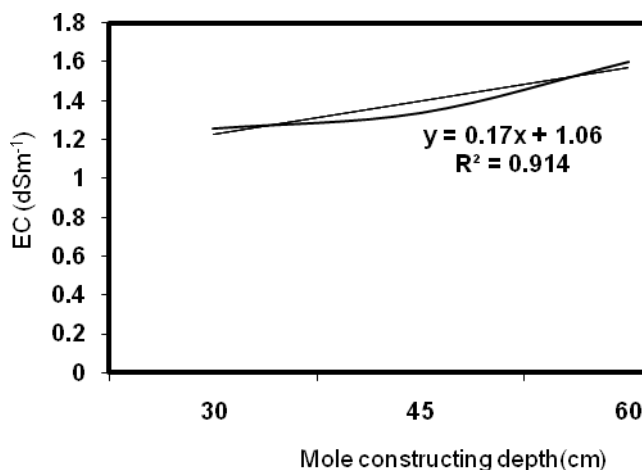

Fig. (8): Effect of mole construction depth on IR

Fig. (9): Effect of mole construction depth on EC

CONCLUSIONS AND RECOMMENDATIONS

From the aforementioned results it can be concluded that:

1- The optimum operational conditions for this machine depending on soil salinity and its sodic and mole construction depth and space

2- Expanding the use of this machine to enhancing leaching efficiency through improving internal drainage of these soils and improve the soil physical and chemical properties.

It can be recommended that the use of such manufactured machine to construct mole drains at spacing 2-3 m and 45 -60 cm depth at suitable machine forward speed 4- 5 Km.hr^{-1}, is very successful for accelerating reclamation processes of heavy clay saline – sodic soils, especially in the new reclamation projects.

Acknowledgement

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الملخص العربى

ألة محلية لملء أنفاق المول بالحصى لتحسين عمليات استصلاح الأراضي المتأثرة بالأملاح

د. محمد إبراهيم حسن ورد*

الأراضي الطينية الثقيلة القوام والمتأثرة بالأملاح ذات طبيعة معينة من حيث تركيبها تتصف بسوء خواصها الكيميائية والطبيعية والتي منها نقص معدل التسرب نتيجة لبطء حركة المياه خلال كتلة التربة، مما يقلل من كفاءة صرفها وبالتالي استمرار زيادة ملوح. لذا فهذه النوعية من الأراضي تحتاج وقت طويل وتكاليف باهظة لاستصلاحها وتحسين خواصها.

ومن خلال محاولة لرفع كفاءة الصرف بهذه النوعية من الأراضي تم تصميم تجربة حقلية وزعت فيها المعاملات بنظام القطع المنشقة. تم تصنيع وتطوير آلة محلية تستخدم لصنع أنفاق علي أعماق تصل إلي حوالي ٨٠سم وملء هذه الأنفاق (المول) بالحصى الناعم (أقطار الحصى بعد غربلته من ٣ – ٥مم) وتم تقييم أداء هذه الوحدة المصنعة علي ارض طينية ملحية – صودية ثقيلة القوام في المزرعة الإرشادية الخاصة بمعهد الكفاية الإنتاجية – جامعة الزقازيق خلال الموسم الصيفي ٢٠٠٩.

كانت الأهداف النوعية لهذه الدراسة هي :- (١) تقييم أداء هذه الآلة في صنع أنفاق من خلال المعاملات التالية : ثلاثة أعماق مختلفة ٣٠ ، ٤٥ ، ٦٠ سم وثلاثة مسافات بين خطوط المول ٢ ،٣، ٤ م مع أربعة سرعات أمامية للآلة ٤ ، ٤.٥ ، ٥ ، ٦ كم . ساعة$^{-1}$. (٢) تحديد تأثيرصنع هذه الأنفاق وملئها بالحصى مع العوامل السابقة علي تحسين كلا من معدل التسرب (IR)- ملوحة التربة معبرا عنها في صورة معامل التوصيل الكهربي (EC)، ونسبة امتصاص الصوديوم (SAR).

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ودلت النتائج المتحصل عليها الأتي:

- قلت كمية الطاقة اللازمة لصنع النفق وكفاءة ملء النفق بالحصى بحوالي ٢٢ % ، ٥ % علي الترتيب بزيادة السرعة الأمامية للآلة من ٤ الي ٦ كم . ساعة‾¹. بينما زادت إنتاجية الآلة الفعلية (AFC)، وكذلك نسبة انزلاق عجلات الجرار بحوالي ٢٨ %، ١٢٠ % في هذه الفترة علي الترتيب.

- بزيادة عمق التشغيل من ٣٠ إلي ٦٠ سم أدي إلي نقص معنوي لكلا من AFC بحوالي ٥% وزيادة غير معنوية في تكاليف التشغيل وزيادة معنوية جدا للطاقة المستهلكة لتشغيل الآلة بحوالي ١٥٨% وكذلك زيادة قيم كلا من كفاءة ملء النفق ونسبة انزلاق عجلات الجرار بحوالي ٦% ، ٦٤ % علي الترتيب.

- بالنسبة إلي المسافة بين خطوط الأنفاق (المول) فأثر تناقصها من ٤ إلي ٢ م بزيادة معنوية علي معدل التسرب (IR) بحوالي ٤٣%. وهذا بدوره أدي إلي تحسن معنوي في كلا من ملوحة وقلوية التربة، حيث قلت قيم EC ، SAR بحوالي ٥٧%، ٦٠ % علي الترتيب. في حين أدت زيادة عمق التشغيل من ٣٠ إلي ٦٠ سم الي نقصان معنوي لمعدل التسرب بحوالي ٤٧ % مما أدي الي زيادة قيم EC ، SAR بحوالي ٢٧ % ، ٤٩ % علي الترتيب ولكن نضطر لزيادة عمق التشغيل للمحافظة علي عمر النفق وحتي لا يهدم من أثر تكرار مرور الآلات الزراعية والإنسان أثناء خدمة التربة.