J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 5 (7): 945 - 967, 2014

MODERN TECHNIQUE FOR THE FERTIGATION OF SUGAR CANE IN UPPER EGYPT.

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ABSTRACT

The experimental fieldwork was carried out in sugarcane production areas in Upper- Egypt at Qena Governorates during growing season 2010-2012. Sugar cane is the major source of sugar production in Egypt. Insect pests are limiting factors affecting its production. One of which, is the soft scale insect, Pulvinaria tenuivalvata (Newstead) (Hemiptera: Coccidae). As a new pest, it threatens sugar cane cultivation in Egypt. High scale densities cause significant reduction in sugar cane weight and juice quality, particularly sucrose content. To avoid the sugar cane infection with the soft scale insect, (Pulvinaria tenuivalvata), it is necessary adding diesel fuel through irrigation water. But in the cultivated areas using gated pipes system, irrigation water flowing through closed pipes from branch canals to the fields. It is difficult to add diesel fuel into these canals. Therefore, this paper describes design and locally manufactured of a simple and inexpensive fertilization system suitable of small holding in Egypt called "Vacuum Fertilization System" using in both function, add diesel fuel or any chemicals and fertilization system through gated pipes or any piping closed system during irrigation operation, in spit of, their were another systems using solution fertilizer; but these systems are not available directly in this region and its expensive. Also, evaluating the performance of the designed mechanism in performing this operation. The results showed that:

1- There were a drop in the pressure head measured at the first portion of the gated pipe due to accumulative friction head losses effect and then there were a gradual increase in it due to the increasing in superimposed pressure head, decreased the effect of accumulative friction head losses.
2- The slope of the curve of the actual measured pressure head (hon) along the gated pipe representing the effect of gated pipe length on the pressure head variation, and its value was about 18.2 %.
3- The outlets discharge rate along the gated pipe system were dropped at the first portion of the gated pipe due to accumulative friction head losses effect and then there were a gradual increase in it due to the increased in superimposed pressure head overcome the effect of accumulative friction head losses.
4- The water distribution uniformity along the 18 meter apart of the 6 inch gated pipe before using fertigation system, was about 95.4%. But the water uniformity distribution along the gated pipe during fertigation system using fertilization system was about 93.8%. This mean that the water distribution uniformity decreased slightly during fertigation system using fertilization system under irrigation gated pipe system due to apply the fertilizer through irrigation water, consequently change in irrigation water density affecting outlets flow rates through irrigation gated pipe system.
5- The fertilizer concentration uniformity through the gated pipe system was about 98.1%. This means that, the concentration variation along the gated pipe system was about 1.3%. The reason of this reduction is due to, deposition of some fertilizer in the tank and other system components. Also, the experiment

measurements were taken in a certain time from the start of fertigation. Therefore, data exhibit that there are no more difference in the values of fertilizer concentration under the fertigation method along the gated pipe length.

6- The value of the water use efficiency (WUE) was about 4.37 kg/ m3, on the other hand, the value of the nitrogen use efficiency (NUE) was about 280 kg-y/kg-N.

7- The total annual cost of the Vacuum Fertilization System was about 82.33 L.E/year.

INTRODUCTION

Sugar cane is the major source of sugar production in Egypt. The total sugar cane area in Egypt is 300 thousand feddan (General Administration of Agricultural Economics 2009), consuming about 10% of the available irrigation water. Most fields in the old valley in Egypt are small holdings ranging from 0.2 feddan to 5.0 feddan. On the other hands, the traditional surface irrigation system is still most widely used and prefer for farmers. Also, most farmers still use some primitive means in irrigation, fertilization, and weed and pest control. It has become necessary to develop adequate surface irrigation techniques such as irrigation gated pipe system. This will be more useful for small holders to cultivate their farms without using costly new irrigation techniques. The most important objective of irrigation gated pipes is to provide adequate water quantity and better manage nitrogen fertilization to each irrigated plant.

Sugar cane, (Saccharum officinarum L.) is the major source of sugar production in Egypt. Insect pests are limiting factors affecting its production. One of which is the soft scale insect, Pulvinaria tenuivalvata (Newstead) (Hemiptera: Coccidae). As a new pest, it threatens sugar cane cultivation in Egypt (Ali *et al*., 1997 and Abd-El Samea,S.A., 2003). High population of this scale insect cause sever injury to sugar cane plants either by sucking the plant sap resulting in severe wilting or by sooty mould growth on the honeydew execration. Both effects impair photosynthesis and inhibit growth of infested plants, Stithanathan and Saivaraj (1974). The high scale densities cause significant reduction in cane weight and juice quality, particularly sucrose content, Washburn *et al.* (1985). The experiments showed that adding diesel fuel into irrigation canals during irrigation operation on the first irrigation reduced the infection with the soft scale insect, Pulvinaria tenuivalvata by about 63.1% than another without using diesel fuel through irrigation water. Also, the plants areas of sugar cane irrigated by irrigation gated pipes system reduced the infection with the soft scale insect, Pulvinaria tenuivalvata than another areas irrigated by traditional methods of surface irrigation system, Sugar Cane Crops Council, (2007). With increasing demands on limited water resources and the need to minimize adverse environmental consequences of irrigation and chemical fertilizers, modern irrigation technology will undoubtedly play an important role in the future in the Egyptian agriculture. It provides many unique agronomic benefits that address many of the challenges facing irrigated agriculture, Heikal et al. (2008). Modern surface irrigation methods and practices can achieve significantly higher performance levels than existing methods and practices, (Strelkoff *et al.,* 1999). Gated pipe irrigation is a type of irrigation in which conventional head ditch and siphons are replaced by an above-ground pipeline (El Awady *et al*., 2009). The app1iction through the irrigation system of plant nutrients (fertigation) or other chemicals (chemigation) has recently expanded because of efficiency and convenience (Breslar, 1977; Elfving, 1982; Papadopoules, 1985). The term of chemigation began to be used in the 1970's (Abdel-Aziz, 1998). Chemigation can be defined as the application of a chemicals, bacterium, etc., via an irrigation system by injection the chemicals into the water flowing through the system (Badr *et al*., 2006). Meanwhile the first reported injection of herbicides and fertilizers through both drip and sprinkler irrigation system by EI-Gindy (1988). Advantages of fertigation are: improved efficiency of fertilizer recovery and minimal losses due to leaching (Breslar, 1977; Papadopoulos, 1985, 1986b ;), optimizing the nutrient balance by supplying the nutrients directly to the root zone (Bar-Yosef and Sheikhoislami, 1976; Breslar, 1977; Papadopoulos, 1985), control of nutrient concentrations in soil solution (Bar. Yosef, 1977; Papadopoulos 1986a, 1986b), savings in labour and energy, and flexibility in timing fertilizer application in relation to crop demand (Breslar, 1977). Chemigation technique has been introduced to improve the application of agricultural chemicals via irrigation systems. Uniform application of such chemicals is necessary to insure considerable increase in vegetable production and real decrease in production costs, (Abdel-Aziz and El-Bagoury, 2008). Aboukhaled (1991) said that in addition to direct use of irrigation pumps, three other major categories of chemigation equipment are in use in countries of the Near East namely: venturi type devices, differential pressure tanks and positive displacement pumps. El-said et al. (2004) mentioned that added fertilizer with irrigation water is very important (fertigation) because it provides crops with constant fertilizer at low concentrations which minimize damage to roots. Bazza (1991) said that the dry fertilizers may be completely dissolved in a holding tank and an injector pump injects the solution. Jannings and Martin (1990) reported that soluble leaching was reduced due to fertigation. Bravdo and Hepmer (1987) reported that availability of N fertilizer, and K fertilizer were increased by fertigation and this was reflected in improved yields of grapes compared with broadcasting. Abo Soliman *et al.* (2005) indicated that the irrigation by gated pipe achieved the highest values of yield and saved amount of irrigation water applied by 11.9%. El-sayd and El-araby (1998) stated that the cost of chemigation is generally less than when applying chemicals through conventional irrigation methods. Farmers can save up to 35% on their chemicals bills if appropriately used.

The main task of work was to design and locally manufactured simple and low cost fertilization system through the surface irrigation using gated system in small holding in Egypt to be suitable for all farmers to overcome the problems of high cost of the fertilizers system. Also, study the performance of the fertigation system designed under irrigation gated pipe system, its effect on the water distribution uniformity through irrigation gated pipe system. The fertilizer distribution uniformity was evaluated in order to clarify the fertigation system in the experimental farm.

MATERIALS AND METHODS

The research experimental work was carried out at the special farm in Esna village, Esna city, Qena Governorate in Upper Egypt on sugarcane areas during seasons 2010-2012. Physical and analysis of the soil was determined, according to Black et al. 1965 as shown in Table (1). On the other hands, the average values of some chemical properties of irrigation water along each season are represented in Table (2).

Table (1): The physical and mechanical analysis of the soil.

Depth, cm.	Particle size distribution				Soil texture	Field capacity, %	Wilting point, %	Bulk density, g/cm^2
	Clay	Silt	Sand					
			F.S.	C.S.				
0-15	56.71	19.53	16.20	7.56	Clay	36.50	17.60	1.12
15-30	58.24	20.42	15.13	6.21		37.20	18.40	1.15
30-45	55.90	22.06	16.00	6.04		35.51	19.52	1.16
45-60	60.02	21.04	14.42	4.52		35.64	18.67	1.17

F.S.: fine sand-- C.S.: coarse sand

Table (2): chemical analysis of irrigation water:

EC dS/m	pH	Cations (meq / L)				Anions (meq / L)				
		Ca^+	Mg^{++}	Na^+	K^+	SO_4^{--}	Cl^-	CO_3^{--}	HCO_3^-	SAR
0.45	7.2	0.75	0.384	3.24	0.31	2.28	0.46	0.00	1.78	4.05

1- Irrigation system network:

Surface irrigation system technique using gated pipes was considered in this study. The main components of this irrigation system network are:

Pumping unit:

The experimental pumping unit consists of pump operated by a diesel motor. The pump was connected through pipes, spools, elbows, tees and other pipe fitting. The pump was equipped with an individual suction pipe and 5 inch hose ending with a trash screen and non- return valve. The upper end of the suction pipe just before the entrance of the suction pump is fitted with 1.0 inch valve to attach with the another 1.0 inch valve fixed on the lower part of the fertilizer tank through small 1.0 inch diameter of rigid plastic pipe. The discharge side of the pumping unit was connected to the inlet of the tested gated pipe through a discharge valve, flow-meter and a gated pipe. This discharge side of the pumping unit was equipped with a priming valve, pressure gauge, pressure manometer to measure flow head at pumping head. The specifications of the pumps and engines are shown in Table (3).

Table (3): pumping unit specifications.

Type of pump	Pump Made	Motor Power (Hp)	Rpm	Max. discharge (m^3/h)	Max. operating pressure (bar)	Suction pipe diameter (Inch)	Delivery pipe diameter (Inch)
Centrifugal	Diesel	7.8	1460	130	1.0	6	6

Main line:

PVC pipes, 200mm.nominal diameter used to convey the water from the source to sub-main line. It is buried at 1m depth under the ground surface.

Sub-main line:

Aluminum pipe, 160-mm. outer diameter used for converting the water through gates under control with flow meter.

Irrigation gated pipe:

The experiment studied using aluminum gated pipes technique for conveying and distributing irrigation water on sugar cane yield.

2- Flow rate and pressure head measuring devices :

The flow meter

A six inch flow meter was used to measure pumping unit flow rate and the inlet flow of the gated pipe.

Spirit bubble level

Spirit bubble level was used to assure that the gated pipe was kept, as much as possible, in a horizontal position.

Steel telescopic stands:

Five steel metal telescopic stands of different height were locally manufactured. They were used for adjust and fixing the long gated pipe system at horizontally or at any desired inclination.

Pressure gauge:

The pumping unit discharge head was measured using a pointer pressure gauge fixed just before the flow- meter. Its reading range was from 0.0 to 0.6 bars with 10 cm increment and fixed one at each pipe just before the inlet pipe.

Peizometers:

Home-made pure plastic hose peizometers were locally manufactured using 8 mm inside diameter plastic pipes connected with plastic hoses. Each peizometers was fixed on a 2- meter wooden board. The plastic hose of each peizometers was connected to the opening existing in the (gated) gated pipe connection by a plastic fitting. The purpose of using these peizometers was to measure the flow absolute pressure at each connection of the pipe.

Air release valve:

The air release valve attached to the connection of the pumping unit before six inch valve was used to exhaust air under various pressure head conditions during normal pipeline operation while restricting the outflow of water.

EC meter:

Electrical conductivity (EC) "as indicator for movable chemicals" was measured.

3- Innovative design considerations of the fertilization system:

The design of the fertilization system has to be based on some important considerations as:

1- Simplicity of system design and the ease of system local manufacturing.
2- Moving parts must be minimum and light material to offer easy and

same operation.

3- Permit easy adjustment and avoid mechanical damage and broken.
4- Avoiding any realizing reasonable productive capacities.
5- Being easy to maintain and to clean after working.
6- Using standard components and locally available materials.
7- Keeping smooth constant flow of the irrigation system without any interruption.
8- Allows the chemical to be applied with any appropriate amount of water.
9- The ease of system maintenance and the flexibility in controlling fertilizer rates.
10- Realizing reasonable productive capacities to suit different kind of fertilizers.

Design description:

In this study, a fertilization system suitable for local Egyptian farms called "Vacuum fertilization system" was locally manufactured in private workshop in Esna city, Qena governorate under support of Agricultural Engineering Research Institute, ARC, and ministry of Agricultural from low cost, available materials to overcome the problems of high cost. A fertilization system design consists of a semi-closed fertilizer tank is made of pure rigid plastic or a galvanized iron sheet. It must withstand the effect of vacuum pressure. Cylindrical tank dimensions were 40 cm in diameter and 160 cm in height (total volume = 200 liters). Fertilizer tank was connected to the upper end of the pump suction pipe through two valves and rigid plastic hose, as shown in fig. (1). One of the valves fixed on the lower part of the fertilizer tank called "discharging fertilizer valve" and another valve fixed on the upper end of the pump suction pipe, "called fertilizer suction valve". Also, the tank has another valve fixed on the upper end of the fertilizer tank called "safety valve". This valve was connected by "floating valve" fixed into the lower part of the fertilizer tank just before and on the top of the fertilizer valve outlet inside the fertilizer tank through 0.5 inch rigid plastic pipe. Safety valve connected by another 0.5 inch valve fixed on the pump delivery pipe just before the gated pipe irrigation system through 0.5 inch rigid plastic hose, as shown in fig. (2). the flow rate of the solution is monitored by a one inch flow meter installed on the discharging fertilizer valve. Check valves fixed just before any valves above mentioned.

Gated pipes system and their connection:

The gated pipes system was locally manufactured in the workshop in Esna village, Esna city, Qena Governorate. The gated pipe made of aluminum pipe (6-inch outer diameter). Six meter length of 152 mm inlet aluminum pipe diameter was used for the gated pipe system. They were manufactured using 18 meter long pipe (3 pipes) of 160 mm outside diameter with closed end. 24 outlets of 38 mm diameter were drilled on the pipes with small rectangular slot permit moving gates to close or open the outlets. The distance between two consecutive gates was to be 0.75 m., continuously 24 plastic gates fixed on the outlets were drilled. The individual pipe connected with a spigot and faucet rubber to prevent water leakage. The aluminum pipes were connected together with their couplers. The last one of the gated pipe was equipped with a plug at its end. The aluminum gated pipe (6-inch diameter) was equipped with the required valves, flow meter, pressure gauge and peizometers. The schematic diagram of the gated pipe system network is shown in fig. (3).

Field experimental work:

Sugar cane variety G.T.54-9 was planted as cane on March 15th during growing season 2009-2011. The pilot area was precision land leveled using laser technique with 10cm/100m slope and long strip (100m).180 kg N/fed. (Urea 46.5% N) was divided into 2 doses and added with irrigation water at concentration of 780 g/l as recommended by (Threadgill et al., 1991) by using the previous mentioned fertigation system designed. It was applied in two equal doses with potassium fertilizer. All agricultural practices were the same as recommended for the area.

Fertigation system operating:

The process for chemigation calibration for surface irrigation systems is very essential. It is basically a matter of determining the land area irrigated per set and knowing the amount of time required to irrigate that set. if the system is not equipped with a reuse system, then it is not advisable to chemigate. for adequate distribution of the chemical under this condition, it is probably desirable to delay injection of any chemical until the water has advanced approximately one- half way across the field, the chemical can then be injected during the last half of the advance phase. Also they recommended that, when chemigation with surface irrigation tail water recovery systems must be used, (Hoffman *et al.* 1992). At the beginning before operating the system calibrating the individual fertilizer tank before attached with the irrigation system. Filled the tank with water and regulating the valve to collect the required discharging at adjust time needed a certain period of the irrigation.

1- Attached the designed fertilizer system unit with the network of the gated pipe irrigation system as shown in fig. (2).
2- Firstly, closed all the valves fixed on the fertilizer tank and also, closed another one fixed on pump suction pipe. Adding the required fertilizer solution amount on the top of fertilizer tank.
3- Starting operating diesel pump for irrigation.
4- If the irrigation water flows into the irrigation gated pipe system network then, open the safety valve firstly, after that open the fertilizer suction valve. Thus, the stream of the fertilizer solution drowns from the fertilizer tank through rigid plastic hose into the pump housing and flowing with the irrigation water drowns by the pump into the irrigation gated pipe affecting by the pump pressure vacuum.
5- If the fertilizer solution level into the fertilizer tank reduced until reached lower level under the floating valve fixed into the fertilizer tank, the floating valve open automatically allowing irrigation water flowing from pump delivery pipe into the fertilizer tank through the safety valve to fill fertilizer tank with irrigation water and then raise the floating arm and automatically closed the floating valve. This way protect the irrigation pump stopped suddenly due to the fertilizer tank become empty from any fertilizer solution, especially under the level of the fertilizer discharging valve and

simultaneously the fertilizer tank filled with air. Therefore the irrigation pump drowns this air instead of a fertilizer liquid and suddenly stopped the operating irrigation system.

Methodology of the system:

The calibration of the used gated pipes and pumping unit were tested through water re-circulation system. The pumps drawn water from lining canal and pumping the water into the gated pipe and the canal received these discharge again that keeping continuous **flow. The flow rate recommended per each outlet was about 4.2 m^3/h, as (Hassan 2004).** The pumping unit discharge rate was adjusted to be as close as possible to pumping discharge rate 100 m^3/h measured by 6 inches flow meter. The actual pressure head measured by the peizometers at the gated pipe inlet. The determination of the flow head inside the gated pipe along its whole length were carried out to compute the suitable outlet opening along the gated pipes giving the flow rate required per each furrow. The determination was being based on the actual flow rate and the actual pressure head measured from pumping unit. As a general assumption for determination, the flow rates from the entire outlet along the gated pipe are equal. Measuring the outlet flow rate along the gated pipes system under actual field operating condition tested the actual performance of the gated pipes system. From the experimentally measured of pressure head, the discharge velocity of each outlet, and flow rate passing before any outlet, the friction losses, the superimposed pressure head were estimated according, Morcos et al. (1994), The total friction head losses inside the gated pipe and the superimposed pressure head are estimated by the following equations:

$$Q_n = \sum_{n=1}^{N} q_n \quad \ldots\ldots\ldots\ldots (1)$$ Where:

Qn = The flow rate inside the gated pipe just before any outlet, l/s,
qn = The actual measured outlet discharge rate, l/s
N = The total outlet number were applied.

$$\mathbf{V_n = 0.001.\,Q_n / A \quad \ldots\ldots \; \ldots. (2)}$$ Where,

V_n = The flow velocity inside the gated pipe just before any outlet, m/s and
A = The gated pipe cross section area, m^2

$$h_{fn} = k\left(\frac{Qn}{CHw}\right)^{1.852} .\times D^{-4.87} \times s \quad (3)$$ Where,

D = inside gated pipe diameter, mm, CHw = Hazen William' s coefficient, dimensionless, h_{fn} = the friction head losses inside the gated pipe just before any outlet, m, K = Conversion factor, (1.2 X 10^{10}), S = the spacing between outlet along the gated pipe, m

$$h_{ft} = \sum_{n=1}^{N} h_{fn} \text{ , m} \ldots \ldots \quad \ldots \quad \ldots (4)$$ Where,

h_{ft} = total friction head losses inside the gated pipe before any outlet, m,
h_{sn}= (V^2_{max} - V^2_n)/ 2g ………… (5) Where

h_{sn} = The superimposed pressure head, m,
V_{max} = The maximum inside flow velocity at gated pipe inlet, m/s,
g = Gravitational field, m/s^2.

$h_{on} = hp + h_{sn} - h_{ft}$ …………………… (6)

h_{on} = The resultant pressure head, cm.
hp = pump unit pressure head, m.
Also, the pressure head variation determined according to, Chu (1984):

$H_{var} = (H_{max} - H_{min}) / H_{max}$…..……….(7), Where:

H_{var} = pressure variation along sub-main,
H_{max} = maximum pressure in sub-main, m, and H_{min} = minimum pressure in sub-main, m.
For a practical design, the pressure variation is usually kept less than 20%, which is about equivalent to 10% variation in lateral line flow along sub-main.
Jensen (1983) stated that the hydraulic characteristics of each outlet are directly related to the mode of fluid motion (flow regime) inside the gated pipe characterized by the Reynolds number "RNn"

$$RNn = \frac{VD}{\upsilon} \quad \ldots (8)$$

Where (V) fluid flow velocity, m/s, D is the inlet gated pipe diameter, m and (υ) is kinematics viscosity, m^2/s. The flow regimes are usually characterized as
(1) Laminar flow RNn < 2000. (2) Unstable flow 2000< RNn <4000
(3) Partially turbulent flow 4000 < RNn < 1000 (4) fully turbulent flow 10000 < RNn.

Fertilization system discharge rate:

The fertilizer discharge calculating as keller and karameli (1975), equation had been used:
Q=F.A / C.T.I ……………. (9) Where:
Q = discharge rate of completely soluble fertilizer into the irrigation system, l/h.,
F = fertilizer application rate per irrigation cycle, kg/fed,
A = irrigation area in limited time, fed.,
C = concentration of the actual nutrients in liquid fertilizer, kg/l,
T = irrigation time, h.
I = ratio between fertilizing and irrigation time.

A- Water distribution uniformity (WDU):

The water uniformity distribution from outlet along the gated pipe system was experimentally tested under the field condition before and during fertigation system using equation (10).
Jensen (1983) defined that the uniformity distribution as: The expression of evaluating uniformity distribution through the variation of flow through outlet

along the lateral line named as flow variation along the lateral line. The uniformity distribution increased as flow variation decreased.

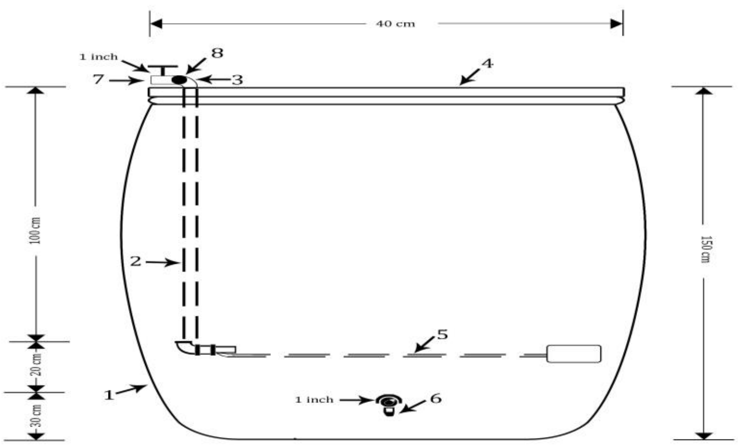
$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} \quad \dots \ (10)$$

Where:

q_{var} = The outlet flow variation %, q_{max} = The maximum outlet flow along the lateral line.

q_{min} = The minimum outlet flow along the lateral line.

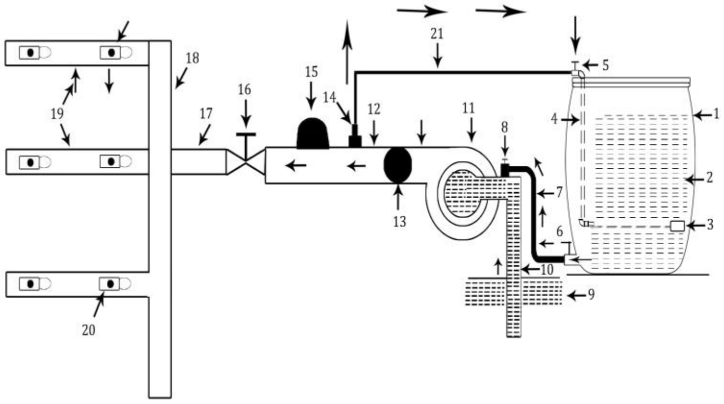
Fig (1): Schematic diagram of the designed and locally manufactured fertigation system.



Key to schematic diagram:

1-	**Fertilizer tank.**	**5- Floating valve.**
2-	**Connection pipe**	**6- Fertilizer suction valve**
3-	**To pump delivery pipe.**	**7- Valve**
4-	**Cover.**	**8- Check valve**

Fig. (2): Schematic diagram of the typical installation and connection of the "Vacuum Fertilization system" designed through irrigation



gated pipe system.

Key to schematic diagram:

1- Fertilizer tank.	**10- Pump suction pipe.**
2- Fertilizer solution.	**11- Pump.**
3- Floating valve.	**12- Pump delivery pipe.**
4- Connection pipe.	**13- Check valve.**
5- Safety valve.	**14- Delivery valve.**
6- Discharging fertilizer	**15- Air relieve valve.**
7- Plastic hose.	**16- Irrigation main valve.**
8- Suction valve.	**17- Main line.**
9- Irrigation water source.	**18- Submarine line.**

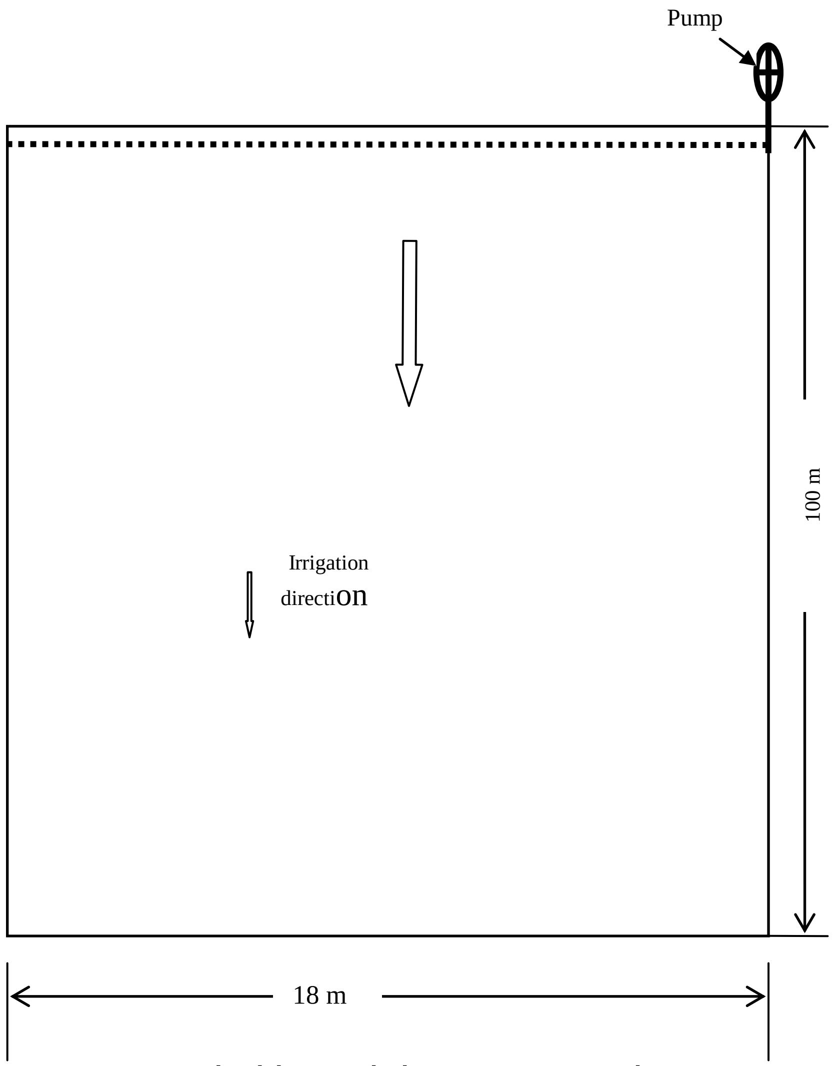


Fig. (3): Gated pipe system network

<u>Fertilization concentration change:</u>

Irrigation water samples taken every 15 minutes during fertigation process, (for accuracy in results) for measuring the fertilizer concentration. EC meter was used for measuring electrical conductivity. The relationship between fertilizer concentrations (g/l) and electrical conductivity (mmhos/cm) was delivered according to El-said et al., 2004 by using the following equation:

$Y = 0.4398\ e^{0.0007x}$ ………… (11)

Where:

Y = electrical conductivity (mmhos/cm), and X = fertilizer concentration, g/l.

Fertilizer distribution uniformity, (F.D.U):

The fertilizer distribution efficiency of the fertigation system designed was determined by measuring the weight of the fertilizer (mg) in the total volume of water cached from the different gates along the irrigation gated pipe system, during a 20 min from the start of fertigation operation. The total water cached from gates at the inlet, 1/3, 2/3 and the end of gated pipe. The fertilizer distribution efficiency was determined as follows:

F.D.U. = Wfm / Wfa …………. (12)

Where:

F.D.U.: the fertilizer distribution uniformity %,

Wfm: mean weight of the fertilizer in water of the lowest 1/4 gates, (mg), and

Wfa: mean weight of the fertilizer in water during chemigation.

Water use efficiency (WUE):

Water use efficiency (WUE) values were calculated according to Jensen (1983) as follows:

$$WUE = \frac{\text{Sugar cane yield kg/fed.)}}{\text{Applied irrigation water (m}^2\text{/fed.)}} \quad (\text{kg/m}^3) \text{ ……. (13)}$$

Ni**trogen use efficiency (NUE):**

It was determined according to the same reference of "WUE" by using the following equation:

$$NUE = \frac{Y}{Na} \quad (\text{kg - y/kg - N}) \text{ ……. (14)}$$

Where:

NUE: Nitrogen use efficiency, kg-y/kg-N

Y: Total yield, kg/fed; and

Na: Total applied nitrogen fertilizer, kg N/fed

Cost analysis of the vacuum fertilization system:

Fixed cost:

The cost of the fertilization system designed was calculated according to **Worth and Xin, (1983)**. The annual fixed costs of capital invested in the irrigation system were calculated according the following equation:

F.M.C= D+I+T …………. (15)

Where: F.M.C = The annual fixed cost, LE/year.

D = The depreciation, LE/year.

I = The interest, LE/year.

T = Taxes and overheads ratio, LE/year.

Depreciation was calculated using the following equation:

D = (IC) / (EL) ………. (16)

Where:

IC = The initial cost of the fertilization system, LE/year.

EL = The expected life, 5 years.

Interest of the capital was calculated according to the following equation:

I = (IC) / 2 x IR ……….. (17)

Where:

IR = The interest rate /year, (taken 14%).

Taxes and overheads ratio, taken 2% from initial cost.

2- Running cost:

The annual running cost of the capital investment in the fertilization system design was calculated using the following equation:

RC = E.C + (R& M) + L.C …………. (18)

Were:

RC = Annual running cost (LE/year),

L.C = labor costs (LE/year),

E.C = Energy cost, (LE/year) and(R& M): Repairs and maintenance cost (LE/year).

The labor cost was estimated as follows:

L.C = Tx N x P ………… (19)

Where:

L.C = Annual labor cost (LE/year),

T = Annual irrigation time, h/year,

N = labor number / fed. And

P = labor cost, (LE/h)

The energy cost for diesel type source was calculated by using the following equation:

E.C. = 1.2 Bp x H x S x F ……….. (20)

Where:

E.C. = Energy cost for diesel type (LE/year),

H = Annual operating hours, h,

S = Specific fuel consumption, L/kw/h.

F = Unit-fuel price, L.E/L and

1.2 = factor according for lubrication.

The annual cost of repairs and maintenance were taken as 2-3% of the initial cost.

The annual system costs = fixed cost + running cost.

RESULTS AND DISCUSSION

Gated piping system performance:

The field experiment work covered the determination of the gated pipe performance under pumping unit discharge rate 100 m^3/h as, the accumulative friction head losses“hft” along the gated pipes computed according to equation (1) through and (4), generated pressure head due to the decrease in flow velocity “h_{sn}” (superimposed pressure head) estimated using equation (5), and Reynolds number value “RN_n” just before any outlet computed by equation (8). On the other hands, the original pressure head "h_{on}” was measured using a pressure gauge and peizometers. Also, the actual measured gate flow rate measured by using direct method.

Pressure head distribution of the irrigation gated pipe system:

Referring to the 6-inch gated piping system having 18 meter apart, the results of the h_{ft}, h_{sn}, and h_{on} against outlets along the gated pipe system were graphically expressed in fig. (4) to facilitate the discussion. In all these experiments, the gated pipe was always fixed with its outlets near the bottom.

Fig.(4), showed that there was a drop in the measured pressure head at the first portion of the gated pipe system and this dropping trend ended about 54.2 percent of the gated pipe length. The minimum value of the measured pressure head was about 82.3 percent of the pressure head at the gated pipe inlet. After that, the measured pressure head increased gradually until it reached at gated pipe end, and its values was about 100.6 percent of the pressure head measured at the gated pipe system inlet. The slope of the curve representing the change of pressure head along its whole length. The variation of the pressure head along the 18 meters apart of the gated pipe computed by equation (1-7) was about 18.2 percent..

Dealing with the accumulative friction head losses inside the gated pipe (hft), fig (3-1), showed that the slope of the curve representing the total friction head losses was greater gradually from the first portion of the gated pipe system until it reached as a maximum at the last portion of the gated pipe, and its values ended at about -27.6 percent of the original pressure head at the gated pipe inlet.

Concerning the superimposed pressure head (hsn), the slope of the curve representing the values of the superimposed pressure head was greater gradually until it reached as a maximum at the last portion towards the dead end of gated pipe, and its values ended at about (+48.6) percent of the original pressure head at the gated pipe inlet.

Discharge rate of the irrigation gated pipe system:

The results of the "qn" were graphically expressed in fig. (5) to facilitate the discussion. The results showed that the most flow in gated pipes occurs at Reynolds number "RN_n" computed as equation (8), between 10^4 and 10^5 and the flow was about fully turbulent flow agreement with **Kincaid and Kemper (1982).** Figure (5) showed that the outlet discharge rate dropped gradually in the first portion of the gated pipe and this dropping trend about 50 percent of the gated pipe length. The minimum values of the measured outlet discharge rate were about 83.4 percent of the measured outlet discharge rate at the gated pipe inlet. After that the measured outlet discharge rate increased gradually until it reached at the gated pipe end and its values was 101.0 percent of the measured outlet discharge rate at the gated pipe inlet.

Water distribution uniformity along the irrigation gated pipe system, (WDU):

The water distribution uniformity of the gated pipe system is the most important factor in evaluating the efficiency of the gated pipe system. The "WDU" depend on the resultant pressure head of pumping units and also, the calibrating the system using sliding gates along the gated piping system. The flow variation (q_{var}) through 18 meters apart of the gated piping system computed as equation (10) before operating fertilization system and during operating it. The results of determination of both two cases showed that the flow variation through gated pipe before using fertigation system was about 4.6%. Therefore the water distribution uniformity along the 18 meter apart of the 6 inch gated pipe in this case was about 95.4 percent. But the flow variation through the gated piping system computed during fertigation system using fertilization system was about 6.2 % as shown in fig. (3-3). Thus, the water uniformity distribution along the 18 meter apart of the 6 inch gated pipe in this case was about 93.8%. Then, the water distribution uniformity decreased slightly during fertigation system using fertilization system under irrigation gated pipe system due to apply the fertilizer through irrigation water, consequently change in irrigation water density affecting on outlets flow rates through irrigation gated pipe system.

Water distribution uniformity along the irrigation gated pipe system, (WDU):

The water distribution uniformity of the gated pipe system is the most important factor in evaluating the efficiency of the gated pipe system. The "WDU" depend on the resultant pressure head of pumping units and also, the calibrating the system using sliding gates along the gated piping system. The flow variation (q_{var}) through 18 meters apart of the gated piping system computed as equation (2-2) before operating fertilization system and during operating it. The results of determination of both two cases showed that the flow variation through gated pipe before using fertigation system was about 4.6%. Therefore the water distribution uniformity along the 18 meter apart of the 6 inch gated pipe in this case was about 95.4 percent. But the flow variation through the gated piping system computed during fertigation system using fertilization system was about 6.2 % as shown in fig (3-3). Thus, the water uniformity distribution along the 18 meter apart of the 6 inch gated pipe in this case was about 93.8%. Then, the water distribution uniformity decreased slightly during fertigation system using fertilization system under irrigation gated pipe system due to apply the fertilizer through irrigation water, consequently change in irrigation water density affecting on outlets flow rates through irrigation gated pipe system.

Fertilizer distribution uniformity (F.D.U):

Fertilizer distribution uniformity (F.D.U) through fertigation system under using the Vacuum fertilization system, computed as equation (2-4) was 96.3 %

Fertilizer concentration variation:

Fertilizer concentration change during irrigation time was used to describe fertilizer behavior along irrigation time, where uniformity of fertilizer concentration shows reliability of irrigation unit to use and obtain maximum benefit of fertilizer. The results of fertilizer concentration measured were graphically in figure (3-3). The data in figure (3-3) showed that the highest concentration was 995 mg/l at 30%of irrigation time, while the minimum value was 680 mg/l at 80%of irrigation time.

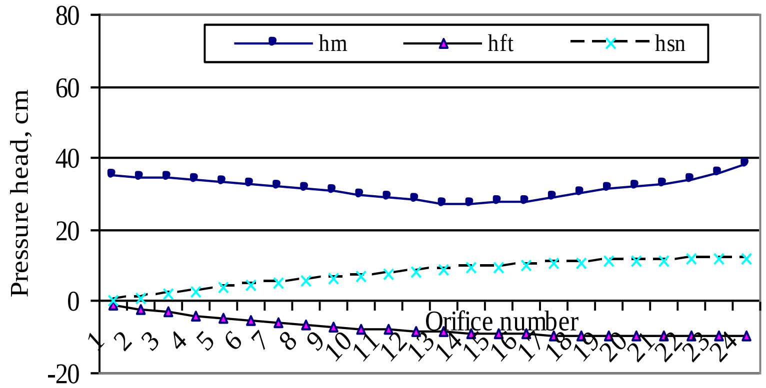


Fig. (3-1):The performance of irrigation gated pipe system.

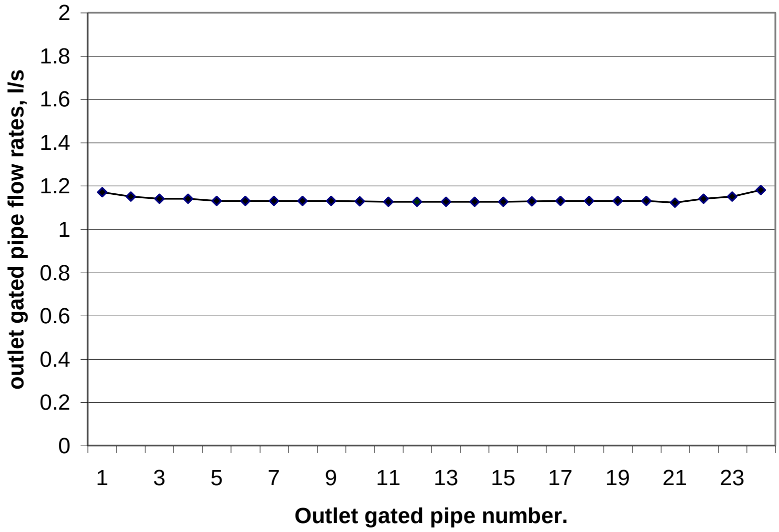


Fig. (3-2): Outlets flow rates along gated pipe system.

Fertilizer concentration along the gated pipe system:

One of the most important advantages of the irrigation gated pipe irrigation system is the fertigation with irrigation water. Generally the data indicated that the concentration of fertilizer was effected by gated pipe length. Figures (3-5) showed that the effect of gated pipe length on the fertilizer concentration along the gated pipe system. The data exhibit that there are no more difference in the values of fertilizer concentration under the fertigation method along the gated pipe length. It is clear from the data that the minimum concentrations under the irrigation gated pipe irrigation system was 1.52 ds/m and the maximum concentrations was 1.55 ds/m.This mean that, the concentration variation along the system was about 1.3%. Therefore, the uniformity of concentration through the gated pipe system was about 98.1%. It is noticed from the results that the fertilizer concentrations decreased from the first gate to the last one. The reason for the reduction is due to deposition of some fertilizer in the tank and other system components. In the meantime, the experiment measurements were taken over 20 minute duration from the start of fertigation. After this duration some of the repositions was wasted during washing of the tank other exposed equipment.

Water use efficiency:

The total amount of irrigation water received by sugarcane plants of 19 irrigation was measured by 6 inches flow meter mounted on the pumping unit. The results revealed that the total amount of water in case of 0.1% slope using gated piping system was 9240 m^3/fed./year. On the other hands, the average total sugar cane yield was 50.4 ton per feddan. Therefore, water use efficiency (WUE) value was calculated according to eq. (2-5). The results showed that the value of the water use efficiency was about 4.37 kg/ m^3.

Nitrogen use efficiency (NUE):

Nitrogen use efficiency (NUE) was determined according to eq. (2-6). The results revealed that the value of the Nitrogen use efficiency (NUE) was about 280 kg-y/kg-N.

Cost analysis:

A simple practical economical was analysis was considered through calculating the cost of the Vacuum Fertilization System. The results revea
led that the fixed cost of the system was about 29.0 L.E/year and running cost was about 54.33 L.E/year, therefore the total annual cost of the vacuum fertilization system was about 82.33 L.E/year.

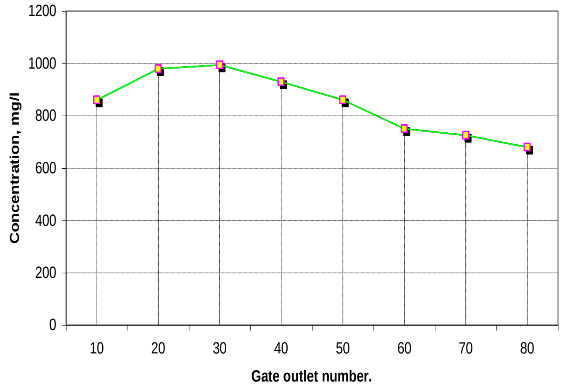


Figure (3-3): Fertilizers concentration change during irrigation time.

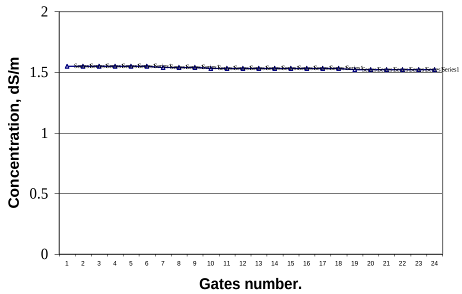


Figure (3-4): Fertilizers concentration along the gated pipe system.

CONCLUSION

This paper describes design and locally manufactured of a simple and inexpensive fertilization system using in small holding in Egypt called "Vacuum fertilization system".

The results indicated that:

1. The most flow in gated pipes occurs at Reynolds number “RNn” between 10^4 and 10^5 and the flow was about fully turbulent flow.
2. The total friction head losses was greater gradually from the first portion of the gated pipe system until it reached as a maximum at the last portion of the gated pipe, and its values ended at about -27.6 percent of the original pressure head at the gated pipe inlet.
3. The superimposed pressure head was greater gradually until it reached as a maximum at the last portion of the gated pipe towards the dead end of the system, and its values was about (+48.6) percent of the original pressure head at the gated pipe inlet.
4. Concerning the curves representing the measured outlets pressure head along the gated pipe length, there were a drop in the pressure head measured at the first portion of the gated pipe due to accumulative friction head losses effect and then there were a gradual increased in it due to the increasing in superimposed pressure head decreased the effect of accumulative friction head losses.
5. The slope of the curve of the actual measured pressure head (h_{on}) along the gated pipe representing the effect of gated pipe length on the pressure head variation, and its value was about 18.2 %.
6. The outlets discharge rate along the gated pipe system were dropped at the first portion of the gated pipe due to accumulative friction head losses effect and then there were a gradual increase in it due to the increased in superimposed pressure head overcome the effect of accumulative friction head losses.
7. The water distribution uniformity along the 18 meter apart of the 6 inch gated pipe before using fertigation system, was about 95.4 percent. But the water uniformity distribution along the gated pipe during fertigation system using fertilization system was about 93.8%. This meant that the water distribution uniformity decreased slightly during fertigation system using fertilization system under irrigation gated pipe system due to apply the fertilizer through irrigation water, consequently change in irrigation water density affecting on outlets flow rates through irrigation gated pipe system.
8. The fertilizer concentration uniformity through the gated pipe system was about 98.1%. This means that, the concentration variation along the gated pipe system was about 1.3%. The reason of this reduction is due to, deposition of some fertilizer in the tank and other system components. Also, the experiment measurements were taken in a certain time from the start of fertigation. Therefore, data exhibit that there are no more difference in the values of fertilizer concentration under the fertigation method along the gated pipe length.

9. The value of the water use efficiency (WUE) was about 4.37 kg/ $m^{3,}$ on the other hands, the value of the Nitrogen use efficiency (NUE) was about 280 kg-y/kg-N.
10. The total annual cost of the Vacuum Fertilization System was about 82.33 L.E/year.

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التقنية الحديثة لتسميد زراعات قصب السكر مع الرى فى صعيد مصر.

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****معهد بحوث الأراضى والمياة والبيئة – مركز البحوث الزراعية – الجيزة.**

يعتبر محصول قصب السكر من المحاصيل الرئيسية الهامة في جمهورية مصر العربية و المنتشر زراعاتها بالوجه القبلي: و تقدر المساحة المزروعة بحوالي 300000 فدان. و في الاونة الاخيرة اصيبت معظم مزارع القصب بالوجه القبلي بالحشرة القشرية الرخوة، و هذة الحشرة تعتبر من الحشرات الجديدة التي تهدد انتاجية قصب السكر في مصر و قد تؤدي الي هدم المحصول حيث تؤثر تأثيرا بالغا في وزن محصول القصب و جودة العصير و بخاصة المحتوي السكري. و تبيين من التجارب أن اضافة السولار مرة واحدة مع أول رية قصب، ليس له تأثير ضار بالنبات، كما أن اضافة السولار أدي الي انخفاض الاصابة بالحشرة القشرية في الحقل المعامل بالسولار بمقدار ٦٣.١%. فلزم الامر اضافة السولار في الريات الاولي، فكانت معظم الحقول التي يتم ريها بالغمر تضيف السولار خلال المراوي الصغيرة المكشوفة و تعذر للمزارعين المنفذ بحقولهم نظام الري باستخدام الانابيب ذات البوابات اضافة السولار نظرا لتغذية هذا النظام من الترع الفرعية التي عادة تبعد عن حقول القصب المزروعة و يصعب أساسا اضافة السولار في المجاري المائية المتسعة.

حيث تم تصميم وتنفيذ وحدة تسميد ضمن نظام الرى السطحى بالانابيب المبوبة. في بداية التشغيل تكون المحابس مغلقة تماما و بمجرد تشغيل و ادارة الطلمبة و خروج المياه من فتحة الطرد للطلمبة الي داخل خط الري السطحي بالانابيب المبوبة يتم فتح المحبس المتصل بخط السحب لطلمبة الري و كذلك المحبس المتصل ببرميل السولار، و لوحظ البدء في سحب السولار من برميل السولار و دخوله بالتبعية الي خط الري السطحي بالانابيب المبوبة.

هذا الامر تتطلب التفكير في استغلال و دراسة النظام المطبق في اضافة السماد في هذة المزارع كوسيلة رخيصة و تصنع من الخامات المحلية. فتم بالفعل تصميم و تنفيذ نظام تسميد منخفض التكاليف, و تمت دراسة اداء النظام الجديد, من حيث اداء نظام الري بالانابيب المبوبة قبل و بعد عملية التسميد و كذلك تماثل تركيز السماد بمياه الري الخارج من فتحات النظام و تقدير كل من كفاءة الاستخدام المائي و كفاءة استخدام سماد النيتروجين خلال نظام الري بالانابيب المبوبة.

و اوضحت النتائج الاتي:

1- يتناقص الضاغط المائي المقاس علي امتداد خط نظام الري بالانابيب المبوبة تدريجيا، حيث ان معدل التغير في الضاغط المائي المقاس عند فتحات النظام علي امتداد خط نظام الري بالانابيب المبوبة تكون قيمته18.2%.
2- - تماثل توزيع خروج المياه من الفتحات علي امتداد نظام الري بالانابيب المبوبة قبل استخدام عمليةالتسميد وصل الي 95.4%. بينما تناقصت هذة القيمة الي 93.8% أثناء عملية التسميد.
3- يتغير تركيز السماد في مياه الري المتدفقة من فتحات نظام الري بالانابيب المبوبة مع زمن الري, حيث تبين ان اعلي تركيز للسماد تم الحصول عليه بعد حوالي 30% من بداية زمن الري و أقل تركيز تم الحصول عليه بعد حوالي 80% من بداية زمن الري.
4- ان تماثل توزييع تركيز السماد الخارج من فتحات نظام الري بالانابيب المبوبة تصل الي حوالي 98.1% وهذا يدل علي ارتفاع كفاءة التسميد من خلال النظام الذي تم تصميمه.
5- قيمة كفاءة الاستخدام المائي (WUE) لمحصول قصب السكر المنزرع تحت نظام الري بالانابيب المبوبة 4.37 كجم/م3 ، بينما وصلت قيمة كفاءة الاستخدام للسماد النتروجيني (NUE) الي 280 كجم. محصول/كجم نتروجين.
6- اظهرت التقديرات أن التكاليف الكلية لنظام التسميد الذي تم تصميمه 82.33 جنيها/العام

أ