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New Engineering Method to Improve Water Use Efficiency of Maize under Drip Irrigation System Using Irregular Volumetric Distribution of Compost along Laterals

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ABSTRACT

Egypt is one of the countries facing great challenges due to its limited water resources represented mainly by its fixed share of the Nile water and its aridity as a general characteristic. So, we had to innovate any technique to increase from water use efficiency on farm to achieve this goal, two field experiments were carried out during growing seasons 2012 and 2013, it executed in research farm of national research center (NRC) in Nubaryia province, Egypt to study the effect of new engineering method for irregular volumetric distribution ratios of compost under reduction of emission uniformity on yield and water use efficiency of maize crop (Zea mays-L, HF-10 Varity). Study factors were irregular volumetric distribution ratios of compost on four zones along lateral were [D1= (25%,25%,25%,25% compost), D2= (20%,20%,25%,35% compost), D3= (15%,15%,30%,40 compost) and D4= (10%,10%,35%,45% compost)] under reduction of emission uniformity and emitter discharge along lateral, EU [EU1= 90%, EU2 = 80%, and EU3 = 70%] . The following parameters were studied to evaluate the effect of study factors on: (1) Application efficiency along lateral. (2) Water stress along lateral (3) Yield of maize, (4) Irrigation water use efficiency of maize "$IWUE_{maize}$. Statistical analysis of the effect of irregular volumetric distribution ratios of compost on along laterals under reduction of emission uniformity indicated that, maximum values of yield and irrigation water use efficiency of maize were obtained under D1, D2 with EU1and D2 appropriate with EU2 and D3 appropriate with EU3.

Key word: Emission uniformity, Application efficiency, along lateral, compost, Drip irrigation, Variation of emitter discharge along lateral.

Introduction

Irrigation uniformity is the most important indicator for evaluation of the irrigation system performance (Letey *et al.*, 2000). Uniform distribution of water means that all the plants have equal access to water (Tagar *et al.*, 2010). All emitters in the system should discharge equal amounts of water, but flow rate differences between two supposedly identical emitters may exist due to some factors including pressure differences and emitters' sensitivity to pressure changes (Mizyed, *et al.*, (2008). EU uniformity expresses the uniformity of emitters under constant pressure ASAE, (1994). Low EU will necessitate applying more water to satisfy the need of plants receiving less than their water requirements. EU as a uniformity parameter has the advantage of including other uniformity parameters through its calculation process which are manufacturing coefficient of variation (CV) and emitters' flow rate variation (Wu, et al. 2006, Barragan *et al.*, 2006). A system designed for more uniform water application, may usually be considered as more efficient. In drip irrigation, water is carried in a pipe network to the point where it infiltrates into the soil. Therefore, the uniformity of application depends on the uniformity of emitter discharges throughout the system. No uniform discharge is caused by differences due to friction loss and elevation, variations between emitters due to manufacturing tolerances and clogging. Emission uniformity "EU" of drip irrigation system is a measure of the uniformity of emissions from all the emission points for field test. There are many methods to improve water use efficiency on the farm level. Adding organic matter to the soil increase from water holding capacity (Vengadaramana and Jashothan, 2012). According to Lal, R., (1997), one of the key conditions to increase soil productivity in the sub-Saharan zone is to ensure effective water infiltration and storage in the soil. The soil's water-holding capacity is intimately linked to its texture, structure and organic matter content (Hillel, 1980, Ouattara, 1994). (Bationo, 1998) have pointed out that in the Sudanian zone, important benefits resulting from the maintenance of soil organic matter (SOM) in low-input agro-systems include the retention and storage of nutrients and a greater water-holding capacity. Indeed, SOM improves the soil structure and thus affects the stocking of the soil water reserves (Ouédraogo *et al.*, 2001). Hence, maintaining SOM is a key component of sustainable land use management (Feller and Beare, 1997). Water holding capacity of soils is controlled primarily by: (i) the number of pores and pore-size distribution of soils; and (ii) the specific surface area soils. Because of increased aggregation, total pore space is increased (Kladiviko *et al.*, 1979, Tiarks, 1974, Volk and Ullery, 1993, Williams and Cooke, 1961). Furthermore, as a result of decreased bulk density, the pore-size distribution is altered and the relative number of small pores increases, especially for coarse textured soils (Volk and Ullery, 1993). Since the tension which causes a particular pore to drain is dependent on the effective diameter of the pore, greater tension is required to drain small pores,

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compared to large pores. The increased WHC at lower tensions such as those at field capacity is primarily the result of an increase in number of small pores. At higher tensions close to wilting range, nearly all pores are filled with air and the moisture content is determined largely by the specific surface area and the thickness of water films on these surfaces. Sandy soils have much less surface area than clayey soils and, thus, retain much less water at higher tensions. However, with the addition of organic matter, specific surface area increases resulting in increased WHC at higher tensions (Volk and Ullery, 1993, Gupta *et al.*,1977). Soil "holds" water available for crop use, retaining it against the pull of gravity. This is one of the most important physical facts for agriculture. If the soil did not hold water, if water was free to flow downward with the pull of gravity as in a river or canal, we would have to constantly irrigate, or hope that it rained every two or three days. There would be no reason to pre-irrigate. And there would be no such thing as dry-land farming. Soil texture and organic matter are the key components that determine soil water holding capacity. Application of wastes, either for plant nutrient supply or for disposal purposes, increases the C content of the soil. An increase in C content of the soil increases aggregation, decreases bulk density, increases water holding capacity, and hydraulic conductivity (Kladiviko and 1979, Tiarks *et al.,* 1974, Volk and Ullery, 1993, Williams and Cooke, 1961, Gupta *et al.,* 1977, Biswas and Khosla, 1971, Klute and Jacob, 1949, Mays *et al.,*1973, Salter and Haworth, 1961, Unger and Stewart, 1974, Webber, 1978, Weil and Kroontje, 1979).

The objective of this study is to improve water use efficiency of maize under sandy soil conditions by irregular distribution of compost along lateral to appropriate with reduction of emission uniformity and emitter discharge along lateral.

Materials and Methods

2.1. Description of Study Site:

2.1.1. Location and climate of experimental site:

Field experiments were conducted during two maize seasons from 10 May to 20 September 2012–2013 at the experimental farm of National Research Center, El-Nubaria, Egypt (latitude $30^{o}\ 30^{\prime}\ 1.4^{\prime\prime}$ N, and longitude $30^{o}\ 19^{\prime}\ 10.9^{\prime\prime}$ E, and mean altitude 21 m above sea level) as shown in fig. (1). The experimental area has an arid climate with cool winters and hot dry summers prevailing in the experimental area. The data of maximum and minimum temperature, relative humidity, and wind speed were obtained from “Local Weather Station inside El-Nubaria Farm” as shown in table (1).

Table 1: The data of maximum and minimum temperature, relative humidity, and wind speed were obtained from “Local Weather Station inside El-Nubaria Farm.

Items	Precipitation [mm]	Wind speed [m/sec]		HC Air temperature [°C]			HC Relative humidity [%]		
	sum	Aver.	Maxi.	Aver.	Mini.	Maxi.	Aver.	Mini.	Maxi.
2012	0.0	1.9	5.0	23.3	14.7	32.2	60.5	23.7	95.4
	0.0	2.0	5.1	26.0	18.8	34.2	65.9	30.0	97.0
	0.1	1.9	5.1	27.7	21.3	35.5	70.1	30.7	99.4
	0.1	1.6	4.7	27.2	20.6	35.1	72.1	29.8	99.9
	0.1	1.4	4.3	24.4	17.4	32.0	74.2	37.2	100.0
2013	0.0	2.2	5.7	23.9	16.3	33.2	64.2	24.2	98.3
	0.0	2.3	5.5	25.6	18.4	33.5	66.1	26.6	99.3
	0.0	2.0	5.3	25.4	19.2	32.5	74.6	35.6	100.0
	0.0	1.3	4.2	26.1	19.5	34.1	76.0	34.8	100.0
	0.0	1.6	4.8	24.5	17.5	32.6	72.5	33.2	99.4

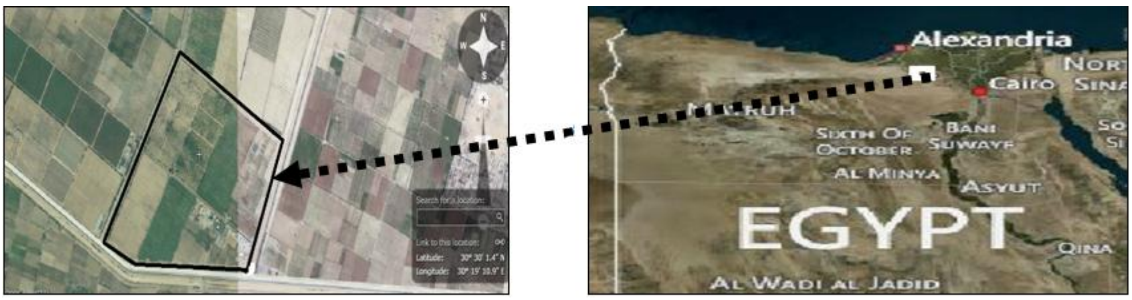

Fig. 1: Location of the experimental farm in EL-NUBARIA Region, Egypt.

2.1.2. Irrigation System:

Irrigation system components consisted of control head, pumping and filtration unit. It consists of centrifugal pump with 45 m^3/h discharge and it was driven by electrical engine and screen filter and back flow prevention device, pressure regulator, pressure gauges, flow-meter, control valves. Main line was of PVC pipes with 110 mm in diameter (OD) to convey the water from the source to the main control points in the field. Sub-main lines were of PVC pipes with 75 mm diameter (OD) was connected to the main line. Manifold lines: PE pipes was of 63 mm in diameter (OD) were connected to the sub main line through control valve 2`` and discharge gauge. Emitters, built in laterals tubes of PE with 16 mm diameter (OD) and 30 m in long (emitter discharge was 4 lph at 1.0 bar operating pressure and 30 cm spacing between emitters.

2.1.3. Some Physical and Chemical Properties of Soil and Irrigation Water:

Some Properties of soil and irrigation water for experimental site are presented in (Tables 2, 3 and 4).

Table 2: Some chemical and mechanical analyses of soil study site.

	Chemical analysis				Chemical analysis			Texture
Depth	OM (%)	pH (1:2.5)	EC (dSm^{-1})	$CaCO_3$ %	Course sand	Fine sand	Silt+ clay	
0-20	0.65	8.7	0.35	7.02	47.76	49.75	2.49	Sandy
20-40	0.40	8.8	0.32	2.34	56.72	39.56	3.72	
40-60	0.25	9.3	0.44	4.68	36.76	59.40	3.84	

OM= organic matter. pH= power of hydrogen EC= Electrical Conductivity

Table 3: Soil water characteristics.

Depth	SP (%)	F.C (%)	W.P (%)	A.W (%)	Hydraulic conductivity(cm/hr)
0-20	21.0	10.1	4.7	5.4	22.5
20-40	19.0	13.5	5.6	7.9	19.0
40-60	22.0	12.5	4.6	7.9	21.0

S.P. = saturation point, F.C. = field capacity, W.P. = wilting point and A.W. = available water.

Table 4: Some chemical characteristics of irrigation water in the open channel at farm study site.

pH	EC (dSm^{-1})	Cations and anions (meq/L)								SAR %
		Cations				Anions				
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	--CO3	HCO3-	Cl^{-}	SO4--	
7.35	0.41	1	0.5	2.4	0.2	--	0.1	2.7	1.3	2.8

pH= power of hydrogen EC= Electrical Conductivity SAR= Sodium Adsorption Ratio

2.2. Crop Requirements:

2.2.1. Irrigation requirements:

Seasonal irrigation requirements were estimated. The seasonal irrigation water applied was found to be 1808 m^3/fed./season for drip irrigation system by following equation and as tabulated in table (5):

$$IRg = (ET_O \times Kc \times Kr) / Ei - R + LR \quad (1)$$

Where:
IRg = Gross irrigation requirements, mm/day
ET_O = Reference evapotranspiration, mm/day (estimated by the meteorological data of local sation in EL-NUBARYIA farm and according to Penman-Monteith equation)
Kc = Crop factor (FAO reference)
Kr = Ground cover reduction factor, Values of Kr suggested by different authors (FAO, 1984)
Ei = Irrigation efficiency = Ea x EU where Ea = (Vs/Va) x 100 where Vs = Average water stored in root zone; Va = Average water applied; EU = Coefficient reflecting the uniformity of application= (qm / qa) x100 where qm = the average flow rate of the emitters in the lowest quartile, (l/h); and qa = the average flow rate of all emitters under test, (l/h).
R = Water received by plant from sources other than irrigation, mm (for example rainfall)
LR = Amount of water required for the leaching of salts, mm = LRt x (IRn/Ei) where: LRt = leaching requirement ratio under drip irrigation = ECw /(2 x max ECe) where ECw = electrical conductivity of irrigation water (ds/m); max ECe = electrical conductivity of saturated soil extract that will reduce the crop yield to zero (dS/m); IRn (net irrigation requirement) = ETo x Kc x Kr

Table 5: Estimation of total irrigation requirements for maize per season in EL-NUBARYIA province (average of two seasons, 2012-2013).

No.	Items	Growth stages of maize			
		Init.	Dev.	Mid	Late
		12 May – 31May	1 June – 5 July	6 July – 14 Aug.	15 Aug. – 10Sep.
1	Eto(mm/day)	6.3	6.3	5.6	5.0
2	Crop coefficient, Kc	0.7	0.95	1.2	0.48
3	Reduction factor, Kr, %	0.24	0.35	0.82	0.47
4	Emission uniformity, EU	0.9	0.9	0.9	0.9
5	Application efficiency, Ea, %	0.91	0.91	0.91	0.91
6	LR, mm/day	0.03	0.05	0.14	0.03
7	R , mm	0	0	0	0
8	No. of days/ month	20	35	40	27
9	IRg, (mm/month)	26	91	275	38
10	IRg, (m^3 / fed. / month)	111	382	1155	160
11	IRg, (m^3/fed./season)	1808			

*Hectare =2.4 fed.**;** R= water received by plant from sources other than irrigation, mm (for example rainfall)**;** IRg = Gross irrigation requirements, mm/day L = Leaching requirement*

2.2.2. Fertilization Program, Weed and Pest Control:

Fertilization program had been done according to the recommended doses throughout the growing season (2012 - 2013) for maize crop under the investigated irrigation systems using fertigation technique. These amounts of fertilizers NPK (20-20-10), were 80 kg/fed of (20 % N) and 40 kg/fed of (20 % K_2O). While 65 kg/fed of (10 % P_2O_5) in addition to, adding 20 $m^3_{compost}$/ fed. For all plots, weed and pest control applications followed recommendations of maize crop in El-Nobaria, Egypt.

2.3. Experimental Design:

Experimental design was complete randomized block design with three replications. Effect of irregular volumetric distribution ratios of compost on four zones along laterals D1= (25%,25%,25%,25% compost), D2= (20%,20%,25%,35% compost), D3= (15%,15%,30%,40 compost) and D4= (10%,10%,35%,45% compost) as shown in fig. (2) under three cases of emission uniformity EU1= 90%, EU2 = 80%, and EU3 = 70% were determined by relation between lateral length and distribution uniformity as shown in fig. (3). The distribution uniformity (EU) of water was estimated (Marriam and Keller, 1978) along laterals drip irrigation system in every plot area under pressure range of 1.0 bar by using 20 collection cans and following Equation:

$$EU = (qm / qa)\ 100 \quad (2)$$

Where: EU = Emission uniformity, %; qm = the average flow rate of the emitters in the lowest quartile, (l/h); and qa = the average flow rate of all emitters under test, (l/h). First measure, EU was 90 % with 30 m lateral length and we make extension for lateral length every 2 m than we repeated the measuring of EU until making the relation between lateral length and distribution uniformity. Experimental design was formed according to fig. (2) and fig. (3) as shown in fig. (4).

2.4. Evaluation Parameters:

2.4.1. Application efficiency:

Application efficiency relates to the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field. According to El-Meseery, (2003) application efficiency "AE" was calculated using the following relation:

$$AE = V_s / V_a \quad (3)$$

Where: AE = Application efficiency, (%), V_s = Volume of stored water in root zone (cm.^{3}) where:

$$V_s = (\theta_1 - \theta_2) * d * \rho * A \quad (4)$$

V_a = Volume of applied water (cm^3), A = The Space allocated to one plant (cm^2), d = Soil layer depth (cm), θ_1 = Soil moisture content after irrigation (%), θ_2 = Soil moisture content before irrigation (%), ρ = Relative bulk density of soil (dimensionless). Table (6) show estimation method of application efficiency in the field.

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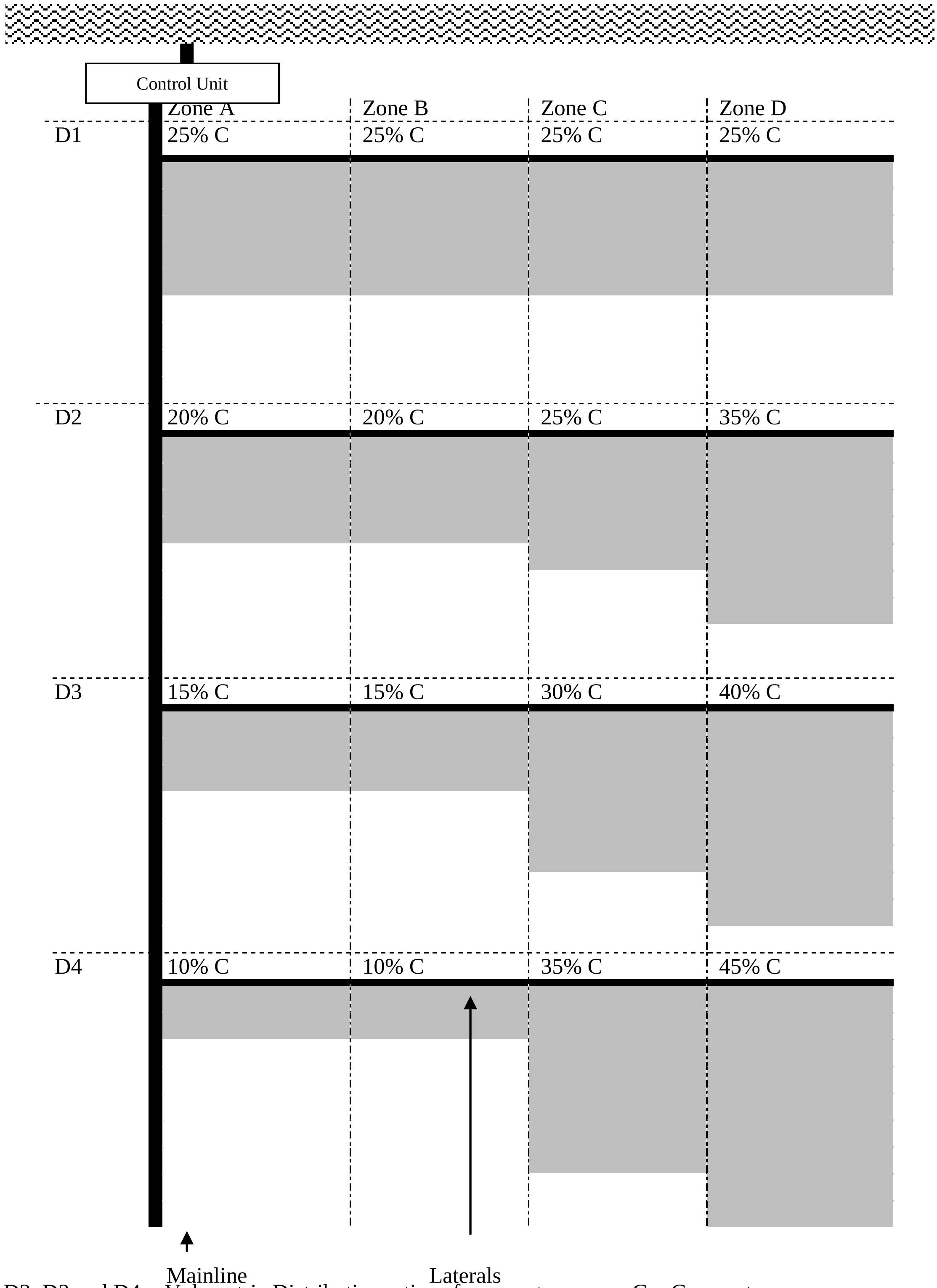
Table 6: Estimation method of application efficiency.

Soil depth, cm	θ_1 %	θ_2 %	d, cm	P	A, cm^2	$V_s = (\theta_1 - \theta_2) * d * \rho * A$ cm^3	V_a, cm^3 or l	$AE = V_s / V_a$ $AE = (V_{s1} + V_{s2} + V_{s3}) / V_a$
0 -15						V_{s1}		
15 -30						V_{s2}		
30 -45						V_{s3}		

AE = Application efficiency, V_s =Volume of stored water in root zone, V_a =Volume of applied water, A = The Space allocated to one plant, d =Soil layer depth, θ_1 =Soil moisture content after irrigation, θ_2 = Soil moisture content before irrigation, ρ = Relative bulk density of soil (dimensionless). V_{s1}= Volume of stored water in root zone from 0 – 15 cm , V_{s2}= Volume of stored water in root zone from 15 – 30 cm, V_{s3}= Volume of stored water in root zone from 30 –45cm



D1, D2, D3 and D4 = Volumetric Distribution ratios of compost C = Compost

Fig. 2: Irregular volumetric distribution ratios of compost on four zones along laterals.

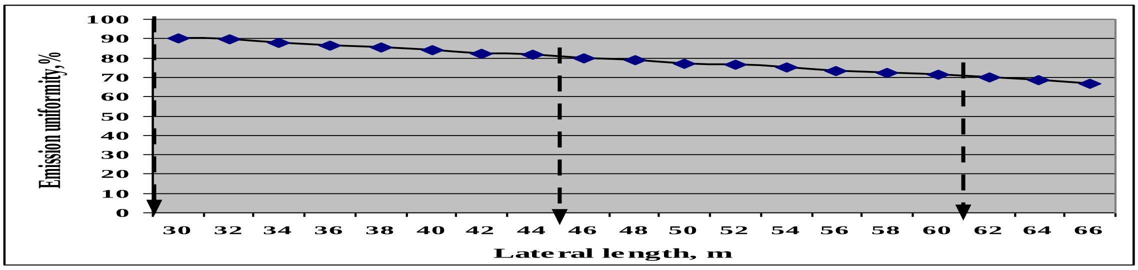


Fig. 3: The relation between emission uniformity and increasing of lateral length (Lateral length 30 m, 46 m, and 62 m appropriate with emission uniformity 90%, 80%, and 70% respectively)

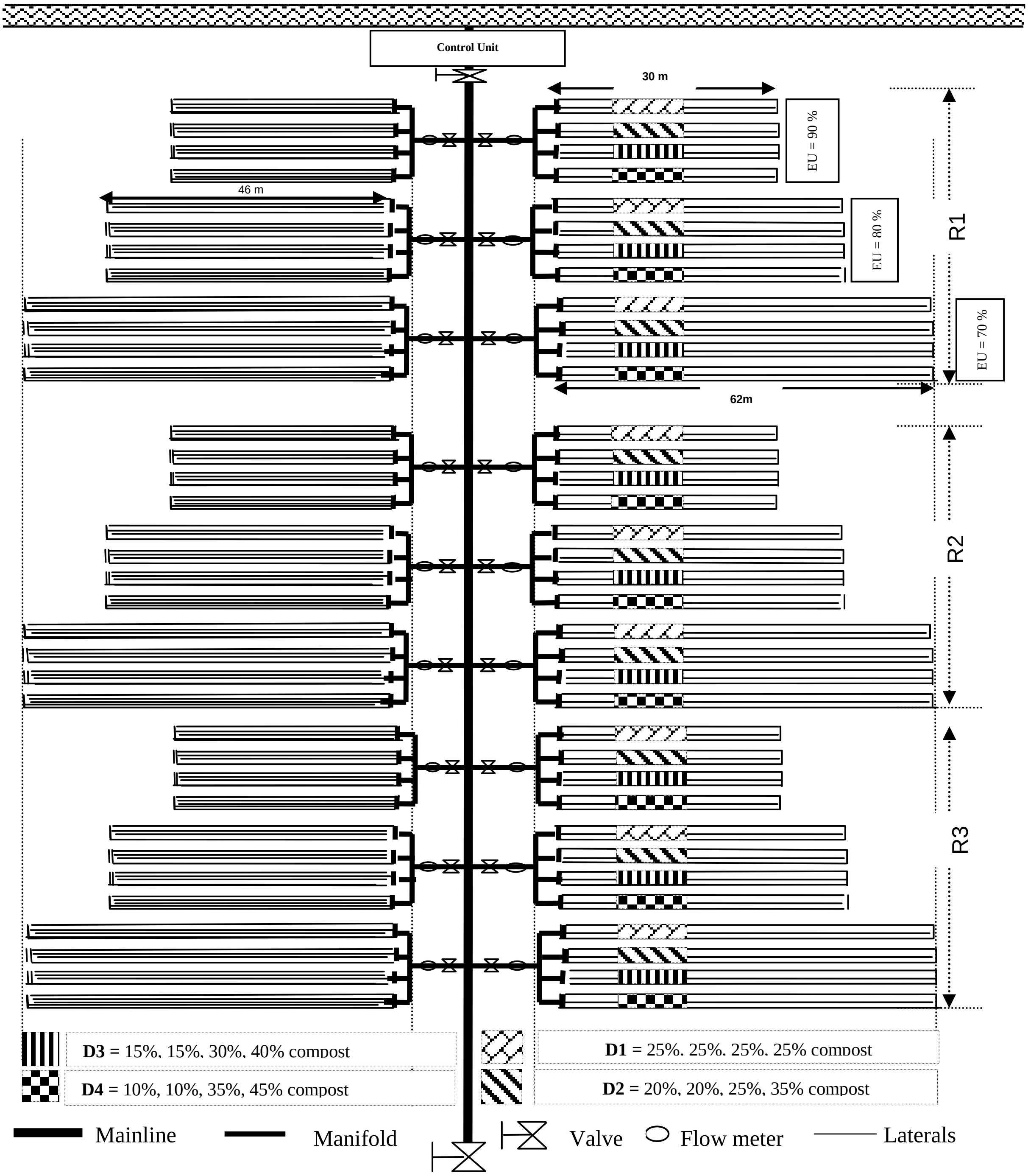


Fig. 4: Schematic diagram for the experiment design layout.

2.4.2. Water stress:

Measuring soil moisture content in effective root zone before the irrigation is considered as an evaluation parameter for exposure range of the plants to water stress "WS".

2.4.3. Yield of maize:

At harvest, a random sample of 100 X 100 cm was taken from each plot to determine grain yields in the mentioned area and then converted to yield (ton/fed.).

*2.4.4. Irrigation water use efficiency of maize***:**

"$IWUE_{maize}$" was calculated according to James, (1988) as follows:

$$IWUE_{maize} = (Ey/Ir) \times 100 \quad (5)$$

Where: $IWUE_{maize}$ is the irrigation water use efficiency (kg $_{grain}$ / m^3 $_{water}$), Ey is the economical yield (kg grain /fed.); Ir is the amount of applied irrigation water (m^3 $_{water}$ /fed./season).

2.5. Statistical Analysis:

The obtained results were subjected to statistical analysis of variance according to method described by (Snedecor and Cochran, 1982) since the trend was similar in both seasons the homogeneity test Bartlet's equation was applied and the combined analysis of the two seasons was calculated according to the method of Gomez and Gomez (1984).

Results and Discussion

Although drip irrigation system achieves the highest efficiency of water use between different irrigation systems, but there are cases represent the reduction in its performance. The first case is a drip irrigation system with right design, which allows differences in emitters discharge along laterals by 10%, if the average discharge of some emitters at the beginning of laterals are equal 4 liters / hour the average discharge of the emitters at the end of laterals should not be less than 3.6 liters / hour. The second case is incorrect design, which have a larger negative impact on water distribution uniformity which leads to a much larger difference of 10% between the discharge of drippers along laterals. The third case is the decline in the performance of a network of drip irrigation with the passage of time. All previous cases suffer from a difference in the size of available water under the cultivated plants. This mean some of plants will be given amount of water larger than its needs and other plants take amount of water less than their needs which will reflect negatively on crop productivity. All the above-mentioned cases, there is a lack of uniformity for the discharge of drippers along laterals so, it is better when you add organic matter or compost to the sandy soils the adding will be irregularly along laterals. The importance of compost in its ability to retain water and improve soil properties. The aim of this research is to study the ratios of distributions volumetric irregular amounts of compost to suit the differences in drippers discharge along laterals to reach to the equality in the volume of available water along laterals, which will eventually lead to increasing in the homogeneity of productivity along laterals thus, improving water use efficiency. The following parameters were studied to evaluate the effect of new engineering method for irregular volumetric distribution ratios of compost under three cases from emission uniformity on : (1) Application efficiency along lateral, (2) Water stress along lateral (3) Yield of maize, (4) Irrigation water use efficiency of maize.

3.1. Application efficiency along laterals:

AE affected by two factors, one of them is soil characterizes and the other factor is the performance of irrigation network. Changing in soil characterizes will affected by changing in the organic matter and the performance of irrigation network will affected by changing in EU. Fig. (5, 6 and 7) indicated the effect of irregular volumetric distribution ratios of compost on four zones along laterals on AE at every zone under three cases for EU. AE under 90% emission uniformity affected by changing in volumetric distribution ratios of compost on four zones along laterals. Data presented in Fig. (5) clearly indicate that best AE occurred under D1 and D2 this may be due to increase in EU and variation of emitter discharge along laterals not consider but AE under D3 and D4 decreased by increasing the variation of organic matter this mean irregular volumetric distribution of compost on four zones along laterals not useful under 90% emission uniformity. Data presented in Fig. (6) clearly indicate that best AE occurred under D2 this may be due to decrease in EU and variation of

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emitter discharge along laterals will mitigate by increasing the organic matter in the end of laterals this mean irregular volumetric distribution of compost on four zones along laterals is useful under 80% emission uniformity. Data presented in Fig. (7) clearly indicate that best AE occurred under D3 this may be due to reduction in EU up to 70% and variation of emitter discharge along laterals is very low and this reduction will mitigate by increasing the organic matter in the end of laterals this mean irregular volumetric distribution of compost on four zones along laterals is very useful under 70% emission uniformity.

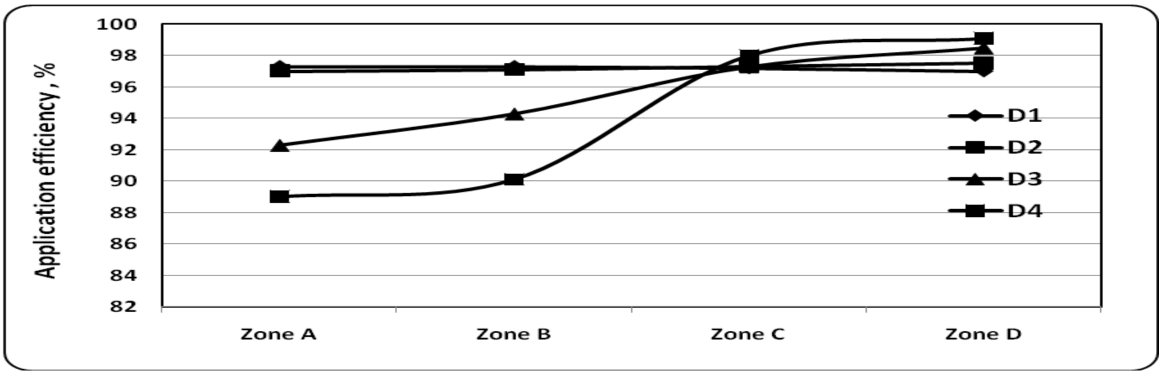

Fig. 5: Effect of volumetric distribution ratios of compost on four zones along lateral on application efficiency under 90% emission uniformity**.**

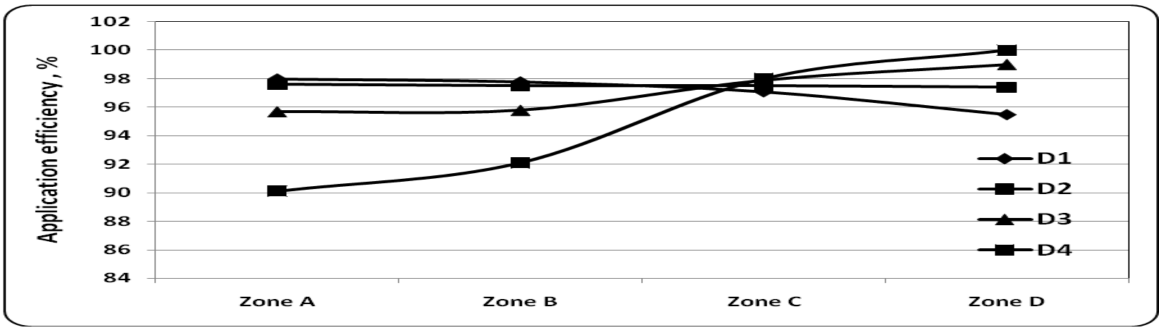

Fig. 6: Effect of volumetric distribution ratios of compost on four zones along lateral on application efficiency under 80% emission uniformity.

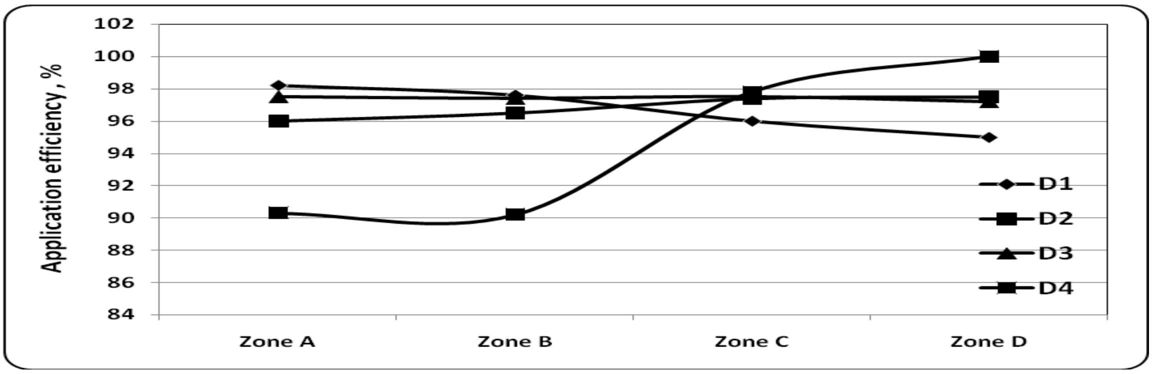

Fig. 7: Effect of volumetric distribution ratios of compost on four zones along lateral on application efficiency under 70% emission uniformity.

3.2. Water Stress along Laterals:

Measuring soil moisture content of effective root zone before irrigation is considered as an evaluation parameter for exposure range of the plants to water stress "WS". WS along laterals also, affected by two factors, changing in the organic matter along laterals and variation of emitter discharge along laterals. Fig. (8, 9 and 10) indicated the effect of irregular volumetric distribution ratios of compost on four zones along laterals on WS at every zone under three cases for EU. Data presented in Fig. (8) indicate that highest values of moisture content before irrigation occurred under D1 and D2 this may be due to increase in EU and variation of emitter discharge

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along laterals not considered but WS under D3 and D4 was very high by increasing the variation of organic matter under 90% emission uniformity. Data presented in Fig. (9) indicate that minimum WS occurred under D2 this may be due to variation of emitter discharge along laterals will mitigate by increasing the organic matter in the end of laterals this mean irregular volumetric distribution of compost on four zones along laterals is useful under 80% emission uniformity. Data presented in Fig. (10) clearly indicate that minimum WS occurred under D3 this may be due to reduction in EU up to 70% and variation of emitter discharge along laterals is very high and this reduction will mitigate by increasing the organic matter in the end of laterals this mean irregular volumetric distribution of compost on four zones along laterals is very healthy under 70% emission uniformity.

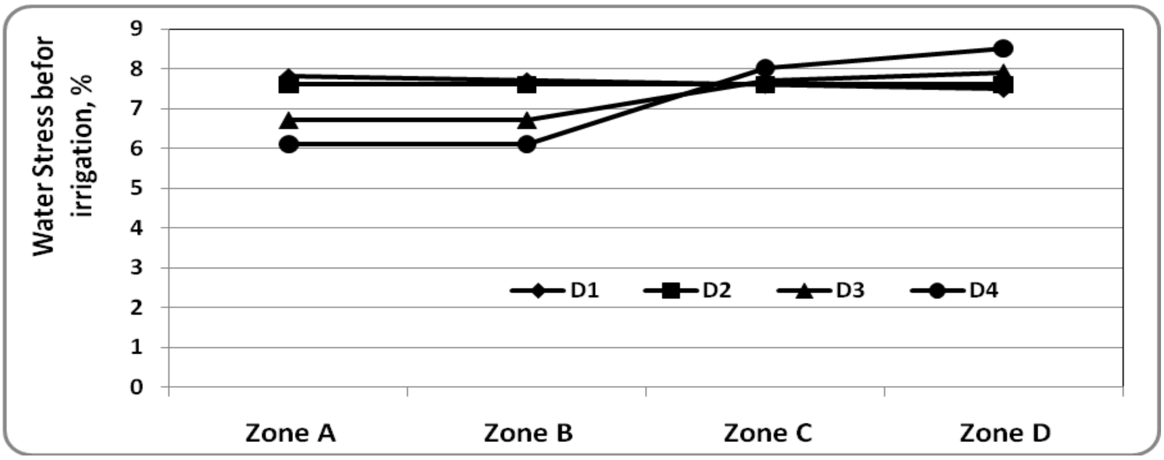

Fig. 8: Effect of volumetric distribution ratios of compost on four zones along lateral on the water stress before irrigation under 90% emission uniformity.

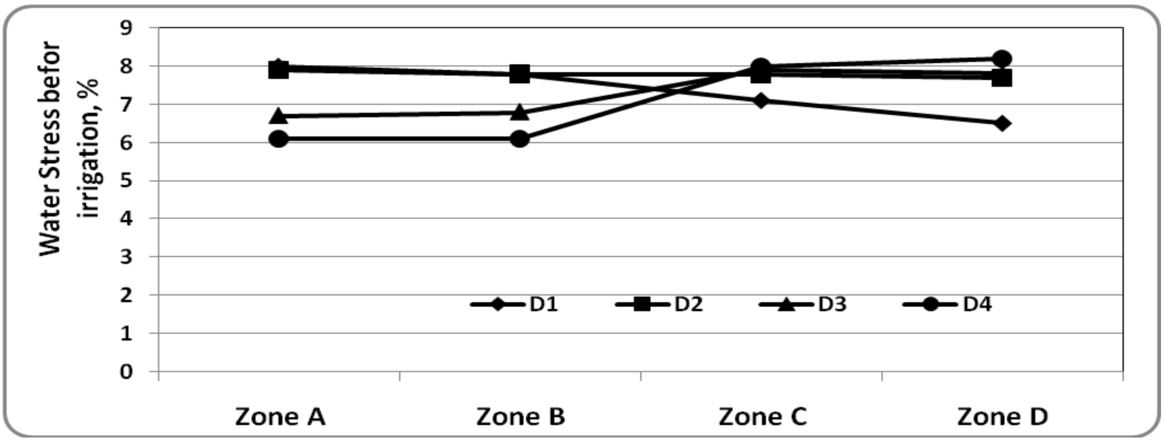

Fig. 9: Effect of volumetric distribution ratios of compost on four zones along lateral on the water stress before irrigation under 80% emission uniformity.

3.3. Yield of maize:

Yield of maize affected by volumetric distribution ratios of compost. According to the effect of volumetric distribution ratios of compost on AE and water stress along laterals the yield of maize was affected also and take the same trend. So, under EU=90% occurred the best yield with D1 and D2 as shown as in fig. (11) and under EU = 80% occurred the best yield with D2 as shown as in fig.(12) and under EU = 70% occurred the best yield with D3.

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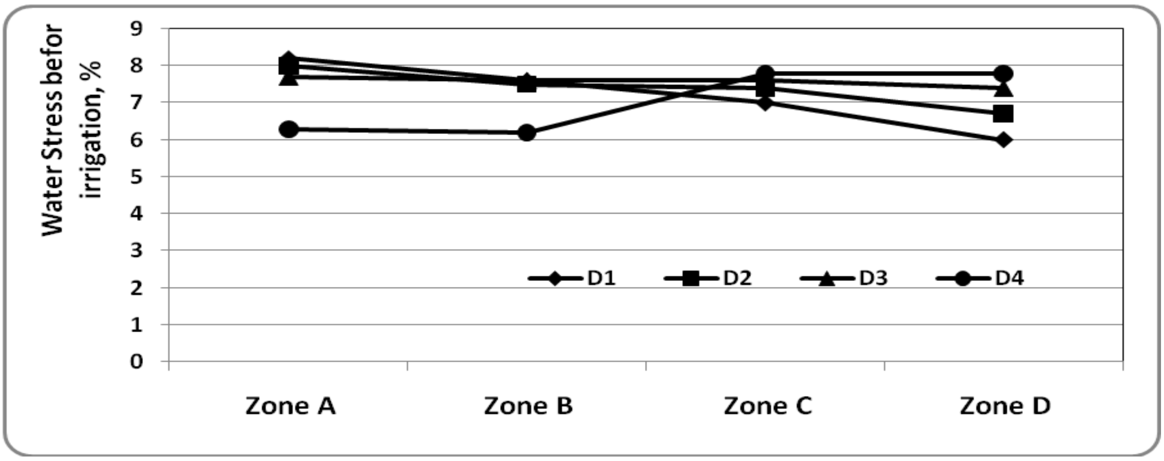

Fig. 10: Effect of volumetric distribution ratios of compost on four zones along lateral on the water stress before irrigation under 70% emission uniformity.

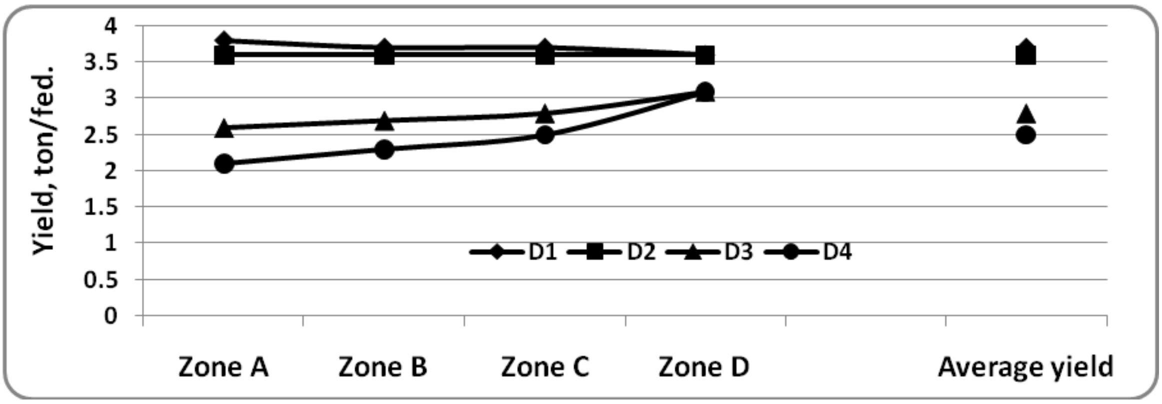

Fig. 11: Effect of volumetric distribution ratios of compost on four zones along lateral on the yield of maize under 90% emission uniformity.

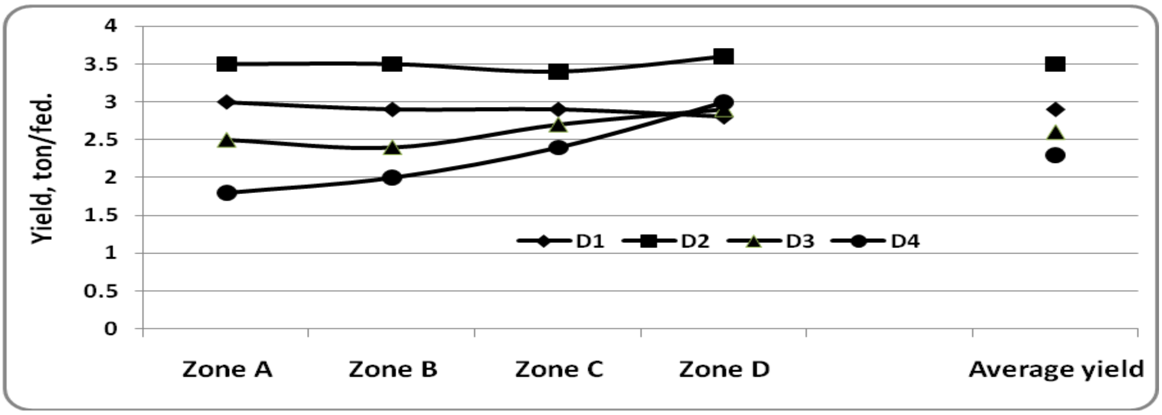

Fig. 12: Effect of volumetric distribution ratios of compost on four zones along lateral on the yield of maize under 80% emission uniformity.

3.4. Irrigation water use efficiency of maize:

IWUE $_{maize}$ affected by two factors. First of all is yield of maize and the other factor is the total amount of irrigation water per season. So, under EU=90% occurred the highest value of IWUE $_{maize}$ with D1 as shown as in fig. (14) and under EU = 80% occurred the highest value of IWUE $_{maize}$ with D2 as shown as in fig.(15) and under EU = 70% occurred the highest value of IWUE $_{maize}$ with D3 as shown as in fig.(16).

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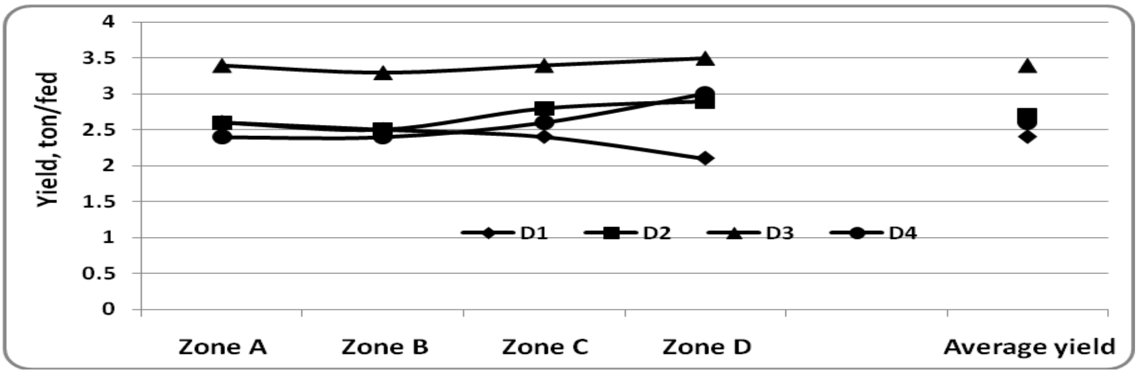

Fig. 13: Effect of volumetric distribution ratios of compost on four zones along lateral on the yield of maize under 70% emission uniformity.

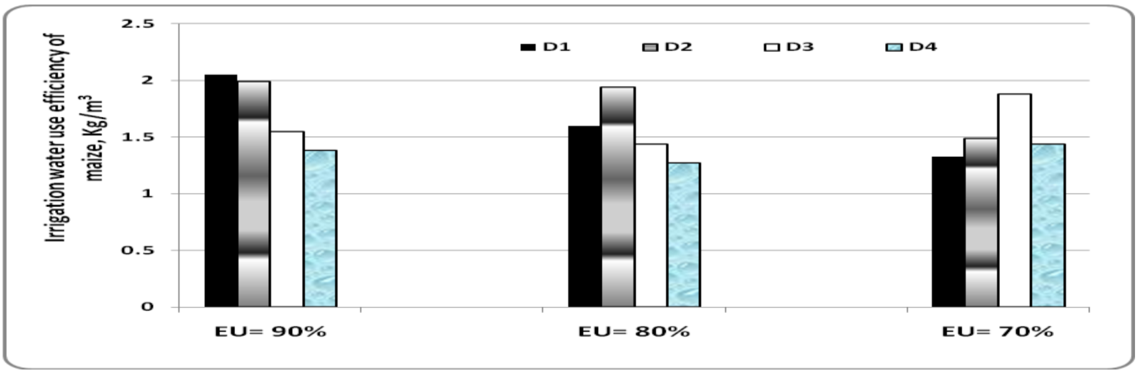

Fig. 14: Effect of volumetric distribution ratios of compost on irrigation water use efficiency of maize under 90%, 80% and 70% emission uniformity.

Table 7: Effect of volumetric distribution ratios of compost on four zones along lateral on yield and irrigation water use efficiency of maize under 90% emission uniformity.

VDRC, %	Yield of Zone A, ton/fed.	Yield of Zone B, ton/fed.	Yield of Zone C, ton/fed.	Yield of Zone D, ton/fed.	Average yield, ton/fed.	$IWUE_{maize}$ Kg/m^3
D1	3.8	3.7	3.7	3.6	3.7 a	2.05
D2	3.6	3.6	3.6	3.6	3.6 a	1.99
D3	2.6	2.7	2.8	3.1	2.8 b	1.55
D4	2.1	2.3	2.5	3.1	2.5 b	1.38
LSD at 5%					0.554	

VDRC = Volumetric Distribution Ratios of Compost, D1=(25%,25%,25%,25% compost), D2=(20%,20%,25%,35% compost), D3=(15%,15%,30%,40 compost), D4=(10%,10%,35%,45% compost), $IWUE_{maize}$= Irrigation water use efficiency of maize

Table 8: Effect of volumetric distribution ratios of compost on four zones along lateral on yield and irrigation water use efficiency of maize under 80% emission uniformity.

VDRC, %	Yield of Zone A, ton/fed.	Yield of Zone B, ton/fed.	Yield of Zone C, ton/fed.	Yield of Zone D, ton/fed.	Average yield, ton/fed.	$IWUE_{maize}$ Kg/m^3
D1	3.0	2.9	2.9	2.8	2.9 b	1.60
D2	3.5	3.5	3.4	3.6	3.5 a	1.94
D3	2.5	2.4	2.7	2.9	2.6 c	1.44
D4	1.8	2.0	2.4	3.0	2.3 c	1.27
LSD at 5%					0.596	

Table 9: Effect of volumetric distribution ratios of compost on four zones along lateral on yield and irrigation water use efficiency of maize under 70% emission uniformity.

VDRC, %	Yield of Zone A, ton/fed.	Yield of Zone B, ton/fed.	Yield of Zone C, ton/fed.	Yield of Zone D, ton/fed.	Average yield, ton/fed.	$IWUE_{maize}$ Kg/m^3
D1	2.6	2.5	2.4	2.1	2.4 b	1.33
D2	2.6	2.5	2.8	2.9	2.7 b	1.49
D3	3.4	3.3	3.4	3.5	3.4 a	1.88
D4	2.4	2.4	2.6	3.0	2.6 b	1.44
LSD at 5%					0.513	

VDRC = volumetric Distribution Ratios of Compost, D1=(25%,25%,25%,25% compost), D2=(20%,20%,25%,35% compost), D3=(15%,15%,30%,40 compost), D4=(10%,10%,35%,45% compost), $IWUE_{maize}$= Irrigation water use efficiency of maize

Conclusion:

According to the case of EU of drip irrigation, you can determine the optimum distribution of compost along laterals. After measuring the EU in the field, you do not need to make irregular volumetric distribution for compost if you found EU= 90% but D2 (20%, 20%, 25%, 35% compost) is appropriate with EU= 80% and D3 (15%,15%,30%,40 compost) is appropriate with EU= 70%.

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