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Improving Water Use Efficiency for Peanut (Arachis Hypigaea) Productivity by Using Irregular Volumetric Distribution of Compost under Drip Irrigation System

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Abstract:According to limited water in arid regions and its sharp drop per capita, we have to maximize water use efficiency under the best system for saving water (drip irrigation). To achieve this goal, two field experiments were carried out during growing seasons 2013 and 2014, it was 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 peanut crop. 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 (EU) and emitter discharge along lateral, [EU1= 90%, EU2 = 80%, and EU3 = 70%] .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 peanut crop. 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 peanut, (4) Irrigation water use efficiency of Peanut "IWUE Peanut.

Keywords: Emission uniformity, Application efficiency, along lateral, compost, Drip irrigation, Variation of emitter discharge along lateral

I. Introduction

In Egypt, crop water use efficiency takes a great attention where irrigation water resources are limited or diminishing and where rainfall is a limiting factor, Drip irrigation, nowadays, is the most efficient plant watering system (Hozayn, et. al., 2013). Abdelraouf, (2014) indicated that although drip irrigation system achieves the highest efficiency of water use between different irrigation systems, there are cases represent the reduction in its performance. Using pulse drip irrigation with organic agriculture if we want to get a major utilization from organic agriculture. (Bakeer, et. al., 2009). The current study is strongly indicating the importance of the included organic resources in improving the productivity and quality of flax crop. The results directly confirm the role of humic acid, mycorrhiza, and biochar in fertilizing the soil and building the organic carbon which may help in improving soil quality of the sandy soils and increasing the water holding capacity and consequently increasing yield and productivity. (Bakry et al. 2014). 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). 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 discharged throughout the system. None uniform discharge is caused by differences due to friction loss, elevation and 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 at the farm level. Adding organic matter to the soil increases water holding capacity (Vengadaramana and Jashothan, 2012). The soil's water-holding capacity is intimately linked to its texture, structure and organic matter content (Ouattara, 1994). Bationo, et al(1998) has 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). 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 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).The objective of this study is to improve water use efficiency of peanut under sandy soil conditions by irregular distribution of compost along lateral to be appropriate under reduction of emission uniformity and emitter discharge along lateral.

II. Material and Methodology

2.1. Description of Study Site

2.1.1. Location and climate of experimental site: Field experiments were on farm of National Research Center, El-Nubaria, Egypt (latitude 30^o 30\ 1.4\\ N, and longitude 30^o 19\ 10.9\\ E, and mean altitude 21 m above sea level) as shown in table (1).. Seeds were sown on May 12th and 15th in the first and second seasons, respectively.

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 4lph 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 1, 2 and 3).

Table 1. Some chemical and mechanical analyses of soil study site.

Chemical analysis				Chemical analysis				Texture
Depth	OM (%)	pH (1:2.5)	EC (dS m^{-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 2: Soil water characteristics.

Depth	S.P. (%)	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 3: Some chemical characteristics of irrigation water in the open channel at farm study site.

Cations and anions (meq/L)										SAR %
pH	EC (dSm^{-1})	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 2110 m^3/season for drip irrigation system by following equation:

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

Where:

IRg = Gross irrigation requirements, mm/day,ET_O = Reference evapotranspiration, mm/day ,Kc = Crop factor (FAO reference) ,Kr = Ground cover reduction factor ,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 = 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).

2.2.2. Fertilization Program, Weed and Pest Control: The amount of irrigation water was estimated and added according to the recommended rates and intervals for each treatment during the growing season. The seeds (Giza 6 c.v.) were coated just before sowing with the bacteria inoculants, using Arabic gum (40 %) as adhesive agent and were sown in hills 10 cm apart. Phosphorus (calcium superphosphate, 15.5 % P_2O_5) at level 75 kg P_2O_5 /ha was added during the seed bed preparation and potassium (potassium sulfate (48.52 % K_2 O) was applied at the rate of 125 kg/ha before the first and third irrigations in two equal doses, while nitrogen fertilizer was added at level of 100 kg N /ha as ammonium sulfate, 20.6 % in four equal doses weekly starting from 15 days after sowing as shown in table (4).

Table 4. Chemical analysis of compost

Item		Compost	Item		Compost
pH		5.90	**EC, (ds/m)**		0.65
Anions (meq./L)	**HCO^-_3&$Co^=_3$**	1.25	**Cation (meq./L)**	**Ca^{++}**	2.00
	CL^-	3.55		**K^+**	2.20
	$SO4^=$	2.94		**Mg^+**	1.00
Nitrogen, (%)		0.91		**Na^+**	2.40
Phosphorus, (%)		0.85	**Organic Matter, (%)**		97.2
Potassium, (%)		0.90	**Moisture content, (%)**		18.00

2.3. Experimental Design: Experimental design was under three cases of emission uniformity EU1= 90%, EU2 = 80%, and EU3 = 70% were determined by relation between lateral length and distribution uniformity. Each EU was completely randomized block design with three replications and the effect of irregular volumetric distribution ratios of compost was put in four zones alonglateralsD1=(25%,25%,25%,25%compost),D2=(20%,20%, 25%,35%compost),D3=(15%,15%,30%,40 compost) and D4= (10%,10%,35%,45% compost). The emission 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:

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

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. (1), fig. (2) and fig. (3).

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:

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

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

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

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) as shown in fig. (5).

Table (5) 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, Vs =Volume of stored water in root zone, Va =Volume of applied water, A = The Space allocated to one plant, d =Soil layer depth, θ1 =Soil moisture content after irrigation, θ2 = Soil moisture content before irrigation, ρ = Relative bulk density of soil (dimensionless). Vs1= Volume of stored water in root zone from 0 – 15 cm , Vs2= Volume of stored water in root zone from 15 – 30 cm, Vs3= Volume of stored water in root zone from 30 –45cm

2.4.2. Water stress: 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".

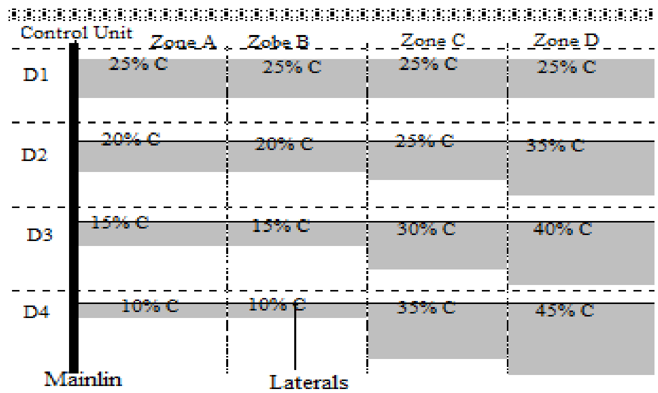

Fig. 1. Irregular volumetric distribution ratios of compost on four zones along laterals

2.4.3. Yield of peanut: 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/ha.).

2.4.4. Irrigation water use efficiency of peanut "IWUE peanut" was calculated according to James, (1988) as follows:

$$IWUE\ peanut = (Ey/Ir)\ x100 \ \ldots\ (5)$$

Where: IWUE peanut is the irrigation water use efficiency (kg grain / m3 water), Ey is the economical yield (kg grain /ha.); Ir is the amount of applied irrigation water (m3 water /fed./season).

2.5. Statistical Analysis

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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).

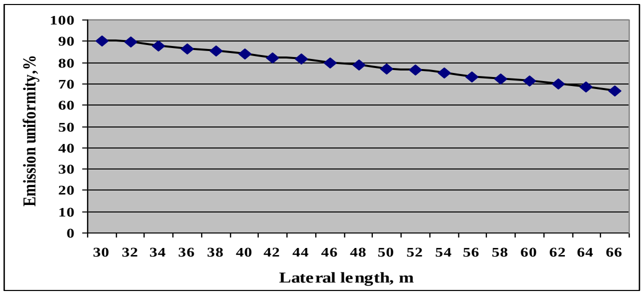


Fig. 2. The relation between emission uniformity and increasing of lateral length (Lateral length 30 m, 46 m, and 62 m appropriate with emission uniformity 90%, 80%, and 70% respectively)

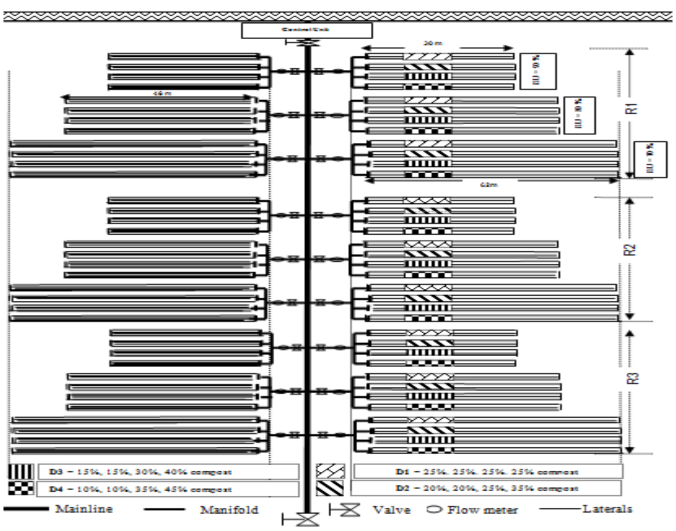


Fig. 3. Schematic diagram for the experiment design layout

III. Results and Tables

The new technique in this research (irregular volumetric distribution of compost under drip irrigation system) found to rise improve the efficiency of water use. But there were three cases of EU represent decrease in its performance. The first case is a drip irrigation system with the right design, which allows differences in behaviour along laterals by 10%, if the average behaviour of a group at the beginning of laterals equal to 4 L/ hr should not be less than 3.6 litters / hour at the end of laterals. The second case is that the design is incorrect, which have a larger negative impact on the distribution of 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, also resulting in an increase in the difference between the discharges of drippers. All the above-mentioned cases, there is a lack of uniformity for the discharge of drippers along laterals must also when you add organic matter or compost is added to the other irregularly sandy land along laterals. The importance of compost is in its ability to retain water and improve soil properties. Differing in size distribution of quantities along laterals will result in variations in the volume of water stored in the roots spread along laterals.The aim of this research is to study the ratios of irregular volumetric distribution 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 an increase 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 peanut, (4) Irrigation water use efficiency of peanut.

3.1. Application efficiency along laterals

Application efficiency (AE) is affected by two factors, one of them is soil characteristics and the other factor is the performance of irrigation network. Changing in soil characteristics will be affected by changing in the organic matter and the performance of irrigation network affected by changing in EU. Fig. (4) indicated the effect of irregular volumetric distribution ratios of compost on four zones along laterals on AE at each zone under three cases for EU. AE fewer than 90% emission uniformity is affected by changing in volumetric distribution ratios of compost on four zones along laterals. Data presented in Fig. (4) clearly indicates that best AE occurred under D1 and D2, this may be due to an increase in EU with no consideration for the variation of emitter discharge along laterals but AE under D3 and D4 decreased by increasing the variation of organic matter, this means that irregular volumetric distribution of compost on four zones along laterals are not useful under 90% emission uniformity. Data presented in Fig. (4) clearly indicates that the best AE is occurred under D2. This may be due to decrease in EU and variation of emitter discharge along laterals by increasing the organic matter at the end of laterals. This is achieved by irregular volumetric distribution of compost in the four zones along laterals which is useful under 80% emission uniformity. Data presented in Fig. (4) clearly indicates 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. This reduction will mitigate by increasing the organic matter at the end of laterals this means that irregular volumetric distribution of compost on four zones along laterals is very useful under 70% emission uniformity.

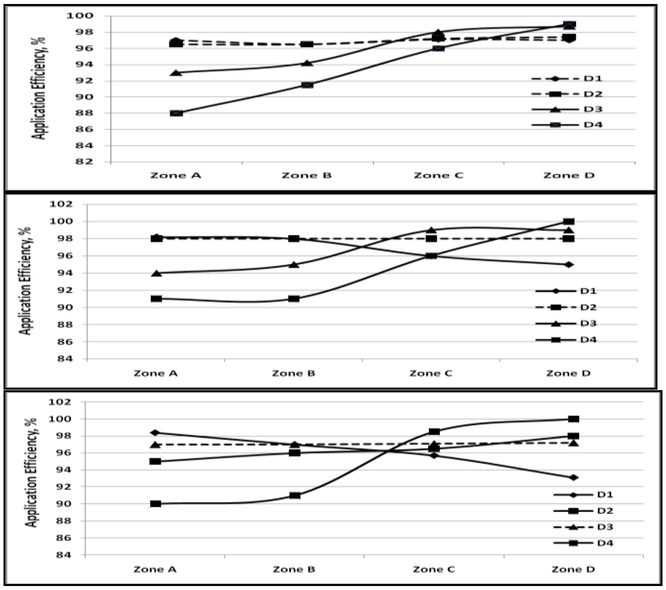
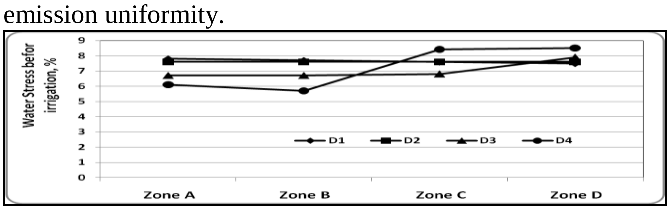


Fig. 4. Effect of volumetric distribution ratios of compost on four zones along lateral on application efficiency under 90%, 80% and 70% emission uniformity

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, is affected by two factors: (1) changing in the organic matter along laterals (2) variation of emitter discharge along laterals. Fig. (5) 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. (5) indicates that highest values of moisture content before irrigation occurred under D1 and D2 this may be due to an increase in EU with no consideration for the variation of emitter discharge along laterals, WS under D3 and D4 was very high by increasing the variation of organic matter under 90% emission uniformity. Data presented in Fig. (5) indicate that minimum WS occurred under D2, this may be due to variation of emitter discharge along laterals. This will mitigate by increasing the organic matter at the end of laterals this means that irregular volumetric distribution of compost on four zones along laterals is useful under 80% emission uniformity. Data presented in Fig. (5) clearly indicates that minimum WS occurred under D3. This may be due to reduction in EU up to 70% and variation of emitter discharge along laterals. This reduction will be increase the organic matter at the end of laterals. This means irregular volumetric distribution of compost in four zones along laterals is very healthy under 70% emission uniformity.



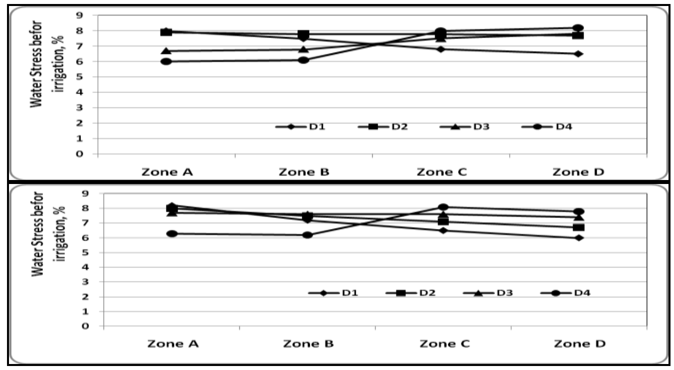


Fig. 5. Effect of volumetric distribution ratios of compost on four zones along lateral on the water stress before irrigation under 90%, 80% and70% emission uniformity

3.3. Yield of peanut: Yield of peanut 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 peanut was affected also and take the same trend. So, under EU=90% occurred the best yield with D1 and D2 and under EU = 80% occurred the best yield with D2 and under EU = 70% occurred the best yield with D3 as shown as in fig.(6).

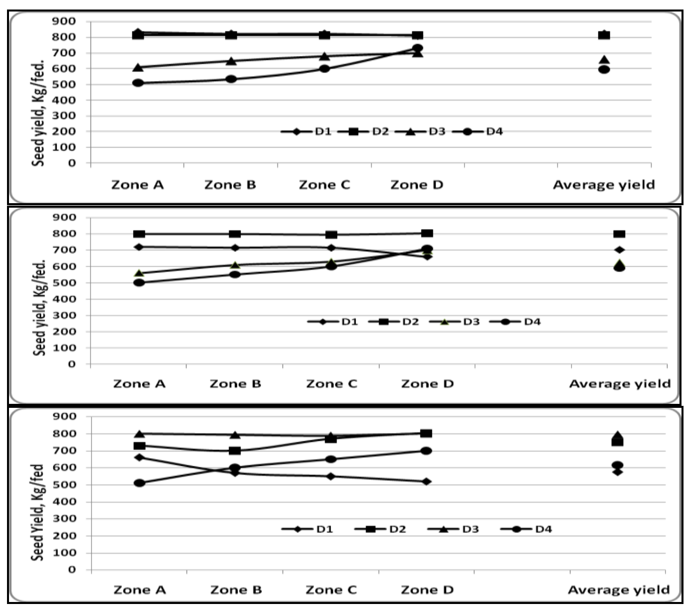


Fig. 6. Effect of volumetric distribution ratios of compost on four zones along lateral on the yield of peanut under 90%, 80% and 70% emission uniformity

3.4. Irrigation water use efficiency of peanut

IWUE peanut affected by two factors. First of all is yield of peanut and the other factor is the total amount of irrigation water per season. So, under EU=90% occurred the highest value of IWUE peanut with D1 as shown as in fig. (14) and under EU = 80% occurred the highest value of IWUE peanut with D2 as shown as in fig.(7) and under EU = 70% occurred the highest value of IWUE peanut with D3.

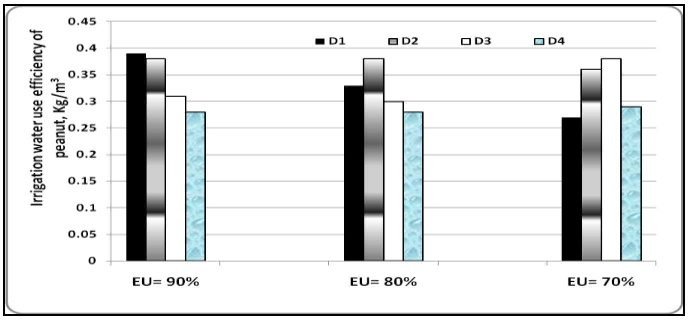


Fig. 7. Effect of volumetric distribution ratios of compost on irrigation water use efficiency of peanut under 90%, 80% and 70% emission uniformity

Table (6) Effect of volumetric distribution ratios of compost on four zones along lateral on yield and irrigation water use efficiency of peanut under 90%, 80% and 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	Aver. Yield, ton/fed	IWUE peanut Kg/m^3
D1	830	820	820	810	820 a	0.39
D2	812	812	812	812	812 a	0.38
D3	610	650	680	700	660 b	0.31
D4	510	534	600	732	594 c	0.28
LSD at 5%					16.95	

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 peanut Kg/m^3
D1	720	715	715	660	702.5 b	0.33
D2	800	800	795	805	800 a	0.38
D3	560	610	630	700	625 c	0.30
D4	500	550	600	710	590 d	0.28
LSD at 5%					2.63	

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 peanut Kg/m^3
D1	660	570	550	520	575 d	0.27
D2	730	700	770	804	751 b	0.36
D3	800	794	789	801	796 a	0.38
D4	510	600	650	700	615 c	0.29
LSD at 5%					8.38	

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

IV. Conclusion

According to the case of EU of drip irrigation, users can determine the optimum distribution of compost along laterals. After measuring the EU in the field, the volumetric distribution ratios of compost (VDRC) (25%, 25%, 25%, 25%) are appropriate with EU= 90% but the VDRC (20%, 20%, 25%, 35%) is appropriate with EU= 90% & 80% and VDRC (15%, 15%, 30%, 40) is appropriate with EU= 70 %.).

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