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Hydraulic Performance of Different Emitters under Varying Watertank Height

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ABSTRACT

Drip or Trickle irrigation system is designed to apply precise amount of water near the plant with a certain degree of uniformity. This study was conducted at the Experimental Farm of the Faculty of Agricultural Sciences, University of Gezira, during January, 2021. The study was aimed to evaluate the hydraulic performance of different emitters types under varying watertank height including: average discharge (Q_{avg}), discharge variation (Q_{var}%), coefficient of manufacture variation (C_V%), application uniformity (AU%), coefficient uniformity (CU%), distribution uniformity (DU%) and statistical uniformity (Us%). Three emitters type were used under drip irrigation system namely regular gauges, high compensating pressure and low compensating pressure. Three varying tank height including: H1=1m, H2=1.5m and H3=2m.The treatments were laid out in a split plot design with three replications. Results showed that there were significant differences ($P \leq 0.05$) in all tested hydraulic performance parameters and their interactions. Discharge values of interaction consider quite good and found to be within the acceptable range. The highest discharge value was obtained by E2H3 emitter, followed by low compensating pressure with tow meter the least by low compensating pressure with tow meter. For C_V% the highest value was obtained by regular gauges with one meter, followed by high compensating pressure with tow meter it consider acceptable while the least by regular gauges with one meter and high compensating pressure with tow meter it consider excellent. The highest results of AU%, CU%, DU% and Us% value was obtained by high compensating pressure with one meter, followed by low compensating pressure with one meter it consider excellent, while the least of AU%, CU% and Us% was obtained by regular gauges with one meter and high compensating pressure with tow meter it consider fair. The lowest values of DU% and Us% were obtained by high compensating pressure with tow meter and low compensating pressure with tow meter it consider acceptable. Thus the study recommended that it is more efficient to use high compensating pressure (CP) emitters type with one meter tank hight.

Keywords: Drip irrigation, hydraulic performance, emitters, uniformity, tank height

1. Introduction

Drip irrigation (trickle or micro irrigation) is a promising system for economizing the available irrigation water. It is also necessary to manage the available water efficiently for max crop production. Drip irrigation can apply water both precisely and uniformly at a high irrigation frequency compared with furrow and sprinkler irrigation (Hanson and May, 2007). Drip irrigation is taken into account because most efficient irrigation system, but there's proof from literature this technique also can be in-efficient, as a results of water quality, mismanagement and maintenance problems (Koegelenberg *et al.,* 2003). In drip irrigation, water is applied to every plant separately in small, frequent, precise quantities through dripper emitters. It is the most advanced irrigation method with the highest application efficiency (Phocaides, 2000). Drip irrigation system is designed to apply precise amount of water near the plant with a certain degree of uniformity. The uniformity describes how evenly an irrigation system distributes water over a field. It is regarded as one of the important features for selection, design, and management of the irrigation system (Mirjat *et al.,* 2010). The application uniformity basically depends on the uniformity of discharge from the emission devices (emitters). Thus, the design strategy for trickle

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irrigation systems focuses on achieving the desired emission uniformity (Keller and Bliesner, 1990). Emitter plays a crucial role in system performance and the hydraulic performance significantly affected by the optimum selection of emitters, lateral diameter and length, ideal manufacturer‟s coefficient of variation (C_V%), and pressure variations (Bush, 2016). In drip irrigation system, water is delivered precisely through the emitters. The capacity of the emitters available within the market varies from 2 to 16 lph. These are categorized as pressure and non-pressure compensating (Sharma, 2013). Emitters also can be pressure-compensating, which suggests discharge rates remain relatively constant over a variety of pressures (Saskatchewan trickle irrigation manual, 2011). Mohamed Nour, *et al.,* (2017) tested three types of emitters have the trade names of Turbo, Octa and Burrell. Results indicated that the Turbo and the Octa types of emitters are better than the Burrell type of emitter under the three operating pressures. Elamin *et al.,* (2017) reported that the emitter types and operating pressure have profound effect on the uniformity parameters of Drip irrigation system. Hisham *et al.,* (2020) tested three types of emitters have the trade names of regular gauges (RG), high compensating pressure (HCP) and low compensating pressure (LCP). Results indicated that the RG is the best one of emitter's type because it has the highest hydraulic performance as compared other emitters in condition in Gezira state Sudan. The main objective of this work to study the performance of three types of emitters (regular gauge (RG), high pressure compensated (HPC) and low pressure compensated (LCP) under three different tank height (H_1=1m, H_2=1.5m and H_3=2m).

2. Materials and Methods

Experiments were carried out during the season of 2021 at the experimental farm, University of Gezira. It lies north of Wad Medani town, Lat. 14° 06` N, Long. 33° 38` E and altitude of 405 masl. The soil is Vertisol, with a high CEC, a pH of 7.5 and alkaline with low permeability (Alhilo, 1996). The experiment was laid call at a split plot design with three replicates. The main objective of this work to study the performance of three types of emitters (regular gage (RG), high pressure compensated (PC) and low pressure compensated (NCP) under different watertank height (H_1=1m, H_2=1.5m and H_3=2m). Three sorts of emitters commonly utilized in Sudan were selected for the experiment. Two of them were online pressure compensating and the third emitter type was an inline. The performance parameters evaluated include: average discharge (Q_{avg}), discharge variation (Q_{var}%), coefficient of manufacture variation (C_V%), application uniformity(AU%), coefficient uniformity (CU%), distribution uniformity (DU%) and statistical uniformity (Us %).

2.1. Discharge measurement

Average discharge rate was measured using graduated measuring cylinder, catch cans and stopwatch. The model was lifted to work for 10 minutes, and then the collected water in catch cans measured. The test was repeated three times to get the average volume in liter. The average volume divided by time, to obtain the discharge (q) l/hr (Eq. 1).

$$\mathbf{q = V/t} \quad \text{.......} \quad (1)$$

Where:
q = Discharge (L/h)
V = Volume collected (ml)
t = Time taken (hours).

2.2. Discharge variation (Qvar)

Flow variation is additionally a design parameter to gauge a trickle lateral design. The defining equation for flow variation is:

$$\mathbf{qvar = (qmax - qmin)/qmax} \quad \text{.......} \quad (2)$$

Where:
qvar = Flow variation
qmax =maximum emitter discharge rate in system (l/h)
qmin =the lowest emitter discharge rate in system (l/h)

General criteria for Q_{var} values are 10% or less (desirable) and 10 to 20% acceptable and greater than 25%, not acceptable (Guguloth, 2016).

2.3. Coefficient of manufacture variation (CV %)

The CV can be calculated, using the following formula (Burt and Styles, 2007).

CV% = Sq/qavg ……………………………………………………………………………….. (3)

Keller and Bliesner (1990) represented localized irrigation sub-units classification according to coefficient of variations as presented in Table (1).

Table 1: Classification of coefficient of variation

Coefficient of variation, Cv	Classification
> 0.4	Unacceptable
0.4 – 0.3	Low
0.3 – 0.2	Acceptable
0.2 – 0.1	Very good
< 0.1	Excellent

2.4. Application uniformity (AU %)

Equation (4) was wont to calculate water application uniformity (AU), where it depends on the uniformity of water discharge. This equation also gives information on how water distributed efficiently in the field (Jusoh *et al.,* 2020).

AU% = (1.0 − Cv)×100 ………………………………………………………………….……….(4)

Water application uniformity obtained was compared with the general criteria for uniformity value as depicted in Table 2.

Table 2: Percentage of application uniformity (AU %) and its corresponding classification

AU (%)	Classification
< 60	Unacceptable
70-65	Poor
80-75	Fair
90-85	Good
100-95	Excellent

2.5. Uniformity coefficient (CU %)

One of the widely used CU is Christiansen uniformity coefficient. Uniformity coefficients of emitters were tested using the Christiansen„s formula (1942). It gives the knowledge that how efficiently water is distributed within the field.

CU = 100 – (80*Sd/V_{avg}) ………………………………………………………………………… (5)

Where:
CU = Uniformity coefficient (%),
Sd = Standard deviation of observations,
V_{avg} = Average volume collected.

The coefficient of uniformities and classifications is presented by (ASABE standards EP458, 1999) in Table 3.

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Table 3: Classification/standards of uniformity coefficient

Uniformity coefficient, CU (%)	Classification
Above 90%	Excellent
90 – 80%	Good
80 – 70%	Fair
70 – 60%	Poor
Below 60%	Unacceptable

2.6. Distribution uniformity (DU)

Distribution uniformity (DU) was computed consistent with Keller and Karmeli (1974):

$$\mathbf{DU\ (\%) = (q_{avg25\%}/\ )*100} \quad \ldots\ldots (6)$$

Where:
$q_{avg25\%}$ = mean of the lowest 0.25 of emitter discharge.
q = average emitter flow rate (L/h).

According to Merriam and Keller (1978), the classifications of distribution uniformities are expressed in Table 4.

Table 4: Classifications of emission uniformity

Eu (%)	Classification Merriam and Keller (1978)
<70%	Poor
70 – 80%	Acceptable
80 – 86%	Good
86 – 90 %	Good
90 – 94%	Excellent
>94%	Excellent

2.7. Statistical uniformity (Us %)

Statistical uniformity between the emitters is determined by Eq. (7) (Bralts and Kesner 1983).

$$\mathbf{Us= 100\ (1 - Sq/\bar{q})} \quad \ldots\ldots (7)$$

Where:
Us= statistical uniformity (%)
Vq = overall change in emitters discharge
Sq = standard deviation of emitters discharge (l/h)

Statistical uniformity is evaluated according to ASAE (2003) based on the classification criterion presented in Table 5.

Table 5: System classification according to statistical uniformity values

Us (%)	Classification
<60	Un acceptable
60 – 70	Poor
70 – 80	Acceptable
80 – 90	Good
>90	Excellent

2.8. Statistical analysis

Analysis of variance appropriate for split plot design was applied by using Statistics.8 programme.

3. Results and Discussion

3.1. Discharge (l/h)

Discharge (l/h) of the three emitter"s type and watertank height were shown in Fig. (1). There were differences in discharge (l/h) among emitters type. From this Figure it is seen that regular gauges (RG) and high compensating pressure (CP) emitter discharge had a same trend. Discharge rates from the emitters ranged between 3.9 and 8.2 L/h. The highest discharge value was obtained by low compensating pressure (NCP) emitter, followed by (CP) the least by (RG).This result may be due to the fact that inline emitter type (RG) is sensitive to clogging. Hezarjaribi *et al.,* (2008) and Manisha and Tripathi (2015) stated that the discharge flow rate of emitter is increased when the increase of the pressure means the pressure directly affected the discharge rate of emitter. Also, Mofoke *et al.,* (2004) stated that the overall variability in discharge might be attributed to major and minor losses occurring at the delivery pipe joints and fittings right from the supply tank to the emitters.

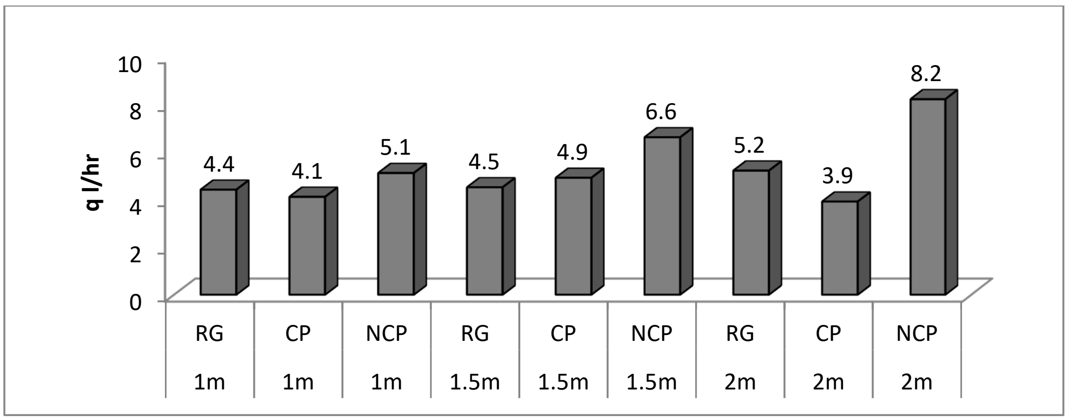

Fig. 1: Discharge (l/h) of the three emitter"s type under three different tank height

3.2. Discharge variation (Q_{var})

Average discharge variation (Q_{var}) was significantly ($P \leq 0.05$) influenced by the emitter"s type and watertank height (Table 1). RG emitter"s had significantly lower Q_{var} than CP and NCP. The general criteria Q_{var} values are ≤10%, desirable; 10-20%, acceptable; and > 20% is not acceptable. The overall performance description for discharge variation was acceptable for all emitter"s type. Manisha and Tripathi (2015) stated that the coefficient of variation is increased when the pressure is decreased means the pressure directly affected the discharge rate of emitter. The effects of watertank height on discharge variation were significant ($P \leq 0.05$). The highest discharge variation was obtained by H3, followed by H2 and the least by H1 (Table 1).

Table 1: Effect of emitter's type and tank hieght on coefficient of variation and coefficient of variation

Treatments	Q_{var}	Classification	Cv	Classification
E1	0.14 c	Acceptable	0.186 a	Very good
E2	0.15 b	Acceptable	0.162 c	Very good
E3	0.16 a	Acceptable	0.167 b	Very good
CV%	0.71		1.12	
SE±	0.0013		0.008	
Sig. L	**		**	
H1	0.149 c	Acceptable	0.129 c	Very good
H2	0.151 b	Acceptable	0.183 b	Very good
H3	0.159 a	Acceptable	0.203 a	Acceptable
CV%	0.29		1.10	
SE±	0.0055		0.007	
Sig. L	**		**	

The interaction effects between emitters type and watertank heights on discharge variation were significant (Table 2). Results showed that E1*H3 recorded the lowest discharge variation, whereas

E2*H3 recorded the highest value. The overall performance description for discharge variation was acceptable.

3.3. Manufactures Coefficient of variation (C_V %)

To decide whether the system was excellent, good and marginal, it was necessary to determine the manufactures coefficient of variation (Pragna *et al.,* 2017). The coefficient of variation was significantly (P≤0.05) affected by the emitters type and watertank height (Table 1). The effect of emitters type and watertank height treatments on coefficient of variation is shown in Table 3. There were significant differences (P≤0.05) among emitters type treatments. The highest values were obtained by E1 (0.186), followed by E3 (0.167) and the lowest by E2 (0.162). The classification of all treatments of emitters type were found to be less than 20 % were very good. The effect of tank height on coefficient of variation was significant differences (P≤0.05). The highest values of coefficient of variation by emitters were obtained by H3 (0.203), followed by H2 (0.183) and the lowest by H1 (0.129). The classification of tank height H1, H2 and H3 were very good, very good and acceptable, respectively.

The interaction effects of watertank height and emitters type on coefficient of variation were significant (P≤0.05) Table 2. The highest values were obtained by E1H1 (0.26), followed by E2H3 (0.25) and the lowest by E2H1 (0.053) followed by E3H1 (0.074). These results were in line with those obtained by Halil *et al.,* (2004) who found that non-compensating emitters widely used in the region had very high manufacturer‟s variations that are classified as unacceptable. Also, Muharrem *et al.,* (2010) determined that emitter coefficient of variation varied in the ranges of 0.43 and 0.63, 0.43 and 0.69, 0.48 and 0.58, 0.56 and 0.73 for unused emitters, for one year, for 2 years and for 3 years used emitters.

Table 2: Effect of interaction between emitter's type and tank height on discharge variation and coefficient of variation

Treatments	Qvar	Classification	Cv	Classification
E1*H1	0.167	Acceptable	0.2605	Acceptable
E1*H2	0.140	Acceptable	0.1635	Very good
E1*H3	**0.116**	Acceptable	0.1345	Very good
E2*H1	0.124	Acceptable	**0.0530**	Excellent
E2*H2	0.147	Acceptable	0.1830	Very good
E2*H3	**0.188**	Acceptable	0.2515	Acceptable
E3*H1	0.161	Acceptable	**0.0740**	Excellent
E3*H2	0.161	Acceptable	0.2035	Very good
E3*H3	0.171	Acceptable	0.2245	Acceptable
SE±	0.01		0.0013	
Sig. L	**		**	

N.S= not significant, *and** significantly different at 0.05 and 0.01 probability levels, respectively. E1=RG emitters, E2= CP emitters, E3= NCP emitters, H1=1m height, H2=1.5m height H3= 2m height

3.4. Application uniformity (AU %)

Application uniformity was significantly (P≤0.05) affected by emitters type and watertank height (Table 3). The highest application uniformity value of 83.8% (Good) was observed at E2 and the lowest application uniformity value of 81.4 (Good) was observed at E1. The classification of all emitters type were found to be good.Water application uniformity express how evenly the uniformity of water is spread over the irrigated area used. Similar result obtained by Ali and Talukder (2008) who tested the performance of a drip irrigation system and located that average uniformity for drip irrigation system under the greenhouse was 80%. Also, Asif *et al.,* (2015) reported that application uniformity was depending on the manufacturing variation in emitters and pressure variation in the system due to pipe friction and elevation changes. Watertank hieght, on the other hand, showed highly significant (P≤0.01) differences in on uniformity coefficient. The largest uniformity coefficient was obtained by H1, followed by H2 and the least by H3. The classification of H1,H2 and H3 were found good, good and fair, respectively.

The interaction effects of emitters type and watertank height treatments on application uniformity were significant (P≤0.01) Table 3. Results indicated that E2*H1 gave highest uniformity coefficient followed by E3*H1, the classification was excellent. On the other hand, E1*H1 produced the lowest uniformity coefficient followed by E3*H3, the classification was fair.

Table 3: Effect of emitter's type and tank height on application uniformity and uniformity coefficient

Treatments	AU%	Classification	CU%	Classification
E1	81.4 a	Good	84.6 c	Good
E2	83.8 c	Good	86.6 a	Good
E3	83.3 b	Good	86 b	Good
CV%	1.12		0.10	
SE±	0.008		0.035	
Sig. L	*		**	
H1	87.1	Good	89.2 a	Good
H2	81.7	Good	84.9 b	Good
H3	79.7	Fair	83.1 c	Good
CV%	1.10		0.27	
SE±	0.007		0.095	
Sig. L	**		**	

N.S= not significant, *and** significantly different at 0.05 and 0.01 probability levels, respectively. E1=RG emitters, E2= CP emitters, E3= NCP emitters, H1=1m height, H2=1.5m height H3= 2m height

3.5. Uniformity coefficient (CU %)

Uniformity coefficient was significantly ($P \leq 0.05$) affected by emitters type and watertank height (Table 4). The highest uniformity coefficient value of 86.6 % was observed at E2 emitters and the lowest uniformity coefficient value of 84.6 was observed in E1. The classification of all treatments of emitters type were found to be less than 20 % were good. Tagar *et al.,* (2010) found that the pressure compensated emitters perform better and manage the pressure losses at different locations along the laterals length, hence could be preferred over micro tube emitters. Also, Alamin (2017) reported that the types of emitters and operating pressures have a clear effect on the performance of drip irrigation system. Shareef *et al.,* (2016) found that the emitter type and water quality are the main factors affecting the hydraulic performance of drip irrigation systems. Watertank height, on the other hand, showed highly significant ($P \leq 0.01$) differences in on uniformity coefficient. The largest uniformity coefficient was obtained by H1, followed by H2 and the least by H3 (Table 3). The classification of all treatments of tank height were found to be less than 20 % were good. Based on these results, they concluded that the operating pressure value has an impact on the uniformity coefficient.

Table 4: Effect of interaction between emitter's type and tank height on application uniformity

Treatments	AU%	Classification	CU%	Classification
E1*H1	73.9	Fair	79.1	Fair
E1*H2	83.65	Good	86.3	Good
E1*H3	86.55	Good	88.4	Good
E2*H1	94.7	Excellent	95.3	Excellent
E2*H2	81.7	Good	85.1	Good
E2*H3	74.85	Fair	79.4	Fair
E3*H1	92.6	Excellent	93.4	Excellent
E3*H2	79.65	Fair	83.2	Good
E3*H3	77.55	Fair	81.4	Good
SE±	0.0013		0.165	
Sig. L	**		**	

N.S= not significant, *and** significantly different at 0.05 and 0.01 probability levels, respectively. E1=RG emitters, E2= CP emitters, E3= NCP emitters, H1=1m height, H2=1.5m height H3= 2m height

The interaction effects of emitters type and watertank height treatments on uniformity coefficient were significant ($P \leq 0.01$) Table 4. Results indicated that E2*H1 gave highest uniformity coefficient followed by E3*H1, the classification was excellent. On the other hand, E1*H1 produced the lowest uniformity coefficient followed by E2*H3, the classification was fair. According to the classification of irrigation system performance by ASAE, a CU rating of 90 - 95% is considered excellent and the system would only require regular maintenance. In general, uniformity coefficient values increased with increasing tank height (H1) for E1 emitters and decrease in E2 and E3 with increasing tank height H2 and H3. This result is confirmed by Rigve *et al.,* (2018) who indicate that average emitter discharge as well as CU of the system increases with increase in head.

3.6. Distribution uniformity (DU %)

Distribution uniformity was significantly (P≤0.05) affected by emitters type and watertank height (Table 5). The highest distribution uniformity value of 76.2 % (acceptable) was observed at RG emitters and the lowest distribution uniformity value of 72.5 (Acceptable) was observed in E3. According to the classification of irrigation system performance by ASAE, a distribution uniformity of 85% or greater is considered excellent. In this study, the average of all values of DU% emitters were acceptable. The reduced uniformity coefficient is due to high variation in flow rates. The results also agreed with the results obtained by Bush (2016) who revealed that uniformity of water application in drip irrigation system was significantly suffering from emitter type. Charles (2004) reported that approximately 45% of the non-uniformity was due to pressure differences, 52% was due to “other causes”, 1% due to unequal. The effects of tank height on distribution uniformity were significant (P≤0.05). The highest distribution uniformity was obtained by H1, followed by H2 and the least by H3. The classification of tank height H1, H2 and H3 were good, acceptable and poor, respectively.

The interaction effects of emitters type and watertank height treatments on distribution uniformity were significant (P≤0.05) Table 6. Results indicated that E2*H1 gave highest uniformity coefficient followed by E3*H1, the classification were excellent and good, respectivly. On the other hand, E2*H3 gave the lowest distribution uniformity followed by E3*H3, the classification were poor.Similar results were also obtained by Sharu and Ab Razak (2020) who found that slope is one of the factors that afects the uniformity of water distribution.

3.7. Statistical uniformity (Us %)

The statistical uniformity was significantly (P≤0.05) affected by the emitters type and watertank height (Table 5). It shows the statistical uniformity for emitters type fell within the a good range as specified by Michael (1978). The effects of tank height on statistical uniformity were highly significant (P≤0.01).

Table 5: Effect of emitter’s type and tank height on distribution uniformity and statistical uniformity

Treatments	DU%	Classification	Us%	Classification
E1	76.2 a	Acceptable	80.9 c	Good
E2	72.7 b	Acceptable	83.3 a	Good
E3	72.5 b	Acceptable	82.8 b	Good
CV%	0.29		0.23	
SE±	0.087		0.076	
Sig. L	**		**	
H1	85 a	Good	86.6 a	Good
H2	70.8 b	Acceptable	81.2 b	Good
H3	65.5 c	Poor	79.2 c	Acceptable
CV%	0.31		0.20	
SE±	0.131		0.069	
Sig. L	**		**	

N.S= not significant, *and** significantly different at 0.05 and 0.01 probability levels, respectively. E1=RG emitters, E2= CP emitters, E3= NCP emitters, H1=1m height, H2=1.5m height H3= 2m height

The highest statistical uniformity was obtained by H1, followed by H2 and the least by H3. The classification of statistical uniformity of tank height H1, H2 and H3 were good, good and acceptable, respectively. These results were within those obtained by Ali and Akbar (2014) in Pakistan it is between 82.8 to 100%. Zamaniyan (2014) reported that performance of micro irrigation systems in Iran is low and poor, the average distribution uniformity, statistical uniformity, and coefficient of variation values in different sites were 52.8, 61.3, and 38.2%, respectively. Most frequent problems detected in irrigation units were: inadequate working pressure and emitters clogging.

The interaction effects of emitters type and watertank height treatments on statistical uniformity were highly (P≤0.01) significant (Table 6). Results indicated that E2*H1 gave highest statistical uniformity followed by E3*H1, the classification were excellent. On the other hand, E1*H1 gave the lowest statistical uniformity followed by E2*H3, the classification were acceptable. These results support by the findings of Sharu and Ab Razak (2020).

Table 6: Effect of interaction between emitter's type and tank hieght on distribution uniformity and statistical uniformity

Treatments	DU%	Classification	Us%	Classification
E1*H1	75.4	Acceptable	73.4	Acceptable
E1*H2	74.1	Acceptable	83.2	Good
E1*H3	79.1	Acceptable	86.1	Good
E2*H1	91.4	Excellent	94.2	Excellent
E2*H2	70.5	Acceptable	81.2	Good
E2*H3	56.2	Poor	74.4	Acceptable
E3*H1	88.3	Good	92.1	Excellent
E3*H2	68	Poor	79.2	Acceptable
E3*H3	61	Poor	77.1	Acceptable
SE±	0.161		0.119	
Sig. L	**		**	

N.S= not significant, *and** significantly different at 0.05 and 0.01 probability levels, respectively. E1=RG emitters, E2= CP emitters, E3= NCP emitters, H1=1m height, H2=1.5m height H3= 2m height

4. Conclusion

The highest discharge value was obtained by E2H3 emitter, followed by E3H3 the least by E1H3. Highest CV%value was obtained by E1H1 emitter, followed by E2H3 it consider acceptable while the least by E1H1 and E2H3 it consider excellent. The highest results of AU% value was obtained by E2H1 emitter, followed by E3H1 it consider excellent, similar results and classification obtained by CU% , DU% and Us% while the least of AU% and CU% was obtained by E1H1and E2H3 it consider fair. The lowest values of DU% and Us% were obtained by E2H3 and E3H3 it consider acceptable.

5. Recommendations

From the results obtained and conclusions drawn from this study the following recommendations can be made:

1. It is more efficient to use high compensating pressure (CP) types of emitters in drip irrigation systems especially under 1m tank height than the other type of emitters.
2. The performance of pressure compensating and non-pressure compensating emitters should be tested under field conditions in large systems.

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