Int. J. Forest, Soil and Erosion, 2014 4 (3): 82-88
ISSN 2251-6387

Research Paper

The estimation of wet bulb dimensions in the drip irrigation by dimensional analysis model

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Abstract: As the dimensions of wet bulb depends on the important parameter such as hydraulic properties of oil, emitters discharge and the period of irrigation, the existed study was done in the GHAEM ABAD region of Kerman in a sand-loamy soil with discharge amount of 4, 8, and 24 lit per hour instead of different periods of irrigation in order to evaluate the ratio of wet bulb advances in the horizontal and vertical directions of oil under the emitters. The field experiment were conducted after the irrigation for determining the maximum diameter and depth of wet bulb in the different period finally, by using the dimensional analysis and BAKINGHAMN Theorem, semi experimental equation were achieved. The resulted equations were analyzed and they were assessed (synonym for evaluate) for evaluation the ratio of accuracy. The results show that the equations have estimated carefully the dimensions of wet bulb and they are useable in the designing of drip irrigation.

Key words: wet bulb, drip irrigation, dimensional analysis

Introduction

The drip irrigation can be used in the per kind of climate of dry, semi dry, semi humid , and even greenhouse position under the plastic cover. In the drip irrigation method, some parts of soil usually become wetted. This amount of wetting depends on miscellanies factors which include discharge of emitter, the distance among the emitters, the distance of laterals from each other, kind of soil, and the slope of land and period of irrigation or volume of water which is left from emitter in per irrigation. The wetted parts which are around per emitter is usually small and it is extended like a upside down bulb in the depth of soil as if under per emitter the volume of soil which is called wet bulb becomes wet. Accordingly, it is necessary that the wetting pattern of soil profile or the volume of wet bulb will be predetermined for per land which should be irrigated with drip method.A.2008.

The movement of water in the soil is one of most important parameters in the designing of irrigation systems. The water advance in the soil from a point source, emitter, and expansion of wet bulb depends on many factors such as soil texture, amount of discharging of emitters, the period of performance and bulk density of soil. The selection of emitter in the drip irrigation method is one of the most important factor of designing because the efficiency of a drip system depends on the selection of emitters and standards of designing and not paying attention to the problem of emitters contribute to decrease of monotony of water distribution, increasing in period of performance of system and permanent replacement of emitters, HOORI and ALIZADEH (2007).

In the drip irrigation systems designing, the simple farm experiment is the most reliable way for determining the ratio of wet barrier advance, shape of wet bulb. The shape of wet bulb depends on the different factors such as texture and layering of soil, water distribution ratio, applied water volume, the distance of the emitters, the initial moisture of soil and slip line, HAGHIGHAATI, 1998.

HAGHIGHAATI, 1998,in order to evaluate the effect of soil kind , discharge , distance and emitter pattern on the wetted surface made a design by three soil texture , three emitter distance , three amount discharge of emitter: 4,8,12 lit per hour , three emitter pattern :one, two , rows , and centralized. The results of this plan showed that the increase in discharge of emitters contribute to increase the percent of wetted surface of soil , and the increase trend according to soil texture and pattern of emitters is different. Also, he presented tables for the soils which were under study for different amounts of discharge and distances of emitters and distances among the rows of plants , so that the percent of wetted surface can be estimated.

Mirzaee et al, 2008 in order to making samples of wetted barrier, they earned equations by effective physical factors on the volume of moisture soil under linear simple borrow and BAKINGHAM Theory and dimension analysis which showed good harmony with the results of experiments as if there is always the possibility of calculation of diameter and depth of wetted surface of soil.

Pelangi and Akhondali, 2008.They evaluated the soil which has sand texture, for estimating the form of wetted barrier which is resulting from a point source, and they measured the maximum diameter and depth of wet bulb in different times after beginning of irrigation instead of per discharge. Thus, the semi-experimental equations were earned with the assistance of physical factors which dominate the movement of water in the soil in the drip irrigation, under a drip source and Buckingham Theory and dimension analysis.

Schwartzman and Zur, 1986.They were the first persons who have significant studies in the area of wet bulb dimensions estimation and determination of distance between the emitters. They evaluated the volume form of wetted soil under drip irrigation, and they presented experimental equations. Also, they earned coefficients for these equations on the basis of experiments and solutions of two dimension flow equations. Moreover, they showed that the ratio of width to depth of wetted soil, with increasing in amount of hydraulic conduction of soil tended to decrease and increasing in amount of depth of applied water will decrease the ratio of width to depth, particularly in the soils with fine texture is significant.

$$d = 1.32k_s^{(-0.33)}\, q^{(0.33)}\, z^{0.35}$$

Thorburn et al, 2003.They concluded that among the distance of drip irrigation, the ratio of flow, the moisture characteristics of soil and period of irrigation should be a harmony in the drip irrigation for improvement of efficiency of consumption water and mineral material.

Li et al, 2004.They studied on the sandy and loamy soils and they recorded the replacement situation of the wet barrier on the soil surface and in vertical surface in the different times in the period of examination. Therefore, they saw that wet patterns which are determined according to wet radius r, and depth of wetting, z, from a drip source, and they presented equations which are effective for determination of this wet dimensions for estimating of essential period of irrigation in order to achieving radius and depth of wetted with selection of amount of discharge for a certain soil.

Thabet and Zayani 2008.They studied the effect of emitter discharge: 1.5 and 4 lit per hour on the wetted patterns in sandy-loamy soil and they achieved equations in order to determination of ratio of wet barrier advance in different directions.

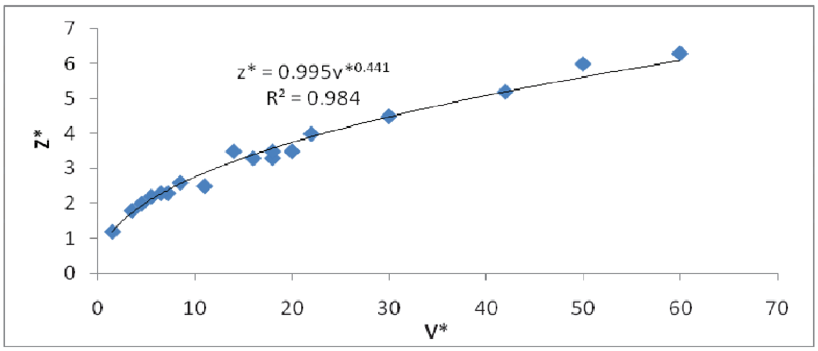

Figure 1. The equation of dimensionless numbers of V*and Z*

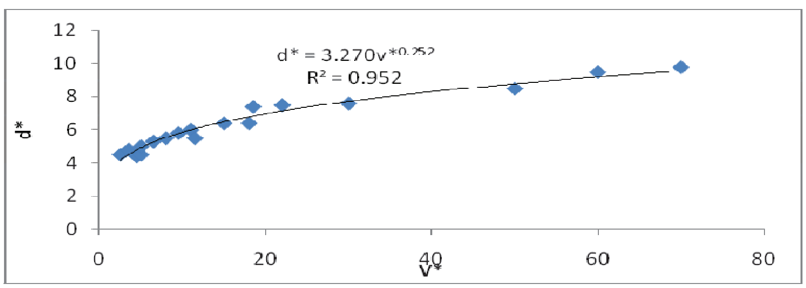

Figure 2. The equation of dimensionless numbers of V*and d*

Acer et al 2009 they examined the effect of discharges: 2 and 4 lit per hour on amount of vertical and horizontal advance of wet barrier in the soil which have loamy- sandy soil and they saw that different values of discharge of emitter have no significant impact on horizontal and vertical movement on the wet barrier ,but the application of different values of water has significant effect on vertical movement of wet barrier; also, increase of water irrigation volume cause the growth of vertical movement and it has no effect on horizontal movement inside of soil profile and horizontal movement on the soil surface.

In this study, not only the amount of emitter discharge, applied water volume, hydraulic characteristics of soil but also the period of irrigation which is not in the model of Schwartzman are considered for evaluating the effective factors on the advance of wet barrier in a soil with sandy-loam texture. In the next step equations are presented in order to determine the dimensions of wetted plan of soil, the wetted depth and diameter, by dimensional analysis technique. Finally, by using the equations, the amount of depth and wetted diameter of wet bulb instead of different period of irrigations can be determined according to applied discharge of emitters.

The Theory of research

The plan of soil profilewettingby a source point, emitter, which is called wet bulb, has an important role in the designing of drip irrigation, and it has effect on the amount of irrigation water. In fact, the first step for guarantying the irrigation performance is the determination of advance ratio of wet barrier in the horizontal and vertical directions.

For knowing the effective parameters on an event dimensional analysis is a suitable method when the relationships between the parameter are not determined.

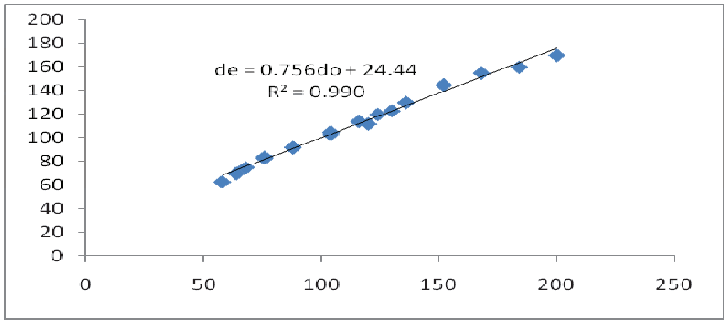

Figure 3. The equation of amounts of measured, do, and estimated, de, diameter

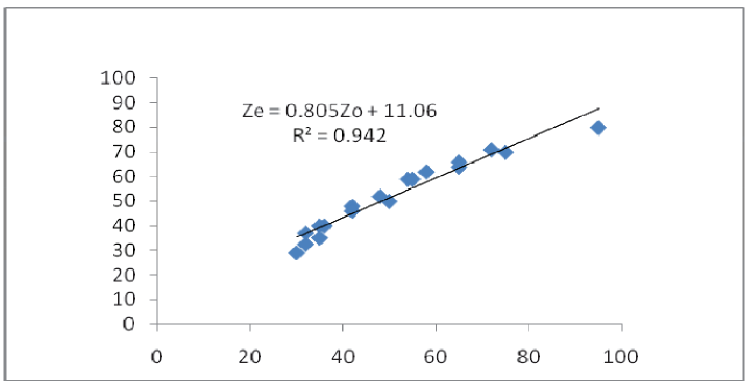

Figure 4. The equation of amounts of measured, zo, and estimated, ze, depth.

Backingham theorem (1914) is one of the most important theorems in the fluid mechanic. In this theorem, if a process has K dimensional parameter, it can be decreased to an equation with k-r independent dimensionless parameter where ris minimum number of required reference dimension for presenting the variations. Dimensionless parameters are calledπ. The first step in the dimensional analysis, is determining the variations which are in the process. The following equation can be used according to the mention explanations:

$f(d, z, v, k_s, T)$

$q = (L^3T^{-1})$

$v = (L^3)$

$d = (L)$

$t = (T)$

$k = (LT^{-1})$

Where

If there are 6 dimensional variations, (d, z, v, q, k_s, T), and two main dimensions of (L, T), there are k-r dimensionless number. Then, in the basis of Backingham π theorem for achieving the dimensionless equation cab be performed according to the following form:

$f(d, z, v, q, k_s, T) \quad k = 6, r = 2 \quad k - r = 4$

(q, k_s): $The\ repeated\ variables$

In the next step, the following equations can be written with forming the dimensional equations:

$$\pi_1 = q^{a}.k_s^{b}.d$$
$$\pi_2 = q^{c}.k_s^{d}.z$$
$$\pi_3 = q^{e}.k_s^{f}.v$$
$$\pi_4 = q^{g}.k_s^{h}.T$$

Then, all dimensions of l variables reference should be written:

$$L^0T^0 = (L^3T^4)^{a1}.(LT^4)^{a1}.L^a$$

L: $\quad 0 = 3a_1 + b_1 + 1$

T: $\quad 0 = -a_1 - b_1$

With solving the aboveequation$a = -\frac{1}{2}, b = \frac{1}{2}$, soπ:

As these numbers are dimensionless, they are shown with star index

$$\pi_1 = d\left[\frac{k_s}{q}\right]^{\frac{1}{2}} \qquad d^* = d\left[\frac{k_s}{q}\right]^{\frac{1}{2}}$$

$$\pi_2 = z[\frac{k_s}{q}]^{\frac{1}{2}} \qquad z^* = z[\frac{k_s}{q}]^{\frac{1}{2}}$$

$$\pi_3 = v[\frac{k_s}{q}]^{\frac{3}{2}} \qquad v^* = v[\frac{k_s}{q}]^{\frac{3}{2}}$$

$$\pi_4 = T\frac{(k_s)^{3/2}}{(q)^{\frac{1}{2}}} \qquad T^* = T\frac{(k_s)^{\frac{3}{2}}}{(q)^{\frac{1}{2}}}$$

In order to finding equation between the dimensionless parameters (Zur, B.1996), the amounts of d^*,z^*were drawn instead of amounts of v^* , the following equations were concluded:

$$d^* = A_1 * V^{n1}$$
$$z^* = A_2 * V^{n2}$$

The amounts of n1, n2, A_1, A2 are the constant factors which are concluded by farm experimental or numerical simulation. The combinations of previous equations provide the following equations:

$$d = A_1 k_s^{\left(\frac{3}{2}n_1-\frac{1}{2}\right)} q^{\left(\frac{1}{2}n_1+\frac{1}{2}\right)} t^{n_1}$$

$$z = A_2 k_s^{\left(\frac{3}{2}n_2-\frac{1}{2}\right)} q^{\left(\frac{1}{2}n_2+\frac{1}{2}\right)} t^{n_2}$$

These equations show the amount of wetted diameter and depth as a function of volume of irrigation water, emitter discharge, hydraulic conductivity of soil, and period of irrigation. The determination of the constant coefficient of these equations will be discussed.

Table 1. The results of measured physical properties of the soil

The depths of making samples)cm(	Sand (%)	Clay (%)	Silt (%)	Soil texture	The sodium absorption ratio (SAR)	ρb (gr/cm^3)	PH	EC (ds/m)
0-30	65/6	8/60	25/80	Sandy-loam	8/07	1/73	8/09	1/92
30-60	54/00	17/40	28/60	Sandy-loam	8/76	1/70	7/88	5/30
60-90	50/00	11/00	39/00	loam	12/85	1/72	7/70	10/73
90-120	71/00	5/00	24/00	Sandy-loam	10/67	1/75	7/66	8/15

Table 2. The parameters of variation equation of maximum vertical advance of wet barrier with the period

equation	A	n	R
$d^*=A_1v^{*n1}$	**3.27**	**0.252**	**0.975**

$z^*=A_2v^{*n2}$	**0.995**	**0.441**	**0.991**

Materials and Methods

The available researchwas done on July of 2010 on a soil which has sandy- loam texture around the city of Kerman and GHAEME ABAD region that has 57^0, 07' eastern longitude and 30^0, 18' northern latitude. The climate of this region which has 140 mm average annual rainfall and the average of temperature on Jul is 28^0c, is dry.In order to achieving soil texture which has effect on developing of wetted pattern, making samples from soil in different depths: 0-30, 30-60, 60-90, 90-120 Cm was done.The conclusions of measurement of texture percent of soil and physical and chemical characteristics of soil which is under study are collected. (Table1). The amount of hydraulic conductivity of soil is 0.3m.hr^{-1}.Three types of emitter were selected, and they have different discharges: 4,8,24 lit per hour.

Three rows of polyethylene pipe which have certain distance with considering three amount of discharge emitter were put on the soil surface for per step of examination, and the emitters were installed on the pipes.

After finishing of period of irrigation of per series of emitters, the flounce of that bifurcation broke off. After passing 24 hours from interruption of flow that the gravity water was existed, the soil moisture arrived in the farming capacity, and the measurement of ratio of horizontal and vertical movement of wet barrier in the profile soil was done as thought with creating a vertical cut from the installation of the emitter to the end of wet bulb.

Finally, the maximum amount of diameter and depth of wet bulb instead work-hours of emitter for related calculations in the next steps of research were chose.

Table 3. The comparison of the amounts of measured, z_o, and estimated, z_e, depth of wet barrier

Row	**q (lit/hr)**	**t (hr)**	**V_w (lit)**	**Z_o (cm)**	**Z_e (cm)**	**Relative error (%)**
1	4	4	16	33	32/5	-1/5
2	4	8	32	36	40	-11
3	4	12	48	42	48	-14
4	4	16	64	54	59	-9
5	4	20	80	65	66	-1/5
6	4	24	96	72	71	1/4
7	8	2	16	30	29	3
8	8	4	32	32	37	-15
9	8	6	48	35	40	-14
10	8	8	64	48	52	-8
11	8	10	80	55	59	-7
12	8	12	96	65	64	1/5
13	24	1/5	36	35	35	0
14	24	3	72	42	46	-9
15	24	4/5	108	50	50	0
16	24	6	144	58	62	-6
17	24	7/5	180	75	70	6
18	24	9	216	95	80	15
RMSE			4/9			
The results of regression			$Z_e= 0.805Z_o+11/06$ $R^2 = 0.942$			

After collecting and acquisition of data, the statistic calculations were done and equations in order to determine the vertical and horizontal advancing of wet barrier with aid of dimensional analysis so that with the assistance of these equations the ratio of depth and diameter of wetted soil instead of different periods of irrigation will be determined after the irrigation. Finally, the evaluation of results was conducted with statically parameter and comparison between the measured and estimated amounts by the dimensional analysis.

Results and Discussion

The amounts of d^* and $z*$ were drawn against v^* for determining the coefficient of equations of 1 and 2.Then, the coefficients were achieved by regression and fitting of the best graphs.Table2.Also, the graph of resulted equations are shown. Fig 1 & 2

With putting the resulted coefficients in the dimensionless equation of d & z the following equation will be achieved:

$$d = 3.27k_s^{(-0.122)}q^{(0.374)}t^{0.252}$$

$$z = 0.995k_s^{(0.16)}q^{(0.28)}t^{0.441}$$

Where

D: The maximum wetted diameter of the soil (m)

Z: The wetted depth of the soil (m)

Q: The emitter discharge (m^3/s)

K_s: hydraulic conductivity of the soil (m/s)

T: The period of irrigation (s)

By these equations, the amount of wetted depth and diameter of the soil can be determined instead of different discharges in per moment after the irrigation.

Table 4. The comparison of the amounts of measured, Do, and estimated diameter of wet barrier.

Row	q (lit/hr)	t (hr)	V_w (lit)	D_o (cm)	D_e (cm)	Relative error (%)
1	4	4	16	56	63	-8
2	4	8	32	68	75	-10
3	4	12	48	76	84	10
4	4	16	64	88	92	-4
5	4	20	80	104	103	0/96
6	4	24	96	124	120	3
7	8	2	16	64	70	-9
8	8	4	32	76	83	-9
9	8	6	48	88	82	-4
10	8	8	64	104	105	-0/96
11	8	10	80	116	114	1/7
12	8	12	96	130	123	5
13	24	1/5	36	120	112	6
14	24	3	72	136	130	4
15	24	4/5	108	152	140	4/6
16	24	6	144	168	155	7
17	24	7/5	180	184	160	13
18	24	9	216	200	170	15
RMSE			10/8			
The results of regression			$D_e = 0.756\ D_o + 24.45$ $R^2 = 0.990$			

The different amounts of wetted diameter and depth which are measured in the farm were compared with the achieved wetted depth and diameter from the equations of 5 & 6 instead of different amounts of emitter and period of irrigations in the separate table. Also, the relative error, root mean square error, RMSE, linear regression, and correlation coefficient, R^2, were calculated.Also, the amount of relative error for estimating the wetted diameter was between 0.96 to 15 Percent, 6.7 percent in average, and 55 percent of cases estimated the amounts of model more than actual amounts.

Also, the amount of relative error for estimating the wetted diameter was between 0.96 to 15 Percent, 6.7 percent in average, and 55 percent of cases estimated the amounts of model more than actual amounts.
TORABI and SADREGHAEN estimated the amount of error about 30 percent in the different texture of soil, but they achieved minimum zero percent of error in their calculations.
Also, Risse and chesnesee achieved the amount of error about eleven to nineteen percent for estimating the wetted radius by an emitter in a soil by sandy loom texture. Moreover, Pelangi and AkhondAli achieved the amount of error about 5.8 percent for wetted diameter and depth.

The RMSE amount shows the relative efficiency of model such that how much is gap between the estimated amounts and the regarded measured amounts whether they are less or more.
These mention amounts for depth and diameter of wet bulb achieved 4.9 and 10.8 respectively. TORABI and SADREGHAEN estimated RMSE about 10, and PELANGI and AKHOND ALI achieved it 3.6 and 3.8 respectively AS RMSE con not shows actually the efficiency of models, the correlation coefficient, R^2, Can be a better choice, and it is better to use these criteria's together.

The amount of correlation coefficient which is between the depths and measured diameter with the estimated amounts by the model are shown in the graphs. (5 & 4). As it is shown the coefficient is 0.942 and 0.990 for wetted depth and diameter, and if they are compared with the amounts of 0.999 and 0.992 for diameter and Z respectively (Mirzaee et al.), 0.992 for both of them Schwartzman and ZUR , 0.962 and 0.936 for depth and diameter PELANGI & AKHONDALI, they have small gab. Accordingly, the model has a high quality in estimating the case parameters.

Conclusion

According to the evaluated information, in the drip irrigation designing, estimation of wet bulb dimensions, which is the amount of wetted diameter and depth , is important because the ratio of wetted diameter should be as much as to provide the required moisture for the root of plan. Also, the determination of wetted diameter is necessary for finding the distance which should be considered between the emitter.

The distance between the exhausts, the severity of flow, and period of irrigation should choose in the way that the wetted volume of soil become close to the root of plan. Hence, knowing of shape and volume of wetted soil under the emitter are necessary for satisfying the water requirement, optimized management and increasing the efficiency of irrigation. Whether the desired area in the oil is wetted by the emitter or not, the wetted plan is necessary in order to determine the distance between the emitters.

As the mention equations in this study, which are achieved according to the field experimental results and dimensional analysis technique, the dimensions of wet bulb are estimated according to the effective parameter in the equation, and they can be used in the drip irrigation.

According to the presented equation in this study, the ratio of wetted depth of soil instead of different period of irrigation with considering the applied discharge can be determined. Then, the distance between the emitter can be determined according to the area which becomes wetted by the emitter with a certain discharge. Finally, the wetted depth ratio of wet barrier can be achieved instead of different period of irrigation and different amount of discharge in the experiment.

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