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Measurement of vertical water percolation through different soil textures of paddy field during rice growth season

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ABSTRACT

The water percolation loss beyond root zone in the soil is one of the important parameters to determine water requirement of rice plant. If the amount of water percolation rate into the soil is estimated more carefully, determination of water requirement will be evaluated better and designing for system of irrigation, drainage and related establishments will be more easily done. The purpose of this research is determination the amount of irrigation water losses via vertical percolation in the paddy soils in rice growth duration. This study was carried out in a randomized complete block design (RCBD) with three replications in different areas of Guilan province in 1999. Seven areas which were different in the surface soil texture especially on their clay content or other particle size distribution were selected. For determining of water losses as vertical percolation was used quick method. The soils were sampled contemporary and the effects of some soil physical parameters on vertical percolation were studied too. The soil textures were consisted of: Sandy Loam, Loam, Clay Loam, Silty Loam, Clay and Silty Clay Loam. The results have shown that some physical parameters such as bulk density and particle size distribution especially clay content and sand fractions can be significantly effective on the amount of vertically percolated water. The values of adjusted determination coefficient of linear and nonlinear regressions (adj. R2) for above variables on vertical percolation for bulk density, clay, and sand percentage were 0.32, 0.91 and 0.79 respectively. The mean comparison of vertical percolation showed four different classes of vertical percolation at the 5% level by DMRT: Class I- Very high vertical percolation with 0.73 cm.day-1 or higher, in extremely light soil textures with clay contents less than 8%. Class II- High vertical percolation with 0.54 cm.day-1 in light soil textures with 8 -16% clay content. Class III- Medium vertical percolation with 0.32 cm.day-1 in medium soil textures with 16 - 44% clay content. Class IV- low vertical percolation with 0.15 cm.day-1 in heavy soil textures with more than 44% clay content.

Key words: Percolation, seepage, rice field, puddling, soil texture, particle size distribution, bulk density.

INTRODUCTION

Rice is the second main crop consumed in Iran, after wheat. The production of paddy rice in Iran is currently around 2,000,000 tons from a cropped area of 533,000 hectares, all of which irrigated (FAO). Paddy rice is best grown on clayey which are almost impermeable to reduce percolation losses. Rice could also be grown on sandy soils but percolation losses are high unless a shallow water table can be maintained. Loamy soils are preferred with basin irrigation to avoid water logging (permanent saturation of the soil). Basins of different dimensions are the adopted systems for irrigation rice in Iran. Irrigation is based on a continuous and rotational flooding throughout the growth period so that soil reaches saturation limits, except during harvesting when flooding stops. At the irrigation network level, water is distributed approximately every 4 days on a rotational basis. The depth of water applied each time ranges between 5 and 8 cm. In addition, soil texture and quality in the Northern provinces result in lower wastage of water through percolation compared to the other provinces, which results in significant differences in water efficiency (FAO, 2003).A wide range of studies have shown that the rate of seepage and percolation (S&P) in lowland rice soils is greater for light soils than for heavy ones. Mean seepage and percolation rates for Philippine field areas are about 2 mm. day-1 in the wet season, and 4 mm. day-1 in the dry. Water moves out of the root zone by uptake through the crop, and through seepage and percolation beyond the root zone, which is the primary concern of this paper (Wicham, 1978). Percolation represents the rate of the vertical movement of water beyond the root zone to the water table, while lateral seepage represents the rate of the movement of subsurface water between fields (Huang et al ., 2003). Traditionally, rice is grown under continuous ponded paddies and as a result a large amount of water (about 1500 mm, except land preparation) is required due to high seepage and percolation losses (Islam, 1990) during the growing season.

In principle, percolation refers to the vertical movement of water beyond the root zone to the water table, while seepage is the lateral movement of subsurface water (International Rice Research Institute, 1965). In practice, the two are difficult to separate because of transition flows, which cannot clearly be classed as either seepage or percolation (Wicham, 1978). There are many aspects of soils that influence the seepage and percolation rates beyond the root zone (the top 25 to 30 cm of soil in most lowland conditions). They include soils properties such as texture, shrinkage and cracking, soil compaction, bulk density, mineralogy, salt concentration, organic matter, and management factors such as flooding and water depth, puddling, water table control, distribution of rainfall, and soil amendments and subsurface barriers (Datta, 1981; Wicham, 1978). Soil texture has a strong influence on the magnitude of seepage and percolation losses (Wicham, 1978). Where the soil is heavy and the water table is close to the soil surface, percolation losses are low, about 1 mm/day or less. Where soil is light and the water table is deep, percolation losses may be high, about 10 mm/day or more. If percolation rates are high, it is difficult to maintain a saturated or flooded soil (Datta, 1981). The effects of structure in wet soils are closely associated with puddling of the soil and are included in the section dealing with bulk density, mineralogy, soil salts, organic matter, and puddling (Wicham, 1978). Increased bulk density reduces percolation losses of water through no puddled soils (Ghildyal, 1969). Puddling is considered to be a pre-requisite for successful rice production as its strong influence on percolation losses and enhancing characteristics of water use efficiency (Sanchez, 1973). After puddling, intermittent irrigation is recommended for rice production due to its higher water use efficiency rather than continuous submergence (Islam, 1990). Puddle soils often crack when dry and these cracks are a major problem for intermittent irrigation practices (Luthin, 1982). The infiltration equals the summation of the lateral seepage and percolation. In field studies of percolation, vertical losses through a plow layer can be measured using various infiltrometer and lysimeter techniques (Huang et al., 2003).

The lateral seepage could be greatly reduced by maintaining shallow depths of water in a flat paddy rice field (Walker, 1984).
The main objectives of this study were as following:
Determination of amount of water irrigation losses by percolation and seepage in Guilan province paddy fields with different soil textures.
Effect of some particle size distributions on vertical percolation and lateral seepage.
Effect of some other physical parameters (such as bulk density, water table, and etc) on vertical percolation and lateral seepage.
Modeling of percolation and seepage losses for pounding condition of paddy fields.
Determination of water irrigation requirements based on soil textures having amount of percolation and seepage rates.

Materials and Methods

This study was carried out in 1999 at the rice fields of Guilan province. The treatments were arranged in a randomized block design (RCBD) with three replications. The soil textures were sandy loam, loam, silt loam, silt clay loam, clay loam, silt clay, and clay.
In this study were chosen seven paddy field areas from Guilan those had different textures or different particle size distribution and bulk density. In each place, they were used three instruments of Quick method were used for determination of percolation and seepage during the rice growth season as three replicates. Each quick method instrument (Fig.1) had a sharpened cylindrical metal sleeve of known dimensions is driven into the soil (Loveday, 1974) by a known depth on each place. Then the storage tank was filled by water. The reduction in the height of water level in the transparent plastic pipe on the top of metal cylinder was measured by a scale attached on the benchmark and beside the transparent plastic pipe. After setting the metal cylindrical sleeve up into the soil and preparing it on the experimental field, the height of water in transparent plastic pipe were recorded in different times (by minutes) along two-three hours. The amount of percolation and seepage was calculated by recorded data and following formula:

$$P\left({}^{Cm}\!/_{day}\right) = \left(\frac{a}{A}\right) \times \left(\frac{2.3L}{t_2 - t_1}\right) \log\left(\frac{h_1 + L}{h_2 + L}\right) \times 86400$$

Where:
P= The intensity of percolation into the soil (cm/day)
a= The area of transparent plastic pipe (cm2)
A= The area of metal cylindrical sleeve (cm2)
L= The length of metal cylindrical sleeve that is driven into the soil (cm)
hn= The water height in transparent cylindrical pipe at the tn time (cm)
tn= The time for recording of water height in the transparent cylindrical pipe (Sec)

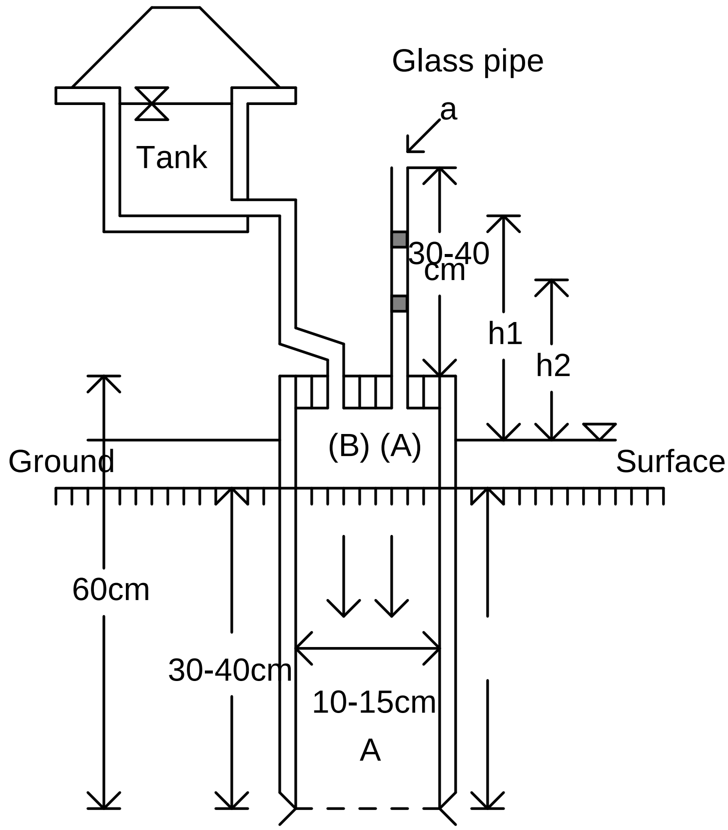

Figure.1: The schematic of quick method instrument for this study

Results and discussion:

Table (1) has shown the data of some soil physical properties in the root zone duration the rice growth season or after puddling in the different areas of Guilan province. It is observed from the table that the soil bulk density are varied at least 0.68 to 1.27 gr/cm3. Amount of bulk density depends to degradation of soil structure by puddling and on the amount of soil particle size distribution. Most important is that in expansive soils (soils that swell on wetting and shrink on drying) bulk density is depended on water content. Swell- shrink potential varies greatly between soils. To compare between sites, or between different areas of one site, samples must be collected at one water content, or over a similar range of water contents (D. Mc Garry). The rangees of the sand, silt and clay contents were 4- 65%, 28- 57%, and 7- 50% in different areas respectively.

Table 1: Some soil physical parameters were measured duration rice growth season At the soil depth of 0- 35 cm

Location	Rep.	Percolation (cm/day)	Clay (%)	Silt (%)	Sand (%)	Texture	Bulk density (gr/cm^3)
A	1	0.11	50	39	11	C	0.90
	2	0.11	48	40	12	C-Si.C	0.92
	3	0.21	47	41	12	Si.C	0.88
B	1	0.15	42	52	6	Si.C.L	0.87
	2	0.12	43	51	6	Si.C- Si.C.L	0.85
	3	0.19	44	52	4	Si.C	0.86
C	1	0.77	8	29	63	S.L	0.82
	2	1.17	7	28	65	S.L	0.81
	3	0.61	9	28	63	S.L	0.84
D	1	0.27	25	47	28	L	0.68
	2	0.29	24	43	33	L	0.69
	3	0.40	24	40	36	C- C.L	0.70
E	1	0.42	10	33	57	S.L	1.27
	2	0.70	12	35	47	S.L	1.26
	3	0.49	8	34	58	S.L	1.24
F	1	0.24	26	55	19	Si.L	0.71
	2	0.39	26	57	17	Si.L	0.70
	3	0.26	30	56	14	Si.C.L	0.70
G	1	0.62	15	28	57	S.L	0.82
	2	0.27	15	28	57	S.L	0.80
	3	0.34	17	31	52	S.L	0.83

A= Rice Research Institute of Iran

B= Soil & Water Station
C= Khomam
D= Lashte- Nesha
E= Lifshagard
F= Vishgah
G= Farshom

Table 2: Linear and nonlinear regression equations of different parameters with the vertical percolation (cm.day-1)

variable	unit	equation	Adj. R^2
bulk density	gr/cm^3	Per= -0.3131+ 0.8 (X)	0.32 **
clay	%	Per= 0.893- 0.033X+ $0.0004X^2$	0.91 **
sand	%	Per= 0.17+ $0.00013X^2$	0.79 **

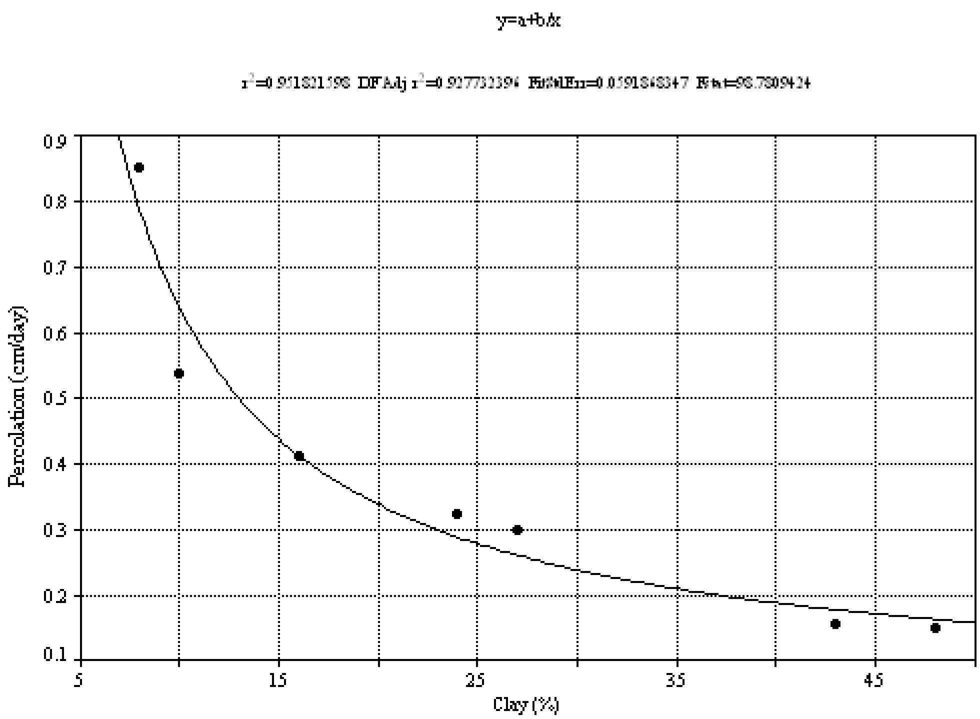

Figure 2: The study areas in the Guilan province map

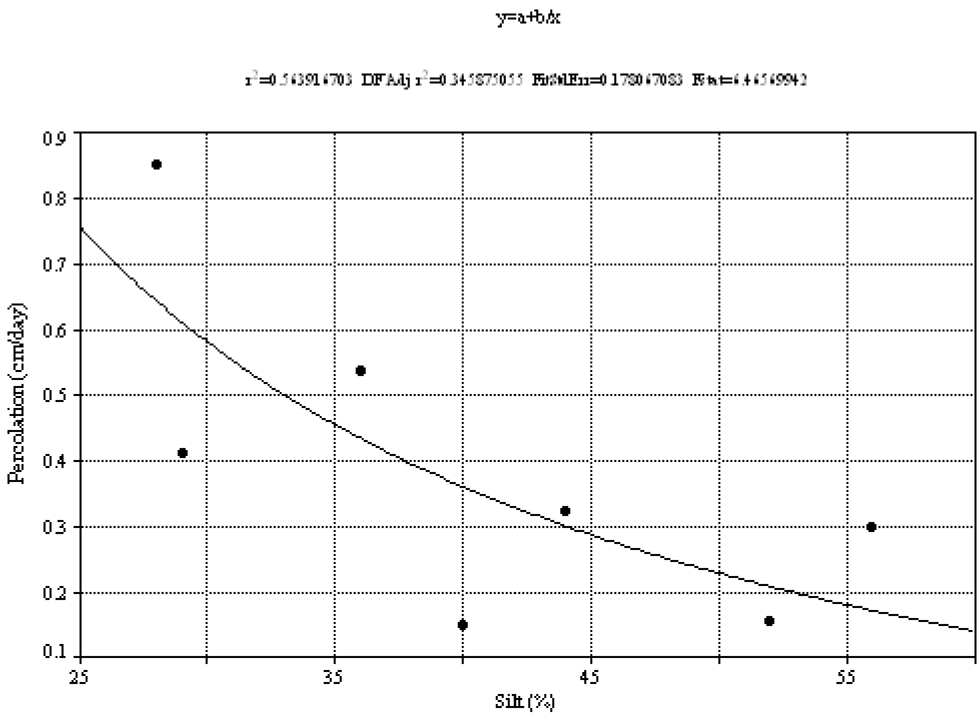

Figure 3: The curve of relation between vertical percolation and Soil clay content duration rice growth season (depth 0- 35cm)

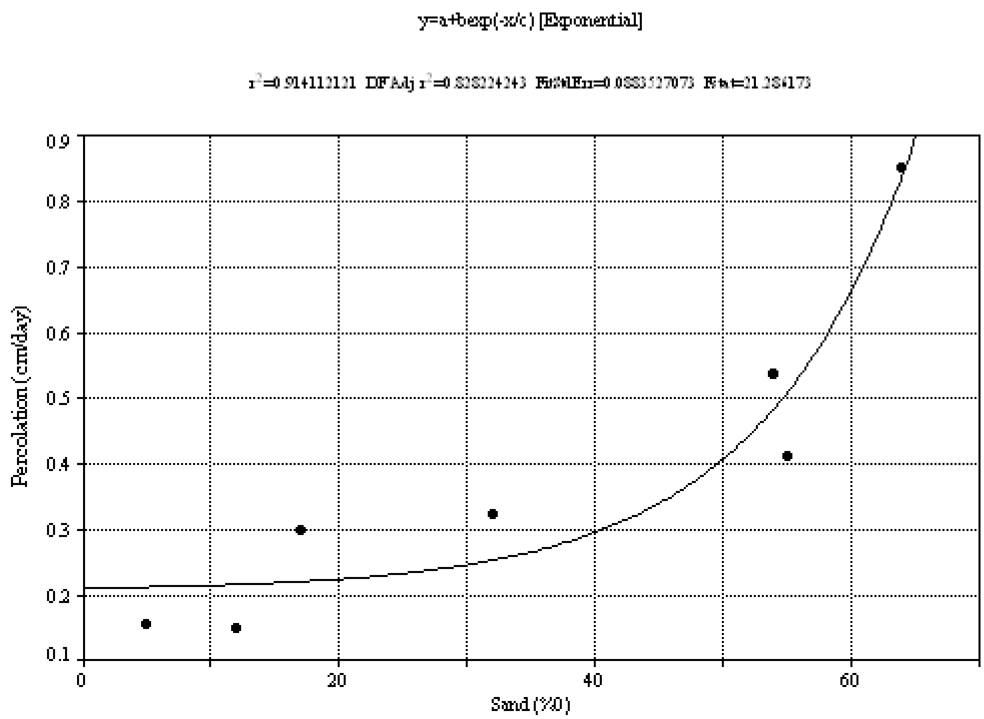

Figure 4: The curve of relation between vertical percolation and Soil silt content duration rice growth season (depth 0- 35cm)

Table 3: Analysis variance for vertical percolation Duration rice growth season (cm.day-1)

SV	DF	SS	MS	F
Location(%clay)	6	0.7968	0.1328	18.72 **
Error	14	0.9930	0.0071	
Total	20	0.8961		

Table 4: Mean comparisons for vertical percolation (cm.day-1) duration rice growth season by DMRT at the 5% level

clay%	rank	mean
≤ 8	1	0.7326 a
10	2	0.5366 b
16	3	0.4005 bc
24	4	0.3204 c
28	5	0.2972 cd
44	6	0.1512 d
> 48	7	0.1460 d

The soil textures for these areas varied and there were different textures including sandy loam, loam, silty loam, silty clay loam, clay loam, silty clay, and clay for 0- 35 centimeter of soil surface depth (table 1). There were nearly some similar textures in these areas, but their vertical percolations and seepages were different together by means of particle size distribution and or bulk density. A significant negative relationship was found between the clay fraction and vertical percolation (adj. R2= 0.91), whereas a significant positive relationship between the sand fraction and vertical percolation (adj. R2= 0.79) was found. The measured vertical percolations were between 0.11 cm.day-1 to 1.17 cm.day-1 by heavy soils to light soils respectively. Therefore, the sum water losses for a period of rice growth season, about 120 days is calculated about 1320 to 14040 m3. hec-1. 120 days-1.

These waters can be reuses by down fields by seepage or can be losses beyond the root zone and can be unavailable for rice. The linear regression were calculated for some soil parameters as a variable including: bulk density, pH, EC, %O.C, and soil particle distribution or sand, silt, and clay fractions, but there was only a linear regression between bulk density and vertical percolation (table 2), however its adj. R2 was very low (adj. R2= 0.32). The relationship between soil surface clay fraction and vertical percolation was as a decreasing quadratic equation (adj. R2= 0.91). In fact, these relationships show that the clay fraction can be affected vertical percolation in the paddy fields. The vertical percolation decreased by increase of clay fraction and it nearly arrives to a constant level (Fig. 2). The relationship between vertical percolation and the sand fraction (Fig. 3) was as an increasing quadratic equation (adj. R2= 0.79).

The mean comparisons between vertical percolation and soil clay fraction were showed (table 3) that there are nearly four texture classes for vertical percolation. This table also shows that there were significant differences between amount of clay fraction about 8 percent or less to a clay fraction about more than 44 percent. The vertical percolation for a clay fraction 8 percent or less is higher than a soil with more clay content. Then, the vertical percolation was decreased by increasing of clay content in the soil.

The mean comparison of vertical percolation showed four different classes of vertical percolation at the 5% level by DMRT:

Class I- Very high vertical percolation with 0.73 centimeter per day or higher, in extremely light soil texture with clay content less than 8%.

Class II- High vertical percolation with 0.54 centimeter per day in light soil texture with 8 -16% clay content.

Class III- Medium vertical percolation with 0.32 centimeter per day in medium soil texture with 16 - 44% clay content.

Class IV- low vertical percolation with 0.15 centimeter per day in heavy soil texture with more than 44% clay content.

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