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Lateral Seepage, Deep Percolation, Runoff, and the Efficiencies of Water Use and Application in Irrigated Rice in Koshkak Region in Fars Province, I. R. Iran

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ABSTRACT- Due to continuous flooding, irrigation management of rice (*Oryza sativa* L.) is very important, particularly in semiarid and arid regions where water is scarce. Rice plantations in I. R. Iran are located mainly in the humid; north, however, it is also grown in arid and semiarid areas of the country, including the Fars province, in the south. In this province, nearly 55000 ha of rice is grown under irrigated conditions. Therefore, research on proper irrigation management has significant impacts on crop and water use efficiency production. The present research was conducted in Kooshkak Agricultural Research Station of Shiraz University in 1997 and 1998 to determine lateral seepage, deep percolation, runoff, irrigation application efficiency and water use efficiency for irrigated rice. The cultivar used was a short season local cultivar, namely Champa-Kamfiroozi, commonly planted by most of the farmers in the studied area. For measuring deep percolation, a pair of cylindrical shape lysimeters, with a 56 cm diameter and a 100 cm height, were used in three locations in the rice field. In each pair, one of the lysimeters was bottom-less to allow for deep percolation. Thus, difference in water used in the two lysimeters was due to deep percolation. For measuring the inflow and outflow of water, 90 degree triangular weirs were used in the entrance and exit of the experimental plot, respectively. The difference between total water used in the field (measured by weirs) and actual evapotranspiration (measured by lysimeter) was considered as sum of lateral seepage and deep percolation. Subtraction of deep percolation from this sum showed lateral seepage. The amounts of daily deep percolation and lateral seepage were 3.4 mm and 0.19 m d^{-1} m^{-1} in 1997, respectively. These amounts were 3.5 mm and 0.22 $m^3 d^{-1}$ m^{-1} in 1998, respectively. Surface runoff which was the main source of water loss was 6.15 and 8.30 mm d^{-1} in 1997 and 1998, respectively. In order to investigate the effect of reusing surface runoff, application efficiency was calculated for both cases of runoff reuse and without reuse. In 1997, irrigation application efficiency with runoff reuse was 49.6% while its value was 30.8% without runoff reuse. For 1998, these values were 46.6 and 31.5%, respectively. The results showed an increase of 15% to 19% in irrigation application efficiency due to the consideration of runoff to be reused for the two years. Water use efficiency for rice grain was 2.9 and 2.5 kg mm^{-1} of water in 1997 and 1998, respectively.

Keywords: Lateral seepage, Deep percolation, Runoff, Water use efficiency, Rice

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INTRODUCTION

In Asia alone, more than 2 billion people obtain 60-70 percent of their calorie intake from rice (3). Rice production in Asia needs to be increased to feed a growing population; however, water for irrigation is getting scarce. Major challenges are (i) to save water; (ii) to increase water productivity and (iii) to produce more rice with less water. Irrigated rice is also popular among the farmers in the southern part of Iran. However, since water is relatively scarce in this area, rice cultivation is also limited. Therefore, increasing water use efficiency of rice is very important. Analysis of water balance components can help in making decisions about how to increase water use efficiency.

Water requirement of rice is related to the amount of evapotranspiration and is dependent on the method of cultivation, climatic factors, soil texture and stage of plant growth. For rice, the saturated hydraulic conductivity of soil is especially important because it affects deep percolation significantly (8). Total rice production can be increased by using water saved in one location to irrigate new land in another. If this is not done, the strategy of saving water at the field level can potentially threaten total rice production at large (2).

According to Fukuda and Tsutsui (4), deep percolation in Japan was 4 to 6 mm/d for sandy loam, 3 to 4 mm/d for loam and 1 to 3 mm/d for clay loam. Results of studies conducted by Kung *et al.* (7), Talsma and Lelij (11) and Wickham and Singh (14) showed that deep percolation and lateral seepage depend on soil type, topography of the field, agricultural practices, depth of water table and drainage flow. According to these studies, amount of deep percolation is 1 mm/d for compact heavy soil and 20 mm/d for light-textured soil with deep water table.

Milton (9) showed that deep percolation for total growing period varies from 305 to 1220 mm depending on the soil type. Tripathi *et al.* (13) showed that the amount of deep percolation in continuous flooding is 25% to 36% higher than intermittent flooding, for different soil types. Wopereis *et al.* (15) measured deep percolation plus lateral seepage in a rice field and showed that, depending on soil texture, it varies from 3.62 to 4 mm/d and for the whole growing season it was 90 to 350 cm.

In the northern part of Iran, in Guilan province, the amount of deep percolation reported by Herve (6) is 1.9 to 4.2 mm d^{-1} for Foman area and 9 mm d^{-1} for Sefidrood area. Tao *et al.* (12) demonstrated that ground cover rice production system has the potential to save substantial amounts of water at relatively minor yield penalties, if stress factors such as low soil temperature, water deficit, and nutrient deficiencies during the vegetative growth stage are avoided by suitable management practices.

The present research was conducted in Fars province (located in the southern part of Iran) to determine lateral seepage, deep percolation, runoff, water use efficiency, and water application efficiency for rice.

MATERIALS AND METHODS

This research was conducted in Kooshkak Agricultural Research Station of Shiraz University during 1997 and 1998. The Physical and chemical properties of soil at the experimental site are shown in Table 1. The rice cultivar used was a short season local cultivar, namely Champa-Kamfiroozi, widely grown by most of the farmers in the study area. Summary of the meteorological data for the experimental site is shown in Table 2.

Table 1. Physical and chemical properties of soil at the experimental site (5)

Soil depth (cm)	Clay (%)	Silt (%)	Sand (%)	Organic matter (%)	pH	EC_e (dS/m)
0-15	35	48	17	1.2	7.9	1.4
15-32	44	43	13	0.9	8.2	1.5
32-58	49	37	14	0.5	8.4	2.0
58-80	38	53	9	0.4	8.3	1.1
80-110	39	55	6	0.3	8.3	0.9
110-135	35	63	2	0.3	8.1	0.8

Calendar of cultivation practices is also shown in Table 3. For measuring deep percolation, a pair of cylinderical shape lysimeters (1) 56 cm in diameter and 100 cm in height, were used in three locations in a 4.5 ha (with 809 m perimeter) rice field (Fig. 1).

Table 2. Summary of meteorological data for the experimental site

Month	Mean pan evaporation rate (mm d^{-1})	Precipitation (mm)	Relative humidity (%)	Mean daily temperature (^{0}C)
Jan.	1.6	81.4	57.5	6.3
Feb.	2.2	76.1	54.8	8.7
Mar.	3.4	61.6	54.4	11.3
Apr.	5.1	35.6	52.8	13.9
May	7.5	10.2	49.0	18.4
June	9.6	0.7	43.5	22.5
July	10.5	0.9	43.0	24.5
Aug.	10.2	0.8	43.9	23.9
Sept.	8.2	1.0	45.8	21.2
Oct.	5.9	11.3	49.3	17.2
Nov.	3.4	44.4	52.7	11.8
Dec.	1.9	78.3	56.2	7.6

In each pair, one of the lysimeters was bottom-less to allow for deep percolation. Thus, difference in water used in the two lysimeters was due to deep percolation.

Table 3. Calendar of rice cultivation practices in the experimental field

Practice	1997	1998
Transplanting	11 & 12 July	28 & 29 June
Irrigation cut off	4 Oct.	6 Oct.
Harvesting	14 Oct.	19 Oct.

For measuring the inflow and outflow of water, 90˚ triangular weirs were used in the entrance and exit of the experimental plot. The obtained data were used to calculate lateral seepage using the following equations:

$$LSDP = I - O - ET_c \qquad [1]$$

where *LSDP* is the sum of lateral seepage and deep percolation, *I* is applied irrigation water, *O* is surface runoff, and ET_c is crop evapotranspiration (all in mm/d). Lateral

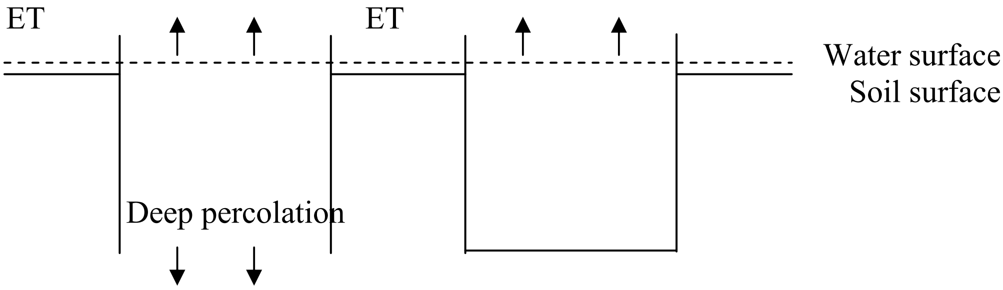

Fig. 1. The lysimeters for measurement of evapotranspiration and deep percolation in rice field

seepage was obtained from the following equation:

$$LS = LSDP - DP \qquad [2]$$

where *LS* is lateral seepage and *DP* is deep percolation, both in mm/d. Irrigation application efficiency (E_a) was calculated from the following equation:

$$E_a = \frac{ET_c}{I} \times 100 \qquad [3]$$

where ET_c is crop evapotranspiration in mm/d and *I* is applied irrigation water, mm d^{-1}. Irrigation application efficiency was calculated by two methods. In the first method, surface runoff was considered as a part of water loss. Thus, applied irrigation water was equal to water inflow. In the second method, surface runoff was assumed to be reused in the same field. Therefore, surface runoff was not considered as water loss and applied irrigation water was equal to difference between water inflow and surface runoff. Furthermore, water use efficiency was obtained as grain yield unit per irrigation water.

RESULTS AND DISCUSSION

Different components of irrigation water in the two growing seasons are presented in Fig. 2 and 3. Deep percolation during the growing period was almost constant, but the difference between water inflow and surface runoff of irrigation varied, affecting lateral seepage (Fig. 4). In 1998, lateral seepage was higher than that of 1997 at the beginning of growing season (Fig. 4). This was due to the larger difference between inflow and lower outflow of water in this year (Fig. 3). The mean for daily evapotranspiration in 1997 and 1998 growing seasons were 6.3 and 7.0 mm/day, the mean for daily deep percolations were 3.4 and 3.5 mm/day, and the mean for daily lateral seepages were 0.19 and 0.22 m^3/d/m (for unit of field perimeter), respectively. The values of surface runoff were 6.15 and 8.30 mm/d in 1997 and 1998, respectively, being the main sources of water loss.

Seasonal surface runoff (outflow), crop evapotranspiration, deep percolation, and lateral seepage in 1997 and 1998 are presented in Table 4. Pudding water in 1997 was not measured but it was 327 mm in 1998. The components of seasonal irrigation water are also presented as the percentage of irrigation water. It is shown that the surface runoff (outflow) has the highest percentage and by selecting proper strategies it

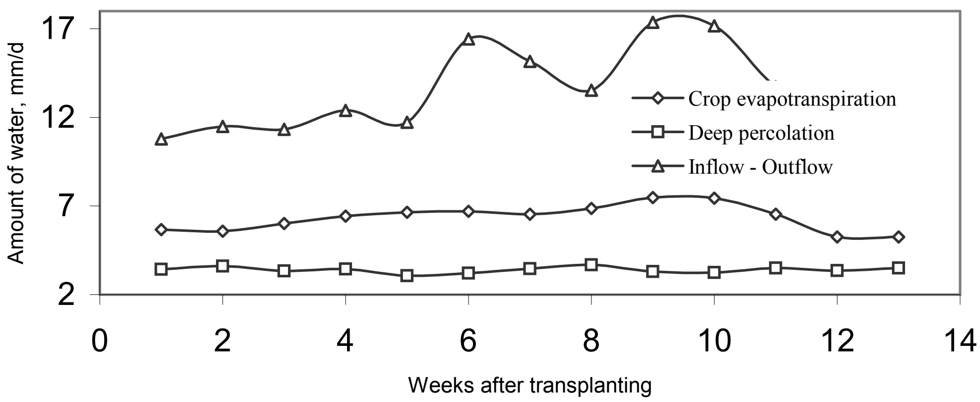

Fig. 2. Variation of different components of irrigation water in 1997

can be decreased or reused. For extensive areas of rice fields, lateral seepage becomes negligible, since neighboring fields are saturated. In these regions, also, runoff of the upstream fields is used as the source of water (inflow) for downstream fields and may not be considered water loss on a project basis. But, in southern Iran, the rice fields are commonly surrounded by crops that are not flooded. In this case, runoff is a part of loss

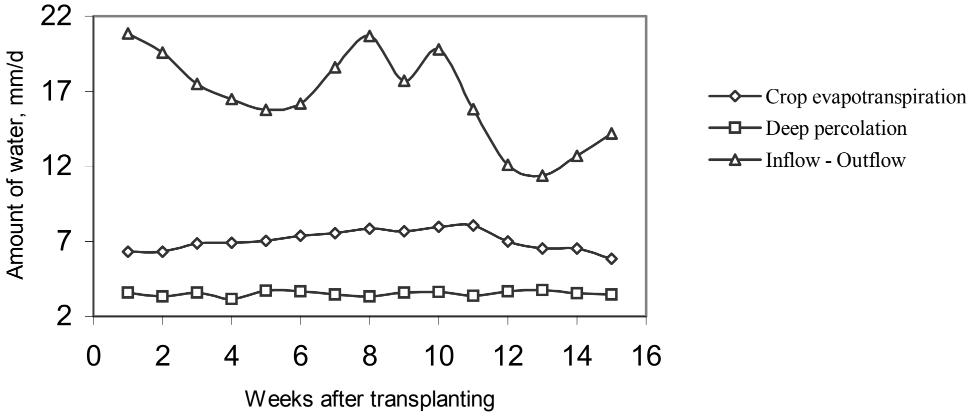

Fig. 3. Variation of different components of irrigation water in 1998

and lateral seepage is also high. The results of this research can be useful for managing irrigation water saving. In the fields under study, water reuse strategy can increase water application and water use efficiencies. Lateral seepage was affected by water level in the field. Higher water level is resulted by quarter difference between water inflow and outflow (Fig. 2, 3, and 4). Therefore, lateral seepage is decreased by reducing the water inflow and regulating water height on plots to a minimum possible level. To decrease the lateral seepage, continuous flooding can be replaced with intermittent flooding which decreases the rice irrigation water needs (10). Furthermore, by pumping runoff water to the field entrance, irrigation application efficiency can also be increased.

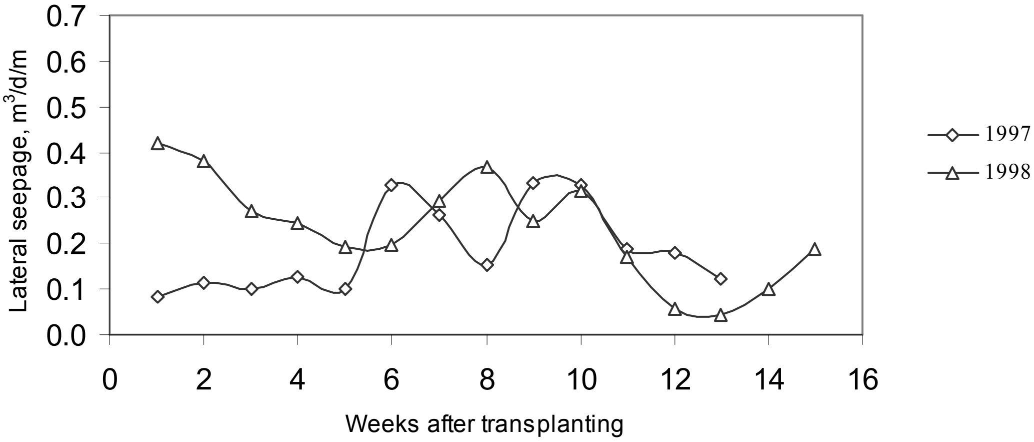

Fig. 4. Variation of lateral seepage for experimental years

In order to investigate the effect of reusing surface runoff (outflow), application efficiency was calculated for both cases of runoff reuse and without reuse. In 1997, irrigation application efficiency was 49.6% considering the surface runoff as reused

Table 4. Components of seasonal irrigation water (mm) for rice in 1997 and 1998

Components†	Year	
	1997	1998
Irrigation water (mm)	**1922 (100%)**	**2557 (100%)**
Runoff (mm)	**718 (37)**	**834 (33)**
Crop evapotranspiration (mm)	**560 (29)**	**757 (30)**
Deep percolation (mm)	**321 (17)**	**390 (16)**
Lateral seepage (m^3 m^{-1})	**16.35 (17)**	**22.16 (21)**

† **Data in parenthesis are in percent of irrigation water**

water and 30.8% when surface runoff was not reused. In 1998 these values were 46.6% and 31.5%, respectively. The results showed an increase of 15 to 19% in irrigation application efficiency and water saving due to reusing of runoff water in the respective years. Grain yields were 5600 and 6400 kg ha^{-1} and water use efficiencies for grain rice was 2.9 and 2.5 kg mm^{-1} of irrigation water in 1997 and 1998, respectively.

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