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SEEPAGE AND PERCOLATION LOSS IN THE RICE FIELD OF BANGLADESH AGRICULTURAL UNIVERSITY FARM

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Abstract

A study was conducted at the Bangladesh Agricultural University (BAU) Farm in order to determine the seepage and percolation (S and P) loss in the transplanted Aman (T. Aman) rice field during the period from 23 August to 6 November 2010. The variety of rice was BRRI dhan49. The soil was silty loam having 78% silt, 12% sand and 10% clay. The study was conducted following two cylinders method for measuring seepage and percolation and Blaney-Criddle method for estimating evapotranspiration. This loss (S and P) was combined with evapotranspiration to determine the total water requirement. It was observed that the seepage and percolation loss in the study area varied from 1 to 8.50 mm day^{-1} with an average of 4.18 mm day^{-1}. Total seepage and percolation loss was 307 mm for the whole growing season. The estimated evapotranspiration for the total growing season was found to be 538 mm with an average of 6.49 mm day^{-1}. The total water requirement was 845 mm for the study period. During the study period seepage and percolation and evapotranspiration was 37% and 63% of total water requirement, respectively. Land soaking, land preparation, and surface drainage loss was not considered to determine water requirement.

Key words: Seepage and percolation loss, *T. Aman* rice, water requirement, yield

Introduction

Agriculture is the largest user of water that use about 70% of the total worldwide consumption (Hagan *et al.* 1967). The World Bank has estimated that on an average annual growth rate of 2% in agriculture, as a whole is required to feed the growing population of the world. However, the growth rate for irrigated agriculture will need to be 3% per year to achieve the average target of 2%. As an agro-based developing country in the third world, Bangladesh has about 9.03 million hectares of cultivable land (BBS, 2001). National Minor Irrigation Census of Bangladesh indicates 4.48 million hectares of land has been covered by both major and minor irrigation system of Bangladesh by 8.85 lacs of irrigation equipments. But Bangladesh has a potential area for irrigation of 7.00 million hectares. So, 2.52 million hectares are yet to be covered. Eighty percent of the cultivable area is covered by rice, mainly Aus (February to July), Aman (July to December), and Boro (November to May). Aman rice covers about 53% of the total rice area with a production of 112.40 millions tons of rice (BBS, 2001).

Bangladesh is blessed with a favourable climate, and thus is able to plant several crops on the same land each year. The crop growing period in Bangladesh is divided into two main seasons, Kharif and Rabi. The Kharif is again subdivided into pre Kharif or Kharif I and Kharif II. Kharif I starts from the last week of March and ends in May. Kharif II starts in April and extends to November. Also Rabi season starts in November and continuous up to April. Aman is a rained rice crop. So it does not depend on irrigation. Water requirement varies among crops. Rice is a semiaquatic plants, it requires more water than other crops. To produce optimum yields of rice, it is very importand to satisfy the evapotranspiration needs of the crops and losses from the paddy areas through percolation and seepage. Timely water supply is equally important for optimum growth and high grain yields of rice. Only a portion of the applied irrigation water provide essential water for the crops to grow and a huge amount of water is lost by evapotranspiration (ET), seepage and percolation, and surface drainage, leakage through banks and closed outlets, overtopping and dead storage. The two types of water losses are: (i) The downward movement or vertical percolation of free water, which relieves the surface soil and upper subsoil of superfluous moisture, and (ii) The runoff of excess water over the field levees. There are a number of factors which affect the rate of seepage and percolation such as climatic factors, land topography, geological location, soil moisture, soil type, specially soil texture and structure, proximity to drains, fluctuation of water table, poorly maintained bunds, etc. It has been observed that S and P occurs at a high rate in sandy (sandy loam) soil and at a lower rate in case of clay soil. A study

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by Harun-ur-Rashid (1998) has showed that S and P losses vary from 2.30 mm day^{-1} to 13.68 mm day^{-1} based on different soil type and geological location of rural Bangladesh.

A study was conducted to get a practical idea about S and P for T. Aman rice grown during August to November 2011. Though T. Aman is not an irrigated crop a reliable idea and practical knowledge of S and P will help to determine the total water requirement of the crop. Evapotranspiration (ET) represents the crop specific water use and facilitates irrigation water requirement. ET is related to climatic factors, geological location, seasonal rainfall, available amount of soil moisture and types of crop in a given climatologically regime, the type of soil, atmospheric condition like solar radiation, wind velocity, relative humidity, crop coefficient, but there is considerable agreement among the hydrologists that lake evaporation may be used as good average estimate of Potential Evapotranspiration (PET). Considering the above mentioned importance a study was carried out with the following objectives:

i. To measure seepage and percolation rate from T. Aman rice field.
ii. To estimate ET for T.Aman rice.
iii. To estimate total water requirement for T. Aman using S and P and ET and
iv. To determine the yield of grain and straw.

Materials and Methods

The field study and experiment were conducted at the T. Aman rice field of BAU farm, Mymensingh during of 21 August to October 2010. The geological location of the experimental plot was $24^0$45’N latitude and $90^0$24’E longitude and 19 m above mean sea level. The experimental field belongs to the agro-ecological region of the old Brahmaputra flood plain (AEZ-9) and specifically the experimental plot was about 300 m from Bangladesh Institute of Nuclear Agriculture (BINA) and 250 m from Bangladesh Fisheries Research Institute (BFRI).

The textural class of the experimental plot soil was silty loam. The climate of locality is subtropical and characterized by high temperature and heavy rainfall during *Kharif season* (April to September) and scanty rainfall with moderately low temperature during *Rabi seasons* (October to March).

The average temperature, monthly rainfall, relative humidity, sunshine hour, pan evaporation, air pressure, air temperature, soil temperature prevailed at the experimental site during the cropping season of the study were collected from the weather yard, BAU campus, Mymensingh, Bangladesh.

Theoretical consideration

As both seepage and percolation occur simultaneously, it is very difficult to separate them in the field. So they are considered together. Usually they are three technique of measuring S and P losses in the field. They are (a) Cylinder method (b) Slopping gauge method and (c) Water balance method.

The study was conducted by following cylinder method due to its simplicity and ease of installation and operation. This method consists of two cylinders (drum) which were buried in the field with crop (rice) inside. During installation of the drums a plough pan (hard compacted layer below the plough sole which results from repeated ploughing for centuries with the traditional plough) was noticed at a depth of 50-60 cm. It has restricted infiltration and movement of water and penetration of roots. Though plough pan has disadvantages, however, it has an advantage that it reduces deep percolation and therefore reduce water loss. Whatever, the tops of the cylinders were open above the soil. One cylinder was the open bottom and the other was closed. At the beginning of the experiment, both cylinders were filled with water to a specified reference level. The amount of water required to refill the closed bottom tank daily is the ET rate and the water required to refill the open bottom tank is ET plus seepage and percolation. Then subtracting the first from the second gives the seepage and percolation rate. If there was any rainfall, it was adjusted to get the correct ET and S and P. For open bottom cylinder total head difference was the sum of S and P plus rainfall and for closed bottom cylinder the total head difference was the ET plus rainfall. The relationship is:

Seepage and Percolation = Net loss from the open bottom drum - Net loss from the closed bottom drum.

Mathematically,

$$\text{S and P} = [(\text{S and P} + ET + RF)-(ET + RF) \quad (1)$$

Where,
S and P = Seepage and Percolation rate in mm day^{-1}
ET = Evapotranspiration in mm day^{-1}

RF = Daily total Rainfall in mm day^{-1}.

Usually there are two approaches for measurement of ET. Such as-

A) Direct measurement of ET
B) Empirical approaches

The principal methods of direct measurement are (i) Tank or Lysimeter experiments; (ii) Field experimental plots; (iii) Soil moisture depletion studies; (iv) Integrated method and (v) Water balance method.

Also the empirical approaches include- (i) Blaney-Criddle method; (ii) Thomthwaite method; (iii) Penman formula; (iv) Modified Penman formula; (V) Lowery-Johnson method; (vi) Blaney-Morin method; and (vii) Hargreaves Class A pan evaporation method.

Blaney-Criddle method

Blaney and Criddle (1950) developed an empirical relationship using temperature and day time hours for arid western portion. The Blaney-Criddle formula generally gives sufficiently accurate estimate of seasonal consumptive use owing to the inclusion of locally developed crop co efficient factor. The mathematical expression for estimating ET (Consumptive Use) by Blaney-Criddle method are as follows:-

$ET = U = KF = \sum Kf = \sum u = \sum k\ [p\times(0.46t+8.13)]$ using t in ^{o}C.
Also, $ET = U= \sum Kf = \sum u = \sum k\times 25.4\times(p\times t)/100$ using t in ^{o}F.

Where,

U = seasonal consumptive use of water by the crop for a given period, mm or inches

U = monthly consumptive use, mm or inches

K = empirical seasonal consumptive use coefficient for the growing season

F = sum of the monthly consumptive use factors (f) for the growing season

K = empirical consumptive use crop coefficient for the month, u/f

F = a factor expressed in mm day^{-1}

T = the mean daily maximum and minimum temperature in ^{o}C or ^{o}F over the month considered, and

P = the mean daily percentage of annual day time hours for a given month and latitude.

Experimental setup

The essencial materials and instruments required for the study were (1) Two numbers large square size drum (2) Driving hammer (3) Spade (4) A millimeter/ centimeter gradding ruler (5) Data-table.

The diameter of open drum was 61 cm, height 51 cm and the diameter of closed drum was 61 cm. height 61 cm. The drums were placed in T. Aman rice field on 21 August 2010 after 20 days of transplanting. Before installation of the drum, field soil was dug out layer by layer and kept them separate place on the field. After setting the drum in the hole the drum was refilled by the previous dug out soil layer by layer again such that the soil in the drum remain same as natural field soil, then the field soil and drum soil was leveled at the same of natural field surface. The age of transplanted seedlings was 30 days and the variety of T.Aman was BRRI dhan49. There were 8 numbers hills on each drum. Intercultural operation that is weeding was done manually as and when necessary. There was no attack by diseases or insects during the growing period.

Data collection and presentation

At first a reference point was fixed at the level soil for both the drums from which all readings were taken during whole growing season. The water level and corresponding rise (due to rainfall and irrigation) and fall (due to S and P and ET) were recorded every 2 days interval. The first reading was taken on 23 August 2010, 23 days after transplanting. At that time there was about 7-8 cm standing water inside the drum. Before taking first reading the depth of water inside the drum kept same for the both the drums. The readings. were taken three times in a week. at 5 PM. The difference between two successive readings were recorded in the data table from which S and P rate was calculated. All data are represented in Table 1. Calculation of difference between teo successive readings and determination of S and P was continued for the whole study period. A ruler gratuated in cm was used to measure the head difference for both the drums throughout the growing season. Data collection was stopped when the field became dry during the last week of November 2010. Evapotranspiration was estimated by following Blaney-Criddle method and presentation in Table 2 and Table 3.

Grain and straw yield

On full maturity, that is, on 28 November 2010, the crop was harvested manually from both the drums. The bundles were marked drum-wise. The grain was separated from the straw by hand and kept in labeled properly. Both grain and straw were sun dried for 4 days. Then the weight was recorded and and the yields were converted to ton ha^{-1} for both grain and straw presented in Table 5.

Results and Discussion

Seepage and Percolation for T. Aman rice

The average S and P found from the study for the month of August, September, October and November were 4.11, 3.08, 4.23, and 5.33 mm day^{-1}, respectively (field data for S and P are shown in Table 1). On an average, the S and P for the whole growing season was 4.18 mm day^{-1}. S and P rate is a dynamic property of the soil water losses which depend on topography, soil texture and structure, location of the field weather and climatic condition, depth of plough pan, etc.

Table 1. Monthly field data of Evapotranspiration, Rainfall, Seepage and Percolation for T. Aman (BRRI dhan49)

Monthly (Date)	RF (cm)	S and P + ET (cm)	ET (cm)	S and P (cm)	Day	Avg. S and P (mm day^{-1})
August (24-31)	7.39	9.29	5.59	3.70	8	4.62
September (01-30)	20.86	26.76	17.51	9.25	30	3.08
October (01-30)	14.9	31.16	18.45	12.71	30	4.23
November (01-08)	9.2	4.4	4.8	4.8	9	5.33

Plough pan is a hard compacted layer below the plough sole which form data table (Table 1). It is noticed that S and P varied from 1 mm day^{-1} to 8.50 mm day^{-1}. The experiment conducted by Harun-ur-Rashid (1998) for S and P losses at different locations in Bangladesh reveals that the same varied from 0.89 to 13.68 mm day^{-1}. So, the S and P losses found from this study is in well agreement and within the range as reported by Harun-ur-Rashid (1998). The total S and P during the period of study was 308 mm.

Evapotranspiration for T.Aman rice

The estimated ET for the months of August, September, October and November, 2011 (for the whole growing season) were 6.89, 6.98, 7.09 and 5.02 mm day^{-1} respectively. The rate and total ET during the study period was 538 mm. The total ET for T. Aman rice found by Karim and Akhand (1982) were 4.59 mm, day^{-1} and 386 mm, respectively. In this study the estimated daily ET (6.49 mm day^{-1}) is in close agreement but the total ET is somewhat higher as compared to their findings.

Total water requirement

Total water requirement includes water needed to raise seedlings, prepare land and to grow a crop of rice from transplanting to harvest. The amount is determined by many factors. Those includes soil type, topography, proximity to drains, depth of water table, area of contiguous rice fields, maintenance of levees, fertility of both top and subsoil, field duration of the crop, land preparation method, and most of all, evaporative demand of the growing season. The total water requirement estimated by combining S and P and ET values during the period of study was 845 mm. The different values of daily and monthly average, monthly total, and total for S and P, ET and water requirement for T. Aman rice and there relationship, that is, graphical analysis are presented in Tables 1, 2, 3, 4 and Fig. 1, respectively.

For the whole growing season the total ET is 499.73 mm.

Table 2. Necessary data for estimating ET

Latitude	Crop	Growing season (month)	Mean daily Temp. (˚C)	Mean daily percentage of day time hours (p)	Crop coefficient for rice (K_c)
25^oN	Rice (T. Aman)	August	29.44	0.29	1.10
		September	28.74	0.28	1.15
		October	27.98	0.26	1.30
		November	24.24	0.25	1.00

Table 3. Estimation of evapotranspiration of T. Aman rice with the help of Blaney-Criddle method

Month	Mean daily Temp. (˚C)	Mean daily percentage of day time hours (p)	Crop factor (K_c)	ET = ΣK[P×(.46T+8.13)] mm day^{-1}	Average ET (mm day^{-1})
August	29.31	0.29	1.10	6.89	6.49
September	28.54	0.28	1.15	6.98	
October	27.98	0.26	1.30	7.09	
November	24.24	0.25	1.00	5.02	

Table 4. Data for graphical analysis (from Table 1 and 3).

Month	S and P (mm day^{-1})	Total S and P (mm)	Cum. S and P (mm)	ET (mm day^{-1})	Total ET (mm)	Cum. ET (mm)	WR (Sand P+ET) (mm)	Cum. WR (mm)
August	4.11	41.10	41.10	6.89	68.90	68.90	110.0	110.0
September	3.08	92.40	133.90	6.98	209.40	278.30	301.8	411.8
October	4.23	131.13	264.63	7.09	219.79	498.09	350.9	762.7
November	5.33	42.64	307.27	5.02	4.02	538.25	82.8	845.5

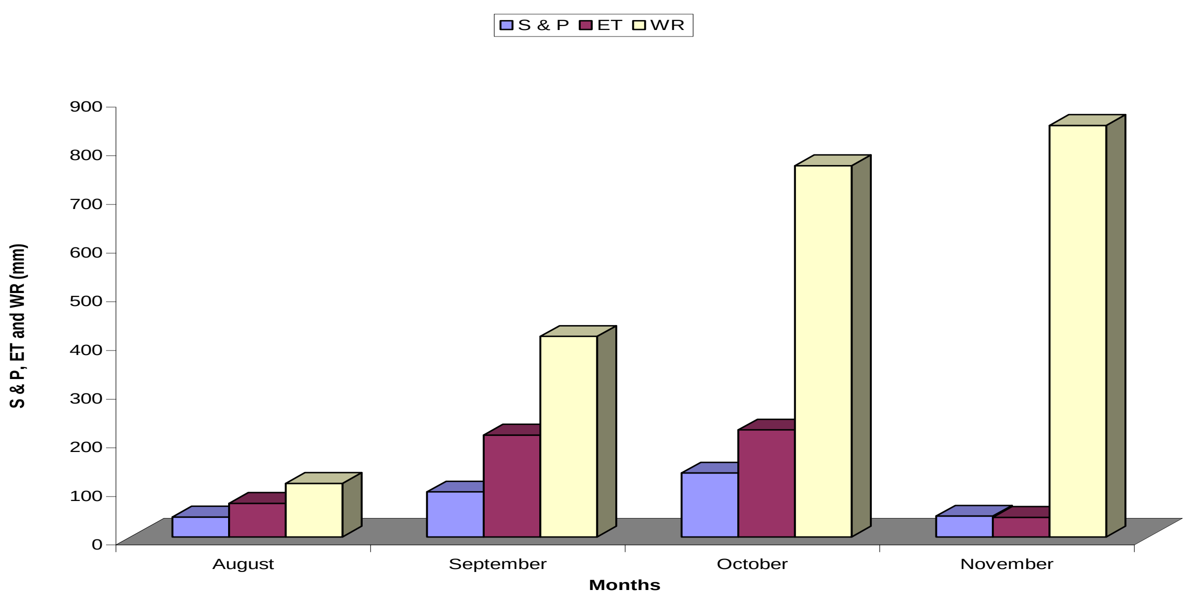

Fig. 1. Cumulative S and P , ET and Water Requirement (WR) for T. Aman rice

Yield from the drums

The average grain yield of BRRI dhan49 (grown as T. Aman in Bangladesh) is 5.0 t ha^{-1} (BRRI, 2003). Yields of grain straw based on drum area were determined and presented in Table 5.

Table 5. Yield and Straw of BRRI dhan49 in T. Aman season of BAU farm

Drum	Area of drum (m^2)	Grain yield ($t\ ha^{-1}$)	Average Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Average Straw yield ($t\ ha^{-1}$)
Open	0.29	9.31	8.4	13.1	11.55
Close	0.29	7.58		10.0	

The yield of the same obtained from the drum was 8.4 t ha^{-1} which is higher than the national average. This might be due to proper care, maintenance and intercultural operations which is possible in case of drums. But the same would be very difficult in farmers' fields for large area. Table 5 shows that both grain and straw yields were higher in case of open bottom drum. This indicates that seepage and percolation helps to increase production.

The research mainly aims to study the mechanisms for infiltration/lateral seepage of paddy field at BAU farm. Results showed that the water movement mainly vertical percolation within a paddy field. The plough sole was the major factors controlling the infiltration rate in paddy rice fields. Infiltration rate increased significantly without plough sole. Apparent lateral seepage may only occur nearby the border between a dry land and a flooded paddy field. The better the soil permeability and the drier the soil in the dry land, the higher the lateral seepage rate. Permeability of soil layers, water content of soils in dry land/flooded paddy rice fields, length of dry/wet border, and total area of flooded paddy rice fields are all key affecting factors for calculating the proportion of lateral seepage in overall infiltration water volume. Inevitably, different calculation bases will result in different results. Irrigation techniques that kept the soil around saturation during part of or the entire growing season generally had lower yields than the control treatments with 2–7 cm of standing water, though in most cases the differences were not statistically significant. This trend is the same in transplanted as well as in direct wet-seeded and direct dry-seeded rice. Keeping the soil continuously around saturation reduced yield from the standing water control on average by 7% for the dry-season transplanted and wet-seeded rice and by 3% for the wet-season dry-seeded rice.

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