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Estimation of Potential Evapotranspiration and Crop Coefficient of Wheat at Rupandehi District of Nepal

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Abstract

This study is carried out to estimate the potential evapotranspiration (PET) and crop coefficient (Kc) for Wheat, BL 3235 variety. A lysimeter is installed to estimate PET at the experimental farm of Agricultural Research Center of Bhairahawa, which is located in western part of Nepal. The Blaney-Criddle formula is used to estimate the Kc for wheat. The estimated values of PET and Kc for wheat at the four crop growth stages (initial, crop development, mid season/reproductive and late season/maturity) are 3.5 cm, 7.82 cm, 11.3 cm, 1.16 cm and 0.34, 0.67, 0.73, 0.06 respectively. The total value of PET and average value of Kc for Wheat is 23.78 cm and 0.45. Aridity index (AI), the ratio of precipitation to PET, is an important parameter to determine the dryness of a region. The average value of AI at the Wheat growing season (January to April, 2011) in Bhairahawa is 0.39, and is classified as a semiarid region.

Keywords:
Potential evapotranspiration, Crop coefficient, Aridity index, Wheat, Lysimeter, Nepal.

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INTRODUCTION

Wheat (Triticum aestivum L.) is the third major cereal crop in Nepal after rice and maize. The wheat yield in Terai is slightly higher than in hills and mountains. Wheat crop has made a spectacular progress mainly due to introduction of high yielding varieties and adoption of production practices. Wheat research is coordinated by the National Wheat Research Program (NWRP), Bhairahawa. It is consumed in the form of Roti/Chapati, bread, noodles, biscuits, cookies and other products. Now the country produces 1.57 million MT and exports wheat to the other countries (CBS, 2007). It is desirable that the minimum and maximum temperature during the wheat growing period should be 30^0 C to 32^0 C and the mean daily temperature for optimum growth is between 20^0 C and 25^0 C (Briggle, 1980).

It is known that the upper limit of crop production is set by the climatic condition specially temperature regimes and the genetic potential of the variety grown. The extent to which this limit can be reached will always depend on how finely the engineering aspects of water supply are in tune with the biological needs for water in crop production (FAO, 1979). For higher yields, water requirements are 350-500 mm depending on climate and length of growing period in Nepal. There should be the adequate water during the establishment period. Water deficit during the filling period results in reduced grain weight. However, during the ripening and drying-off period, rainfall or irrigation have negative impact on the yield (Nayava, 2009).

Several factors contributed to the jump in production and productivity of wheat are: i) Improved varieties endowed with many useful traits (disease resistance, wide adaption, heat tolerant, high yielding potential), ii) seed supply system has been improved through privatization of seed business, iii) wheat agronomy has been considerably improved, planting in time and maintain the stand properly, iv) Increase trend in fertilizer use by farmers, v) Growers are getting good price of wheat grains compared to previous years, vi) cost effective production technologies such as minimum tillage, zero tillage are being introduced. Research has given due consideration to the development of varieties, as variety has become a major technology to enhance productivity. Among the released varieties, Nepal 297 is very popular in Terai and occupies largest area, followed by Bhrikuti, Gautam and BL 1473. BL 3235 is found resistant to yellow rust as well as high yielding in the hills and terai. A study on weed control identified that application of sulfosulfuron, Fenoxaprop and one hand weeding is effective to control weeds in the wheat field (NARC, 2008).

Some sporadic incidences occur due to an army worm (Mythimna separata), grass hopper (Heiroglyphus banian), wire worm (Agrotis spp.) and rodent's infestation on wheat plants. One of the main constraints of increasing wheat production has been the poor crop management practices. Optimum planting date for the terai is found to be the middle of November and that for hills it is the middle of October (NARC, 1997).

Wheat is exposed to both pre and post anthesis moisture stress and hence considerable yield losses occur every year. Grain yield losses are associated with reduced tillering, stunted growth of the wheat plants, poor spike fertility, and reduced grain size. Wheat breeding program has been working to develop varieties suited to rainfed conditions since its inception. However, progress in drought tolerance breeding is slow, mainly due to lack of appropriate techniques to be employed in drought tolerance breeding. Mass screening of large scale genotypes to physiological drought resistance techniques are not available so far. Therefore, current drought tolerance breeding in our conditions is limited to germplasm exposer to drought stress environments only. Wheat varieties developed through this approach are Triveni, Annapurna-4, Nepal 251, BL 1022, BL 1135, and Bhrikuti, which have shown relatively good performance under moisture stress conditions (Bhatta, 1996).

Crop coefficient represents crop specific water use and is essential for accurate estimation of irrigation requirement of different crops in the area. Although there are published Kc values for different crops, these values are commonly used in places where local data are not available. As these values vary from place to place and from season to season, there is a strong need for local calibration of crop coefficients under given climatic conditions (Tyagi *et al.,* 2000). The Kc is affected by a number of factors, which include: the type of crop, stage of growth of the crop and the cropping pattern (Allen *et al.,* 1998). Doorenbos and Pruitt (1979) indicated that plant height and total growing season influence crop coefficient values. The higher the plant height and the longer the growing season the higher the crop coefficient values and vice versa.

The present study was designed especially to estimate the potential evapotranspiration and crop coefficient of wheat of variety BL 3235 grown in Rupandehi district of Nepal.

MATERIALS AND METHDOS

General description of the study area and a lysimeter

Rupandehi district, a part of Lumbini zone, is one of the seventy-five districts of Nepal.

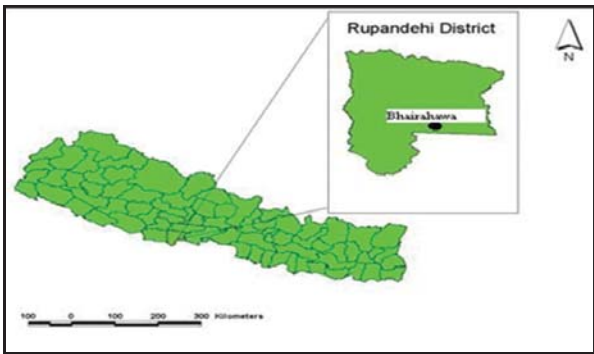

Figure 1: Location map of the study area in a Rupandehi district, Nepal

This district lies in the western terai region of the western development region of Nepal as shown in Figure 1. Its area is 1360 Km^2 and situated between 27^0 20’ 00” to 27^0 47’ 25” N latitude and 83^0 12’ 16” to 83^0 38’ 16” E longitude. The elevation ranges from 100-300 metres (CBS, 2001). The monthly maximum temperature recorded of this district is 32.70 in May 1995 and June 1998. Similarly, the monthly minimum temperature recorded of this district is 13.70 in January 1993 and 1998. The average annual rainfall is 1709 mm. Loam and clay loam soil textures are the dominant soils of the area.

The experimental site is located at NWRP, Bhairahawa. It is situated between 27^o 32’ N latitude and 83^o 25’ E longitude. It is 105 m above the sea level. A lysimeter is made from readily available materials, plastic bucket with an area of 5811 square centimeter and 10 cm deep and is kept at one corner of the wheat growing plot. The first bucket (B1) with tiny holes is completely filled with soil and leveled to the ground surface and holds wheat seeds and the second bucket (B2) with a hole is connected with a pipe to pass out the infilterated water to the receiving vessel which is kept deep underground as shown in figure 2a and 2b respectively. The receiver vessel kept underground and the B2 are connected with a water pipe so as to collect the percolated water.

Crop detail

Before sowing, the land is dug and made ready for sowing the wheat seeds in agricultural land and in a lysimeter. The well known BL 3235 va-

Figure a. Fitting a water pipe in B2

Figure b. Fitting a water pipe in a receiving vessel in connection with B2 which is kept below bucket, B1 with the sowed wheat seeds

Figure 2: Lysimeter installation (a and b)

riety of wheat in the area, NWRP, Bhairahawa, was sowed on January 1, 2011 in agricultural land and in a lysimeter. The crop is harvested on May 1, 2011 (i.e. after 120 days of the sowing date). The effect of 100:40:30 NPK kg/ha is practiced to increase grain yield and obtain reasonable Kc. Some unnecessary plants grown were removed at the crop development period. Representative five plants were selected randomly from an area of agricultural land and compared with the plants of the lysimeter to calculate the differences of the several agricultural parameters like average plant height, tiller, spike length, grains and its weight, canopy temperature and biomass when crop is ripe. It is a non-restrictional design in the sense that there is no blocking and any treatment can be replicated any number of times. As the experimental units are homogeneous, completely randomized design (CRD) has been used for the data analysis and interpretation of results.

Potential evapotranspiration (PET)

The measurement of PET includes the moisture evaporated to the atmosphere from plants and soil. As the soil and vegetation is confined within a small tank (the lysimeter) the measurements are made of the water input: Rainfall (R) and Additional water (A) and output (Percolated water P) collected in the receiving vessel, PET can be estimated from the equation below:

$$PET=R+A-P \qquad \text{(i)}$$

Determination of crop coefficient (Kc)

Kc is calculated by using the value of PET (as obtained in equation i) in a Blaney-Criddle formula (as in equation ii)

$$PET = 2.54\, Kc\, F \qquad \text{(ii)}$$

and $F = \sum P_h\, T_f /100$,

Where,

Kc = an empirical coefficient, depends on the type of the crop

P_h = monthly percent of annual day time hours, depends on the latitude of the place

T_f = mean monthly temperature in oF

F= sum of monthly consumptive use factors for the period

Aridity Index (AI)

AI represents the severity of dryness of a region. Aridity is defined as the more or less repetitive climatic condition, which is characterized by a lack of water (Perry, 1986). It should be noted that aridity can be considered on seasonal or monthly basis. The AI ranges from 0.05 to 0.65 for the dry seasons. AI less than 0.65 correspond to Dry lands that, according to the United Nations Convention to Combat Desertification (UNCCD), may suffer desertification processes. So, AI should be greater than 0.20 during the wheat growing seasons. In this study, UNEP aridity index (Hare, 1993) is used to estimate the AI which can be expressed as:

$$AI = P/PET \qquad \text{(iii)}$$

Where,

P = Precipitation in mm and PET=Potential Evapotranspiration in mm.

Figure 3.

RESULTS AND DISCUSSIONS

PET is calculated using the water balance

(a) Sowing of wheat seeds (b) Mid season (c) Late season

Figure 3: Sowing (a), mid season (b) and late season of Wheat (c)

equation, Eq. (i) and is presented in Table 1. The total PET of the area for the season January to April in which wheat is grown is 237.84 mm. Similarly, the total precipitation of the area for the season January to April, 2011 is 49.84 mm. Similarly, the total water added in a lysimeter to maintain sufficient moisture is 188 mm. There was no any percolated water in the collecting vessel during that period. It can be observed from the table 1 that the PET of wheat is maximum at the mid season and crop development period and is minimum at the sowing and late season. 47 % of the PET is observed at the mid season and only 5 % of the PET is observed in late season during the 120 days of wheat growing period as shown in figure 4. The average temperature at different periods (initial, crop development, mid season and late season) is 12.66 °C, 18.01 °C, 22.36 °C and 27.34 °C respectively. Similarly, the total rainfall at different periods (initial, crop development, mid season and late season) is 7 mm, 26.2 mm, 5 mm and 11.64 mm. The total PET at different periods (initial, crop development, mid season and late season) is 35 mm, 78.2 mm, 113 mm and 11.64 mm. Therefore, high temperature and greater precipitation at the crop development period has increased the PET and a maximum temperature at the mid season has raised the PET of wheat and observed to be a greatest PET i.e. 113 mm. The lower temperature and lower precipitation at the sowing period has reduced the PET of wheat. (Table 1)

AI is obtained by dividing precipitation with PET, Eq. (iii) and is presented in Table 1. It can be observed from the table 1 that AI increases and decreases as increase in the days after plantation of Wheat and reaches to a maximum during late season. The value of AI is 0.04 during the mid season due to fewer amounts of rainfall and higher temperature during that period.

Crop coefficient values of Wheat are obtained by using the Blaney-Criddle formula, Eq. (ii) and are presented in Table 1. It can be observed clearly from the figure 5 that the Kc decreases with increase in the days after plantation of wheat. However, previous research results showed that Kc values varied by many factors such as location, season, crop development stage, irrigation methods, crop height, management etc. (Baille, 1996).

The average plant height, tiller, spike length, grains of five plants, 1000 grains weight, total grains weight, canopy temperature and biomass were analyzed. A greater number of tillers of wheat are observed in an agricultural land as shown in Table 2. However, the number of grains

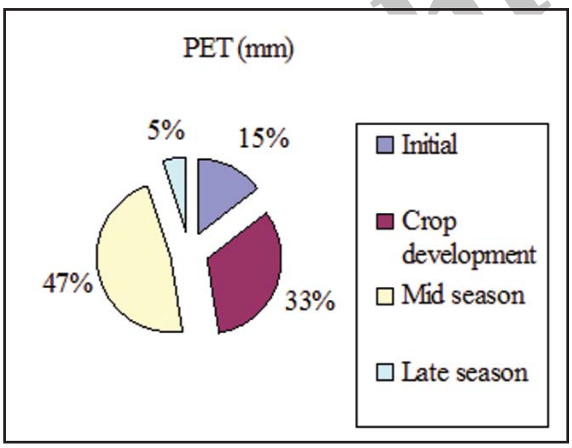

Figure 4: Percentage of PET during the wheat growing period

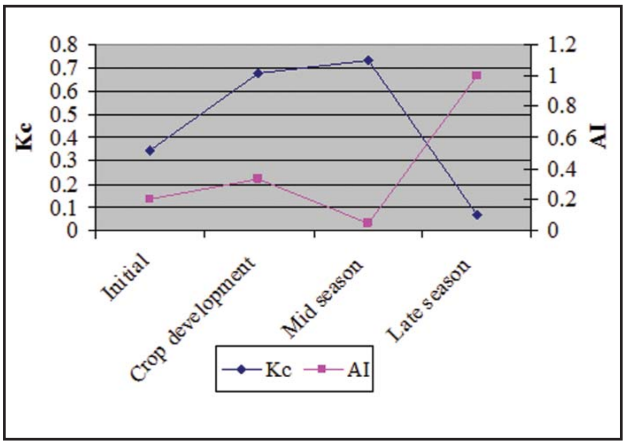

Figure 5: AI and Kc of wheat

Table 1: Average potential evapotranspiration (PET), rainfall (R), aridity index (AI), temperature (T), and crop coefficient (Kc)

Days after plantation	PET (mm)	R(mm)	AI	T (°C)	Kc
Initial (31 days)	35	7	0.2	12.66	0.34
Crop development (28 days)	78.2	26.2	0.33	18.01	0.67
Mid season (31 days)	113	5	0.04	22.36	0.73
Late season (30 days)	11.64	11.64	1	27.34	0.06

Table 2: Agricultural parameters of wheat grown on land and lysimeter

Parameters	Agricultural land		Lysimeter	
Average plant height (cm)	(74, 69, 80, 72, 79)	74.8	(95, 86, 84, 97, 76)	87.6
Tiller		99		86
Spike length (cm)	(9, 8, 9, 10, 6)	8.4	(10, 6, 8, 12, 6)	8.4
Grains of 5 plants		142		200
1000 grains weight (gm)		29		32
Total grains weight (gm)		50		102
Canopy temperature (°C)		26.3		26.29
Biomass (gm)		65		110

in five randomly selected wheat crops of agricultural land and a lysimeter are 142 and 200. 1000 grains weight are observed to be greater in lysimeter of an area 5811 square centimeter and 10 cm deep as shown in Table 2 above. Higher number of grains and maximum weight of 1000 grains was observed in a lysimeter. Similarly, the canopy temperature and the biomass weight were observed more in a lysimeter.

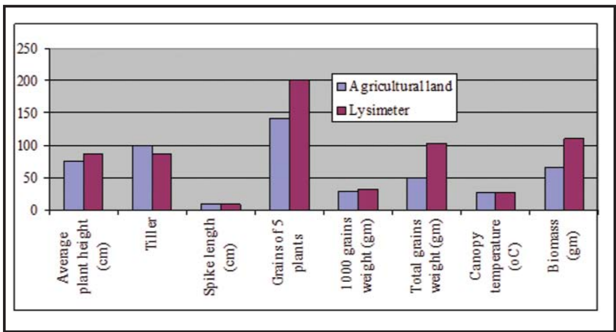

Figure 6: Comparison of different agricultural parameters of wheat grown on land and lysimeter

CONCLUSION

The total precipitation of Rupandehi district for the season January to April, 2011 in which wheat is grown is 49.84 mm. The total amount of water put on a lysimeter is 188 mm. The PET, Kc and AI for wheat is 237.84 mm, 0.45 and 0.39 respectively. Higher temperature and lesser precipitation at the initial and mid season of wheat growing period has increased the PET. The greater precipitation and greater temperature at the crop development period has increased the PET of wheat. AI decreases and increases as increase in the days after plantation of wheat. The lower value of AI at a period of initial and mid season reaches to a maximum at late season. Kc increases with increase in the days after plantation of wheat. Higher grains per tiller in a lysimeter were observed due to the regular preservation of sufficient moisture at the initial period. Thus, the increase in the wheat yield has been observed due to the availability of sufficient moisture at establishment period during the wheat growing period from January to April, 2011. However, the more amount of precipitation at the late season has reduced the yield of wheat in an agricultural land. Kc increases as increases in the number of days after the plantation of wheat and reaches to a maximum with the maximum plant height and finally reduces as the wheat height cease to increase.

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