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Water Requirement and Crop Coefficient of Onion (*Red Bombay*) in the Central Rift Valley of Ethiopia

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Abstract: **Determination of crop water requirement is the primary duty in any irrigation planning. This can be obtained through determining crop coefficient (Kc) which integrates the effect of characteristics that distinguish a typical field crop from the grass reference that has a constant appearance and a complete ground cover. Consequently, different crops will have different Kc coefficients. The changing characteristics of the crop over the growing season also affect the Kc coefficient. Hence crop coefficient (Kc), the ratio of potential crop evapotranspiration to reference evapotranspiration, is an important parameter in irrigation planning and management. However, this information is not available for many important crops for a specific area. A study was carried out at Melkassa Agricultural Research Center of Ethiopian Institute of Agricultural Research, which is located in a semi arid climate of the great central rift valley. A drainage type lysimeters was used to measure the daily evapotranspiration of Onion, Red Bombay variety, on a clay loam soil. Crop coefficient was developed from measured crop evapotranspiration (3.00, 4.58, 6.11 and 4.63) and calculated reference evapotranspiration using weather data (4.92, 5.33, 5.99 and 5.79). The measured values of crop coefficient for the crop were 0.34, 0.70, 1.01 and 0.68 during initial, development, mid-season and late-season growth stages respectively. These locally determined values can be used by irrigation planners and users in the central rift valley and other areas with similar agroecological conditions.**

Keywords: **crop coefficient, crop water requirement, evapotranspiration, lysimeter, Onion, Red Bombay.**

I. INTRODUCTION

Decisions related to agricultural water management such as irrigation scheduling, water resources allocation and planning require the information about the water loss for a given crop. This water loss from a given cropped plot of land can be determined from the knowledge of reference evapotranspiration (*ETo*), potential evapotranspiration (*ETc*), and crop coefficient (*Kc*).

Evaporation and transpiration occur simultaneously and both processes depend on solar radiation, air temperature, relative humidity (i.e., vapor pressure deficit) and wind speed. Transpiration rate is also influenced by crop characteristics, environmental aspects and cultivation practices. Different kinds of plants may have different transpiration rates. Not only the type of crop, but also the crop development, environment and management should be considered when assessing transpiration. For example, when the crop is small, water is predominately lost by soil evaporation because little of the soil surface is covered by the plant, but once the crop is well developed and completely covers the soil, transpiration becomes the main process (Allen et al., 1998).

Most methods of estimating evapotranspiration involve two steps; first, evapotranspiration for a well watered reference crop (grass or alfalfa) with standard canopy characteristics (*ETo*) is estimated (Burman *et al.*, 1980; Doorenbos and Pruitt, 1977).

Currently, the FAO Penman-Monteith method is recommended to estimate *ETo* (Allen *et al.*, 1998). Then evapotranspiration for the crop being considered (*ETc*) is obtained by multiplying *ETo* by a crop coefficient (*Kc*) which varies by growth stage for each crop.

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Crop coefficient represents crop specific water use and is essential for accurate estimation of irrigation requirement of different crops in the command area. It serves as an aggregation of the physical and physiological differences between crops and the reference definition. The variation of the crop coefficient during a growing season is obtained experimentally (Burman *et al.*, 1980; Doorenbos and Pruitt, 1977; Jensen, 1974; Pruitt et al., 1972, 1987; Wright, 1982). 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). There is, therefore, a pressing need to experimentally measure crop coefficients locally, so that project managers can correctly be advised.

Onion is one of the most important vegetable crops produced in Ethiopia. To improve onion production, the agricultural research system of the country has made efforts to generate improved varieties. Red Bombay variety is widely grown in Ethiopia (EARO, 2004).Among different varieties Red Bombay is the most widely used as a cash crop by the farmers in the rift valley areas of Ethiopia. In Ethiopia, the crop is one of the most important vegetables produced by smallholder farmers mainly as a source of cash income and for flavouring the local stew 'wot' [2,3]. The crop is believed to be more intensively consumed than any other vegetable crop. The bulk of onion produced in the county comes from this region where cultivation is mainly carried out using irrigation [6, 7].

However, the water requirement data and crop coefficient of this crop is not locally available. Hence, knowledge of experimentally determined *Kc* value is important for proper irrigation scheduling and efficient water management of the selected crop variety. Therefore, this study was undertaken with the objective of developing crop coefficient for different growth stages of Onion.

II. MATERIALS AND METHODS

General description of the study area and experimental lysimeters:

This research was conducted on lysimeters at Melkassa Agricultural Research Center, Central Rift Valley of Ethiopia. The center is located at an elevation of 1550 m above sea level with latitude of 8◦24' N and longitude of 39◦21' E. The average annual rainfall in the area is 768 mm, which is erratic and uneven in distribution. The site has a mean maximum temperature of 28.5◦C and mean minimum temperature of 12.6^{0}C.

Loam and clay loam soil textures are the dominant soils of the area. In this study, three non-weighing lysimeters having dimensions of 2 m × 2 m × 2 m were used to determine water requirement (ETc) and crop coefficient (Kc) of onion (Red Bombay cultivar) for four consecutive years (2010/11, 2011/12, 2012/13/ and 2013/14). The experimental lysimeters are located near the agro meteorological station of the research center. The lysimeters were of non-weighing type each having an access chamber for aeration and underground steel pipes for disposal of drainage water from the lysimeters.

These pipes are connected to water collecting tank mid way between the eight lysimeters. Rim of each lysimeter protrude 10 cm above the soil surface so that no surface water runoff may occur. One access tube for each lysimeter was installed at the center down to 105 cm depth.

Crop detail:

The well known Onion variety in the area, *Red Bombay*, was planted at mid October of the four consecutive years in and out of the lysimeters in all directions to have similar environment as in normal fields and decrease advective effects. The seedling was grown at nursery for 40 to 45 days after which transplanting takes place on the lysimeters. The crop was harvested on end of January.

The row spacing and plant spacing were 20 cm and 10 cm respectively. Recommended doses of fertilizers of 100 kg/ha Urea and 200 kg/ha DAP were added to increase yield and obtain reasonable *Kc* value. Plant height was measured at each growth stage by taking representative 5 plants from each plot and measuring from the tip to the bottom of the bulb. Bulb height and bulb diameters were also collected from the five representative samples at harvest.

Measurement of soil moisture and irrigation application:

Soil samples were collected at interval of 15 cm up to 60 cm depth for determination of some soil physical properties like field capacity, permanent wilting point, bulk density and texture. The average field capacity and permanent wilting points

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of the root zone profile were 31.6% and 15.0% respectively. The bulk density was 1.1 g/cm^3. Neutron probe was used to monitor the soil moisture content. The probe was calibrated following standard procedure for neutron probe calibration by plotting the results of neutron probe reading and gravimetric sampling around the access tube. The moisture content was monitored at intervals of 15 cm up to 60 cm soil depth at different times during the growing season.

Irrigation water was applied to the crop when there was 25% depletion of the available soil moisture within the crop root zone (Doorenbos and Kassam, 1979). Similar irrigation amount at this depletion level was given to the crop in and outside the lysimeter to ensure uniform plant growth. The application of irrigation was carried out in known volume of buckets by converting the 30% depletion in terms of volume. Irrigation was terminated at crop maturity.

Determination of crop coefficient:

Ideally, *ETo* of the reference crop should be experimentally measured with a lysimeter. However, the alternative procedure is to determine *ETo* from climatic data using the FAO Penman-Monteith method once the necessary variables specific to the location are determined. In this study, *ETo* was calculated using FAO Penman-Monteith Equation (ALLEN et al. 1998) using weather data of the Melkassa weather station. The crop evapotranspiration for each growth stage of the crop was calculated by using water balance equation as:

$$ETc = I + R - D + S \qquad (1)$$

Where *ETc*: crop evapotranspiration (mm), I: irrigation (mm), R: rain fall (mm), D: drainage collected (mm), and S: decrease in storage of soil moisture (mm).

The crop coefficient value over a given period, such as decade, physiological growth stage or whole season, was then calculated as:

$$Kc=ETc/ETo \qquad (2)$$

Where *Kc*: crop coefficient; *ETc*: crop evapotranspiration, and *ETo*: reference crop evapotranspiration.

III. RESULTS AND DISCUSSION

Crop evapotranspiration in different intervals of days were calculated for each year's using the water balance equation, Eq. (1). The result of the average of the four years is presented in Table 1. It can be observed from the Table that the peak water demand occurred almost three months after planting and only two weeks before harvest.

Table 1: Average potential crop evapotranspiration, reference crop evapotranspiration and crop coefficient values

Onion, *Red Bombay*	Growth Stages			
	Initial Stage	Developmental Stage	Mid Stage	Late Stage
Reference Evapotranspiration ETo (mm/day)	4.92	5.33	5.99	5.79
Crop evapotranspiration ETc (mm/day)	3.00	4.58	6.11	4.63
Kc- Melkassa	0.61	0.86	1.02	0.8

Crop coefficient values of onion were obtained by dividing crop evapotranspiration measured using lysimeter by reference evapotarnspiration, Eq. (2). Fig. 1 presents the average crop coefficient values in each year calculated for the four growth stages. There is a general trend of *Kc*, *i.e constant in initial stage*, *increment* from end of initial stage to end of development stage, almost constant values in the midseason stage and decreasing in the late stage.

The evolution of *Kc* values reflected the effects of crop development and physiology on *ETc*.

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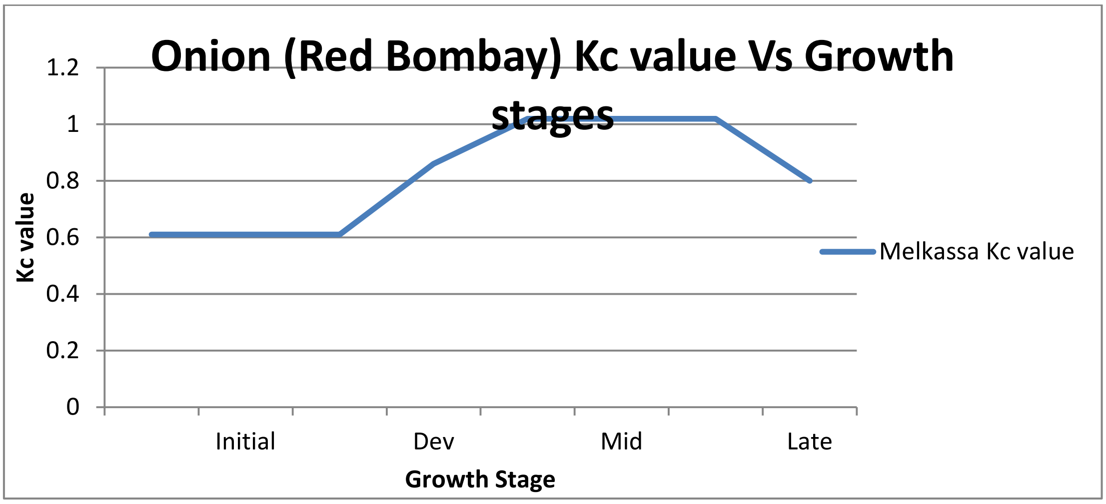

Figure 1: Average Kc value verses growth stages curve of Onion at Melkassa

The observed growth stages of onion at Melkassa were 16, 31, 29, and 22 days during initial, crop development, midseason and late season growth stages. The values of crop coefficients and water requirement calculated for each growth stage of onion for each year is presented in Table 2.

Table 2. crop coefficients and water requirement calculated for each growth stage

Trial year	Kc and CWR	Growth Stages			
		Initial Stage	Developmental Stage	Mid Stage	Late Stage
2010/11	Kc- Melkassa	0.67	1.00	1.17	0.86
	CWR (mm/day)	2.14	4.8	7.97	4.15
2011/12	Kc- Melkassa	0.54	0.69	0.96	0.79
	CWR (mm/day)	3.09	4.06	5.71	5.07
2012/13	Kc- Melkassa	0.6	0.87	0.99	0.75
	CWR (mm/day)	3.07	4.15	5.51	4.91
2013/14	Kc- Melkassa	0.63	0.88	0.96	0.81
	CWR (mm/day)	3.68	5.31	5.26	4.37

The increase in *Kc* value from initial stage up to midseason stage is due to increase in ground cover of the crop, which has impact on evapotranspiration. During this stage, leaf area is small and evapotranspiration is mainly in the form of soil evaporation. This stage is terminated when 10% of the ground is covered (Allen *et al.*, 1998). As the crop develops and shades the ground with increasing plant height and root depth, the amount of water abstraction increased which in turn increased the evapotranspiration. The evolution of *ETc* indicated that maximum crop water requirement occurred at the in the midseason stage, when evaporative demand was high. From the midseason stage to late season stage, there was a general decline in *Kc*. This decline is attributed to leaf senescence and to completion for assimilates between leaves and seed. Senescence is usually associated with less efficient stomatal conductance of leaf surfaces due to the effects of ageing, thereby restricting transpiration and causing a reduction in crop coefficient. Crop coefficient value at late season stage reflects crop and water management practices hence the crop at this stage need not get frequent irrigation as evaporation becomes restricted.

It can be observed that there is a slight variation in *Kc* values between the years observed during the crop development, midseason and late season stages. The computed overall average *Kc* values during initial, crop development; midseason and late season stages were 0.61, 0.86, 1.02 and 0.80 respectively. The Kc values suggested by Allen et al. (1998) for onion (dry) were 0.7, 1.05, and 0.75 for the initial stage, mid-season stage, and end of late-season respectively. These tabulated values are for sub humid climates with average minimum relative humidity (RHmin) of 45% and wind speed (U2) of 2 m/s. Allen et al. (1998) recommended that these Kc(mid) and Kc(end) values be corrected for more or less humid and/or more or less windy conditions. Some of the observed agronomic parameters (yield, plant height, leaf height, bulb diameter and bulb height) of the crop are presented in Table 3. From the table, it can be observed that leaf height increased as the crop passes through the different growth stages and reached maximum at the beginning of the midseason stage. Then it decreased due to maturity of the crop associated with leaf ageing, senescence of leaves and leaf drop.

The recommended yield of this crop is 30ton/ha which is quite close to the observed average yield in this study. There is not as such significant difference in yield between the years indicating that the crop in each year has got the similar management and same depletion level was used for irrigation.

Table 3: Agronomic parameters of onion at Melkassa at lysimeter field

Agronomic parameter	Growth Stage			
	Initial Stage	Developmental Stage	Mid Stage	Late Stage
Plant height (cm)	17.4	49.2	57.2	46.0
Leaf height(cm)	14.4	45.8	53.4	38.6
Number of branch(No)	6.2	8.2	12.4	13
Bulb height at harvest (cm)	6.2			
Bulb diameter at harvest (cm)	6.1			
Bulb yield at harvest (ton/ha)	39.5			

IV. CONCLUSION

From the study, it has been shown that estimates of crop water requirement made with locally determined crop coefficients slightly differ from estimates published in literature (e.g. Allen *et al.* (1998)). This emphasizes the strong need for local calibration of *Kc* for each variety. The fact that *ETc* was measured locally makes the *Kc* values locally calibrated. Although the values may not be exactly the same as would be obtained with measured *ETo*, they should be accurate enough for the purpose of estimating crop water requirements in the climatic region. *ETc* and *Kc* are somewhat dependent on water management, i.e., operational criteria of irrigation system/method and amount of water supplied, variety, climate, location and other cultural differences. Accordingly the obtained Kc values (0.61, 0.86, 1.02, 0.8) and *water requirement in mm (*48, 142, 177, 102) at initial, development, mid and maturity stages respectively can be beneficial to areas with similar agroclimatic condition as that of Melkassa for irrigation planning and management of onion.

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