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Performance Evaluation of Okra (*Abelmoschus esculentus*) under Drip Irrigation System

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Abstract: The aim of the study was to evaluate the yield response of okra under drip irrigation system by measuring the growth, root growth, yield and water use efficiency in red yellow latosol soil. The drip system performance and irrigation scheduling parameters were tested. Three irrigation treatments, different in irrigation duration of 15, 30 min on daily basis and basin irrigation with three days irrigation interval as control were applied with randomized complete block design and with six replicates. The growth performance parameters such as plant height, number of leaves, flowering index, yield, weed count, water use efficiency and root measurements were made. The results revealed that plant height, flowering index, yield, weed population, water use efficiency, root length and fresh weight were significantly recorded in drip irrigation than the plants under basin irrigation. There was a significant yield different between the plant under drip system and control but there were no any significant different in yield between treatments 15 and 30 min irrigation. The yield obtained for the duration of 15 and 30 min and basin irrigation was 1516, 1514 and 1084 kg/1000 m^2, respectively. The maximum water use efficiency of okra for 15 min drip irrigation duration was 705.2 kg/ha/cm. The water saving was 60% by adopting drip irrigation compared to control. Therefore, drip irrigation system with 15 min daily irrigation with the discharge rate of 3.25 L h^{-1} for okra could be introduced with the intention of increasing the yield of the crop with saving groundwater resource.

Key words: Drip irrigation, yield response, okra, water use efficiency, growth performance, weed control

INTRODUCTION

Okra (*Abelmoschus esculentus*) belongs to the family Malvaceae is one of the important vegetable crops grown throughout the tropical and warm temperature regions of the world. Globally, okra is cultivated in an area of 0.78 million ha producing 4.99 million MT with an average yield of 6.39 t ha^{-1} (Thanavendan and Jeyarani, 2009). Okra is one of the most popular fruit vegetables grown in wet, intermediate and dry zone of Sri Lanka. The total area under okra cultivation is reported to be 7066 ha producing average yield of 5.3 t ha^{-1} thus the total annual okra production in Sri Lanka is 37,330 MT with a per capita availability of 2.0 kg ha^{-1} (Department of Agriculture, 2010). A water shortage due to limited groundwater and surface water resources in Jaffna Peninsula has become a major concern in the

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development of irrigated agriculture (Rajasooriyar *et al*., 2002). Increasing water use efficiency by using improved irrigation techniques is a priority for the agricultural sector. The main aim of these techniques has been to achieve efficient water delivery and high productivity while minimizing water usage in lime stone aquifer of Jaffna Peninsula (Punthakey and Gamage, 2006). Since the 1980s, drip irrigation has become popular as the most efficient irrigation system (Peiris, 1990). The drip irrigation is an irrigation system whereby water is supplied under low pressure directly treating only to the plant roots (Nalliah *et al*., 2009). This system has many potential advantages. If well-managed, the advantages of drip irrigation can include minimizing soil water evaporation and nutrient leaching; maintaining a uniform water distribution resulting in greater control of the irrigation water and nutrients, reducing deep percolation losses that can decrease groundwater pollution and increasing flexibility to match various soil type and plant rooting depth (Postel *et al*., 2001).

Controlled method of irrigation would play a very important role to conserve the groundwater resources and to utilize the land in most productive manner (Peiris, 1990).

Santiniketan and Bharati (1994) explained about drip irrigation is that due to localized application of water to the root of the plant, surface evaporation is reduced, runoff is decreased and deep percolation is avoided resulting in up to 60% saving in water used in conventional irrigation. Numerous studies have been conducted in different parts of the country on various crops to quantify the benefits of the use of drip irrigation in terms increase production and productivity as well as saving of water (Padmakumari and Sivanappan, 1989; Raman, 1999; Sivanappan, 1999). Even though drip irrigation is becoming popular in other parts of the world, the knowledge and adaptability of the technology is inadequate among farmers in Jaffna Peninsula, Sri Lanka. Therefore, study related to drip irrigation specially irrigation duration, frequency and yield response of crop is important to convince the farmers to adopt this new technology in the field with confidence. There were no studies under taken under drip system in research level. Also in Jaffna, there was no any yield performance research was done under the drip irrigation for particular soil and climatic condition for any crop. Since, Jaffna has limited groundwater resource, this research will help to minimize over extraction of groundwater from the aquifer than the conventional method of irrigation. The objective of this study was to compare the performance of drip irrigation with basin irrigation as a control and the system was evaluated by comparing the growth performance established by counting the number of leaves and flower buds, measuring plant height, yield, number of weeds in the field and fresh root weight, distribution and tap root length after termination of crop.

MATERIALS AND METHODS

System Evaluation

An experiment was carried out during January to April, 2009 at District Agricultural Training Center, Thirunellveli, Jaffna, in dry zone of Sri Lanka. The pressure compensative online drip system was selected to conduct the research for the cultivation of okra variety TV8. The drip system performance was evaluated initially by measuring the discharge rate of the nozzles and estimating the uniformity co-efficient to decide about the performance of the drip emitter system, soil moisture distribution pattern in the soil profile. Also irrigation scheduling parameters field capacity, permanent wilting point, infiltration rate of the soil (Majumdar, 2000) and vertical and horizontal movement of water within the soil profile were also measured. Three irrigation treatments were applied: different in irrigation duration of

15 min (T_1), 30 min (T_2) on daily basis and basin irrigation with three days irrigation interval as control. Each treatment was replicated into 6 times. Each lateral contains seventeen plants out of which ten plants were randomly selected for the measurements. Experiment was conducted in Randomized Complete Block Design to determine the effect of drip irrigation and conventional basin irrigation in yield. Blocking was done randomly to reduce the experimental error.

Soil Moisture Measurements

Soil moisture deficit and actual evapotranspiration were stimulated by using improved soil moisture balance model (Rushton *et al.*, 2006; De Silva and Rushton, 2007). Environmental parameters required for the estimation of potential evapotranspiration such as monthly average mean temperature, humidity, wind speed and sunshine hours were taken from the meteorological station, Jaffna. Crop data; date of planting, full emergence of crop, duration of initial, development, mid and late stages, date of harvesting and root zone depth were recorded from the field. Frequency of irrigation, rate of pumping and duration of pumping were monitored to estimate the irrigation amount. The CROPWAT programme (crop water requirement) by FAO, land and water division, Version 5.6 was used to calculate the potential evapotranspiration for the study period. The representation of crops and soils was based on FAO guidelines (Allen *et al.*, 1998). Tensiometers were inserted into the field to observe the soil moisture deficit. The results of the model out such as soil moisture deficit and actual evaporation, real field soil moisture deficit and yield were compared to finalize the irrigation duration and frequency.

Measurement of Performance Parameters

The measurements of okra growth performance such as plant height and number of leaves were taken on weekly basis. Number of flowers on each plant was counted on daily basis till 100% of flowering occurred. The harvesting was done according to the maturity of the pods. The yield was measured from each lateral. The weeds were counted by using quadrate (40×40 cm) at 50% of land coverage. Quadrate was placed randomly three times on the field and the numbers of different weed species inside the quadrate were counted. Measurement of amount of water and total time required for basin irrigation was measured. The Water Use Efficiency (WUE) was calculated by yield obtained from ha of land per 1 cm depth of irrigation. The WUE was measured by the ratio of total yield and water consumed by the crop during the cultivation period. Three plants from each replicate were randomly selected for root measurements after the termination of crop.

RESULTS AND DISCUSSION

System Performance

Performance of the drip system shows 91.86% of Christiansen's uniformity and the statistical uniformity of 90.51%. Both uniformity co-efficient were satisfied the requirement of the system. The field capacity, permanent wilting point at volumetric basis and infiltration rate were estimated as 20.56, 10.1 and 330 mm h^{-1}, respectively. The rate of discharge recommended for the pressure compensative online emitters should lie between 2 to 4 L h^{-1} (Sankara and Reddy, 1995). The discharge rate calculated for the field condition was 3.258 L h^{-1} at pressure of 0.5 atm. Since, the rate of discharge calculated lies between the recommended rates, on the basis of rate of discharge the emitter is suitable for the field condition. Average basic infiltration rate of the soil was 330 mm h^{-1} it was agree with the past research by Joshuwa (1973) as 360 mm h^{-1}. Estimated discharge rate of the emitter was 3.25 L h^{-1} (11.5 mm h^{-1}). Since, the rate of discharge was below the infiltration rate of the soil, drip system could be used in the red yellow latosol. Also observation was made in the field there was no generation of run off in the soil. Hence, all system irrigation parameters are satisfying the requirement of field research.

Stimulation of Soil Moisture

The estimated potential evaporation was 399.78 mm but stimulated actual evaporation through soil moisture balance was 358 and 213 mm for 30 and 15 min irrigation, respectively and shown in Fig. 1a and b. The filled bar in Fig. 1 shows the actual evapotranspiration. It occurs at the potential rate if there was sufficient moisture in the soil and the Soil Moisture Deficit (SMD) less than Readily Available Water (RAW). During days with low or zero rainfall, the actual evapotranspiration was less than the potential only when SMD was greater than RAW. The actual evaporation occurs at less than their potential rate due to crop stress arising from limited soil moisture availability. The estimated total actual evapotranspiration during the 30 min irrigation was 89.72% of the potential evapotranspiration mean time it was 53.38% in 15 min irrigation. The SMD with TAW (Total Available Water) and RAW through out the cultivation period was shown in Fig. 2a and b for 30 and 15 min irrigation, respectively. Most of the time the SMD was less than TAW for 30 min irrigation, which was the reason actual evaporation was high in crop irrigated for 30 min. Soil moisture deficit was greater in 15 min.

Performance of Okra Plant

The maximum height of the crop obtained was 100 cm for the treatment of 30 min irrigation and followed by 15 min irrigation till 9th week of cultivation period as indicated in Table 1. The result indicates that when the availability of moisture and moisture retention

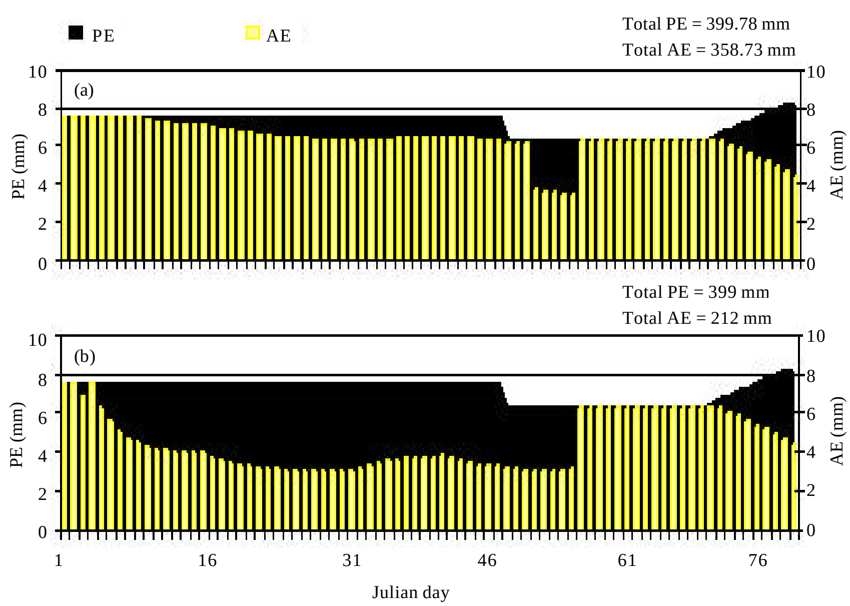

Fig. 1: Potential and actual evapotranspiration during the cultivation period (a) 30 min and (b) 15 min irrigation

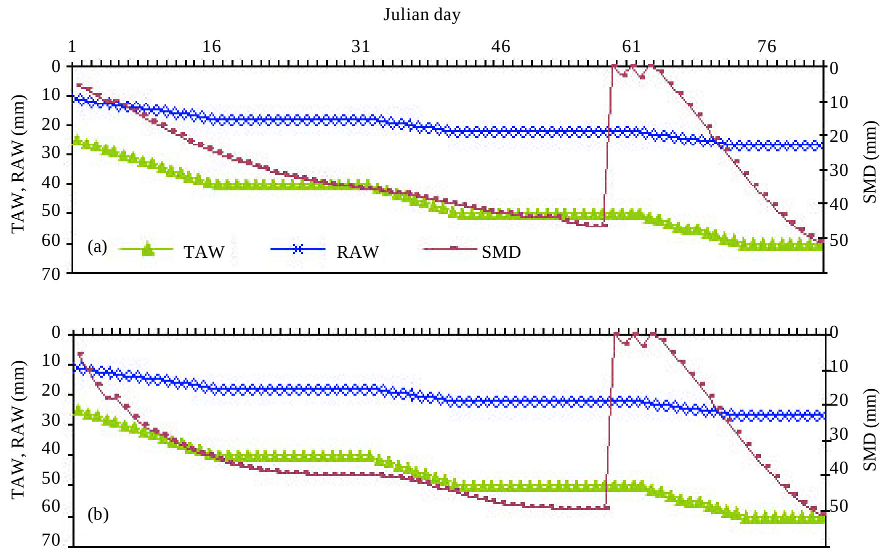

Fig. 2: SMD with TAW and RAW through out the cultivation period, (a) 30 min and (b) 15 min irrigation

Table 1: Measured crop parameters, water use efficiency and weed count for different treatment combination

Treatment	Height (cm)	Average flowering index (3 weeks)	Yield (kg/1000 m^2)	WUE (kg/ha/cm)	Weed (count m^{-2})
15 min T_1	90.68^a	12.53^a	1516^a	705.2^a	24
30 min T_2	96.71^a	12.68^a	1514^a	356.6^b	65
Basin control	70.40^b	8.50^b	1084^b	99.43^c	179

The same letter(s) indicates the non significance

capacity increases the growth of the plant also increases. Because of that crop treated for 30 min irrigation shows the highest growth and followed by 15 min irrigation. Plants under surface irrigation did not grow faster and their height was also less. This was due to the uneven application of water and shortage of water for the crop. The plants under drip irrigation system reached the maximum height of 252 cm at 15th week of cultivation period. This best performance could be due to continues supply of water (less than RAW) to the root zone of the crop. Drip irrigation probably keeps the root zone at the field capacity; therefore there is no any shortage of water for the physiological functions of the plant. Singh and Rajput (2007) reported that the height of okra under the surface and drip comes under 87 to 90 cm, respectively. Although, the plants subjected to different irrigation amount, treatment showed a similar growth pattern to control basin irrigated plants, statistically they were not significantly different in terms of number of leaves. The results obtained from the statistical data analysis for plant parameters, water use efficiency and weed count for different treatment combination are shown in Table 1.

Flowering Index

The okra variety TV8 started to flower 34 days after sowing. From Table 1, among irrigation treatments, 30 min irrigation was better than 15 min irrigation as far as flowering number is concern up to 3 weeks from first flowering. Highest percentage of flowering was around 50% from 30 min irrigation compared to control surface irrigation. But there were no significant different in number of flowers in two different irrigation durations of 15 and 30 min (Table 1). Flowering could be promoted by avoiding water stress in the plant canopy.

Root Length, Weight and Distribution

Table 2 shows vertical length of tap root and root fresh weight of drip irrigated and basin irrigated crops. Comparing root zone development, the highest tap root was observed in 30 min irrigation by drip also lowest was observed in basin irrigation. Length of the tap root of drip irrigated plants was significantly differed from basin irrigated plants but there were no significant different between 30 and 15 min irrigated plants. The root development was low in surface irrigated plants. This could be due to the water stress since it was irrigated in three days irrigation interval. Also results revealed that the slow application of water through emitters had promoted root zone development. Soil water and root depth monitoring can be used in irrigation scheduling to avoid water stress, such monitoring techniques can also save considerable volumes of irrigation water and can increase yield (Hassanli *et al.*, 2010). Santiniketan and Bharati (1994) stated that increase in root length as well as crop growth in drip irrigated crop has been experienced due to slow and frequent supply of water. Figure 2 shows the total water available for the plants which influences the development of root in 30 min irrigation.

Table 3 shows the percentage distribution of roots including lateral roots under different treatments in 10 cm layer different of soil from the soil surface. Higher percentage (80-90%) root was observed within first 0-20 cm of depth from the soil surface for treatments and control. The root density of 66% was observed within 0-10 cm of the soil for basin irrigation. Maximum root growth was observed up to 60 cm below the soil surface for the plants under drip irrigation whereas, for the plants under basin irrigation it was about 40 cm. The vertical movement of water into the soil profile in drip irrigation influences the deep root system and lateral spreading of water in the basin irrigation influences the surface spreading of root system in basin irrigation. Zotarelli *et al.* (2009) reported that the under drip irrigation system the total root length density of tomato was concentrated in the 0-15 cm soil layer while 15-20% of the roots were found in 15-30 cm layer.

Yield Response

The yield obtained from the plants under drip system with different treatments was higher than the control. The yield obtained for 1000 m^2 land area for the duration of 15 min, 30 min and basin irrigation was 1516, 1514, 1084 kg, respectively. The highest yield was obtained for the duration of 15 min But Yield obtained from the treatments 15 and 30 min was not significantly differed. Comparing the operating cost of the drip system for 15 and 30 min,

Table 2: Vertical length of tap root and root mean fresh weight

Treatment	Root length (cm)	Fresh weight (g)
T_1	44.00[a]	12.53[a]
T_2	50.25[a]	12.68[a]
Control	35.50[b]	8.50[b]

The same letter(s) indicates the non significance

Table 3: Percentage distribution of root density (%) in different soil depth

	Soil depth (cm)					
Treatment	0-10	11-20	21-30	31-40	41-50	51-60
T_1	53.61	31.81	11.58	2.55	0.33	0.11
T_2	52.05	30.37	11.94	4.30	1.26	0.07
Control	46.07	23.65	9.87	0.40	-	-

this was higher (around double) for 30 min than 15 min. The plants under the treatment of 30 min responded well in plant height, growth rate and flower number but the yield shows no significant different compared to 15 min irrigation. This is due to succulent nature resulted from excess irrigation. Increased soil moisture content may not be beneficial due to apparent promotion of plants vegetative growth at the expense of reproductive growth (Kwapata, 1991). Sivanappan *et al.* (1987) recommended that drip irrigation could be adopted in place of conventional furrow irrigation due to economy in water utilization to the extent of 84.7% without any loss of yield. Moreover, Sivanappan *et al.* (1987) stated that the increase in the yield of okra to the change of 40% was reported under drip system.

In case of the effect of drip compared to basin irrigation, the fresh fruit yield of okra was significantly different between the plants under drip system than the control. Hence, it was concluded that if the drip system is implemented properly for okra, positive yield response was obtained. The percentage of yield increase of 28.12% was from 15 min irrigation whereas 26% of yield increment from 30 min irrigation compared with control. Hence, 15 min irrigation duration with the discharge rate of 3.25 L h^{-1} for okra by pressure compensative on line drip system is economic than 30 min irrigation duration because of the operation expense of the system and water consumption. Tiwari *et al.* (1998) stated that total marketable yield of okra under drip irrigation system increased significantly with the increase of irrigation level and the use of drip alone or in combination with mulch can increase the okra and tomato crop yield significantly over furrow irrigation. Rekha *et al.* (2005) reported that the furrow irrigated okra showed 54 to 57% lower yield than drip irrigated crop. According to the study of Saxena and Gupta (2004), yield increased for okra under drip irrigation was 20.69% with the water saving of 44.92%. According to the study of Nijamudeen and Dharmasena (2002) the chilli crop yield also increased by 33-48% due to the adoption of drip irrigation system.

Water Use Efficiency

The volume of water need for the irrigation of okra by basin irrigation was 100 m^3. Whereas the amount of water required for the same area for 15 and 30 min were 20, 40 m^3, respectively. This amount was lesser than 5 and 2.5 fold of water applied in basin irrigation for 15 and 30 min, respectively. Water consumption was reduced by 60% due to the adoption of drip system. Therefore, by adopting drip system, considerable amount of groundwater could be saved. Rekha *et al.* (2005) conducted an experiment in okra under drip irrigation and reported high yield (4188 kg ha^{-1}) and water use efficiency (8.23 kg/ha/mm). According to the study of Zotaralli *et al.* (2009) that the drip irrigation system consistently increased tomato yields (11-80%) while greatly improving water use efficiency and there by reduced irrigation water use.

Water Use Efficiency (WUE) of okra under red yellow latosol was 99.43 kg/ha/cm in basin irrigation (Table 1). Comparing the treatments, there was significant different between treatments and control. Anyhow the water use efficiency was much more for the plants under drip irrigation than basin irrigation. Nijamudeen and Dharmasena (2002) stated that water consumption under drip system was reduced by 34-50%. Hence, higher yield was obtained with lower usage of water by implementing drip system for growing okra. Ibragimov *et al.* (2007) reported under drip irrigation, 18-42% of the irrigation water was saved in comparison with furrow irrigated cotton and irrigation WUE increased by 35-103% compared with that furrow irrigation.

Weed Management

The number of weeds counted was higher in surface irrigation than drip irrigation. Table 1 shows distribution of weeds per m^2 in surface irrigation and drip irrigation. Less number of weeds was counted in both drip irrigation treatment compared with surface irrigation. This is due to the spot application of water through emitters to the particular location or to the root zone of the plants. Santiniketan and Bharati (1994) said that growth of the weed is reduced due to partial wetting of soil.

CONCLUSION

Crop response parameters such as plant height, flowering rate and yield of the plants under drip irrigation were significantly different from the plants under basin irrigation but number of leaves was not significantly differed. The yield obtained for 1000 m^2 land area for the duration of 15, 30 min and basin irrigation was 1516, 1514, 1084 kg, respectively. The stimulated soil moisture deficit for both 15 and 30 min drip irrigation were almost level of fulfilled. Therefore, with the intention of water saving with increasing yield, the drip system with 15 min of irrigation duration with the discharge rate of 3.25 L h^{-1} was best to irrigate the okra crop in red yellow latosol soil.

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