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Growth, Crop Water Requirement and Crop Coefficients of Nursery Stage Plants of *Pogostemon heyneanus* Benth. (Lamiaceae) under Different Irrigation Intervals

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ABSTRACT

The effect of four different irrigation intervals; three times per day, two times per day, once a day and every other day on growth, crop coefficient and crop water requirement of nursery stage plants of *Pogostemon heyneanus* was evaluated. During this study, the maximum growth and development in terms of plant height, stem diameter, number of leaves, number of branches and branch length was found in plants irrigated three times per day. Throughout the study, the weekly average daily crop coefficients were highest in the plants irrigated three times per day. The differences of weekly average daily crop coefficients in-between different irrigation intervals of two times per day, once a day and every other day were gradually reduced with the time. This was not significantly contrast in crop coefficient values of two times per day, once a day and every other day during sixth, seventh and eighth week of the study. Also a similar trend was observed during the growth of *Pogostemon heyneanus* in terms of number of leaves and stem diameter. The highest crop water requirement (468.73 mm) was recorded in plants irrigated three times per day followed by irrigation interval of two times per day (361.64 mm), irrigation interval of once a day (340.53 mm) and irrigation interval of every other day (313.45 mm) respectively. Among the selected irrigation intervals on plant growth, the three times per day could be selected as the best for the nursery stage plants of the *Pogostemon heyneanus*. The irrigation interval of every other day could also be considered as an alternative economical option among rest of the irrigation intervals.

KEYWORDS: Irrigation interval, Nursery, Plant crop coefficient, *Pogostemon heyneanus*, Water requirement

INTRODUCTION

Pogostemon heyneanus Benth. (Lamiaceae) is a large, straggling under shrub found from Western to Southern parts in India, Malay Peninsula, Philippine Islands and in Sri Lanka. It is known as *Gan-Kollankola* or *Kollankola* in Sinhala (Jayaweera, 1981). The plant is cultivated to extract patchouli oil. The dry leaves of patchouli on steam distillation yield an essential oil called patchouli oil which is one of the highly demanded ingredients in pharmaceutical, perfumery, food and beverage industries (Singh *et al.*, 2002).

Currently, in Sri Lanka there is a growing demand for commercial scale cultivation of *P. heyneanus* for its fragrance and other therapeutically benefits. Production of quality planting material has become one of the prime requirements in achieving such demand. Therefore, an optimized maintenance of planting materials in nurseries is very important.

Irrigation management is one of the key nursery practices important in producing quality planting materials. Plants that lack of soil moisture can hamper its growth. Low soil moisture availability can cause a decrease in evapotranspiration (Sulistyono *et al.*, 2006). However, the excessive watering may also adversely affect on plant growth and result an additional cost to farmers.

Proper irrigation interval can play a major role in increasing the water use efficiency and the productivity by applying the required amount of water when it is needed (Boamah and Sam-Amoah, 2010). Jamiez *et al.*, (2000) stated that different irrigation intervals have beneficial effects on water balance of plants. Poor irrigation interval can lead to the development of crop water deficit and result in a reduced yield due to water and nutrient deficiency.

Therefore, the objective of this study was to determine the effect of different irrigation intervals on growth, crop coefficients and water requirement of nursery stage plants of *P. heyneanus*.

MATERIALS AND METHODS

Location

Experiment was carried out in the experimental plots of the Department of Plantation Management, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP) from January to May 2016.

Experimental Design and Layout

The experiment was conducted with four changing treatments of irrigation intervals (Three times per day-T_1, two times per day-T_2, once a day-T_3 and every other day-T_4) under a special rain shelter provided with 70% of shade. The Complete Randomized Design (CRD) was used with five replicates. Each replicate was consisted with four poly bags placed closely in net box resulting overall 20 net boxes including 80 poly bags for the study.

Nursery Planting

Double nodal semi hardwood stem cuttings of *P. heyneanus* were planted in poly bags (4 inches×6 inches) filled with a potting medium consisted of 1:1:1 composition of topsoil, sand and compost. Before imposing the treatments of different irrigation intervals, an equal amount of irrigation was provided for a period of one week to all plants for their establishment.

Determination of Crop Coefficients and Crop Water Requirement

One week after planting (WAP), the study on irrigation intervals was initiated. Under each treatment, all five net boxes were weighted separately before irrigation and plants in it were irrigated until reached to saturation. After irrigation, the samples were reweighted allowing adequate time for drainage before appreciable water loss occurred as evapotranspiration. The weight loss of net boxes (w) in between adjacent irrigations was calculated using the following equation to find out weekly averaged daily crop coefficients and total crop water requirements under different irrigation intervals.

$$ETc = \frac{w}{\rho \pi d^2}$$

$$Kc = \frac{ETc}{ETo}$$

Where;
w- Weight loss of net boxes
ρ- Density of water (kg/m^3)
d- Diameter of a poly bag (m)
ETc- Daily crop water requirement (mm)
ETo- Daily potential evapotranspiration
Kc- Daily plant crop coefficient

Potential Evapotranspiration (ETo)

The daily potential evapotranspiration was calculated using the software CROPWAT 8.0. The required climatic data were collected from the meteorological station at Regional Agriculture Research Center, Makandura (NWP).

Determination of Growth

The plant height, girth, number of leaves, number of branches and branch length were recorded in fortnight intervals for a period of two months. Leaf area, shoot and root dry weights were measured at the end of the nursery period.

Statistical Analysis

Statistical comparison of mean values was performed by General Linear Model (GLM) of ANOVA followed by Duncan's Multiple Range Test using the SAS and presented as means±SD with 95% confidence level.

RESULTS AND DISCUSSION

The Growth Response towards Different Irrigation Intervals

Plant Height

From 2 to 6 WAP, the tallest plants were observed in T_3. During 4th and 6th weeks of the study, the plants of T_3 were not significantly different from T_2 and T_1. Throughout the study, the shortest plants were found in T_4 which was irrigated every other day. However, up to the 6th week of the study, the height of plants in T_4 was not significantly different from plants of T_2. During the 8th week of study, the pattern was changed as the tallest plants were observed in T_1 (178.8 mm) followed by T_3 (168.3 mm), T_2 (161.3 mm) and the shortest one was T_4 (152.6 mm). The results indicated that the plants of T_1 were statistically significant fromT_2 and T_4. The water stress could be the reason for the shortest plant height found in plants of T_4. Our result collaborate with the results of Fischer (1980), where water stress resulted a growth reduction in plants and such stress was indicated as a decline in plant height. However, the stress on plants of T_4 due to increased gap of irrigation interval did not significantly affect on plant height as the plants of T_4 were significantly not different from T_2. Further, the findings of plant height at 8th week after planting was also in the agreement with Olalla and Valero (1994), who reported that plant height increased with decreasing of irrigation interval.

Stem Diameter

During the first month of the study, the least stem diameter was observed in T_2 and it was not significantly different from T_3 and T_4. However, during 6th week of the study, the pattern of stem diameter was changed as the lowest was found in T_4 and it was significantly different from T_1 but was not significantly different from T_2 and T_3. At the 8th week of the study, the highest stem diameter was observed in T_1 (5.4 mm), T_2 (5.1 mm), T_3 (5.0 mm) and T_4 (4.8 mm) respectively. Treatment 1 was

Table 1. Response of plant height, stem diameter, number of leaves, number of branches and branch length during the nursery stage of *P. heyneanus.*

Parameter	Irrigation Interval		Weeks after Planting (WAP)			
			2	4	6	8
Plant height (mm)	Three Times per Day	(T1)	81.7^{ab}	100.0^{ab}	119.1^{a}	178.8^{a}
	Two Times per Day	(T2)	75.6^{bc}	95.6^{ab}	110.0^{ab}	161.3^{bc}
	Once a Day	(T3)	87.6^{a}	107.3^{a}	121.7^{a}	168.3^{ab}
	Every other Day	(T4)	70.7^{c}	89.1^{b}	101.4^{b}	152.6^{c}
Stem Diameter (mm)	Three Times per Day	(T1)	4.7^{a}	5.0^{a}	5.2^{a}	5.4^{a}
	Two Times per Day	(T2)	3.9^{b}	4.4^{b}	5.0^{ab}	5.1^{b}
	Once a Day	(T3)	4.3^{ab}	4.6^{ab}	4.9^{ao}	5.0^{b}
	Every other Day	(T4)	4.2^{ab}	4.6^{ab}	4.7^{b}	4.8^{b}
Number of leaves	Three Times per Day	(T1)	11.6^{a}	19.7^{a}	28.5^{a}	33.9^{a}
	Two Times per Day	(T2)	9.9^{ab}	16.6^{ab}	23.3^{b}	29.0^{b}
	Once a Day	(T3)	8.4^{b}	16.7^{ab}	21.9^{b}	28.1^{b}
	Every other Day	(T4)	9.1^{ab}	15.6^{b}	23.1^{b}	28.4^{b}
Number of branches	Three Times per Day	(T1)	2.5^{a}	3.1^{a}	3.6^{a}	3.9^{a}
	Two Times per Day	(T2)	3.3^{a}	3.1^{a}	3.2^{a}	3.3^{a}
	Once a Day	(T3)	2.3^{a}	2.7^{a}	2.9^{a}	3.1^{a}
	Every other Day	(T4)	2.7^{a}	3.0^{a}	3.0^{a}	3.1^{a}
Branch length (mm)	Three Times per Day	(T1)	23.9^{a}	50.1^{a}	65.4^{a}	100.0^{a}
	Two Times per Day	(T2)	14.9^{b}	41.3^{a}	56.0^{a}	89.8^{ab}
	Once a Day	(T3)	22.8^{a}	43.5^{a}	59.7^{a}	82.3^{b}
	Every other Day	(T4)	19.4^{ab}	39.8^{a}	60.2^{a}	86.3^{ab}

Means with same letters are significantly not different at 0.05 level (n = 80)

significantly different from T_2, T_3 and T_4. However T_2, T_3 and T_4 were not significantly different. Further, this was in agreement with the findings of Byari and Al- Sayed (1999), in which a reduction in stem diameter was found with the increase in time between successive irrigations.

Number of Leaves

Throughout the study, the plants of T_1 recorded the highest number of leaves 11.6, 19.7, 28.5 and 33.9 respectively in 2, 4, 6 and 8 WAP. The lowest leaf number was found in T_3 except 2 WAP. During the last month of study, the total number of leaves found in T_1 was significantly different from T_2, T_3 and T_4. However, the total number leaves on T_2, T_3 and T_4 were not significantly different from each other (Table 1).

Number of Branches

Throughout the study, the irrigation interval had not any significant effect on total number of branches. However, T_1 recorded the highest number of branches of 2.5, 3.1, 3.6 and 3.9 respectively in 2, 4, 6 and 8 WAP. Simultaneously, the least number of branches as 2.3, 2.7, 2.9 and 3.1 were recorded in 2, 4, 6 and 8 weeks after planting respectively in T_3.

Branch Length

During the study, the highest branch length was found in T_1. In the first week, the shortest branch length was observed in plants of T_2 and it was not significantly different from T_4. However, during the 4th and 6th weeks after planting, the irrigation interval had not significantly affected on branch length. In the last week of the study, the plants of T_3 showed the least branch length and statistically not significant from T_2 and T_4.

Effect of Different Irrigation Intervals on Leaf Area, Shoot and Root Dry Weights

Leaf Area

A clear difference was found in leaf area of plants of T_1 as it was the highest (210 cm^2) as well as significantly different from all other treatments. A decrease in leaf area was found with the increase in irrigation interval. The pattern in leaf area can be explained as a method of adaptation of plants to withstand to water stress resulted at increased irrigation intervals to limit the rate of transpiration (Lu and Neumann, 1998). However, the plants of T_4 were significantly not different from T_2 and T_3.

Shoot Dry Weight

Treatment 1 had the highest shoot dry weight (1.4 g) and was significantly different from all other treatments. There were no significant differences in between T_2, T_3 and T_4. The results further revealed that the stress of plants due to increased gap of irrigation interval in T_4 had not significant effect on shoot growth even it was recorded the lowest shoot dry weight.

Root Dry Weight

When comparing the effect of irrigation on root dry weight, T_1 had the highest (1.0 g), followed by T_4 (0.6 g), T_2 (0.5 g) and T_3 showed the least (0.4 g). The results indicated that the plants of T_1 were significantly different from all

Table 2. Mean values taken at two months after planting on total leaf area, shoot and root dry weights under different irrigation intervals

Tested Parameters	Irrigation Interval			
	Three Times per Day (T_1)	Two Times per Day (T_2)	Once a Day (T_3)	Every other Day (T_4)
Total leaf area	210.4±26.5^a	174.5±34.7^b	168.6±51.8^b	166.3±47.4^b
Shoot dry weight	1.4±0.2^a	1.1±0.2^b	1.0±0.4^b	0.9±0.3^b
Root dry weight	1.0±0.2^a	0.5±0.1^{bc}	0.4±0.2^c	0.6±0.2^b

Means with same letters are significantly not different at 0.05 level (n = 80)

Table 3. Weekly average daily crop coefficients *P. heyneanus* during the nursery stage under different irrigation intervals

Irrigation interval	Weekly crop coefficient							
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
T_1	1.14±0.2^a	1.12±0.2^a	1.13±0.3^a	1.43±0.4^a	1.79±0.4^a	1.55±0.2^a	1.99±0.4^a	2.17±0.4^a
T_2	1.12±0.1^a	0.87±0.1^b	0.93±0.2^b	1.12±0.2^b	1.43±0.5^b	1.20±0.2^b	1.27±0.2^b	1.53±0.2^b
T_3	1.12±0.2^a	0.76±0.1^c	0.76±0.2^c	1.03±0.3^c	1.39±0.7^b	1.11±0.4^b	1.22±0.3^b	1.53±0.4^b
T_4	1.11±0.2^a	0.68±0.1^d	0.73±0.1^c	0.88±0.2^c	1.13±0.4^c	1.17±0.4^b	1.14±0.3^b	1.44±0.4^b
Weekly ETo	5.01	5.34	5.42	5.58	5.61	5.66	5.80	5.79

Means with same letters are significantly not different at 0.05 level. (n = 80), T_1- Three times per day, T_2- Two times per day, T_3- once a day, T_4- every other day, ETo- Potential evapotranspiration

other treatments. Treatment 2 was statistically not significant from T_3 and T_4. However, the root dry weight of plants of T_4 was significantly not different from plants of T_2. The changing pattern found in root dry weight of T_4 could be due to tolerance mechanism of plants to with stand water stress (Hurd, 1974).

Response of Crop Coefficients and Total Water Requirement towards Different Irrigation Intervals

The highest crop water requirement (468.73 mm) was recorded in irrigation interval of three times per day (T_1) followed by two times per day (361.64 mm), once a day (340.53 mm) and every other day (313.45 mm) (Table 4). This was in consistence with the findings of Sulistyono (2006), where the availability of more water by high levels of irrigation had higher evapotranspiration. The weekly average crop coefficients (Kc) values of T_1, T_2, T_3 and T_4 respectively started from 1.14, 0.99, 0.84 and 0.75 and respectively reached to the peaks of 2.17, 1.53, 1.53 and 1.44 (Table 3). This trend in Kc values at different irrigation intervals were agreed with the characteristic pattern of Kc for initial growth of a crop.

The Kc of different irrigation intervals of first week of the study was significantly not different from each other. This was due to the application of equal amount of water to all plants in ensuring uniform recovery in all. In the second week, the Kc values of different irrigation intervals were significantly different from each other. Second week onwards the highest weekly average daily Kc was observed in T_1 and weekly it was significantly different from T_2, T_3 and T_4. However, the differences in weekly average daily Kc among T_2, T_3 and T_4 were reduced with time. This was highly contrast in last three weeks of the nursery period where no any significant differences were found in between T_2, T_3 and T_4 .The similar pattern of statistical significant was also found in plant stem diameter and number of leaves.

Table 4. Total water requirement under different irrigation intervals

Irrigation interval	Total water Requirement (mm)
T_1	468.73
T_2	361.64
T_3	340.53
T_4	313.45

T_1- Three times per day, T_2- Two times per day, T_3- Once a day, T_4- Every other day

CONCLUSIONS

Among the selected irrigation intervals, the irrigation interval of three times per day where the maximum water use was found had the best growth of plants of *P. heyneanus* during its nursery stage. In terms of cost of irrigation, practicing irrigation in every other day for nurseries of *P. heyneanus* could be partially justified as the best. However, the study has to be continued further on different irrigation intervals above three times per day and below every other day before generalize the recommendations.

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