Growth Dynamics of *Celosia cristata* Grown in Cocopeat, Burnt Rice Hull and Kenaf Core Fiber Mixtures

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Abstract: Problem statement: Understanding the growth dynamics of short-lived plant could be critical as it would complete its life cycle in a short time period. It does not normally has much time to adjust to hostile environmental condition. This study provides a detail account on growth dynamics of *Celosia cristata* grown in five growing media for the production of high quality flowers. **Approach:** *Celosia cristata* plants were grown on five growing media (v/v): 100% Cocopeat (CP); 70% CP: 30% Burnt Rice Hull (BRH); 70% CP: 30% perlite; 70% CP: 30% Kenaf Core Fiber (KCF) and 40% CP: 60% KCF. To explore the dynamics of plant growth and development, data on plant height and canopy diameter were regressed against Days After Transplanting (DAT) by using the equation $y = A/(1+be^{-cx})$ while its derivative $[dy/dx = (Abce^{-cx})/(1+be^{-cx})^2]$ was used to estimate the growth rate of the parameter. The variation in leaf number, flower length and flower diameter were modeled using an exponential function of $y = Ae^{bx}$ and their rate of change was derived using $dx/dy = Abe^{bx}$. **Results:** The growth rates of plant height, canopy diameter and leaf number of plants grown in media containing 100% CP, 70% CP: 30% BRH, 70% CP: 30% perlite, 70% CP: 30% KCF were higher than those grown on media containing 40% CP: 60% KCF. The growth rates of stem and canopy of the plants grown in the later media tended to be higher at the end of the growth cycle. This, however would not be sufficient to compensate their early losses, since the rate of growth in leaf number did not increase concurrently. Negative effects of media containing KCF were also detected in flower size. **Conclusion:** Overall results showed that CP is an excellent growing media for the production of *Celosia cristata*. Replacing 30% of CP with BRH, perlite and KCF did not affect the growth and flowering of the plants.

Key words: Growing media, annual flower, growth analysis, cocopeat, kenaf core fiber, burnt rice hull

INTRODUCTION

Celosia cristata, commonly known as cockscomb is an annual ornamental plant. It is widely used as potted and bedding plant or cut flower and dried flowers. Being a short-lived species, the plant has to be managed with good horticultural practices throughout the growth cycle, as such plant does not have much time to adjust to the new growing conditions if it is initially grown in a less favorable condition. Under poor growing conditions, *Celosia* spp. tend to flower prematurely, giving a poor quality of short-statured plant with small flowers.

Aerial environmental factors such as temperature, photoperiod and irradiance are not of major concern in determining the success of annual flower production of annual flowers in the tropics. Factors associated with root environment especially those related to air-water relationship of the growing season is critical as this would determine plant water availability. Under a set of environmental condition, availability of water is mainly governed by physical properties of the growing media. Due to high evaporative demand faced by annual flowers in the tropics, which is normally grown in the open under intense sunlight irradiance and strong winds and sometime coupled with low mid-day humidity, proper selection of growing media is necessary.

Currently, due to its availability and suitability, most growers use cocopeat as the major media composition in the production of ornamental plants in the tropics (Abad *et al*., 2002; Yahya *et al*., 1997; 1999). Effort has been made to use other organic materials such as burnt rice hull and kenaf core fiber. At the experimental stage, rice hull and kenaf core fiber are often used to replace a certain portion of peat or other growing media in view of increasing utilization of new

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renewable bioresources or agro-waste products (Islam, 2008; Richards and Beardsell, 1986; Sambo *et al*., 2008; Tsakaldimi, 2006; Wang, 1994; Webber *et al*., 1999).

In the earlier report Yahya *et al*. (2009) have highlighted some aspects of physical and chemical properties of cocopeat and its mixes with burnt rice hull, kenaf core fiber and perlite for the production of annual flowers using *Celosia cristata* as the test plant. In this report, we provide a detail account on the growth dynamics of *Celosia cristata* grown on the same media. Understanding the growth dynamics of short-lived plant could be more critical than long-lived plant as the short-lived plant would complete its life cycle in a short time period. If the plant is initially grown in an unfavorable condition and does not grows satisfactorily, it would not have much time to adjust and resume its normal growth although it is supplied with sufficient level of all growth factors. The information generated here would allow the growers to plan and provide good horticultural practices so that high quality flowers can be produced.

MATERIALS AND METHODS

Plant materials and treatments: This study was conducted at the University Agricultural Park, University Putra Malaysia, under a plastic rain shelter condition. The plant used in this study, *Celosia cristata cv.* Kurume Gold' (Takii and Co. Ltd., Kyoto, Japan) were germinated and raised in plug trays (406 cells/tray) containing 40% Cocopeat (CP), 40% Burnt Rice Hull (BRH) and 20% sand, incorporated with 5.0 g of a slow release fertilizer (Agroblen®, 17N: $8P_2O_5$: $9K_2O$: 3MgO) and 2 g.L^{-1} of Ground Magnesium Limestone (GML). At day 12 (when the seedlings were about 2 cm in height with 3-4 true leaves), the seedlings were transplanted into 15 cm pots containing five soilless media comprising of (v/v): 100% CP; 70% CP: 30% BRH; 70% CP: 30% perlite; 70% CP: 30% Kenaf Core Fiber (KCF) and 40% CP:60% KCF. The properties of the mixes used have been described in the earlier report (Yahya *et al*., 2009). The initial fertility of the media was elevated by incorporation of 5.0 g of the foresaid slow release fertilizer and 2.0 g GML in every liter of media. The seedlings were watered manually twice daily (250 mL plant^{-1}) and sprayed with a complete foliar fertilizer containing (mg L^{-1}) 232 N, 67 P, 239 K, 120 Ca, 30 Mg, 3 Fe, 0.62 Mn, 0.44 B, 0.02 Cu, 0.11 Zn and 0.048 Mo (IMPRA®, Mega Prima Resources Sdn Bhd., Shah Alam, Selangor, Malaysia) together with 0.71 g Ca(NO$_3$)$_2$. 4H$_2$O/L at weekly interval.

Measurement of growth and flowering parameters: The plant growth was monitored by weekly measurement of plant height and canopy diameter. Plant height was measured by using a measuring tape, from the medium surface to the top of the plant while the diameter of the canopy was measured from one tip to another tip of leaves at the opposite side of the plant at the widest diameter. The measurements were carried out weekly until the sixth week after transplanting. Non-destructive counting of the leaves was also done at weekly interval for 6 weeks.

The growth of flower was monitored by measuring the length and diameter of the primary inflorescence. In this study, flowers began to emerge at 19-20 DAT and the measurement of their dimension was continued for 4 weeks. All the above measurements were performed on six plants per replication.

Experimental design and data analysis: The study was conducted in a completely randomized block design with four replications. For determination of plant growth and flowering parameters, all the six plants in each plot were used in the measurement. Analysis of Variance (ANOVA) on data obtained was performed using Statistical Analysis System (SAS 9.1, SAS Institute, Inc. Cary NC. USA). To explore the dynamics of plant growth and development, quantitative data on the change in plant height, canopy diameter, number of leaves, flower length and diameters were modeled using the logistic growth model (Hunt, 1982). Data on plant height and canopy diameter were non-linearly regressed against Days After Transplanting (DAT) by using the equation $y = A/(1+be^{-cx})$, where y = growth parameter, x = DAT, while A, b and c are regression constants. The 'A' and $A/(1+b)$ were the asymptotic level and initial value of each parameter, respectively. The derivative of the above growth function [$dy/dx = (Abce^{-cx})/1+be^{-cx})^2$], where y, x, A, b and c were used in estimating the growth rate (unit.day^{-1}) of each parameter.

Table 1: Constants of plant height and canopy diameter of *Celosia cristata* using a function $y = A/(1+be^{-cx})$

Growing media	Constants			f-value	Approx. Pr>F	Approx. R^2
	A	b	c			
Plant height						
100% CP	66.04	139.82	0.2154	975.4	<0.0001	0.99
70% CP: 30% BRH	68.60	162.40	0.2125	1686.2	<0.0001	0.99
70% CP: 30% Perlite	62.07	164.23	0.2159	600.4	<0.0001	0.99
70% CP: 30% KCF	62.62	92.94	0.1740	292.1	<0.0001	0.99
40% CP: 60% KCF	49.47	52.93	0.1330	651.0	<0.0001	0.99
Canopy diameter						
100% CP	27.02	6.98	0.1236	798.1	<0.0001	0.99
70% CP: 30% BRH	26.03	8.57	0.1402	984.5	<0.0001	0.99
70% CP: 30% Perlite	27.56	9.76	0.1344	923.3	<0.0001	0.99
70% CP: 30% KCF	27.01	14.74	0.1483	733.7	<0.0001	0.99
40% CP: 60% KCF	23.95	18.72	0.1344	963.6	<0.0001	0.99

Table 2: Constants of leaf number, flower length and flower diameter of *Celosia cristata* using an exponential function $y = Ae^{bx}$. The data were analyzed by its Ln(y) Vs Ln(x), where $Ln = \log_e$

Growing media	Constants				
	A	B	F-value	Pr>F	R^2
Leaf number					
100% CP	7.086	0.0480	280.8	<0.0001	0.95
70% CP: 30% BRH	6.512	0.0515	503.5	<0.0001	0.97
70% CP: 30% Perlite	5.589	0.0525	239.5	<0.0001	0.94
70% CP: 30% KCF	5.435	0.0509	244.1	<0.0001	0.94
40% CP: 60% KCF	3.676	0.0515	117.1	<0.0001	0.89
Flower length					
100% CP	7.086	0.0479	280.8	<0.0001	0.95
70% CP: 30% BRH	6.512	0.0514	503.5	<0.0001	0.97
70% CP: 30% Perlite	5.589	0.0524	239.5	<0.0001	0.94
70% CP: 30% KCF	5.435	0.0509	244.1	<0.0001	0.94
40% CP: 60% KCF	3.676	0.0515	117.1	<0.0001	0.89
Flower diameter					
100% CP	0.2157	0.0836	51.4	<0.0001	0.78
70% CP: 30% BRH	0.1000	0.1032	27.7	<0.0001	0.66
70% CP: 30% Perlite	0.1770	0.0879	32.9	<0.0001	0.70
70% CP: 30% KCF	0.1706	0.0876	56.9	<0.0001	0.80
40% CP: 60% KCF	0.1367	0.0870	54.5	<0.0001	0.79

The variation in leaf number, flower length and flower diameter were modeled using another non-linear function of $y = Ae^{bx}$ and their rate of change was calculated using its derivative, $dx/dy = Abe^{bx}$. The fitness of the models for all parameters were tested and results shown that all growth curves had high F-values with approximate probability $\alpha > F$ of <0.001 (Table 1 and 2).

RESULTS AND DISCUSSION

Vegetative growth: Changes in the height of *Celosia cristata* plants were monitored at every seven days beginning from the first week after transplanting. The performance of plants on different growing media are illustrated in Fig. 1, which indicated that the pattern of growth are well fitted into the growth function of $y = A/(1+be^{-cx})$, but with different growth rates. Plant grown on 100% CP, 70% CP: 30% RBH and 70% CP: 30% perlite had no difference in both plant height (Fig. 1) and the growth rate (Fig. 2 and Table 3). Maximum stem growth rate occurred at 22-23 DAT for plants grown on 100% CP, 70% CP: 30% RBH and 70% CP: 30% perlite, whereas the maximum stem growth rate for plants grown on KCF containing media occurred slightly later; i.e. at 25 and 28 DAT for 70% CP: 30% KCF and 40% CP: 60% KCF, respectively. However, the respective stem growth rates for the latter media were much lower, thus the plants were smaller. The stem growth rates of plant grown on KCF containing media were higher than those grown on the other media, at the end of the experimental period.
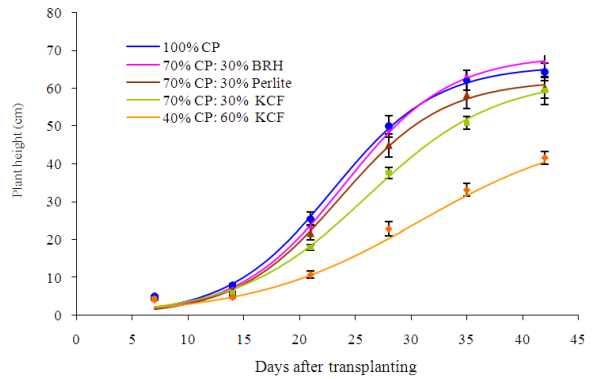

Fig. 1: Plant height in the form of $y = A/(1+be^{-cx})$ of *Celosia cristata* during 42 days growing duration
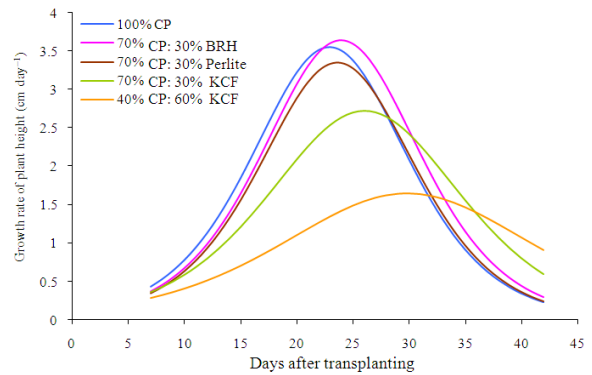

Fig. 2: Growth rate of plant height in the form of $dy/dx = (Abce^{-cx})/(1+be^{-cx})^2$ of *Celosia cristata* during 42 days growing duration

Similar effects of media mixtures on expansion of canopy was detected and this is reflected by the changes in canopy diameter of the plants at all measurement dates (Fig. 3). The canopy diameter of plant grown in 100% CP, 70% CP: 30% BRH, 70% CP: 30% perlite and 70% CP: 30% KCF were markedly broader than the canopy of the plants grown on 40% CP: 60% KCF (Fig. 3). There was different in the size of canopy among plant grown in 100% CP, 70% CP: 30% BRH, 70% CP: 30% perlite and 70% CP: 30% KCF. The results observed here are linked to the faster rates of canopy expansion as in the first 15-16 DAT (Fig. 4 and Table 3). The canopy expansion rate of plants grown on the media containing 60% KCF was maximum at a much later date (23 DAT) eventhough it occurred at relatively high expansion rate (ca. 0.8 cm.day^{-1}), an evident similar to the stem elongation.

Table 3: Growth rates of plant height and canopy diameter of *Celosia cristata* at five selected dates during 42 days growing duration estimated using a function dy/dx = $(Abce^{-cx})/(1+be^{-cx})^2$

Growing media	Days after transplanting	Plant height (cm day^{-1})	Canopy diameter (cm day^{-1})
100% CP	12	1.13	0.79
	18	2.71	0.82
	24	3.51	0.65
	30	2.09	0.42
	36	0.76	0.23
70% CP: 30% BRH	12	0.99	0.86
	18	2.50	0.88
	24	3.64	0.64
	30	2.47	0.37
	36	0.97	0.18
70% CP: 30% Perlite	12	0.93	0.83
	18	2.36	0.92
	24	3.34	0.75
	30	2.16	0.47
	36	0.81	0.25
70% CP: 30% KCF	12	0.80	0.82
	18	1.73	1.00
	24	2.64	0.83
	30	2.43	0.50
	36	1.39	0.25
40% CP: 60% KCF	12	0.51	0.54
	18	0.93	0.75
	24	1.42	0.79
	30	1.64	0.60
	36	1.40	0.36

Table 4: Growth rates of leaf number of *Celosia cristata* at six selected dates during 42 days growing duration estimated using a function dy/dx = Abe^{bx}

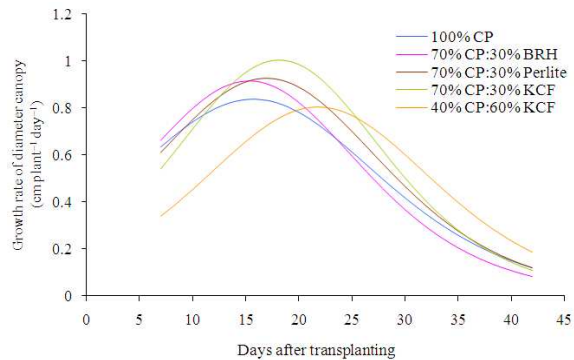| Growing media	Days after transplanting	Leaf no. (no. day^{-1})
100% CP	7	0.48
	14	0.67
	21	0.93
	28	1.30
	35	1.82
	42	2.55
70% CP: 30% BRH	7	0.48
	14	0.69
	21	0.99
	28	1.42
	35	2.03
	42	2.92
70% CP: 30% Perlite	7	0.42
	14	0.61
	21	0.88
	28	1.27
	35	1.84
	42	2.65
70% CP: 30% KCF	7	0.40
	14	0.57
	21	0.81
	28	1.15
	35	1.65
	42	2.35
40% CP: 60% KCF	7	0.27
	14	0.39
	21	0.56
	28	0.80
	35	1.15
	42	1.65

Fig. 3: Diameter canopy in the form of y = a/ (1+be^{-cx}) of *Celosia cristata* during 42 days growing duration

The number of leaves increased exponentially following the function of y = Ae^{bx} with DAT (Fig. 5) but the rate of increase differed between treatment (Fig. 6 and Table 4). The final leaf number of these plants were lower than those grown on other media due to the lower rate of increase in the generation of leaves by plants grown on KCF containing media (Yahya *et al*., 2009). At the end of the study, the increase rate of leaf number for 40% CP: 60% KCF was 1.65 leaves.day^{-1} whereas the corresponding values for other treatments were in the range of 2.35-2.92 leaves.day^{-1}.

Fig. 4: Growth rate of diameter canopy in the form of dy/dx = $(Abce^{-cx})/(1+be^{-cx})^2$ of *Celosia cristata* during 42 days growing duration

Results of growth analysis showed that the effects of varying growth media were different among plant vegetative parts. The rate of increase in stem growth rate (and hence plant height) and canopy extension (and hence canopy diameter) for plants grown on media without KCF were faster than those grown on KCF containing media, but the growth of these parameters tended to increase at a later stage.
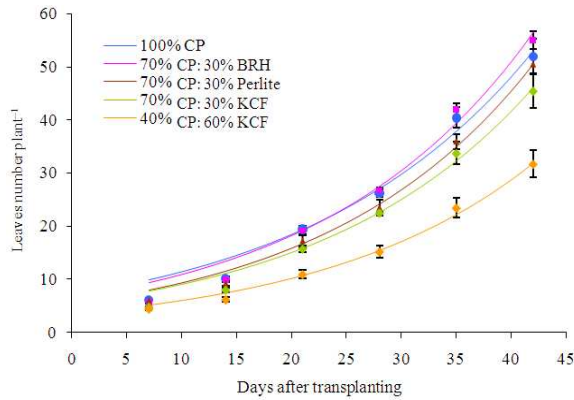
Fig. 5: Leaf number per plant in the form of $y = Ae^{bx}$ of *Celosia cristata* during 42 days growing duration
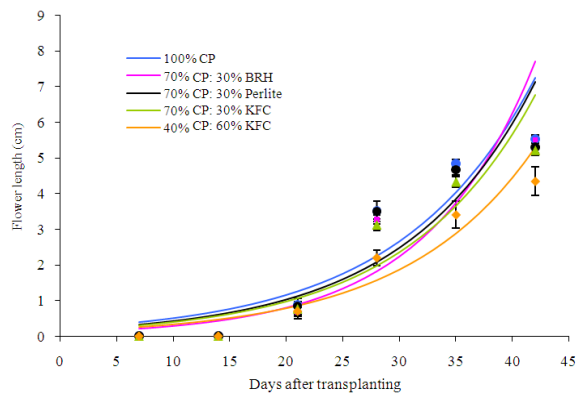
Table 5: Growth rates of flower length and flower diameter of *Celosia cristata* at four selected dates during 42 days growing duration estimated using a function of $dy/dx = Abe^{bx}$

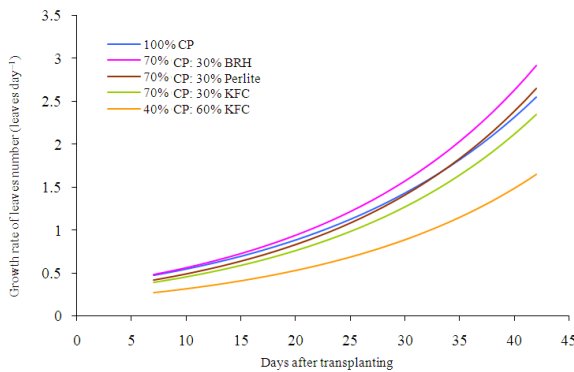| Growing media	Days after transplanting	Flower length (cm.day^{-1})	Flower diameter (cm.day^{-1})
100% CP	21	0.10	0.06
	28	0.19	0.12
	35	0.34	0.24
	42	0.61	0.49
70% CP: 30% BRH	21	0.09	0.06
	28	0.14	0.14
	35	0.33	0.33
	42	0.78	0.78
70% CP: 30% Perlite	21	0.10	0.06
	28	0.13	0.13
	35	0.26	0.26
	42	0.55	0.55
70% CP: 30% KCF	21	0.09	0.05
	28	0.11	0.11
	35	0.21	0.21
	42	0.41	0.41
40% CP: 60% KCF	21	0.07	0.03
	28	0.14	0.07
	35	0.25	0.13
	42	0.46	0.25

Fig. 6: Leaf number growth rate in the form of $dy/dx = Abe^{bx}$ of *Celosia cristata* during 42 days growing duration

Fig. 7: Flower length in the form of $y = Ae^{bx}$ of *Celosia cristata* during 42 days growing duration

This suggests the possibility for the plants grown on KCF containing media to continue their growth for a longer period. However, being a short-lived plant, increase growth rates both in stem and canopy at the end of the life-cycle would not be sufficient to compensate losses that occurred earlier. Reduction in the rate of leaf generation by plants grown on media containing high proportion of KCF also reflect the inability of these plants to catch-up the early losses in their growth.

Flower development: Flower length and diameter are the vertical and horizontal measurements of the first produced flower of the plant. Variation in media significantly affected both length and diameter of the flowers (Fig. 7-10). Flowers produced by plants grown on 70% CP: 30% RH tended to be larger although F-test showed that differences in flower length and diameter of plants grown on 100% CP, 70% CP: 30% BRH, 70%: 30% perlite and 70% CP: 30% KCF were not significant (Yahya *et al*., 2009). Flowers produced by plants grown on 40% CP: 60% KCF were markedly smaller than the flowers produced by plants on other media. This is clearly shown by the lower increase rates of flower length and diameter (Table 5).

Plants with bigger flowers are normally regarded as high quality and preferred by consumers for most purposes, whether to be used as bedding plants, cut-flowers or potted plants. Results obtained in the present study suggest that production of high quality *Celosia cristata* is highly dependent on the choice of media used. Suitable media should be the one that provide continuous support for good plants growth at all growth phases. As observed in this study, a rapid growth rate that occurred at the first 20 DAT determined the final plant size and flower development.
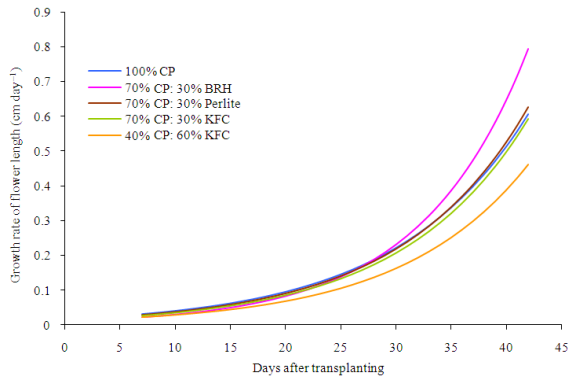
Fig. 8: Flower length growth rate in the form of $dy/dx = Abe^{bx}$ of *Celosia cristata* during 42 days growing duration
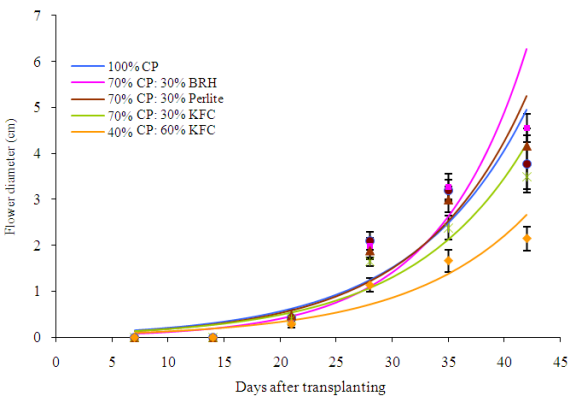

Fig. 9: Flower diameter in the form of $y = Ae^{bx}$ of *Celosia cristata* during 42 days growing duration
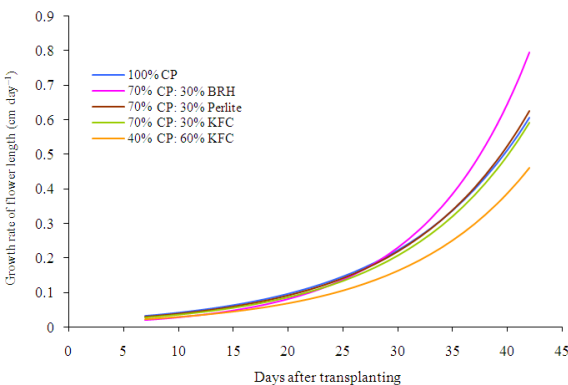

Fig. 10: Flower diameter growth rate in the form of $dy/dx = Abe^{bx}$ of *Celosia cristata* during 42 days growing duration

This was important as the time (days) to flowering of the plant used in this study was not affected by the media composition (Yahya *et al*., 2009). Once reaching the flowering stage, plants would allocate most of the current assimilates to support flower development and therefore the growth rates of vegetative plant parts would be reduced. For this reason, although the increased in rates of stem growth and canopy diameter occurred at the end of the growth cycle, but marked increase in plant size cannot be expected, unless the flowering process is disturbed, such as by pinching of the flower buds.

Faster growth rates and hence larger plants, recorded for the plants grown on 100% CP, 70% CP: 30 BRH and 70% CP: 30% perlite were mainly attributed to a better water availability and favorable aeration conditions of the media. Earlier report indicated that the leaf nutrient contents of the plants were non-significant among treatment (Yahya *et al*., 2009). However, due to smaller plants, it would be expected that total mineral nutrients harvested by plants grown in 40% CP: 60% KCF were lesser compared with those grown on the other media and therefore, the former plants can be considered less efficient in utilizing the available nutrients.

Replacing BRH or perlite in the cocopeat-based media with KCF may have some negative impact on plant growth. However, this would depends very much on the proportion of KCF being used. Incorporation of KCF up to 30% or more (vol. basis) reduced the growth rate of plants. Such negative impact may be confounded with a lot of other factors. As highlighted earlier that the growth rates and hence the final plant size, was mainly linked with the physical conditions of the rhizosphere i.e., air-water relationship of the media. Hence, investigations lead to the understanding on the mechanism underlying the effect of the particle size distributions of KCF and use of wetting agent on media air-water relations could be further explored as these two factors have been shown to have great influences on plant water availability (Bilderback and Lorscheider, 1997; Reichert and Baldwin, 1996). High rate of decomposition of KCF that linked to the shrinkage of media volume and hence aeration was reported to cause poor growth of *Pinus halepensis* seedlings (Sambo *et al*., 2008). Negative effect of KCF was also reported for *Vinca minor* (Wang, 1994).

CONCLUSION

Overall results of the study show that variations in the growth and development of plants grown on different growing media can be clearly seen when the

data were subjected to detail analyses. Apparently, the growth of plants grown on media containing 100% CP, 70% CP: 30% BRH, 70% CP: 30% perlite, 70% CP: 30% KCF were faster than those grown on media containing 40% CP: 60% KCF. This was reflected by higher growth rates of stem, canopy and leaf number and flower development. Replacing 30% of CP with BRH and KCF, in view of increasing utilization of new bioresources, did not affect the growth and flowering of the plants.

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