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Biomass Production and its Accumulation in *Coleus forskohlii* Briq.: Impact of Spacing and Time of Harvest

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Abstract

A field experiment was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka, for two years to study the influence of spacing and time of harvest on biomass production and its accumulation in *Coleus forskohlii*. Pooled analysis of yield data indicated that significantly higher total biomass (TBP) was produced when planted at a spacing of 60 cm x 20 cm (10.08 t ha^{-1}) followed by 75 cm x 20 cm (9.92 t ha^{-1}). There was increase in tuber biomass production with decrease in plant to plant spacing (1.04 t ha^{-1} at 60 cm x 30 cm and 1.57 t ha^{-1} at 60 cm x 20 cm). Shoot biomass accumulation was higher at 75 cm x 20 cm and 60 cm x 20 cm. Increase in biomass accumulation in tubers was not significant beyond 160 days after planting (DAP) (1.39 and 1.45 t ha^{-1} at 160 and 180 DAP, respectively). The total biomass production and its accumulation in the above ground portion and tubers were significantly higher in the treatment combinations, 60 cm x 20 cm at 180 DAP (11.15, 9.38 and 1.77 t ha^{-1}, respectively) and also at 160 DAP (9.45, 7.72 and 1.73 t ha^{-1}, respectively). Harvest index (HI) was found higher at closer spacing of 60 cm x 20 cm (0.121) and at 160 DAP (0.135). Interaction effects of spacing and time of harvest indicated that coleus cultivar K-8 may be planted at a spacing of 60 cm x 20 cm and harvested at 160 DAP to get higher tuber yield and harvest index.

Key words: *Coleus forskohlii*, spacing, time of harvest, tuber dry matter, total biomass production, partitioning

Introduction

Coleus forskohlii belonging to the family lamiaceae is a perennial aromatic herb with annual stems and perennial roots (Shah, 1996) and originated in the Indian sub-continent (Valdes et al., 1987). It produces fasciculate swollen brown roots. Recently it is cultivated on a commercial scale due to the demand in drug industries. The alkaloid forskolin present in the roots is used to develop drugs to treat hypertension, glaucoma, asthma, congestive heart failure and certain types of cancers (DeSouza, 1986). The biomass production and its accumulation in plants are largely affected by the agronomic manipulations apart from the nature of the species. In field crops, the dry matter production and its accumulation in economic parts is of concern to the scientist. When economic part is below the ground, inputs like fertilizers and water have greater influence on the differential accumulation in the above and below ground portion of the plants (Marschner, 1995). The agronomic manipulations and practices (spacing, time of harvest etc.) aimed at improving the yield of tubers through optimizing source-sink ratio is of more practical significance. Optimum spacing provided to each plant helps to utilize growth resources optimally resulting in better yields. Similarly, higher crop yield can be realized by harvesting at its physiological maturity. Hence, a study was undertaken to know the influence of spacing and time of harvest on biomass production and its partitioning to the various plant parts in *Coleus forskohlii*.

Materials and Methods

A field experiment was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka during *kharif* 2004 and 2005 under irrigated conditions. The soil of the experimental site is clay loam in texture. The initial soil properties were organic C content: 0.62%, pH: 8.0, electrical conductivity (EC): 0.2 dS m^{-1} and bulk density: 1.34 g cm^{-3}. The available N was low (228 kg ha^{-1}), available P was medium (17.5 kg ha^{-1}) and available K was high (300 kg ha^{-1}). The rainfall during 2004 and 2005 was 366.3 and 527.4 mm respectively as against the normal of 406.9 mm. The minimum and maximum temperature was 21.58 and 29.68°C respectively during 2004 and 19.53 and 28.93°C during 2005 respectively as against the normal minimum and maximum temperature of 20.86 and 30.44°C, respectively.

The experiment was laid out in split plot design and replicated thrice. The main plot treatments consisted of four spacings (60 cm x 30 cm, 75 cm x 20 cm, 45 cm x 30 cm and 60 cm x 20 cm with a plant population of 55,555, 66,666, 74,074 and 83,333 plants per hectare respectively) and sub plots comprised three stages of harvest (140, 160 and 180 days after planting (DAP)). The gross plot size was 9.0 m x 3.0 m. Farmyard manure @ 10 t ha^{-1} was applied to all the treatments three weeks before planting. Ridges and furrows were made as per treatments. The terminal shoot cuttings (10-12 cm long having 3-4 pairs of leaves) of *Coleus forskohlii* cultivar K-8 was planted as per the spacing treatments. The cuttings were dipped in 0.1% carbendazim solution for five minutes before planting. Irrigation was given once in 4-5 days during the initial period till establishment and once in 10-12 days at later stages to maintain optimum soil moisture. Chemical fertilizers to supply NPK @ 50: 60: 50 kg ha^{-1} were applied. Half of N and full P and K were applied 20 days after planting and the remaining quantity of N was applied 30 days after the first application. The data on total biomass production (TBP) and its accumulation in the different parts were recorded at 140, 160 and 180 DAP. Data were analyzed statistically as per the standard procedure (Gomez and Gomez, 1984) and the means were subjected to the Duncan's Multiple Range Test (DMRT).

Results and Discussion

Effect of spacing

Main plot treatments viz., different spacings significantly affected the TBP of plants during both the years. The spacing of 60 cm x 20 cm resulted in the maximum biomass production during 2004 (10.99 tha^{-1}). During 2005, 75 cm x 20 cm spacing produced the greatest biomass production (9.41 tha^{-1}). However, during 2005, the TBP produced under 60 cm x 20 cm (9.17 tha^{-1}) was on par with that obtained from 75 cm x 20 cm spacing (Fig. 1). The pooled data showed that, significantly higher TBP was produced under a spacing of 60 cm x 20 cm (10.08 t ha^{-1}) and 75 cm x 20 cm (9.92 t ha^{-1}). The total biomass production per hectare increased from 8.69 to 10.08 t ha^{-1} with decrease in plant to plant spacing from 30 cm to 20 cm (Fig. 1). Biological yields become asymptotic with increase in plant density (Vidovic and Pokorny, 1973). The increased above ground biomass production from 7.65 to 8.51 t ha^{-1} with decrease in spacing (60 cm x 30 cm to 60 cm x 20 cm) might have contributed to increased dry tuber yield (1.04 to 1.57 t ha^{-1}). The increase in the above ground biomass was only 11.2% compared to below ground biomass (51%) with decrease in plant to plant spacing (from 60 cm x 30 cm to 60 cm x 20 cm). The contribution of the above ground biomass towards the total biomass production reduced from 88.0 to

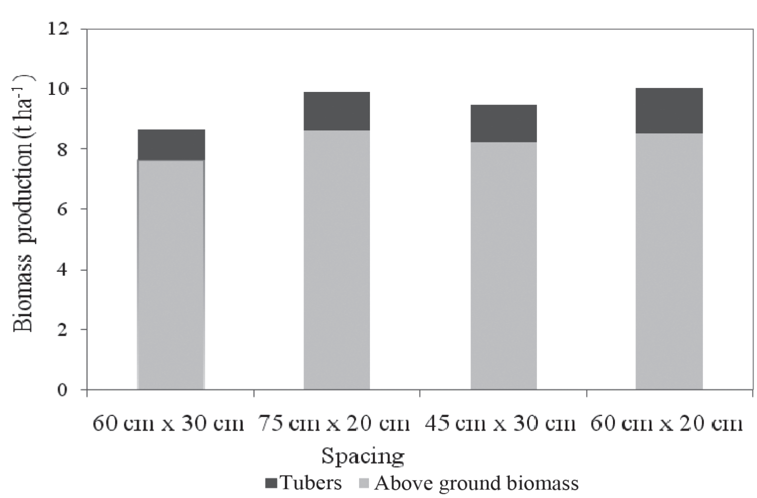

Fig.1. Total biomass production and its partitioning in *Coleus forskohlii* as influenced by plant spacing (Pooled mean of two years)

84.4 % as the spacing reduced from 60 cm x 30 cm to 60 cm x 20 cm. On the contrary, the contribution of tuber biomass towards the total biomass production increased from 12.0 to 15.6% with decrease in plant to plant spacing (60 cm x 30 cm to 60 cm x 20 cm). The results clearly indicated that dry matter apportioned to the tubers increased gradually with decrease in plant to plant spacing. The accumulation of dry matter in tubers increased (11.1, 11.4, 11.8 and 12.1% at 60 cm x 30 cm, 75 cm x 20 cm, 45 cm x 30 cm and 60 cm x 20 cm, respectively) with decrease in spacing, though yield per plant decreased. Suja and Nayar (2005) also recorded similar trend in arrowroot. The biomass production and its distribution tended in favour of tubers with decrease in spacing (60 cm x 30 cm to 60 cm x 20 cm) and consequent increase in plant density (55,555 to 83,333 plants per hectare). The decrease in spacing resulted in increased plant density, which increased the harvest index (HI) progressively (0.111, 0.114, 0.118 and 0.121 at 55,555, 66,666, 74,074 and 83,333 plants per hectare, respectively) (Fig. 2). The increased HI with decrease in spacing could be ascribed to the increased accumulation of dry matter in tubers.

Effect of time of harvest

The time of harvest influenced the TBP significantly during both the years. Maximum TBP was produced when harvested at 80 DAP (10.48, 10.14 t ha^{-1} during 2004 and 2005 respectively) (Fig. 3). However, harvesting the crop at 160 and 180 DAP produced significantly higher biomass in tubers than 140 DAP during both the years (1.39 and 1.45 t ha^{-1}, at 160 and 180 DAP, respectively). During 2004, the above ground biomass was significantly higher when the crop was harvested at 140 and 180 DAP. But, during 2005 and in pooled data, significantly higher above ground biomass

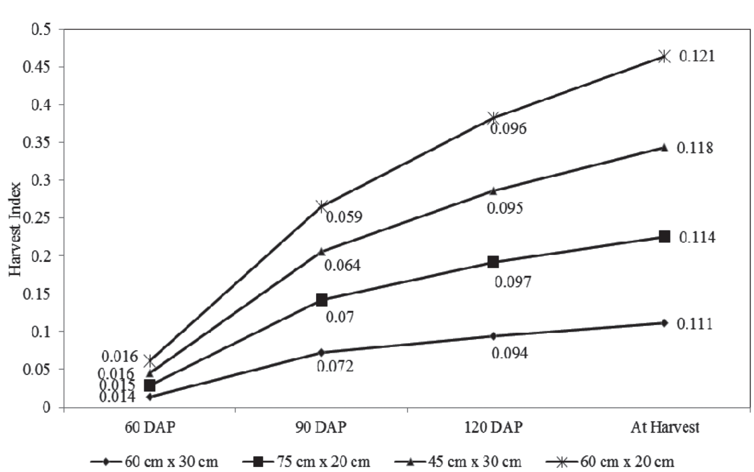

Fig. 2. Effect of spacing on harvest index in *Coleus forskohlii* at different growth stages (Pooled mean of two years); DAP= Days after planting

was produced when harvested at180 DAP (8.84 and 8.86 t ha^{-1}, respectively). The total biomass produced at 180 DAP was higher by 10.0 and 15.1% over 140 and 160 DAP, respectively. Whereas, the per cent accumulation of the above ground biomass at 180 DAP was higher by 6.0 and 17.0% over 140 and 160 DAP, respectively. Accumulation of dry matter in tubers increased with increase in the age of the crop with a peak at 160 DAP, and at a slow rate at 180 DAP. Food material synthesized in leaves gets translocated and deposited into tubers at a faster rate during initial stages and at slow rate towards tuber maturity. Hegde (1992) observed increase in dry matter in the above ground portion up to 150 DAP with a decline at 175 DAP, while dry matter in tubers increased up to 175 DAP. Results of Joy et al. (2001) in *Alpinia galanga* also indicated similar trend. Differences in accumulation of the above and below ground biomass resulted in variation in harvest indices (HI) also at different intervals. The HI at 160 DAP (0.135) was significantly higher than the HI at 140 (0.091) and 180 DAP (0.122) (Fig. 4).

Interaction effect of spacing and time of harvest

Analysis of pooled data showed that the total biomass in the treatment combination 60 cm x 20 cm and harvesting at 180 DAP (11.15 t ha^{-1}) was significantly higher than the other treatment combinations (Table 1). Biomass accumulation in the above ground portion and also in tubers followed a similar trend. The treatment combination 60 cm x 20 cm and harvesting at 180 DAP produced significantly higher biomass accumulation in the top portion (9.77, 9.0 and 9.38 t ha^{-1} during 2004, 2005 and in pooled data, respectively). The contribution of top and tuber biomass to the total biomass was 87.7 and 12.3%, respectively, in the treatment combination 60 cm x 30 cm and harvesting at 180 DAP as against 84.1 and 15.9%, respectively, in 60 cm x 20 cm and harvesting at 180 DAP and 81.7 and 18.3%, respectively, in 60 cm x 20 cm and harvesting

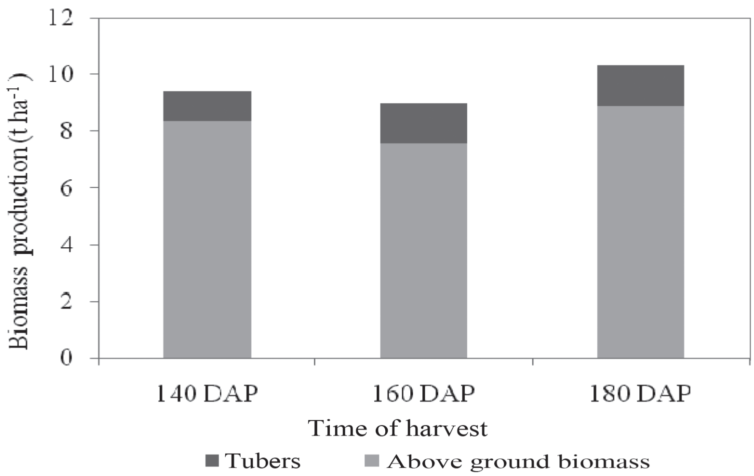

Fig. 3. Effect of time of harvest on total biomass production (t ha^{-1}) and its accumulation in the different plant parts in *Coleus forskohlii* (Pooled mean of two years); DAP= Days after planting

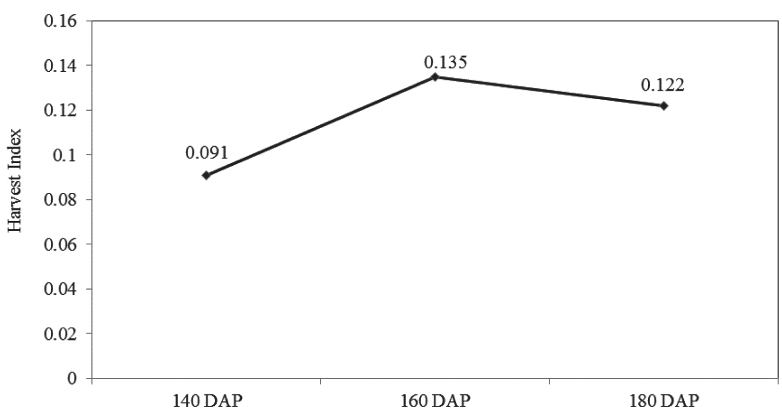

Fig . 4. Effect of time of harvest on harvest index in *Coleus forskohlii* (Pooled mean of two years); DAP= Days after planting

at 160 DAP on pooled basis. The accumulation of biomass in tubers was maximum in the treatment combination 60 cm x 20 cm and harvesting at 160 DAP (17.9, 18.8 and 18.3% during 2004, 2005 and in pooled data, respectively). Higher plant population (83, 333 plants ha^{-1}) with optimum duration of the crop plant resulted in higher tuber yield in the above treatment combination. Higher accumulation of dry matter in tubers resulted in significantly higher harvest index (0.142) in the treatment combination 60 cm x 20 cm and-harvesting at 160 DAP (Fig. 5).

Conclusion

Thus, total biomass production and its accumulation in tubers and above ground portion were higher with closer plant to plant spacing. With increase in the duration of the crop, total biomass also increased with decline after 160 DAP which was mainly due to decline in the biomass of above ground portion as a result of senescence of leaves. Though there was an increasing trend in tuber biomass with increase in crop duration, it was not significant after 160 DAP. Thus the cultivar K-8 may be planted at a spacing of 60 cm

Table 1. Interaction effect of spacing and time of harvest on total biomass production (t ha^{-1}) and its partitioning in *Coleus forskohlii*

Treatments	2004			2005			Pooled		
	Top	Tuber	Total	Top	Tuber	Total	Top	Tuber	Total
60 cm x 30 cm -140 DAP	8.27^{ef}	0.79^{f}	9.05^{de}	7.24^{ef}	0.93^{c}	8.17^{ef}	7.75^{cd}	0.86^{e}	8.61^{fg}
60 cm x 30 cm -160 DAP	7.57^{g}	1.10^{de}	8.67^{e}	6.60^{e}	1.13^{c}	7.73^{d}	7.09^{g}	1.11^{c-e}	8.20^{g}
60 cm x 30 cm -180 DAP	8.23^{ef}	1.12^{de}	9.35^{d}	7.99^{bc}	1.16^{c}	9.15^{b}	8.11^{de}	1.14^{cd}	9.25^{de}
75 cm x 20 cm -140 DAP	9.35^{b}	1.12^{de}	10.47^{bc}	8.31^{b}	0.88^{c}	9.19^{b}	8.83^{b0d}	1.00^{de}	9.83^{cd}
75 cm x 20 cm -160 DAP	8.52^{de}	1.69^{b}	10.21^{bc}	7.28^{de}	1.20^{bc}	8.48^{b-d}	7.90^{ef}	1.45^{b}	9.35^{de}
75 cm x 20 cm -180 DAP	8.97^{bc}	1.63^{bc}	10.60^{bc}	9.34^{a}	1.22^{bc}	10.55^{a}	9.16^{ab}	1.43^{b}	10.59^{b}
45 cm x 30 cm -140 DAP	9.05^{bc}	1.06^{e}	10.10^{c}	7.81^{b-d}	0.89^{c}	8.70^{bc}	8.43^{cd}	0.97^{de}	9.40^{de}
45 cm x 30 cm -160 DAP	7.93^{fg}	1.47^{c}	9.40^{d}	7.19^{de}	1.10^{c}	8.29^{b-d}	7.56^{f}	1.28^{bc}	8.84^{ef}
45 cm x 30 cm -180 DAP	8.54^{de}	1.69^{b}	10.24^{bc}	9.05^{s}	1.22^{bc}	10.27^{a}	8.80^{bc}	1.46^{b}	10.26^{bc}
60 cm x 20 cm -140 DAP	9.23^{b}	1.27^{d}	10.54^{bc}	7.57^{cd}	1.15^{c}	8.71^{bc}	8.42^{cd}	1.21^{b-d}	9.63^{d}
60 cm x 20 cm -160 DAP	8.80^{cd}	1.92^{a}	10.72^{d}	6.64^{e}	1.54^{ab}	8.19^{cd}	7.72^{ef}	1.73^{a}	9.45^{de}
60 cm x 20 cm -180 DAP	9.77^{a}	1.95^{a}	11.72^{a}	9.00^{a}	1.59^{a}	10.59^{a}	9.38^{a}	1.77^{a}	11.15^{a}
CD (0.05)	0.38	0.19	0.48	0.63	0.32	0.83	0.43	0.23	0.55

Values with the same superscript in a coloumn are not significantly different

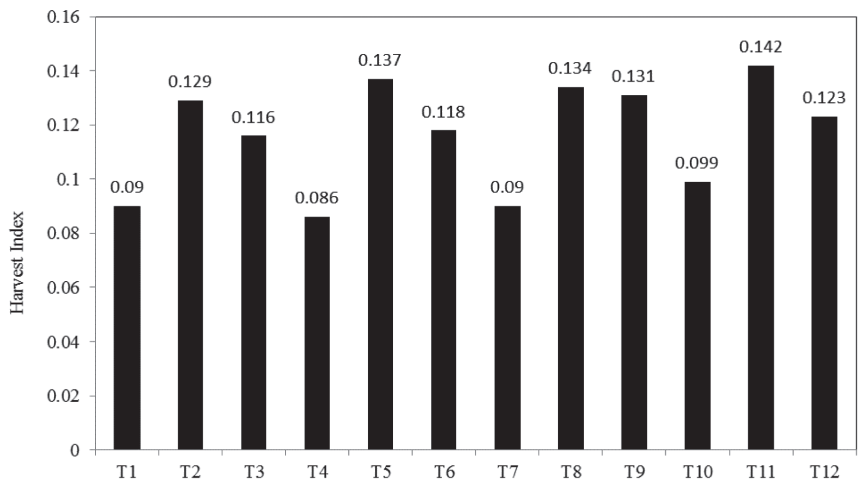

Fig. 5. Interaction effect of spacing and time of harvest on harvest index in *Coleus forskohlii* (Pooled mean of two years)

T_1: 60 cm x 30 cm-140 DAP
T_2: 60 cm x 30 cm-160 DAP
T_3: 60 cm x 30 cm-180 DAP
T_4: 75 cm x 20 cm-140 DAP
T_5: 75 cm x 20 cm-160 DAP
T6: 75 cm x 20 cm-180 DAP
T_7: 45 cm x 30 cm-140 DAP
T_8: 45 cm x 30 cm-160 DAP
T_9: 45 cm x 30 cm-180 DAP
T_{10}: 60 cm x 20 cm-140 DAP
T_{11}: 60 cm x 20 cm-160 DAP
T_{12}: 60 cm x 20 cm-180 DAP

x 20 cm with a population of 83,333 plants per hectare to realise optimum biomass production and effective partitioning. The crop may be harvested at 160 DAP to get the maximum yield.

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