Research Article

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Marigold-globe amaranth sequential cropping in coconut plantations of coastal humid tropics

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Abstract

Marigold (*Tagetus erecta*) and globe amaranth (*Gomphrena globosa*) are two potential commercial loose flower crops with high market demand during festive seasons. Climate of coastal humid tropics is suitable for growing marigold and globe amaranth during October to April and May to September, respectively, where the flowering season coincides with the peak demand fetching higher market price. A field study was conducted in two consecutive years at ICAR-CPCRI, Regional Station, Kayamkulam during 2010-12 for standardising the nutrient management practice for marigold-globe amaranth sequential cropping under coconut based farming system in coastal humid tropics. The treatments were fixed based on nitrogen equivalent basis. In the study, marigold alone was supplied with nutrition and globe amaranth was raised with the available field residues of first crop. Intercropping marigold was supplied with basal dose of vermicompost (16.8 kg N ha^{-1}) followed by 16.8:18:18 kg NPK ha^{-1} at 15 days after transplanting and vermicompost extract (1:10), to meet 4.4 kg N ha^{-1} equivalent, at 30 days and 45 days after transplanting resulted in fresh flower yield of 2 t ha^{-1} of coconut plantations. The plant height, number of primary and secondary branches, number of flowers plant^{-1}, flower yield, and flower carotenoid content of marigold were also higher in this treatment. The growth or yield of globe amaranth did not differ among the treatments, and on an average it produced fresh flower yield of 1.9 t ha^{-1} from the interspaces of coconut. This study on sequential cropping of flower crops revealed that substituting 50 per cent inorganic nitrogen requirement of marigold with vermicompost enhances its growth performance and also provides adequate nutrition for raising globe amaranth during its vegetative phase (upto 60 days after transplanting) resulting in a B:C ratio of 2.8.

Keywords: Coconut, marigold-globe amaranth, sequential cropping, vermicompost

Introduction

In India, floriculture is emerging as an important commercial activity. The proportion of area under traditional floriculture was accounted for 0.72 per cent of the total horticultural crops with an area of 0.23 million hectares (Mamta *et al*., 2016). There is a need to increase the area under flower crops to meet its growing market demand. In general, flower crops come up well in soils rich in organic matter with full sunlight but scarcity of open area in coastal humid tropics is a limiting factor for increasing the area under flower crops. Coconut is the major plantation crop in coastal humid tropics covering an area of 1.98 mha (Mamta *et al*., 2016), which is perennial in nature and planted with wider spacing. It utilizes only 25 per cent of the land area and offers greater scope for intercropping (Maheswarappa *et al*., 2001). Though intercropping in coconut garden is studied widely (Magat and Secretaria, 2005; Mensah and Budu, 2012), only a few reports are available about the scope of ornamental plants (Sudha and Subramanyam,1992). Introduction of annual ornamentals in the interspaces of coconut garden not only enhances the aesthetics but also gives additional farm income in a short period of time. Intensive cultivation of intercrops increases the yield from coconut as well (Girija *et al*., 2011).

Marigold (*Tagetus erecta*) of Compositae family and globe amaranth (*Gomphrena globosa*) of Amaranthaceae family are two potential commercial flower crops that are gaining wider

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popularity as specialty loose flowers. These can be used both as fresh and dry flowers for making various floral decorations. Marigold flower is also an important source of carotenoids with application in the food industry (Barzana *et al*., 2002) and as dye for fabrics (Vankar *et al*., 2009). The flowers of marigold and globe amaranth fetch higher market demand and price in India during December-April and August-September, respectively. Moreover, growing globe amaranthutilizing the residual soil nutrients after marigold helps in keeping the interspaces of coconut free from weeds during the rainy season. Being short duration crops, marigold-globe amaranth sequential cropping system can be adopted in a single year with better economic returns to the farmer.

Vermicompost (VC) is reported to be better organic manure for marigold (Pritam *et al.*, 2010; Shadanpour *et al.*, 2011) and *Amaranthus* species (Uma and Malathi, 2009) for growth and yield. Dried coconut leaves can be effectively recycled to vermicompost and can be utilized as a source of plant nutrients for raising these crops. Growing marigold (October to April) with different gradients of vermicompost followed by globe amaranth (May to September) utilizing the residual nutrients and field residues in the interspaces of coconut garden ensures market oriented flower production. Performance of marigold and globe amaranthunder low fertile soil with reduced sunlight is yet to be studied. Hence, an experiment was conducted in two consecutive seasons at ICAR-CPCRI, Regional Station, Kayamkulam, Kerala, India to assess the effect of combination of vermicompost and fertilizer nutrients on growth, flowering and carotenoid content of marigold and its residual effect in growth and performance of globe amaranth in coconut gardens of coastal humid tropics.

Materials and methods

The experiment was conducted in the research farm (Block III) of Central Plantation Crops Research Institute (Regional Station), Kayamkulam, Kerala State, India. The area is located in coastal humid tropics (9^{o} 8' North latitude, 76^{o} 30' East longitude and 3.1 m above mean sea level). The photosythetically active radiation (PAR) of the site was estimated using light meter Model LI-250, Li-COR serial no. LMA 2505. The average PAR during peak hours was 937.5 μ mol $m^{-2}s^{-1}$ which is estimated as 74 per cent of incident solar radiation (1253 μ mol m^{-2} s^{-1}).

The major weather parameters affecting the growth, yield and flower quality are given in Fig. 1 and 2. The photosythetically active radiation, total illumination and total radiation recorded from the

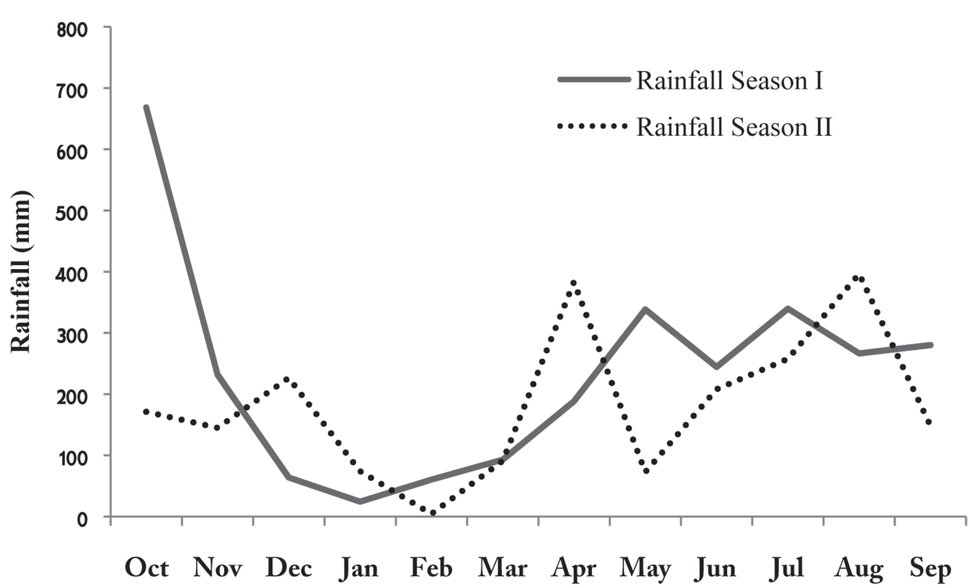

Fig. 1. Rainfall (mm) pattern during the period of study (Season I: 2010-11 and Season II: 2011-12)

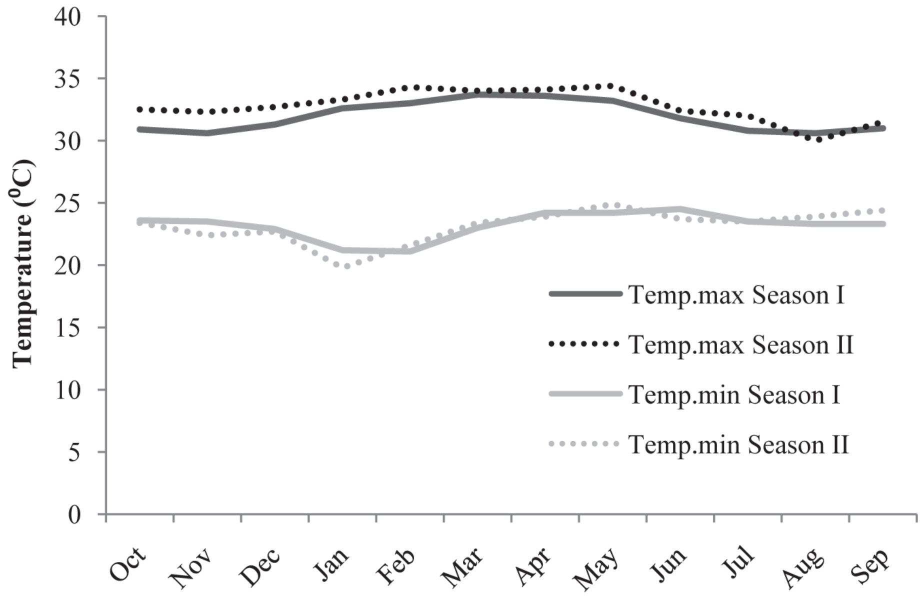

Fig. 2. The maximum and minimum temperature (^{o}C) during the period of study (Season I: 2010-11 and Season II: 2011-12)

experimental site were 937.5 µ mol $m^{-2}s^{-1}$, 2278 Wm^{-2} µA and 8068 Wm^{-2} respectively. Nutrient requirement was estimated based on the area of intercropping and expressed as NPK kg ha^{-1} of coconut garden. All other treatment combinations were formulated on nitrogen equivalent basis and first treatment was fixed as 67.5:18:18 NPK kg ha^{-1} based on the general recommendation of marigold as pure crop ie., 30 per cent of 225:60:60 kg NPK ha^{-1} (KAU, 2011). The soil of the experimental site is sandy loam of the order Entisol with pH of 5.7, 0.15 per cent organic carbon, 23.7 ppm P, 54.6 ppm K, 216.2 ppm Ca, 24.6 ppm Mg, 1.12 ppm Mn, 13.4 ppm Fe and 2.2 ppm Zn.

Residual nutrients in soil (Table1) along with the microbial load like bacteria (161.5x10^5), fungi (172.3 x10^5), actinomycetes (48.9x10^5), fluorescent pseudomonas (10.2 x10^2), P-solublisers (28.9 x 10^4) and N fixers (34.1 x10^5) were utilized for raising globe amaranth till 60 days after transplanting (DAT). As globe amaranth showed prolonged vegetative phase, an additional dose of 18:18:18 NPK (5 g $pant^{-1}$) was given at fortnightly intervals from 60 DAT till two weeks before the final harvest (150 DAT).

The experiment was laid out in completely randomized design with six treatment combinations and four replications in two consecutive years

Table 1. Soil nutrient status after marigold

Treatment	Org. C (%)	P (ppm)	K (ppm)	Ca (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
NPK	0.28	32.4	46.9	104.1	26.9	3.20	1.73
VC (25% N) +NPK	0.31	37.5	35.0	84.5	30.4	2.27	1.71
VC (25% N) +NPK+VCE	0.37	32.2	52.5	100.2	32.1	3.19	1.89
VC (50% N) +NPK	0.26	29.9	35.3	122.2	20.8	2.14	1.49
VC (50% N) +NPK+VCE	0.31	33.8	57.7	115.3	26.7	2.68	1.87
VC (25% N) +NPK +VCE +husk burial	0.38	29.3	40.6	78.9	28.9	1.99	2.02
CD (treat.) (pd≤0.05)	NS	NS	8.21	21.4	5.0	NS	NS

during same cropping season. Nutrients were given only for marigold based on the following treatment combinations. Globe amaranth was grown as a catch crop utilizing the residual nutrients and field residues of marigold.

Dried cow dung was applied uniformly to all the treatments @ 6 t ha^{-1} of intercropped area

T1	67.5:18:18 NPK kg ha^{-1} (control) (where N was given in two splits (1:1) @ basal and 30 DAT***)
T2	VC* equivalent to 8.4 kg N ha^{-1} (25 % RDN) as basal + 42:18:18 NPK kg ha^{-1} @15 DAT (where N was given in three splits (2:1:1) @ 15,30,45 DAT)
T3	VC equivalent to 8.4 kg N ha^{-1} (25 % RDN****) as basal + 25:18:18 NPK kg ha^{-1} @15 DAT+ VCE** (1:10) equivalent to 28kg N ha^{-1} at 30 and 45 DAT
T4	VC equivalent to 16.8 kg N ha^{-1} (50 % RDN) as basal + 42:18:18 NPK kg ha^{-1} @15 DAT (where N was given in three splits (2:1:1) @ 15,30,45 DAT
T5	VC equivalent to 16.8 kg N ha^{-1} (50 % RDN) as basal + 16.8:18:18 NPK ha^{-1} @15 DAT+ VCE (1:10) equivalent to 8.4 kg N ha^{-1} at 30 and 45 DAT
T6	T3 + husk incorporation (One layer of coconut husk was buried with concave surface facing upward at 75cm depth and covered with soil)

*Vermicompost; **Vermicompost extract; ***Days after Transplanting; **** Recommended dose of nitrogen

The nutrient content of vermicompost and VCE used for the study were 1.93:0.13:0.19 per cent NPK and 0.22:0.06:0.44 per cent NPK respectively. Fertilizer sources for N, P, and K elements were urea (46% N), rock phosphate (20% P_2O_5), and muriate of potash (60% K_2O) respectively. Nitrogen was also given as vermicompost and vermicompost extract as per treatment whereas, common dosage of P and K was given in all the treatments.

VCE (1:10) preparation : Vermicompost equivalent to N is taken and mixed with tap water in 1:1(w/v) ratio and kept overnight.The quantity of vermicompost was taken considering the recovery of extract from vermicompost which is estimated as 57 per cent. VCE was diluted with water in 1:10 ratio (w/v) and sprayed to plants. The quantity supplied for the present study was 1.75l m^{-2} at 30 and 45 DAP.

Marigold and globe amaranth were planted in coconut plantations of 35 years old with 26 per cent shade in two consecutive seasons during October to April and May to September, respectively. Considering the light availability, plots of 4m x 4m were taken in between four palms which amount to 30 per cent area of the total cropped area.

Four week-old seedlings at 3-4 true leaf stage were transplanted at 45cm x 45 cm and 60cm x 60cm for marigold and globe amaranth, respectively.

Observations

The growth parameters such as plant height (height of plant from the bottom to tip of the topmost leaf), number of primary branches (branches developed from main stem) and secondary branches (branches developed from primary stem) which determine the flower yield were recorded for marigold and globe amaranth, respectively at vegetative phase (30 DAP and 60 DAP), fifty per cent flowering (60 DAP and 80 DAP) and full bloom stage (120 DAP and 100 DAP).

The number of flowers per plant was recorded from full bloom stage to a total of eight harvests. Yield was calculated as quantity of fresh flowers in kilogram produced per hectare of intercropped area. The flower quality of marigold and globe amaranth was estimated in terms of flower carotenoid content by Acetone method (Saini *et al*., 2001).

The benefit cost ratio (BCR) of the system was worked out based on cost of cultivation and economic returns in terms of flower yield of both marigold and globe amaranth from eight harvests along with number of harvested nuts from the coconut palms.

All statistical analysis were performed separately for each parameter in the first and second cropping seasons based on randomised block design following standard analysis of variance (ANOVA) technique using SAS 9.3 and Microsoft Excel 2007 (http://www.microsoft.com/) software.

Results and discussion

The growth and yield performance of marigold and globe amaranth with different nutritional treatments were found to be similar in both the seasons. The improved soil nutrient and microbial population after growing marigold could be effectively utilized for growing globe amaranth only up to 60 DAT. The higher receipt of rain fall during the months of June and July might have also resulted

Table 2. Effect of intercropping on growth parameters of marigold during vegetative phase (VP), fifty per cent flowering (FP) and full bloom stages (FB) of growth (pooled data of both the seasons)

Treatment	Plant height (cm)			No. of primary branches			No. of secondary branches		
	VP	FP	FB	VP	FP	FB	VP	FP	FB
NPK	60.6	73.6	87.4	6.4	11.5	12.8	16.1	27.4	42.4
25%VC+NPK	67.9	76.8	104.3	8.6	10.5	11.3	21.6	33.6	50.1
25%VC+NPK+VCE	66.7	75.9	97.7	8.8	9.8	12.4	18.1	35.3	51.3
50%VC+NPK	66.9	76.2	87.8	6.9	11.9	12.6	20.3	26.9	38.6
50%VC+NPK+VCE	70.6	78.3	101.9	9.0	12.8	13.3	29.1	33.4	62.3
25%VC+NPK+VCE+husk burial	75.2	72.3	102.7	10.8	16.1	16.0	28.3	30.9	53.1
SE_m	2.1	1.8	1.8	1.1	0.6	0.8	1.2	3.7	1.4
CD (treat.) ($p<0.05$)	4.4	3.8	3.9	2.3	1.4	1.6	2.5	NS	3.1
Season 1	53.9	62.7	99.2	6.9	12.4	15.2	8.2	21.9	42.1
Season 2	82.1	88.3	94.7	9.8	11.8	10.9	36.3	40.5	57.1
SE_m	2.1	1.2	1.2	0.6	0.4	0.5	0.7	2.1	0.9
CD (year) ($p<0.05$)	2.5	2.5	2.6	1.2	NS	1.0	1.5	4.4	1.9

in hastening the leaching of nutrients from soil (Schreiber, 1999). In both the growing seasons, all the growth and yield parameters were on par for globe amaranth confirming that the residual soil nutrients from first crop is not adequate to supply enough nutrients for getting a significant difference in the growth and yield of second crop. The principles governing the effect of nutrition supplied on main crop for N supply to the succeeding crops have been found to differ basically from the N effects of added organic matter (Kristensen *et al*, 2003). Here, the improved soil conditions after growing the main crop was effectively utilized for raising the subsequent crop (Kristensen, 1994) till its vegetative phase.

Growth characters

Integrated nutrient management practices with organics in sandy loam soils play a vital role in production of vigorous plants with optimum plant height and more number of secondary branches which have positive influence on flower production.

Table 3. Effect of intercropping on growth parameters of globe amaranth during vegetative phase (VP), fifty per cent flowering (FP) and full bloom stages (FB) of growth (pooled data of both the seasons)

Treatment	Plant height (cm)			No. of primary branches			No. of secondary branches		
	VP	FP	FB	VP	FP	FB	VP	FP	FB
NPK	49.7	69.1	74.4	5.8	9.6	12.9	3.5	13.5	23.8
25%VC+NPK	44.0	62.8	68.9	5.3	9.6	12.9	1.6	13.3	25.1
25%VC+NPK+VCE	39.9	64.9	72.6	6.0	8.3	13.6	2.1	12.6	25.9
50%VC+NPK	42.2	62.5	70.1	6.8	8.1	12.5	2.1	13.1	24.8
50%VC+NPK+VCE	41.5	62.9	70.9	6.3	9.0	12.8	1.9	12.5	24.8
25%VC+NPK+VCE+husk burial	44.3	66.5	75.2	6.5	9.4	14.3	2.1	13.3	25.8
SE_m	3.9	5.5	5.3	0.8	0.8	1.7	0.8	1.7	1.6
CD (treat.) ($p<0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Season 1	46.2	72.2	64.7	5.3	7.7	13.4	1.8	15.2	25.6
Season 2	41.0	57.4	79.3	6.9	10.3	12.9	2.6	10.9	21.4
SE_m	0.9	0.8	0.9	0.4	0.3	0.4	0.3	0.8	1.1
CD (year) ($p<0.05$)	1.8	1.6	2.1	0.7	0.6	NS	0.6	1.7	2.3

Organic manure plays a direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization, improving the physical, chemical and physiological properties of soils. Growth parameters such as plant height, number of primary and secondary branches, varied significantly among the treatments in all growth stages only for the main crop (Table 2). The growth of marigold was robust during the second year which might be due to favourable weather parameters such as more distributed rainfall. Results reveal that the residual nutrients from marigold were not sufficient enough to give a significant difference in growth parameters even in the initial growth stages ie., vegetative phase of globe amaranth (Table 3).

Plant height was higher in plants applied with 50 per cent VC +NPK+VCE at vegetative, fifty percent flowering and full bloom stages (75.2, 78.3 and 101.9 cm). Higher plant height attained after pinching and disbudding during its vegetative phase indicates the plant vigour (Sandeep *et al*., 2013). The higher plant height in this treatment might be due to the application of vermicompost which is a good source of phyto-hormones such as GA_3, IAA and cytokinin (Gaur and Sadasivam, 1993) resulting in accelerated plant height and flowering (Gul *et al*., 2006).

Primary branches were higher in T_6 (25% VC+NPK+VCE+ husk burial) followed by T_5 (50% VC+ NPK+VCE), whereas number of secondary branches were more in T_5. The increased number of branches in plants grown under husk buried condition may be due to more soil moisture retention. The improved soil moisture content triggers the activation of lateral vegetative buds for production of primary branches. There was a steady increase in the number of primary branches only up to fifty per cent flowering (60 DAT). In marigold, flower production is directly related to the number of primary and secondary branches (Karuppaiah and Krishna, 2005). But in the present experiment it is the number of secondary branches which determined the flower yield of marigold. The reduction in branching rate from main stem in the later phases of growth might be due to the cultural operation of pinching and disbudding favouring stimulation and production of axillary buds (Mohanty *et al.*, 2013) resulting in more number of secondary branches.

Yield and quality parameters

In marigold, plants supplied with 50 per cent VC+NPK+VCE produced higher number of flowers per plant (56) and fresh flowers (2.05 t ha^{-1}) with

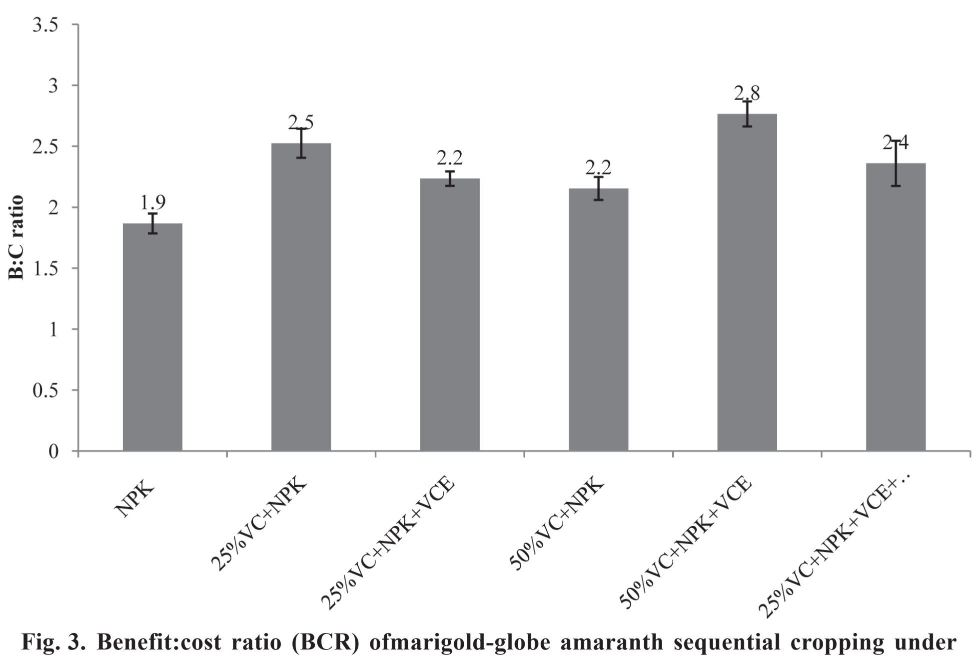

Fig. 3. Benefit:cost ratio (BCR) ofmarigold-globe amaranth sequential cropping under coconut based farming system

Table 4. Effect of intercropping in flower yield and quality of marigold (M) and globe amaranth (G) (pooled data of both the seasons)

Treatment	No. of flowers/plant		Flower yield (kg ha^{-1})		Flower carotenoid content (%)	
	M	G	M	G	M	G
NPK	26.6	127.0	1256.5	1575.8	0.79	0.07
25%VC+NPK	51.9	134.8	1843.3	1944.9	0.55	0.08
25%VC+NPK+VCE	26.8	147.6	1372.2	2001.9	0.97	0.09
50%VC+NPK	28.5	119.8	1569.9	1628.5	0.74	0.08
50%VC+NPK+VCE	55.8	134.0	2051.5	2107.6	1.01	0.08
25%VC+NPK+VCE+husk burial	35.6	144.8	1437.6	1855.0	0.87	0.09
SE_m	1.7	17.9	65.4	340.9	0.02	0.03
CD (treat.) ($p<0.05$)	3.5	NS	139.3	NS	0.04	NS
Season 1	34.4	128.8	1567.3	1774.4	0.82	NS
Season 2	40.7	140.5	1609.7	1930.2	0.82	NS
SE_m	0.4	4.2	35.3	118.4	0.00	0.01
CD (year) ($p<0.05$)	0.8	8.9	NS	NS	0.00	NS

M – marigold; G – globe amaranth

higher carotenoid content (1.01%). This might be attributed to the effect of vermicompost in enhancing flower production (Pritam *et al.*, 2010). Substituting inorganic nitrogen with organics enhances the vegetative growth and assists the plant during blooming period mobilising the process of flowering in marigold (Bil *et al.*, 2010). Flower quality was estimated based on the flower carotenoid content of dry petals. In general, carotenoid content was higher in flowers produced in plants applied with VC+NPK+VCE (Table 4). In general, the flower production and quality recorded higher during the second year. The carotenoid yield (g per 1000 flowers) was also higher in these treatments (T_3:3.67g, T_5:4.14g and T_6:3.83g) revealing the beneficial effect of vermicompost in enhancing the quality of flowers in marigold. The use of vermicompost for enhanced flower quality was also reported in *Chrysanthemum* (Sarojini *et al.*, 2012).

Economics of cultivation

Marigold-globe amaranth sequential cropping system in coconut plantations with more than 75 per cent light intensity is ideal for doubling the income of small and marginal farmers (Fig. 3). Sequential intercropping of marigold- globe amaranth with 50 per cent VC+NPK+VCE helped in effective utilization of residual nutrients from the first crop fetching an additional income from coconut garden with B:C ratio of 2.8.

Conclusion

In marigold-globe amaranth cropping system, marigold can be cultivated during October to April by supplying adequate quantity of organic and inorganic nutrients and globe amaranthas catch crop during May to September, when the climate and market demand for the respective flower crops are favorable. Intercropping marigold in coconut plantations can be done by substituting 16.8 kg ha^{-1} N (50% recommended dose of nitrogen) with coconut vermicompost followed by 16.8: 18:18 kg NPK ha^{-1} at 15 days after transplanting and application of vermicompost extract (8.4 kg N ha^{1}) in two equal splits at 30 days and 45 days. The residual soil nutrients can be effectively utilized for growing globe amaranth till its vegetative phase (60 DAT). Intercropping flower crops in coconut gardens resulted in proper irrigation of the interspaces which might have helped in enhancing water and nutrient use efficiency of palms. Regular irrigation in the interspaces resulted in eleven percentage improvement in yield of coconut palms which was mainly due to reduced button shedding. This crop rotation ensures continuous growing of flower intercrops throughout the year with flower production during months of peak demand and doubling the farmer's income.

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