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Effects of on-farm composted seed spices residues on coriander, nutritional parameters and seasonal carbon offset by the crop and soil

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Abstract

Field experiments were carried out with seven treatments from three types (coriander, fennel and mixture of these two and others) of vermi-composts (vc) and its two doses (5 and 10t) of vc were compared with control taking coriander (Ajmer coriander-1) as a test crop for three years. First year on lower fertile soil and last two years on medium fertile soil belongs to Subgroup Typic Haplustepts and sandy loam in texture. Results revealed that plant height and primary branches were only higher with 10t vermi-compost of mixed residue (vc-mix). Secondary branches and yield parameters were higher with10t vc of each types as well as 5t of mixed vc. Seed yield of last two years was remarkably higher with each type of 10t vc and 5t of mixed. Per cent yield increased with 10t and 5t mixed vc was 48.7 and 36.4, respectively, whereas 5t each of coriander and fennel vc gave 15.4% higher yield on medium fertile soil. In contrast to it, yield was only 2-5% higher on lower fertile soil with these vermi-composts over the control. Uptake of nutrients by coriander was more with 10t vc over 5t and control. Availability of N and K in soil enhanced with 10t vc, however P and Zn were at par with either level and types of vc, while more over control. Availability of Cu, Fe and Mn was improved with 10t either types of vc or 5t mixed vc. Biological carbon sequestration was higher with each level and types of vc over control, whereas soil organic carbon (SOC) was higher only with 10t vc. Net biological and soil carbon enhanced by vc was ranged from 0.34 to 0.41 and 0.27 to 1.38t ha^{-1}, whereas total offset ranged from 0.61 to 1.79t ha^{-1}. Irrespective of treatments, all the soil and plant parameters were more with mixed vc followed by coriander vc except K availability in soil which was more with fennel vc. Based on the above findings it can be concluded that coriander responded well to vc only on medium soil fertility.

Key words : Coriander, carbon offset & sequestration, macro and micronutrients, Vermi-compost.

Introduction

In India, about 273.63 million tons or more crop residues per year obtain from major crops. About 2.42 million tons per year crop residues obtain from the seed spices. In usual practice crop residue either used as fodder or burnt it down. Burning crop residue causes the CO_2 enrichment in the atmosphere which is a major radiative forcing gas contributes to climate change. On-farm composting is an efficient, cost-effective and environmentally safe biological process for the recycling of crop residues for resource recycling (Maniadakis *et al.*, 2004). It is a simple process consisting of user-friendly small composting plants equipped with tools resources available on a farm, where organic biomasses are transformed and stabilized through an aerobic bio-oxidation or vermi-composting (Christian *et al.*, 2009). On-farm composting substantially contributes to solve the problem of disposing agricultural biomasses or weeds and seed spices feedstock, concomitantly provides to farmer; with a self-supply of quality vermi-compost for the improvement of agricultural productivity. Loss of soil quality is related to soil organic matter (SOM) depletion that is increased by continuous cropping without organic input, frequent soil tillage and large use of both inorganic chemical fertilizers and pesticides in semi-arid to dry areas. Intensively exploited soils for crops, an external supply of stabilized organic matter, such as composts, vermi-composts is required to counteract progressive SOM decline. Use of compost contribute to the soil quality recovery and conditioner of plant growing medium (Celano *et al.*, 2012) by providing numerous ecosystem services, including replenishment of soil carbon stocks, increase of microbial activity and biodiversity and restoration of plant nutrition and natural soil quality decline (Pane *et al.*, 2011). Fenugreek residues used as fodder and rest of useless seed spices crop residue could be a very good source of organic matter to be composted and returned to soil. Although some studies focused on vegetable waste composting (Pane *et al.*, 2015, Ghaly *et*

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al., 2006 & Alkoaik and Ghaly 2006), however, little attention has been so far paid to assess the agronomic effectiveness of the produced compost or vermi-compost. Besides that use of spent grass on mustard and medicinal plant production was studied by Patra *et al.,* (2000) and reported good response of both crops yield and soil properties. Favorable responses of manures were observed on coriander and other crops by Shekinah *et al.,* (2007). Jayanthi *et al*., (2009) reported encouraging results on vegetables production with residue recycling under integrated farming. Aishwath and Tarafdar (2007) reported response of crop residue as mulch for medicinal plant production and conserving moisture and nutrients. Use of organic manures gave positive response in yield and oil content in fennel (Mohamed, and Abdu, 2004).

Direct use of crop residue improves the organic matter concomitantly improvement in physical, chemical and biological properties of soil, however many reports proved that crop residue not only immobile nutrients but also leaves allelopathic effect on succeeding crops. Hence to mask the inhibitory effect of residue on crops, three types of seed spices residues (coriander, fennel and mixture of these two and others) was composted by using earthworms. Moreover, there is no such study available for vermicomposting of seed spices feed stock and its impact on these crops and soil. Therefore, it was assumed that on-farm vermi-composting of seed spices crop wastes could be a best sustainable practice to improve soil quality and crop yield was our aim to investigate the effects on growth, yields and their parameters, soil properties and carbon offset for environmental quality.

Materials and methods

Location and climate

The field experiments were carried out for three consecutive years under the Typic Haplustepts during *Rabi* season of 2008–09, 2009-10 and 2010–11 at ICAR-National Research Centre on Seed Spices, Tabiji, Ajmer, Rajasthan, India. This was laid out between 74° 35'39" to 74° 36' 01"E longitude and 26° 22'12" to 26° 22' 31" N latitude. Climate of the Ajmer area characterized as semi-arid. The average annual rainfall of the area is 536 mm and most of it (85-90%) received between June to September. July and August are most rainy months contributing 60.0% of the average rainfall. The moisture control section remains dry for more than 90 cumulative days and hence moisture regime classified as Ustic. The mean annual temperature is 24.5 to 25.0°C. January is the coolest month of the season and temperature remain around 7.0°C. Currently frost is also occurring occasionally in this month with changing climatic pattern (Singh and Shyampura, 2004).

Treatments and cultural practices

The treatments consisted 5.0 and 10.0 tonnes of three types of vermi-composts prepared from crop residues ie coriander (VC Cor), Fennel (VC Fen) and mixture (VC mix) of all seed spices residue including fenugreek and compared with control. The subscript values given with vermi-composts is the amount of those composts applied in the soil (t ha^{-1}). Nutrients amount for the treatments was decided based on the nutrient requirement of crops and soil availability in the experimental field. The vermi-compost was sieved after getting it mature or the decomposed properly. Thereafter, composts were analysed for moisture and nutrient content. All the seven treatments were arranged in a Randomized Block Design (RBD) with three replications. The coriander varieties Ajmer Coriander-1 (ACr-1) was taken as a test crop for the study on sandy loam soil. Seeds of the coriander variety ACr-1 were sown during winter season and plant spacing 30cm line to line apart and from plant to plant distance was maintained at 10 cm or more by thinning. Cultural practices were uniformly followed during the growing seasons in both the years and crop was irrigated as and when required. The crop was harvested, when it matured during all the three years. After harvest, seeds were separated from the stover by beating bundles thereafter winnowing.

Soil analysis

Soil samples were collected from the surface (0-15 cm depth) before sowing of seeds and after the harvest of crop during both year crops. Samples were air dried and powdered with wooden mortar and pestle and passed through a 2 mm stainless steel sieve. Experimental soil was analysed for physicochemical properties ie EC and pH (Richards, 1954), organic carbon content by rapid chromic titration (Walkley and Black, 1934), available N by alkaline permanganate (Subbiah and Asija, 1956), available P by 0.5 M $NaHCO_3$ extractable P (Olsen, *et al*., 1954) and Bray and Kurtz (1945), available K by 1N NH_4OAc extracts method (Jackson, 1973) and available micro-nutrients (Fe, Zn, Mn & Cu) by DTPA (Lindsay and Norvell, 1978).

Texture of experimental soil was sandy loam. Soil EC, pH and organic carbon during 2009-10 and 2010-11 were 0.31 dSm^{-1}, 8.6 and 0.31%, respectively. However, soil available N, P and K were 139.5, 8.2 and 270.6 kg ha^{-1}, respectively. Micronutrient status like iron, zinc, manganese, copper and boron in the soil was 10.8, 4.0, 26.5 and 3.8 kg ha^{-1}, respectively. Soil calcium content was about 7.5 per cent. Available N, P, K and SOC during

2008-09 was 71.7, 6.8, 250 and 0.21 respectively. However, corresponding value of soil available Fe, Zn, Mn and Cu were 11.0, 2.5, 19.2 and 2.1 for the year 2008-09.

Plant analysis

The plant samples were collected after the harvest of crop. These samples were successively washed with tape water and then 0.1 M HCl followed by distilled water and thereafter dried at 70ºC. After proper drying samples were powdered in wily mill and passed through the 20 mesh stainless steal sieve. Nitrogen was estimated by Kjeldahl method (Piper, 1966). The samples were digested in nitric and perchloric acid (10:4) for the estimation of P by Venado-molybdo yellow colour method (Chapman, and Pratt, 1962) and K by flame photometer. Iron, zinc, manganese, and copper were estimated by Atomic Absorption Spectrophotometer and carbon by CHNS Analyser (Thermo Scientific make).

Vermi-compost preparation and analysis

Vermi-compost was prepared at ICAR-National Research Centre on Seed Spices farm with all the possible precautions required for any nutritional contamination of moistures in all the beds including shades. The substrate used for the preparation of three types of vermi-composts was half rotten coriander, fennel and other crop residue with animal dung. To avoid the border effect for shade green net was suspended along the sides of thatched roof up to the bottom level. Moisture and temperature was monitored regularly. Earthworm (*Eisenia fetida*) used for the study was collected from the KVK, Ajmer. Mature vermi-compost was harvested and then sieved for the use. For the nutritional analysis, samples were oven dried at 60-70ºC temperature. Nitrogen was estimated by Kjeldahl method (Piper, 1966) after digestion with H_2SO_4 and digestion mixture. The samples were also digested in nitric and perchloric acid (10:4) for the estimation of P by Venado-molybdo yellow colour method (Chapman, and Pratt, 1962) and K by flame photometer. Iron, zinc, manganese, and copper were estimated by Atomic Absorption Spectrophotometer and carbon by CHNS Analyser (Thermo Scientific make). The nutritive value of the vermi-composts is given in table 1.

Table 1. Macro-nutrients content and C:N ratio in on-farm prepared vermi-composts.

Crop residues	N%	P%	K%	S%	C:N ratio
Coriander	1.7	0.7	1.5	0.8	14.2
Fennel	1.6	0.6	1.8	0.6	17.1
Mixed	2.0	0.9	1.6	0.7	10.0

Statistical Analysis

The data of both the years (2009-10 and 2010-11) were pooled analysed by ANOVA and treatment differences were expressed for Least Significant Differences (LSD) at 5% probability to determine the significance among the treatment means (Cochran and Cox, 1987). However, data for the year 2008-09 were also analysed statistically.

Results and discussion

Growth yield and their parameters

Plant height and primary branches were only higher with 10t vermi-compost (vc) mixed (Table 2). However, secondary branches and yield parameters like umbellate umbel^{-1} and seeds umbel^{-1} were higher with 10t each type of vc as compared to control. Umbels plant^{-1} were higher with 5t vc of mixed substrates and each of vermi-compost applied @ 10t ha^{-1}. This is because of slow release of nutrients by vermi-composts leaves better impact on later phonological stages of crop. Seed yield of last two years was pooled and it was higher with10t each of vermin-composts including 5t vc of mixed resides. Response of coriander was higher with 10t vc of mixed residue over the 5t each of vc prepared from fennel and coriander under medium level of fertility. This is because of vermi-compost provides the nutrients to the crop and improve the soil properties resultant vigorous plant growth. Improved growth, yield and quality of fenugreek in lower to medium fertile soil was also observed by Aishwath *et al.,* (2017), Shekinah *et al.,* (2007) and in other crops by Celano *et al.*, (2012). In contrast to it, there was no statistical variation was observed when these dosed of vc was applied in lower fertile soil. This might be due to coriander plants are able to uptake only water soluble form of nutrients rather to organic bounded and other forms. Under very low available N (70 kg N ha^{-1}), the yield of coriander was about two to two and half time lower than the medium level of soil available N. Overall response crop was more with mixed vc followed by coriander-vc. Composted crop residues not only improves the yield of crops to the applied but also of succeeding crops (Shrivastava and Arya, 2018).

Uptake of nutrients

Nitrogen uptake was significantly higher with all the levels and types of vermi-composts (Fig. 1). Phosphorus and potassium uptake was higher with each of vermi-composts and their doses as that of control. However, P uptake was higher with 10t vc of missed residues over the 5t vc of fennel, while K uptake was higher with 10t mixed vc as compared to 10t vc of fennel and 5t each type of vermi-composts. Moreover, uptake of N, P and K was always higher with mixed vc followed by vc of coriander residue irrespective of their doses. This might

Table 2. Effect of vermi-composts on growth, yield and their parameters of coriander.

Treatments Vermi compost	Pl height (cm)	No of branches		Per plant		Seed/ umbel	Seed yield (q ha^{-1})	
		Primary	Secondary	Umbel	Umbellate		2008-09	Av. of 2009-10 &11
Control	98.1	10.3	15.5	65.3	7.4	8.8	6.7	14.3
5t VC Fen	102.3	11.1	17.2	68.6	7.5	9.0	6.9	16.5
5t VC Cor	103.2	11.3	17.5	69.5	7.6	9.1	7.0	16.5
5t VC mix	105.6	11.5	17.8	70.7	7.8	9.3	7.5	19.5
10t VC Fen	106.6	11.5	18.1	73.2	8.3	9.5	7.8	21.0
10t VC Cor	108.1	11.8	18.5	74.7	8.5	9.7	8.1	21.0
10t VC mix	115.9	12.4	20.3	76.8	8.7	9.8	8.2	21.8
CD at 5%	14.2	1.6	2.4	4.9	0.6	0.5	NS	5.1

t or tn = Tonnes, VC = Vermi-compost, Cor = Coriander residue, Fen = Fennel residue, mix = Mixture of all the seed spices specially coriander + Fennel + Fenugreek + other seed spices residues, Av = Average, Pl = plant

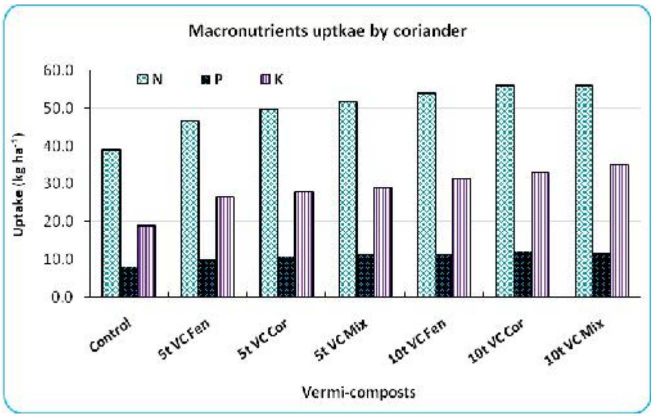

Fig. 1. Effect vermi-composts on macronutrient uptake by coriander.

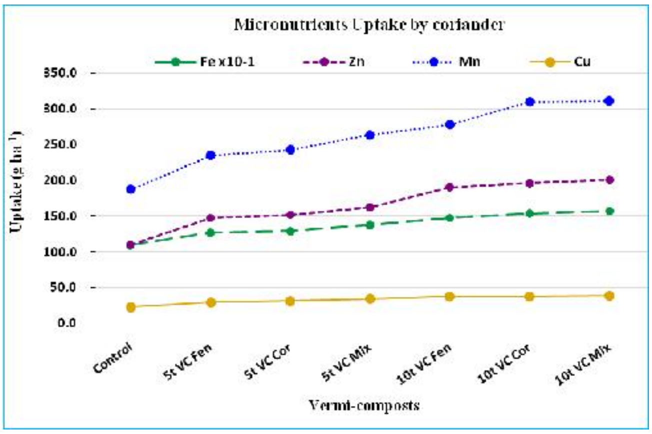

Fig. 2. Effect vermi-composts on micronutrient uptake by coriander.

be due to more content of nutrients in these vermi-composts leads to higher yield and biomass accumulation resultant higher uptake. Higher uptake of N with composts was reported on highly weathered central Amazonian Ferralsol (Steiner, *et al.*, 2008). Application of phosphor-compost @ of 10 t ha^{-1} gave plant growth dry matter accumulation, seed yield and P uptake by soybean equivalent to single superphosphate @ 26.2 kg P ha^{-1} (Manna *et al.*, 2001). Composts of pea residue with chicken manure and chicken manure plus rapeseed residue enriched soil with N, P, K and other nutrients, and increased nutrient accumulation in plant (Khan *et al.*, 2008).

Iron, zinc and manganese uptake enhanced with all the levels and types of vermi-composts, whereas uptake of iron and zinc with 10t vc mixed was more over 5t each of vermi-composts (Fig 2). Moreover, uptake of manganese with 10t vc of mixed residue was higher over the 5t each types of vc and also 10t vc prepared from fennel residues. This might be due to higher yield and nutrient content in crop plants with applied vermi-composts, which not only supplied the nutrients may also conditioned the experimental soil by improving physical, chemical and biological properties of the soil. Uptake of copper was enhanced with 5t each of coriander and mixed vc and10t each types of vermi-composts, while uptake of Cu was higher with 10t mixed vc over the 5t each of coriander and fennel resides vc. Manha and Wang (2014) prepared vermi-compost from rice waste and mixed with rice hulls ash and coconut husk in different ratio and studied their performance on muskmelon seedling (*Cucumis melo* L.). They found that mixture of vermi-compost with rice hulls ash and coconut husk at 1:1:1 resulted highest value of germination rate, plant height, leaf area, plant biomass and the content and uptake of P, K, Ca and Fe.

Soil available nutrients

Availability of N and P was improved by applied vermi-composts irrespective of doses and types over the control (Fig 3). However, availability of N was more with 10t vc of mixed residue over 5t each types of vermi-composts, while there was no statistical variation among the doses and types of vermi-composts appeared might be due to fixation of P with reasonable amount of exchangeable Ca in experimental soil. Potassium availability was higher with 10t each types of vermi-composts as compared to control. However, 5t vc prepared by each types of seed spices residues did not show any statistical variation over the control. This might be due to the fact that the experimental soil having K bearing minerals which released by intermittently wetting and drying of soils with irrigation water applied to the crop. However, K availability was more with vc of fennel residue than the coriander may be due to fennel vc has more content as that of coriander and released more of K in soil. Gurmu *et al.,* (2011) reported improvement in soil available nutrients by incorporation of crop residue in soil. They also suggested that manipulating the time of crop residues application, it is possible to control nutrient release to coincide with the time and course of the nutrient requirements by the crop. When low-quality crop residues (low N and P, high lignin or polyphenol contents) are incorporated into the moist soil, nutrients become available to the plants slowly and this may overlap with the plant requirement for the given nutrient in question. With high-quality residues, nutrients are initially released rapidly in excess of plant demand with a risk of nutrients such as N being lost via leaching or denitrification or a nutrient such as P becoming chemically unavailable.

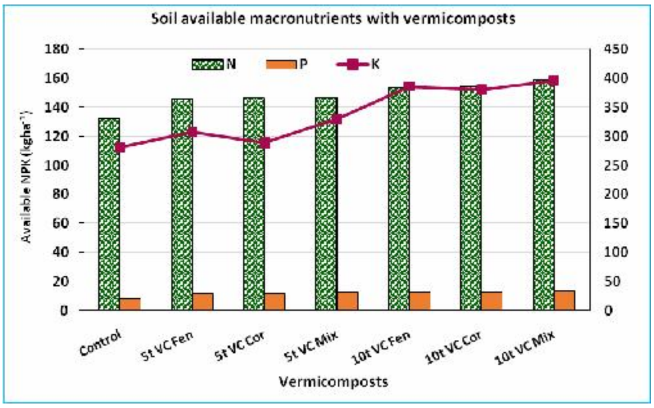

Fig. 3. Effect vermi-composts on soil available macronutrients after coriander.

Copper, manganese and iron availability in soil after the crop enhanced with 5t vc of mixed residues and 10t vc of each three types of seed spices crop residues (Fig 4). Moreover, these treatments were also at par with each other. However 10t vc of mixed residue was having higher Cu, Mn and Fe over with 5t each of fennel and coriander residue. Incase of Zn availability in soil with all types of vermi-composts and their doses were at par, whereas availability enhanced with these composts over the control. This might due to the fact that micronutrients content present in these composts were minute (ppm) in quantity and also having alkaline pH of experimental soil reduced the distinctiveness among the treatments. Moreover, availability of micronutrients including major (N and P) were marginally higher with coriander and mixed residue vermi-composts as compared to vc obtained from fennel residue. It was contrast for the availability of K might be due to content of these elements in vermi-composts. About 50 to 80% of Zn, Cu, and Mn taken up by rice and wheat crops can be recycled through residue incorporation. Therefore, recycling of crop residues can help improve the availability of micronutrients in soil (Gurmu *et al.,* 2011)

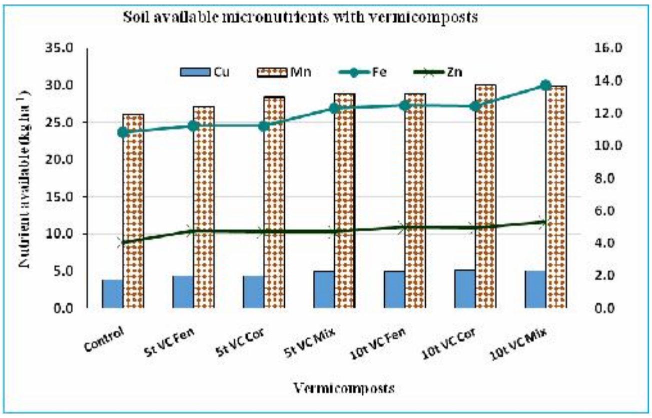

Fig. 4. Effect vermi-composts on soil available micronutrients after coriander.

Soil and biological carbon sequestration/offset

The carbon captured by the crop plants significantly more with each types and doses of vermi-composts as compared to control (Fig. 5). However carbon captured by the crop was marginally higher with coriander vc might

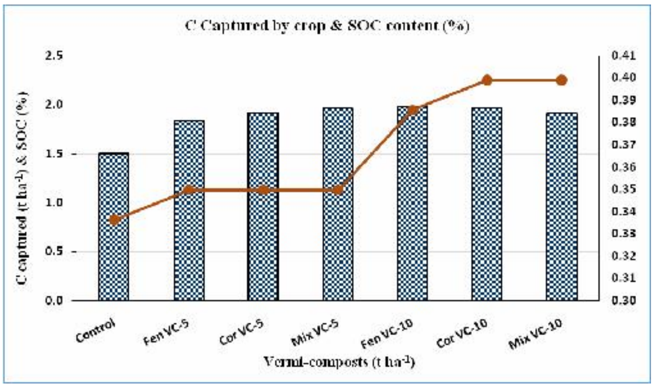

Fig. 5. Effect vermi-composts on carbon captured by coriander and soil organic carbon (%).

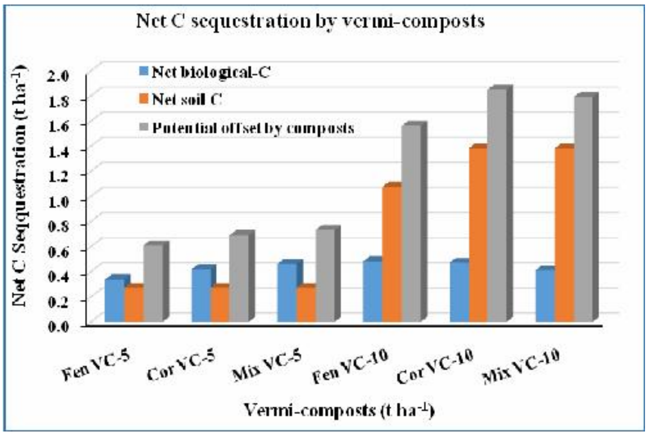

Fig. 6. Effect vermi-composts on net carbon sequestration and potential off-set.

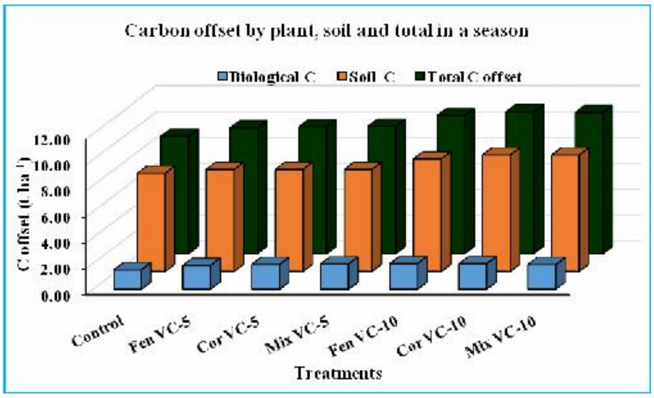

Fig. 7. Effect vermi-composts on carbon offset by crop, soil and total during a season.

be due to more biomass accumulation as compared to fennel vc. Organic carbon content in soil was more with each type of 10t vc as that of control, whereas it was at par to control with each type of 5t vc. This may be due to residence power of soil is poor and higher temperature encourages fast mineralization of organic matter exits lesser in soil. Addition of seven different organic residues (alfalfa, oat, canola, clover, soybean, corn and prairie grasses) to a Webster soil resulted in a rapid, transient increase in aggregate and sequester more carbon in soil by enriching its stable content in soil (Martens, 2000). Average net carbon offset by the crop and soil with vermi-compost was 0.43 and 0.77t ha^{-1}, respectively (Fig. 6). However net offset by crop and soil due to application of vermi-composts only was 1.2t ha^{-1}. Irrespective of treatments, average soil and biological carbon sequestration potential was 8.3 and 1.9 t ha^{-1}, respectively (Fig 7). However, total offset by crop and soil was 10.1t ha^{-1} $season^{-1}$ could be achieved. Hence application of crop residue to crops by transforming through vermi-composting not only recycled the nutrients but also have multifold benefits for higher yield, carbon offset by the crops and soil to avoid burning which leads to environment problems. Cannell (2003) assessed the range of capacities is determined principally by judgements of the areas of land that are likely to be devoted to sequestration or energy crops. Theoretically, enhanced carbon sequestration and energy cropping could offset 2000–5000 Mt C yr^{-1} globally, but a more realistic potential offset is 1000 –2000 Mt C yr^{-1} and there are good reasons to suppose that only 200 –1000 Mt C yr^{-1} is actually achievable.

Conclusion

Coriander responded well with vermi-composts in lower to medium fertile soil, however response was negligible in lower fertile soil. Crop uptake and soil availability of nutrients as well as carbon offset by crop and soil was enhanced by composts. Hence, this is a win-win situation for nutrient recycling, improvement in crop yield, soil health and carbon offset including reduction in black carbon in the atmosphere by avoiding burning of crop residues.

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