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Effects of in-situ composted seed spices residues on growth, yield, nutritional parameters and seasonal carbon offset by anise crop

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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 vermicompost (VC) and its two doses of (5 and 10t) VC were compared with control taking anise (Ajmer Anise-1) as a test crop for two years on lower to medium fertile soil belongs to Subgroup Typic Haplustepts. Results revealed that plant height, umbellate umbel^{-1}, seeds umbellate^{-1} and seed yield and primary branches were only higher with 10t each types of vermicompost. Primary and secondary branches were higher with 10t VC of each types as well as 5t of mixed VC. Per cent yield increased with 10t of fennel-VC, coriander-VC and mixed-VC was 32.1, 33.9 and 35.7%, respectively, whereas 5t each of fennel, coriander and mixed-VC gave 7.1, 14.2 and 25.0% higher yield in comparison to control. Uptake of nutrients by anise was more with 10t VC over 5t and 5t VC over control. Availability of nutrients in soil enhanced with each type and levels of 10t VC except K and Cu, which was more even with 5t mixed VC. Biological carbon sequestration, total offset and soil organic carbon SOC (%) was higher with each level and types of VC over control except 5t VC of coriander and fennel, respectively. Soil organic carbon (SOC) sequestration was only higher with 10t VC. Net biological and soil carbon enhanced by VCs was ranged from 0.13 to 0.39 and 0.27 to 0.86 t ha, whereas total offset by vermicompost was ranged from 0.40 to 1.24 t ha. 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. The corresponding value of Na content and accumulation was 5 and 18 times more in straw than seed indicated it's wide range of adaptability to acidic to alkaline pH discovered an unique feature of the crop. Based on the above findings it can be concluded that anise responded well to VCs on lower to medium fertile soil.

Key words : Adaptability, anise, carbon offset & sequestration, macro and micronutrients, vermicompost.

Introduction

Crop residue, traditionally considered as "trash" or agricultural waste, is increasingly being viewed as a valuable resource. 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 vermicompost 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 are 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

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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 al.*, 2006; Alkoaik and Ghaly, 2006), however, little attention has been so far paid to assess the agronomic effectiveness of the produced compost or vermicompost. 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 and vermicomposts gave positive response in yield and nutrient uptake in fennel and coriander (Mohamed and Abdu, 2004 and Aishwath *et al.,* 2019).

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) were 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 two consecutive years on the Typic Haplustepts soil group during *Rabi* season of 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 tons of three types of vermicomposts prepared from crop residues ie coriander (VC Coriander), Fennel (VC Fennel) and mixture (VC mix) of all seed spices residue including fenugreek and compared with control. The subscript values given with vermicomposts 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 vermicompost was sieved after getting it mature or the decomposed properly. Thereafter, composts were analyzed for moisture and nutrient content. All the seven treatments were arranged in a Randomized Block Design (RBD) with three replications. The anise varieties Ajmer Anise-1 (A Ani-1) was taken as a test crop for the study on sandy loam soil. Seeds of the anise variety AAni-1 were sown during winter season and plant spacing 30 cm line to line apart and from plant to plant distance was maintained at 10-15 cm 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 both the 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 analyzed 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 NH4OAc 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 0.30

dSm^{-1}, 8.5 and 0.21%, respectively. However, soil available N, P and K were 110.6, 8.1 and 250.8 kg ha^{-1}, respectively. Micronutrient status like iron, zinc, manganese, copper and boron in the soil was 10.6, 3.5, 18.2 and 3.6 kg ha^{-1}, respectively. Soil calcium content was about 7.5 per cent.

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 70°C. After proper drying samples were powdered in wily mill and passed through the 20 mesh stainless steel 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).

Vermicompost preparation and analysis

Vermicompost was prepared at ICAR-National Research Centre on Seed Spices, Ajmer 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 vermicomposts 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 vermicompost was harvested and then sieved for the use. For the nutritional analysis, samples were oven dried at 60-70°C 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 vermicomposts is given in Table 1.

Statistical analysis

The data of both the years (2009-10 and 2010-11) were pooled analyzed 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).

Results and discussion

Growth, yield and their parameters

Plant height and branches $plant^{-1}$ were only higher with 10t each type of vermicomposts (VC) and 5t mixed VC (Table 2). However, other yield parameters like umbellate $umbel^{-1}$ and seeds $umbel^{-1}$ were higher with 10t each type of VC as compared to control and 5t each type of VC. Umbels $plant^{-1}$ were higher with 5 and 10t VC of each type. This is because of slow release of nutrients by vermicomposts leaves better impact on later phonological stages of crop. Seed yield of two years was pooled and it was higher with10t each of vermin-composts. Response of anise was higher with 10t VC of mixed residue over the 5t each of VC prepared from fennel and coriander under medium level of soil 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 and coriander in lower to medium fertile soil was also observed by Aishwath *et al.* (2017 and 2019), Shekinah *et al.* (2007) and in other crops by Celano *et al.* (2012). This might be due to anise plants prefer to take up only water soluble form of nutrients rather to organic bounded and other forms. Overall response crop was more with mixed VC followed by coriander-VC. Composted crop residues not only improve the yield of crops to the applied but also of succeeding crops (Shrivastava and Arya, 2018). Darzi *et al.* (2012) was also reported higher growth, yield and their parameters with 10t vermicompost prepared from cow dung and applied @ 0, 5 and 10t ha^{-1}at Karaj condition of Iran.

Uptake of nutrients

Nitrogen and phosphorus was significantly higher with all

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

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

Table 2. Effect of vermicomposts on growth, yield and their parameters of anise.

Vermi-composts	Plant height	Branches		Umbel/plant	Per umbel		Yield (q ha^{-1})	
		Primary	Secondary		Umbellate	Seed	Seed	Stover
Control	52.0	10.4	13.5	37.5	12.0	11.7	5.6	27.5
5t VC Fen	52.5	10.5	13.8	40.4	13.7	12.4	6.0	28.3
5t VC Cor	53.2	10.6	13.9	41.1	13.8	12.7	6.4	28.8
5t VC Mix	55.2	10.9	15.5	42.0	13.9	13.0	7.0	29.5
10t VC Fen	56.9	11.2	16.0	42.4	14.3	13.2	7.4	30.8
10t VC Cor	56.9	11.4	16.9	42.6	14.6	13.9	7.5	31.4
10t VC Mix	58.3	11.6	17.0	44.7	14.8	14.9	7.6	31.8
CD at 5%	2.7	0.8	1.9	2.30	1.9	1.3	1.7	4.2

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

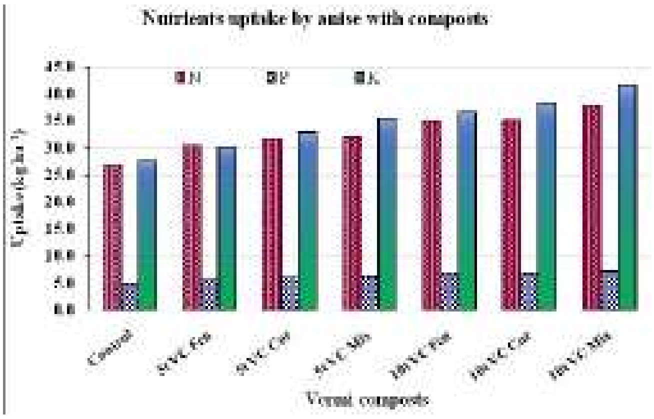

Fig. 1. Effect of vermicomposts on macronutrients uptake by anise.

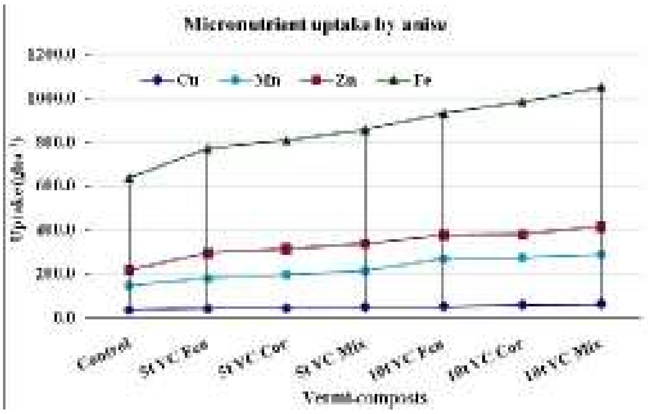

Fig. 2. Effect of vermicomposts on micronutrients uptake by anise.

the levels and types of vermi-composts (Fig. 1). Potassium uptake was higher with each of vermicomposts and their doses as that of control except 5t VC of fennel might be due to lower biomass accumulation with the treatment. Moreover, N and P uptake was higher with 10t VC of mixed residues over the 5t VC of each types, while K uptake was higher with 10t mixed VC as compared to 10t VC of fennel and 5t each type of vermicomposts. 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 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, increased nutrient accumulation in plant (Khan *et al.*, 2008).

Iron, zinc and manganese uptake enhanced with all the levels and types of vermicomposts, whereas uptake of manganese and zinc with 10t VC mixed was more over 5t each of vermicomposts (Fig. 2). However, uptake of iron 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 vermicomposts (Aishwath *et al.* 2019), 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 mixed VC and10t each types of vermicomposts, while uptake of Cu was higher with 10t mixed VC over 10t fennel VC and 5t each of coriander, fennel and mixed resides VC. Manha and Wang (2014) prepared vermicompost 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 vermicompost 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.

Accumulation of Na in seed was only higher at 5t mixed VC and 10t each types of VCs. However, accumulation in stover and uptake was higher with each levels and types of vermicomposts as compared to control (Fig. 3). This might be due to anise originated from Mediterranean regions and Asia minor which provide a dual opportunity for the crop to establish itself for acidic to alkaline environment. Hence the crop developed a genetic set up to sustain in acidic condition as well as at higher pH by accumulating Na in vegetative parts; not in seed to avoid damage of embryo by excessive Na ions. This mechanism makes it more adoptive with pH and also with limited and excessive moisture. Based on the meta-analysis our other work, anise is more adoptive to acidic conditions for both yield and quality, however this study revealed for its

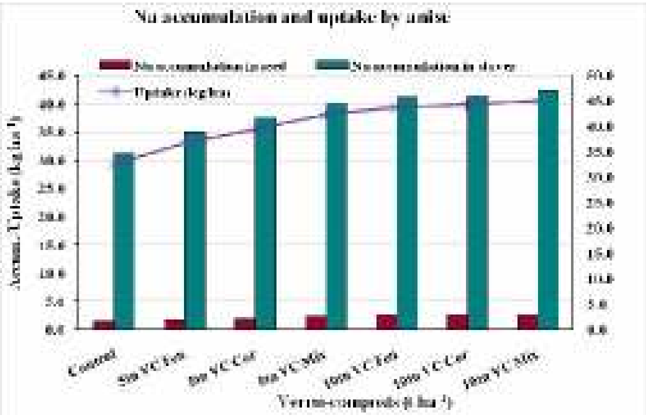

Fig. 3. Effect of vermicomposts on Na accumulation in seed & stover and uptake by anise.

adaptiveness to alkaline conditions too (Aishwath *et al*, 2010).

Soil available nutrients

Availability of P and K was improved by applied vermicomposts irrespective of doses and types over the control (Fig. 4). However, availability of N was more with 10t VC of each type and 5t mixed residue over control and 5t each of fennel and coriander vermicomposts. There was no statistical variation for P among the doses and types of vermicomposts 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 vermicomposts as compared to each type of 5t VCs. 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

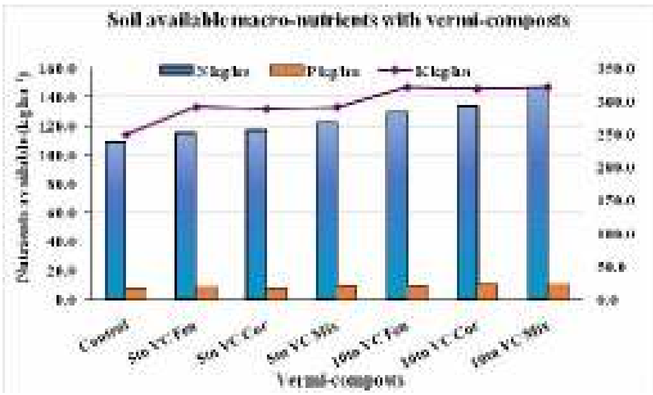

Fig. 4. Effect of vermi-composts on soil available macronutrients after anise.

or denitrification or a nutrient such as P becoming chemically unavailable.

Iron, manganese and zinc availability in soil after the harvest of crop enhanced with 5t VC or 10t of each type residues VC over the control (Fig. 5). Moreover, these treatments were also at par with each other. However 10t VC of mixed residue was having higher Cu and Fe over with 5t each of fennel and coriander residue. In case of Zn and Mn availability in soil with all types of vermicomposts 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 vermicomposts 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 vermicomposts. About 50 to 80% of Zn, Cu, and Mn taken

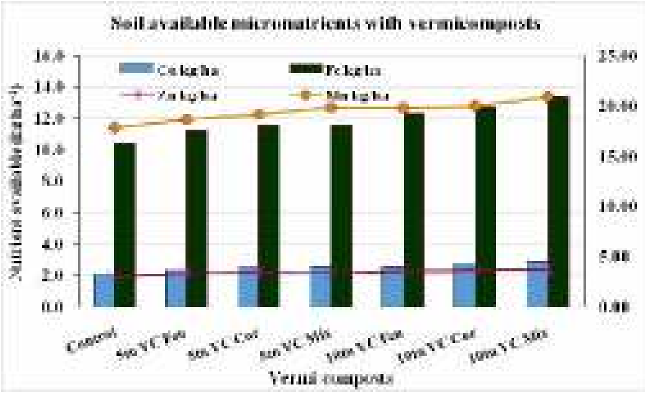

Fig. 5. Effect of vermicomposts on soil available micronutrients after anise.

up by rice and wheat crops can be recycled through residue incorporation. Therefore, recycling of crop residues can help to improve the availability of micronutrients in soil (Gurmu *et al.,* 2011).

Soil and biological carbon sequestration/offset

The carbon captured by the crop plants significantly more with each types and doses of vermicomposts as compared to control (Fig. 6). However carbon captured by the crop

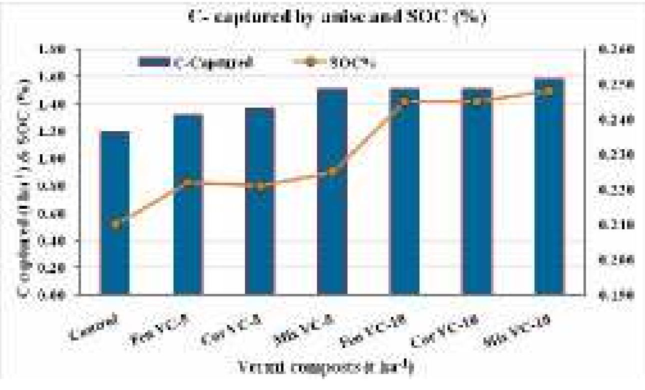

Fig. 6. Effect of vermicomposts on carbon captured by anise and soil organic carbon (%).

with each types of 10t VC and 5t of mixed VC was higher over the 5t of coriander and fennel VC might 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 and each types of 5t VCs, whereas 5t coriander VC was at par to control. 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 vermicompost was 0.27 and 0.55t ha^{-1}, respectively (Fig. 7). However net offset by crop and soil due to application of vermicomposts was only 0.82 t ha^{-1}. Biological carbon sequestration was more with 10t each types of VCs and 5t mixed VC. However, soil carbon sequestration and total offset was more with each types of 10t VCs over 5t each types of VCs and control (Fig. 8). Irrespective of

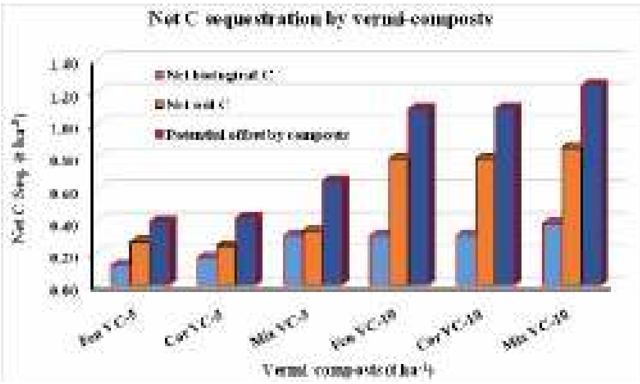

Fig. 7. Effect of verm-composts on net carbon sequestration and potential off-set.

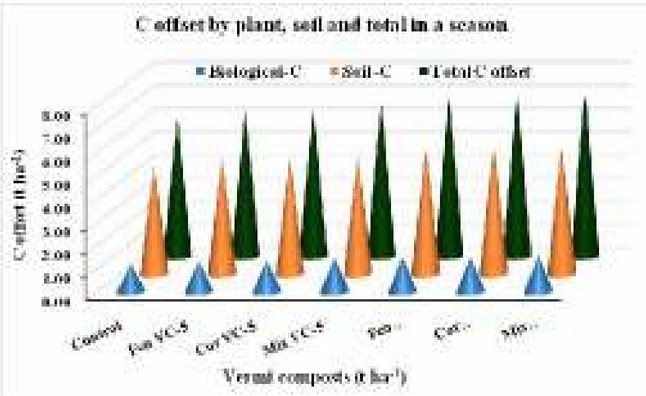

Fig. 8. Effect of vermicomposts on potential C offset by crop, soil and total in a season.

treatments, average soil and biological carbon sequestration potential was 5.2 and 1.4 t ha^{-1}, respectively. However, total offset by crop and soil was 6.6t ha^{-1} $season^{-1}$ could be achieved. Hence application of crop residue to crops by transforming through vermicomposting 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.

Conclusions

Anise responded well with vermicomposts in lower to medium fertile soil. Crop uptake and soil availability of nutrients as well as carbon offset by crop and soil was enhanced by composts. Na accumulation and in seed and straw revealed its adaptability with wide range of pH. Hence, hyper accumulation of Na than any other nutrients could be a boon for reclaiming sodic soil. 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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