

Original Research Article

EVALUATION OF ROCK PHOSPHATE ENRICHED COMPOST ON SOIL NUTRIENT STATUS AFTER HARVEST OF FINGER MILLET-COWPEA CROPPING SEQUENCE IN HIGH PHOSPHORUS SOILS OF CAUVERY COMMAND AREA, KARNATAKA

ABSTRACT

A field experiment was conducted at Zonal Agricultural Research Station, VC Farm, Mandya during *kharif* 2017, summer 2018, *kharif* 2018 and summer 2019 to study the effect of rock phosphate enriched compost on soil nutrient status after harvest of finger millet-cowpea cropping sequence. Prior to initiation of the field experiment, three different composts *viz.*, urban solid waste compost (USWC), vermicompost and farm yard manure (FYM) were enriched with rock phosphate at 5 per cent. Field experiment consisting of eleven treatment combinations comprising recommended N and K, and P through varied levels of enriched composts. The experiment was laid out in RCBD design with three replications and the test crops were finger millet and cowpea. The initial P_2O_5 of the experimental site was very high ($133.58 \text{ kg ha}^{-1}$). The results revealed that application of recommended N and K + 75 per cent P supplied through enriched USWC (T_5) had significantly higher organic carbon (0.56 and 0.58 %) in pooled data of both finger millet and cowpea, respectively. Available N (241.94 and $224.86 \text{ kg ha}^{-1}$), P_2O_5 (138.69 and $120.99 \text{ kg ha}^{-1}$) and K_2O (153.92 and $135.31 \text{ kg ha}^{-1}$) were recorded significantly higher in T_5 of finger millet and cowpea, respectively. Similarly, in pooled mean, exchangeable Ca [4.15 and $4.04 \text{ C mol (P}^+) \text{ kg}^{-1}$] and Mg [2.16 and $2.05 \text{ C mol (P}^+) \text{ kg}^{-1}$] were recorded significantly higher in treatment which received recommended N and K + 75 per cent P supplied through enriched vermicompost (T_8) in both finger millet and cowpea, respectively. **The decrease of available P_2O_5 was 20.98 per cent from initial ($133.58 \text{ kg ha}^{-1}$) to final crop (summer 2019) ($105.55 \text{ kg ha}^{-1}$).**

Key words: USWC, Vermicompost, FYM, Rock phosphate, Finger millet, Cowpea.

INTRODUCTION

The intensive cropping and overuse of inorganic fertilizers without organic inputs degrade the soil quality and cause environmental pollution. Depletion of soil quality could be avoided by proper and careful soil management practices. The application of organics along with inorganic fertilizers is an important practice to improve soil quality, enhance microbial activity and nutrient cycles to produce quality crops. Organic manures act not only as a source of nutrients, but also increases microbial activity, influence structure, nutrients turnover and many other related physical, chemical and biological parameters of the soil (Albiach *et al.*, 2000).

Composting is gaining interest as suitable option for chemical fertilizers with environmental benefit, since this process eliminates or reduces toxicity of municipal solid waste (Kaushik and Garg, 2003; Araujo and Monteiro, 2005) and leads to a final product which can be used in improving and maintaining soil quality. Conventional organic fertilizers, such as urban solid waste compost (USWC) vermicompost and farmyard manure (FYM), are widely recommended for agricultural production as nutrient source and soil conditioner. Use of such compost to the crops could able to save about 50 per

cent of chemical fertilizers and save millions of dollars on exchequer from importing of chemical fertilizers to the country. It can be used as an alternative to other organic matter in agriculture and as a soil conditioner. The quality of the USWC can be improved by use of beneficial microorganisms, nutrient additives and organic amendments (Rao and Radhakrishna, 2001). Jat and Ahlawat (2006) reported that vermicompost application enhanced soil nutrient status (N and P) in subsequent crops compared to no vermicompost application. Orozco *et al.* (1996) and Parthasarathi (2004) reported that vermicompost contains nutrients in forms that are readily taken up by the plants, such as nitrates, exchangeable phosphorus and soluble potassium, calcium and magnesium. Tomati *et al.* (1990) and Parthasarathi *et al.* (2006) also reported that vermicompost contains higher amount of humic acid and biologically active substances such as plant growth regulators.

Phosphorus (P) is one of the major essential macronutrients required for the plant growth. Globally more than 5.7 billion hectares of land contain very low available P (Hinsinger, 2001). Recently, rock phosphate (RP), which is used as a raw material for phosphatic fertilizers, is appeared to be a potential source of plant P nutrition (Yu *et al.*, 2012). Unfortunately, P in RP is not easily available in soils with an alkaline pH and even when conditions are optimal, plant yields are lower than those obtained with soluble phosphate (Khasawneh and Doll, 1978). Availability of P from relatively insoluble RP can be improved by integrating it with organic residues (Biswas and Narayanasamy, 2006) and phosphate solubilizing microorganisms (Chi *et al.*, 2007). Many studies have shown that the enriched compost improves physical and chemical properties of soils by increasing nutrient content, organic matter, water holding capacity and cation exchange capacity. Thus contributing to improvement of crop yield and quality (Mylavarapu and Zinati, 2009; Iovieno *et al.*, 2009). Keeping in view, the benefits of organic manuring as well as its inherent limitations such as analysis and slow action, a study was taken up to investigate the possibility of conversion of compost (USWC, vermicompost and FYM) into phosphate enriched compost through RP and to evaluate their nutritional quality of the crop.

Finger millet-cowpea is a major cereal-pulse based cropping system followed in southern dry zone of Karnataka (Zone 6). Finger millet (*Eleusine coracana* (L.) Gaertn) is an important cereal that belongs to the grass family *Poaceae*, sub family *Chloridoideae*. It is estimated that finger millet accounts for some 10 per cent of the 30 million tons of millet produced globally (Dida *et al.*, 2008). In India, it is cultivated on 1.8 m ha with average yields of 1.3 t ha⁻¹. In Karnataka, finger millet is grown in an area of 0.76 m ha producing 1.32 m t with a yield of 1715 kg ha⁻¹ (FAO. Stat., 2014). Cowpea (*Vigna unguiculata* (L.) Walp.) is a legume mainly grown in tropical and subtropical regions in the world for vegetable and grains and to lesser extent as a fodder crop. It also serves as cover crop and improves soil fertility by fixing atmospheric nitrogen. In view of this, the present study was initiated with the following objectives;

1. To study the effect of phosphorus enriched composts on soil nutrient status after harvest of finger millet
2. To study the residual effect of phosphorus enriched composts on soil nutrient status after harvest of cowpea.

MATERIAL AND METHODS

Site and experimental details

A field experiment was carried out to assess the effect of rock phosphate enriched compost on soil nutrient status after harvest of finger millet-cowpea cropping system in high phosphorus build up soil at ZARS, Mandya in Southern Dry Zone of Karnataka state lying between 12° 34' 03" North (latitude) and 76° 49' 08" East (longitude) with an altitude of 697 m above mean sea level. Finger millet (variety KMR 204) was taken as a main crop (*khariif*) and cowpea (variety C 152) was taken up as residual crop (summer) with a spacing of 30 x 10 cm.

The soil was sandy loam in texture with 87.42, 1.62, and 9.87 per cent sand, silt and clay, respectively and bulk density of 1.38 Mg m⁻³. The soil was neutral in reaction (pH 7.12) and low in soluble salts (0.21 dS m⁻¹). The soil was low in organic carbon (0.48 %) content, low in available N (210.80 kg ha⁻¹), K₂O (130.20 kg ha⁻¹) and high in available P₂O₅ (133.58 kg ha⁻¹). The exchangeable Ca and Mg content of soil was 2.57 and 1.08 C mol (P⁺) kg⁻¹, respectively and available S was 8.85 mg kg⁻¹. The DTPA extractable micronutrient content *viz.*, Cu, Zn, Fe and Mn were 0.83, 1.21, 1.94 and 14.04 mg kg⁻¹, respectively.

The experiment was laid out in a randomized complete block design (RCBD) with eleven treatments and replicated thrice. The treatment combination include, T₁: Absolute control, T₂: Package of practice (100 % NPK + FYM @ 10 t ha⁻¹), T₃: Recommended N and K + 25 % P supplied through enriched USWC, T₄: Recommended N and K + 50 % P supplied through enriched USWC, T₅: Recommended N and K + 75 % P supplied through enriched USWC, T₆: Recommended N and K + 25 % P supplied through enriched vermicompost, T₇: Recommended N and K + 50 % P supplied through enriched vermicompost, T₈: Recommended N and K + 75 % P supplied through enriched vermicompost, T₉: Recommended N and K + 25 % P supplied through enriched FYM, T₁₀: Recommended N and K + 50 % P supplied through enriched FYM and T₁₁: Recommended N and K + 75 % P supplied through enriched FYM. FYM @ 10 t ha⁻¹ was common for all the treatments except Absolute control (T₁). Recommended dose of fertilizer was 100:50:50 kg of N, P₂O₅ and K₂O per ha and net plot size was 12 m².

Soil analysis

Before transplanting and at harvest of both the crops, soil sampling at a depth of 0-15 cm were collected using a soil auger. The soil samples collected were air dried and passed through a 2 mm sieve. The processed soil samples were analyzed for selected basic chemical properties.

Soil pH and electrical conductivity (EC)

Soil pH and electrical conductivity of the samples were measured on a 1:2.5 soil: water suspension separately using Systronic digital pH meter and digital conductivity meter at 25 °C, respectively (Jackson, 1973).

Organic carbon (OC)

The organic carbon content in soil samples ground to pass through a 40 mesh sieve was determined by Walkley and Black (1934) wet oxidation method where organic matter present in the soil is oxidized by chromic acid by making use of heat of dilution of H₂SO₄ for reaction by following method described by Jackson (1973).

Available nitrogen (N)

Available nitrogen was estimated by alkaline potassium permanganate method, where organic matter present in the soil was oxidized with hot alkaline KMnO_4 solution in the presence of NaOH . The ammonia (NH_3) evolved during oxidation was distilled and trapped in boric acid-mixed indicator solution. Amount of NH_3 trapped in boric acid + mixed indicator estimated by titrating against standard acid (Subbaiah and Asija, 1956).

Available phosphorus (P_2O_5)

Available phosphorous was extracted with 0.5M sodium bicarbonate at pH 8.5 (Olsen's reagent) and amount of phosphorous in the extract was estimated at 660 nm using spectrophotometer as outlined by Jakson (1973).

Available potassium (K_2O)

Available potassium was extracted from soil using neutral N ammonium acetate at 1:5 soil to extractant ratio and the concentration of potassium in the extract was determined by flame photometer (Jackson, 1973).

Exchangeable calcium (Ca) and magnesium (Mg)

Exchangeable Ca and Mg were extracted from soils using neutral N ammonium acetate at 1:5 soils to extractant ratio. The concentrations of Ca and Mg in the extract were determined by EDTA titration method as outlined by Jackson (1973).

Available sulphur (S)

Available sulphur was extracted with 0.15 % CaCl_2 solution using turbidimetric method and amount of S in the extract was estimated at 420 nm using spectrophotometer as outlined by Black (1965).

RESULTS AND DISCUSSION

Soil nutrient status of finger millet

Soil reaction (pH)

Irrespective of treatments, after harvest of finger millet in both first and second season, the pH of the soil decreased from its initial level (7.12). Treatments which received POP: 100 per cent NPK + FYM @ 10 t ha^{-1} (T_2) and recommended N and K + 75 per cent P supplied through enriched USWC (T_5) noticed significantly lower pH (6.92) compared to rest of the treatments (Table 1). In first season, treatment T_2 recorded significantly lower pH (6.87) compared to other treatments except T_5 (6.88) and T_8 (recommended N and K + 75 per cent P supplied through enriched vermicompost) (6.93) and in second season, T_5 recorded significantly lower pH (6.95) compared to other treatments and was on par with T_2 (6.97) and T_8 (6.97). Slightly lower pH values were recorded in these treatments could be attributed to buffering capacity of humic substances in the soil. It is known that incorporation of organic matter leads to stabilizing pH and resist the fluctuation of pH due to management practices (Manjunatha, 2011). Wafaa *et al.* (2013) also reported that application of cyanobacteria inoculation with compost slightly decreased pH in paddy crop.

Electrical conductivity (EC)

Similar to pH, the EC of the soil decreased from its initial level (0.21 dS m⁻¹). However, no significant differences were observed in second season and pooled data (Table 1). In first season (2017), treatment T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) had significantly lower EC (0.17 dS m⁻¹) compared to other treatments but found at par with T₂ (POP: 100 per cent NPK + FYM @ 10 t ha⁻¹) (0.19 dS m⁻¹). Significantly lower EC could be due to organic matter contributed humic substances which might be due to chelating, which detoxify the toxic ions, especially Na⁺ and Cl⁻, resulting low EC in soil treated with organic matter (Zahid and Niazi, 2006). No significant differences in EC due to application of inorganic fertilizer either alone or in combination with manures. Similar results were reported by Badanur *et al.* (1990) and Manjunatha (2011).

Organic carbon (OC)

Significantly higher organic carbon (0.54, 0.59 and 0.56 %) was observed in season 1, season 2 and pooled data, respectively in treatment T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) (Table 1). In first season, T₅ was on par with T₂ (POP: 100 per cent NPK + FYM @ 10 t ha⁻¹) (0.50 %), T₄ (recommended N and K + 50 per cent P supplied through enriched USWC) (0.53 %), T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) (0.51 %), T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (0.53 %) and T₁₁ (recommended N and K + 75 per cent P supplied through enriched FYM) (0.50 %). In second season, T₅ was on par with T₄ (0.58 %) and T₈ (0.58 %) and in pooled data, T₅ found on par with T₄ (0.55 %), T₇ (0.53 %) and T₈ (0.55 %).

The reason for significant increase of OC might be due to the application of manures which provided carbonaceous materials for decomposition and also presence of inorganic nitrogenous fertilizer enhancing the activity of soil micro-organisms and in turn hasten the decomposition of organic matter as a result of optimum C:N ratio and converting them to mineralized organic colloids, besides adding them to soil reserves. This was in conformity with the findings of Devarajan and Krishnasamy (1996). Bandole and More (2010) also revealed that the addition of compost, which has enhanced the soil organic-C due to mineralization as well as the residues left over from the main crop. Soil organic content was increased by application of enriched urban compost reported by Montemurro *et al.* (2006) and Sutaria *et al.* (2010).

Available nitrogen (N)

Irrespective of treatments, treatment which received recommended N and K + 75 per cent P supplied through enriched USWC (T₅) recorded significantly higher soil available N (241.94 kg ha⁻¹) and was on par with T₂ (POP: 100 per cent NPK + FYM @ 10t ha⁻¹) (232.41 kg ha⁻¹) and T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (232.08 kg ha⁻¹) in pooled analysis (Table 2). In 2017 season, T₅ recorded significantly higher soil available N (241.43 kg ha⁻¹) compared to other treatments but at par with T₂ (231.87 kg ha⁻¹), T₄ (recommended N and K + 50 per cent P supplied through enriched USWC) (217.47 kg ha⁻¹), T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) (211.33 kg ha⁻¹), T₈ (231.57 kg ha⁻¹), T₁₀ (recommended N and K + 50 per cent P supplied through enriched

FYM) (213.10 kg ha⁻¹) and T₁₁ (recommended N and K + 75 per cent P supplied through enriched FYM) (213.10 kg ha⁻¹) (220.60 kg ha⁻¹) and in 2018 season, only T₅ had significantly higher soil available N (242.45 kg ha⁻¹) compared to rest of the treatments.

Significant increase of soil available N could be attributed to the addition of urban compost which released N as a result of mineralization and also due to the effect of microbial inoculation *viz.*, N fixers which might have favored the fixation of atmospheric nitrogen and conversion of organically bound N to inorganic form. The results are in conformity with the findings of Reddy and Krishnaiah (1999), Soumare *et al.* (2003) and Reddy (1999). Combined application of NPK and USWC increased N content of several types of crops when compared to application of mineral fertilizers alone as indicated by Kropisz and Wojciechowsky (1978) and Kropisz and Russel (1978). Similar results obtained by Ramesh *et al.* (2007), when enriched banana compost was incorporated resulted in higher available N content in soil at harvest. There was build-up of N and P₂O₅ with the inclusion of legumes in cropping system Hemalatha *et al.* (2013).

Available phosphorus (P₂O₅)

Significantly higher soil available P₂O₅ (139.23 and 138.69 kg ha⁻¹) was observed in season 1 and pooled data, respectively in T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) and was on par with T₂ (POP: 100 % NPK + FYM @ 10 t ha⁻¹) (137.94 and 135.89 kg ha⁻¹), T₄ (recommended N and K + 50 per cent P supplied through enriched USWC) (136.55 and 137.13 kg ha⁻¹), T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) (136.28 and 137.09 kg ha⁻¹), T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (137.81 and 138.31 kg ha⁻¹) and T₁₁ (recommended N and K + 75 per cent P supplied through enriched FYM) (135.24 and 135.64 kg ha⁻¹) in season 1 and pooled data, respectively (Table 2). In second season, T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) had significantly higher soil available P₂O₅ (138.80 kg ha⁻¹) and was on par with T₂ (133.84 kg ha⁻¹), T₃ (recommended N and K + 25 per cent P supplied through enriched USWC) (135.31 kg ha⁻¹), T₄ (137.70 kg ha⁻¹), T₅ (138.16 kg ha⁻¹), T₇ (137.90 kg ha⁻¹) and T₁₁ (136.03 kg ha⁻¹).

The increase in available P at harvest of finger millet could be ascribed to increased solubility of native soil phosphorus by the means of mineralization of applied composts. Further, it may be due to the action of P solubilizers which solubilizes the organically bound P into inorganic form. Jimenez *et al.* (1993) and Zhang *et al.* (2006) reported that application of municipal solid waste compost effectively supplied P to soil by reducing the fixation of P through chelation of organic ligands and increase the soil P concentration with increasing application rates. The magnitude of increase in available P from first to second crop was low due to only 20-25 per cent of applied phosphorus becomes available to the immediate crop and rest adds to the soil pool which increased the available P status of soil after the harvest of finger millet (Punitha, 2016). Increase in P was also due to solvent action of inorganic and organic acids on soil phosphates, simultaneously, some inorganic P may be released from mineralization of organic P pools of soil and applied organic materials during the decomposition. These observations are in conformity with the findings of Singh *et al.* (1976). Mishra and Sharma (2005) and Bangar *et al.*

(1985) reported that addition of higher doses of garbage compost slightly increased the amount of P in soil.

Available potassium (K₂O)

Among the treatments, significantly higher soil available K₂O (151.40 and 156.78 kg ha⁻¹) was observed in first and second season, respectively in T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) and was on par with T₂ (POP: 100 % NPK + FYM @ 10 t ha⁻¹) (149.53 and 153.13 kg ha⁻¹), T₃ (recommended N and K + 25 per cent P supplied through enriched USWC) (131.67 and 136.46 kg ha⁻¹), T₄ (recommended N and K + 50 per cent P supplied through enriched USWC) (142.13 and 147.23 kg ha⁻¹), T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) (151.23 and 156.60 kg ha⁻¹), T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) (144.33 and 149.49 kg ha⁻¹) and T₁₁ (recommended N and K + 75 per cent P supplied through enriched FYM) (142.53 and 147.64 kg ha⁻¹) in first and second season, respectively (Table 2). In pooled data, T₈ had significantly higher soil available K₂O (154.09 kg ha⁻¹) and was on par with T₂ (151.33 kg ha⁻¹), T₄ (144.68 kg ha⁻¹), T₅ (153.92 kg ha⁻¹), T₇ (146.91 kg ha⁻¹) and T₁₁ (145.09 kg ha⁻¹).

Significant increase in potassium content was observed due to release of K from composts and due to solubilization of mineral bound or native K. Application of the composts also results in prevention of leaching loss due to retention of more K by organic colloids. The results are in consonance with the findings of Giusquiani *et al.* (1988) who also reported increase in K content even when very low rates of USWC was used. Increase in the available potassium status of soil was due to application of organic materials, which could be ascribed to greater capacity of organic colloids to hold the nutrients at the exchange site and also reduction of potassium fixation and release of potassium to the available pool of soil. The observations are in conformity with the findings of Sailaja and Ushakumari (2002). The increased the availability of nutrients in enriched vermicompost especially P would have enhanced root proliferation which helped in more uptake of K and also K linearly increases with N uptake (Biswas, 1987). Basker *et al.* (1993) reported that the availability of K was enhanced significantly following soil ingestion by earthworm and this must be due to the changes in the distribution of K between non exchangeable to exchangeable forms. Enriched vermicompost cannot increase the total amount of nutrient in the soil but can make them more available and they may increase the rate of nutrient cycling, thereby increasing the quantity of nutrients available (Sharpley and Syers, 1997). The results are found in finger millet crop which are agreement with findings of Gupta *et al.* (2002) and Bhargavi (2001) who also recorded increase in K content with the application of urban compost.

The results could be conformed with the findings of Manjunatha (2011) who also reported higher sunflower seed yield, nutrient uptake and residual soil N, P and K content compared to control when cotton stalk enriched compost along with higher levels of RDF NPK were used. Zayed *et al.* (2013) reported that application of 5 t ha⁻¹ paddy straw compost + 110 kg N ha⁻¹ had potential to increase soil nutrient availability than the sole application of chemical nitrogen fertilizer under rice crop.

Exchangeable calcium (Ca) and magnesium (Mg)

Significantly higher exchangeable Ca was recorded in treatment which received recommended N and K + 75 per cent P supplied through enriched vermicompost (T₈) (4.11, 4.19 and 4.15 C mol (P⁺) kg⁻¹ in first season, second season and pooled data, respectively) (Table 3). This treatment was on par with T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) (3.97, 4.10 and 4.03 C mol (P⁺) kg⁻¹) and T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) (3.97, 4.05 and 4.01 C mol (P⁺) kg⁻¹ in first season, second season and pooled data, respectively).

Among the treatments, significantly higher exchangeable Mg was recorded in T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (2.14, 2.18 and 2.16 C mol (P⁺) kg⁻¹ in first season, second season and pooled data, respectively) (Table 3). This T₈ treatment was on par with T₅ (recommended N and K + 75 per cent P supplied through enriched USWC), T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) and T₁₁ (recommended N and K + 75 per cent P supplied through enriched FYM) (2.04, 2.07 and 2.05 C mol (P⁺) kg⁻¹, respectively) in first season and T₄ (recommended N and K + 50 per cent P supplied through enriched USWC), T₅, T₆ (recommended N and K + 25 per cent P supplied through enriched vermicompost), T₇, T₉ (recommended N and K + 25 per cent P supplied through enriched FYM), T₁₀ (recommended N and K + 50 per cent P supplied through enriched FYM) and T₁₁ (1.89, 2.10, 2.03, 2.09, 1.88, 2.01 and 2.10 C mol (P⁺) kg⁻¹, respectively) in second season. In pooled analysis, T₈ was on par with T₅, T₆, T₇, T₁₀ and T₁₁ (2.07, 2.02, 2.08, 2.01 and 2.07 C mol (P⁺) kg⁻¹, respectively).

The increase in Ca may be ascribed to higher initial content of nutrient in enriched compost. Organic molecules like organic acids produced during the process of decomposition can increase the solubility of native Ca and its retention by the colloids. The increase in Ca and Mg may also be ascribed to the mineralization of urban compost resulting in release of native Ca and its retention by organic colloids. Municipal solid waste compost has been reported to increase total and extractable soil Ca concentrations (Shanmugam and Warman, 2004). Adediran *et al.* (2004) also observed an increased in secondary nutrient status in soils amended with organic materials. The results are in conformity with the findings of Reddy and Ahmed (2009) and Anand (2016).

Available Sulphur (S)

Irrespective of the treatments, significantly higher available S was recorded in treatment which received recommended N and K + 75 per cent P supplied through enriched USWC (T₅) (11.06, 11.21 and 11.13 mg kg⁻¹ in first season, second season and pooled data, respectively) (Table 3). This treatment was on par with T₄ (recommended N and K + 50 per cent P supplied through enriched USWC) (10.88, 11.02 and 10.95 mg kg⁻¹) and T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (10.91, 11.05 and 10.98 mg kg⁻¹ in first season, second season and pooled data, respectively).

Significant increase in soil available S could be attributed to the release of organic bound and native S through mineralization process. Similar results reported with enriched FYM was applied and resulted in higher available S content (Meena *et al.*, 2008). This might be due to

mineralization of S from organic matter and the release of S from S containing amino acids during decomposition of organic manures (Shivakumar, 1999) and also due to the addition of S containing fertilizers (Ponnamperuma, 1972). Zhang *et al.* (2006) documented an increase in soil S concentrations as a result of mineralization of municipal solid waste compost.

Soil nutrient status of residual cowpea

Soil reaction (pH)

In first season (2018), no significant difference was observed among the treatments with respect to residual soil pH in cowpea (Table 4). Treatment T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) recorded significantly lower pH (6.98 and 6.98) compared to other treatments but at par with T₂ (POP: 100 % NPK + FYM @ 10 t ha⁻¹) (7.02 and 7.00), T₄ (recommended N and K + 50 per cent P supplied through enriched USWC) (7.00 and 7.02) and T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (7.00 and 6.99) in second season and pooled data, respectively. A marginal increase in pH might be attributed to mineralization process and addition of more bases from enriched organics. A slight increase in pH was due to mineralization of carbon from USWC and vermicompost and the subsequent production of OH⁻ ions by ligand exchange as well as the introduction of basic cations, such as K⁺, Ca²⁺, and Mg²⁺ which was similar to the findings of Mkhabela and Warman (2005).

Electrical conductivity (EC)

The data shown in the Table 4 indicated that there was no significant difference in EC of soil in both seasons among all the treatments. However, the EC values ranged from 0.19 to 0.22 dS m⁻¹. Non-significant differences were observed however, a slight increase in EC was noticed in treatments when enriched composts were used. This was due to high EC of enriched composts and upon mineralization releases bi-carbonates, Fe, Mn and NH₃ content and subsequent formation of soluble salts of Ca (Gil *et al.*, 2000; Warman, 2001; Warman *et al.*, 2004).

Organic carbon (OC)

Significantly higher OC (0.56, 0.61 and 0.58 %) was observed in season 1, season 2 and pooled data, respectively in T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) treatment (Table 4). This treatment was on par with T₄ (recommended N and K + 50 per cent P supplied through enriched USWC) (0.55 %) and T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (0.55 %) in first season, T₈ (0.60 %) in second season and T₄ (0.57 %) and T₈ (0.57 %) in pooled analysis. This might be attributed to the addition of compost and FYM which have enhanced the soil organic carbon (SOC) due to mineralization as well as the residues left over from the main crop as documented by Bandole and More (2010). Montemurro *et al.* (2006) reported an increase in SOC status with the application of urban compost.

Available nitrogen (N)

After harvest of residual cowpea crop, treatment T₅ (recommended N and K + 75 per cent

P supplied through enriched USWC) recorded significantly higher soil available N (223.96, 225.76 and 224.86 kg ha⁻¹) in first, second season and pooled data, respectively (Table 5). This treatment was on par with T₂ (POP: 100 % NPK + FYM @ 10 t ha⁻¹) (211.40 kg ha⁻¹) and T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (211.10 kg ha⁻¹) in first season. The incorporation of enriched composts to soil along with inorganic fertilizer enhanced the soil N concentration. This might be due to the inherent higher value of N in the enriched compost and build-up of NO₃-N and NH₄-N in the soil due to release of mineralizable N from the constituents in the compost by the nitrification process as reported by Kavitha and Subramanian (2007) and Rathod *et al.* (2012). Marginally lower available N might be due to efficient uptake of N by the crop plant and also due to nutrient loss by leaching. The results are in line with the findings of Kropisz and Russel (1978) who observed that the amount of NO₃-N in soil increased in compost treated plots compared to both controls and plots treated with exclusively mineral fertilizers. The above findings are in confirmation with the findings of Kamlesh *et al.* (1991) that the nature and quantity of applied organic manure has greater control on available N content of the soil. The decreasing trend of N content at harvest of residual cowpea crop was noticed due to the removal of N by the crop as described by Prakash *et al.* (1994).

Available phosphorus (P₂O₅)

Among the treatments, T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) had significantly higher soil available P₂O₅ (118.61 and 123.37 kg ha⁻¹) compared to rest of the treatments except T₂ (POP: 100 % NPK + FYM @ 10 t ha⁻¹) (115.29 and 117.72 kg ha⁻¹), T₃ (recommended N and K + 25 per cent P supplied through enriched USWC) (113.43 and 117.53 kg ha⁻¹), T₄ (recommended N and K + 50 per cent P supplied through enriched USWC) (115.82 and 121.58 kg ha⁻¹), T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) (114.02 and 121.78 kg ha⁻¹), T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (116.92 and 122.68 kg ha⁻¹) and T₁₁ (recommended N and K + 75 per cent P supplied through enriched FYM) (114.15 and 119.91 kg ha⁻¹) in first and second season, respectively (Table 5). In pooled analysis, T₅ noticed significantly higher soil available P₂O₅ (120.99 kg ha⁻¹) and was on par with T₄, T₇, T₈ and T₁₁ (118.70, 117.90, 119.80 and 117.03 kg ha⁻¹, respectively).

The increase in availability of the P content in soil could be attributed to the application of organics through USWC, vermicompost and FYM, their enrichment with rock phosphate released organic which lead to accumulation of more P in soil pool and contributed to increase in the available P₂O₅. Kavitha and Subramanian (2007) opined that application of municipal solid waste compost to the soil forms stable complexes or chelates with cations responsible for P fixation and in turn could have increased its availability. The results are in line with the findings of Singh and Singh (1990) reported that organic manure added to the soil was effective in increasing the P availability to the plants. Borkar *et al.* (1991) revealed that the application of organic manure reduced the P fixation in the soil and increased the microbial activity, thus making it more available to the plants. Santhy *et al.* (1998) ascribed that the applied composts forms coating on sesquioxides causing reduction in phosphate fixing capacity of soil in organic manure treated plots and thus improve the available P content of the soil. The magnitude of increase in available

P from first to second crop is low might be due to only 20-25 per cent of applied P becomes available to the immediate crop and rest adds to the soil pool which increased the available P status of soil after the harvest of finger millet (Punitha, 2016). The pooled P was efficiently utilized by the succeeding residual cowpea crop and hence there was decline in available P in post-harvest soils of cowpea compared to post harvest soils of finger millet.

Available potassium (K_2O)

In 2018 season, treatment T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) recorded significantly higher soil available K₂O (134.87 kg ha⁻¹) compared to others and was on par with T₂ (POP: 100 % NPK + FYM @ 10 t ha⁻¹), T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) and T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) (131.34, 134.70 and 129.80 kg ha⁻¹, respectively) (Table 5). In 2019 season, T₅ registered significantly higher soil available K₂O (135.93 kg ha⁻¹) compared to other treatments except T₈ (135.10 kg ha⁻¹). And in pooled analysis, T₅ (135.31 kg ha⁻¹) had significantly higher soil available K₂O and was on par with T₂ (131.45 kg ha⁻¹) and T₈ (134.98 kg ha⁻¹). Higher available K₂O content of soil may be attributed to the application of enriched USWC and vermicompost which minimizes the leaching loss of K by retaining K ions on exchange sites of its decomposed products and thus contributes to accumulation of more K in soil pool. Giusquiani *et al.* (1988) who revealed an increase in K content with the application of urban compost. Marginal decline in the available K₂O content of the soil at harvest of residual cowpea may be due to leaching loss and depletion of K by crop uptake (Prasad and Umar, 1993).

Exchangeable calcium (Ca) and magnesium (Mg)

Significantly higher exchangeable Ca was recorded in treatment T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (4.00, 4.09 and 4.04 C mol (P⁺) kg⁻¹ in first, second season and pooled means, respectively) (Table 6). This treatment was on par with T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) (3.86, 4.05 and 3.96 C mol (P⁺) kg⁻¹) and T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) (3.86, 3.99 and 3.93 C mol (P⁺) kg⁻¹) in first, second season and pooled data, respectively. Irrespective of the treatments, significantly higher exchangeable Mg was recorded in T₈ (2.02, 2.08 and 2.05 C mol (P⁺) kg⁻¹ in first season, second season and pooled data, respectively) (Table 6). This T₈ treatment was on par with T₅, T₆ (recommended N and K + 25 per cent P supplied through enriched vermicompost), T₇, T₁₀ (recommended N and K + 50 per cent P supplied through enriched FYM) and T₁₁ (recommended N and K + 75 per cent P supplied through enriched FYM) (1.95, 1.94, 1.98, 1.93 and 1.96 C mol (P⁺) kg⁻¹, respectively) in 2018 season and T₄ (recommended N and K + 50 per cent P supplied through enriched USWC), T₅, T₆, T₇, T₉ (recommended N and K + 25 per cent P supplied through enriched FYM), T₁₀ and T₁₁ (1.83, 2.01, 1.95, 2.01, 1.81, 1.93 and 2.01 C mol (P⁺) kg⁻¹, respectively) in second season. In pooled means, T₈ was on par with T₅, T₆, T₇, T₁₀ and T₁₁ (1.98, 1.94, 1.99, 1.93 and 1.99 C mol (P⁺) kg⁻¹, respectively). Exchangeable Ca and Mg contents of the soil was higher in enriched composts treated plots at harvest of residual cowpea may be attributed to USWC, vermicompost and FYM being an additional source of Ca and Mg would increase dissolution of Ca and Mg

resulting in increasing soil solution Ca concentration upon mineralization of compost. Maynard (1995) opined that an increase in total and extractable soil Ca concentrations with the application of municipal solid waste compost.

Available Sulphur (S)

Significantly higher available S was noticed in T₅ (recommended N and K + 75 per cent P supplied through enriched USWC) (11.00, 11.13 and 11.06 mg kg⁻¹ in first season, second season and pooled data, respectively) (Table 6). This treatment was on par with T₃ (recommended N and K + 25 per cent P supplied through enriched USWC), T₄ (recommended N and K + 50 per cent P supplied through enriched USWC), T₇ (recommended N and K + 50 per cent P supplied through enriched vermicompost) and T₈ (recommended N and K + 75 per cent P supplied through enriched vermicompost) (10.05, 10.82, 10.19 and 10.85 mg kg⁻¹, respectively) in first season and T₄ and T₈ (10.95 and 11.01 mg kg⁻¹, respectively) in second season. In pooled analysis, T₅ was on par with T₄ and T₈ (10.88 and 10.93 mg kg⁻¹, respectively). Higher S content might be due to oxidation of elemental S and mineralization of S by microorganisms from the native soil (Zhang *et al.*, 2006). The decreasing trend in available S content at harvest of cowpea may be ascribed to more uptake of S by the residual crop. The results are in accordance with the findings of Nega (2000) and Shanthakumari (2007).

Conclusion

Under phosphorus rich soil condition, application of recommended N and K along with 50-75 per cent P through rock phosphate enriched USWC and vermicompost had beneficial effect on enhancing soil nutrient status after harvest of finger millet-cowpea cropping sequence as compared to control and package of practices. **Instead of application of sole inorganic P fertilizer, apply combination of both inorganic and organic P fertilizer will alter the high P build up in Cauvery command area, Karnataka.**

REFERENCES

- ADEDIRAN, J. A., TAIWO, L. B., AKANDE, M. O., SOBULO, R. A. AND IDOWU, O. J., 2004, Application of organic and inorganic fertilizer for sustainable maize and cowpea yields in Nigeria. *J. Pl. Nutr.*, **27**(7): 1163-1181.
- ALBIACH, R., CANET, R., POMARES, F. AND INGELMO, F., 2000, Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. *Bioresour. Technol.*, **75**(1): 43-48.
- ANAND, 2016, Drum composting of segregated and unsegregated urban solid waste and its effect on growth and yield of finger millet (*Eleusinecoracana* L.). *M.Sc. (Agri.) Thesis*, Univ. Agril. Sci., Bengaluru (India).
- ARAUJO, A. S. F. AND MONTEIRO, R. T. R., 2005, Plant bioassays to assess toxicity of textile sludge compost. *Scientia Agricola.*, **62**(3): 286-290.
- BADANUR, V. P., POLESHI, C. M. AND NAIK, B. K., 1990, Effect of organic matter on crop yield

- and physical and chemical properties of *Vertisol*. *J. Indian Soc. Soil Sci.*, **38**: 426-429.
- BANDOLE, S. B. AND MORE, S. D., 2010, Soil organic carbon status as influenced by organic and inorganic nutrient sources in *Vertisols*. *J. Maharashtra Agril. Univ.*, **25**(2): 220-222.
- BANGER, K. C., YADAV, K. S. AND MISHRA, M. M., 1985, Transformation of rock phosphate during composting and the effect of humic acid. *Plant Soil*, **85**: 259-266.
- BASKER, A., SUDHAKAR, G., LOURDURA, C., RANGASAMY, A., SUBBIAN, P. AND VELAYUTHAM, A., 1993, Effect of vermicompost application on the soil properties, nutrient availability, uptake and yield of rice. *Soil Biol. Biochem.*, **25**(2): 1673-1677.
- BHARGAVI, M. V., 2001, Bio remedial recycling of solid urban waste. *M.Sc. (Agri.) Thesis*, Univ. Agri. Sci., Bangalore.
- BISWAS, C. R., 1987, N, P and K uptake of rice on coastal saline soils. *IRRN*, **12**(2): 42.
- BISWAS, D. R. AND NARAYANASAMY, G., 2006, Rock phosphate enriched compost: An approach to improve low grade Indian rock phosphate. *Bioresource Technology*, **97**: 2243-2251.
- BLACK, C. A., 1965, Methods of soil analysis part II. Chemical and microbial properties No. 9 in the series of Agronomy. *American. Soc. Agron. Inc.*, Maadison, Wisconsin, USA.
- BORKAR, D. K., DESHMUKH, E. S. AND BHOYAR, V. S., 1991, Manurial values of FYM and compost as influenced by raw materials used, methods and period of decomposition. *J. Soil Crops.*, **1**: 117-119.
- CHI, R., XIAO, C., HUANG, X., WANG, C. AND WU, Y., 2007, Bio decomposition of rock phosphate containing pyrites by *Acidithiobacillusferrooxidans*. *J. Central South Uni. Technology*, **14**: 170-175.
- DEVARAJAN, R. AND KRISHNASAMY, R., 1996, Effect of enriched organic manures on rice yield. *Madras J. Agric. Sci.*, **83**(5): 280-283.
- DIDA, M. M., SRINIVASACHARY, S., RAMAKRISHNAN, J. L., BENNETZEN, M. D. AND DEVOS, K., 2008, Population structure and diversity in finger millet (*Eleusinecoracana*) germplasm. *Trop. Pl. Biol.*, **1**: 131-141.
- FAO statistics division 2014, 04 August 2014.
- GIL, G. J. C., PLAZA, C., ROVIRA, S. P. AND POLO, A., 2000, Long-term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass. *Soil Biol. Biochem.*, **32**: 1907-1913.
- GIUSQUIANI, P., MARUCCHINI, C. AND BUSINELLI, M., 1988, Chemical properties of soils amended with compost of urban waste. *Pl. Soil.*, **109**: 73-78.

- GUPTA, N., KUMAR, R. P., CHAND, N., KUMAR, S. AND JOSHI, H. C., 2002, Potential use of MSW compost and sewage sludge in wheat.2: 2nd *Int. Agron. Cong.*, pp. 1168-1169.
- HEMALATHA, S., RAO, P. V., REDDY, K. P. A. AND SURESH, K., 2013, A critical review on the influence of phosphorus on available nutrient status of soil in sunflower-groundnut crop sequence. *Int. J. Pl. Animal Env. Sci.*, **3**(3): 165-167.
- HINSINGER, P., 2001, Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical changes: A review. *Plant Soil*, **237**: 173-195.
- IOVIENO, P., MORRA, L., LEONE, A., PAGANO, L. AND ALFANI, A., 2009, Effect of organic and mineral fertilizers on soil respiration and enzyme activities of two Mediterranean Horticultural soils. *Biol. Fert. Soils*, **45**: 555-561.
- JACKSON, M. L., 1973, *Soil Chemical Analysis.*, Prentice Hall (India) Pvt. Ltd., New Delhi.
- JAT, R. S. AND AHLAWAT, I. P. S., 2006, Direct and residual effect of vermicompost, biofertilizers and phosphorus on soil nutrient dynamics and productivity of chickpea-fodder maize sequence. *J. Sustain. Agric.*, **28**(1): 41-54.
- JIMENEZ, I. E., GARCIA, V., ESPINO, M. AND HERNANDEZ, J., 1993, City refuse compost as a phosphorus source to overcome the P-fixation capacity of sesquioxide-rich soils. *Pl. Soil.*, **148**: 115-127.
- KAMLESH, K., MISHRA, M., DHANKAR, S. S., KUNPOOR, K. K. AND GUPTA, A. P., 1991, Effect of long term manurial application on microbial biomass. *J. Indian Soc. Soil Sci.*, **39**: 685-688.
- KAUSHIK, P. AND GARG, V. K., 2003, Vermicomposting of mixed solid textile mill sludge and cowdung with the epigeic earthworm (*Eisenia foetida*). *Biores. Tech.*, **90**: 311-316.
- KAVITHA, R. AND SUBRAMANIAN, P., 2007, Effect of enriched municipal solid waste compost application on growth, plant nutrient uptake and yield of rice. *J. Agron.*, **6**(4):586-592.
- KHASAWNECH, F. E. AND DOLL, E. C., 1978, The use of phosphate rock for direct application to soils. *Advances in Agronomy*, **30**: 159-206.
- KROPISZ, A. AND RUSSEL, S., 1978, Effect of fertilization of light loamy soil with the dano compost on microflora as well as on yields and chemical composition of lettuce and spinach. *Rocz. Nauk. Rol. Ser.*, **103**: 20-37.
- KROPISZ, A. AND WOJCIECHOWSKY, J., 1978, Mutual effects of mineral fertilizers and composts made from municipal wastes on yields and chemical composition of cabbage. *Rocz. Nauk. Rol. Ser.*, **103**: 164-80.
- MANJUNATHA, C. K., 2011, Preparation of cotton stalk based enriched compost and its effect on black soil properties and growth and yield of sunflower (*Helianthus annuus L.*). *M.Sc. (Agri.)*.

Thesis, Univ. Agril. Sci., Raichur (India).

- MAYNARD, A., 1995, Cumulative effect of annual additions of MSW compost on the yield of field-grown tomatoes. *Compost Sci. Util.*, **3**(2): 47-54.
- MEENA, M. C., PATEL, K. P. AND RATHOD, D. D., 2008, Effect of Zn and Fe enriched FYM and removal of nutrients under mustard-sorghum (Fodder) cropping sequence in semi-arid region of Gujrat. *Indian J. Dryland Agric. Res. Develop.*, **23**(2): 28-34.
- MISHRA, V. K. AND SHARMA, R. B., 2005, Influence of integrated nutrient management on soil health and energy requirement of rice based cropping systems. *Oryza*, **34**: 165-170.
- MKHABELA, M. S. AND WARMAN, P. R., 2005, The influence of municipal solid waste compost on yield, soil phosphorus availability and uptake by two vegetable crops grown in a Pugwash sandy loam soil in Canada. *Agric. Ecosys. Env.* **106**: 57-67.
- MONTEMURRO, F., MAIORANA, M., CONVERTINI, G. AND FERRI, D., 2006, Compost organic amendments in fodder crops: effects on yield, nitrogen utilization and soil characteristics. *Compost Sci. Util.*, **14**(2): 114-123.
- MYLAVARAPU, R. S. AND ZINATI, G. M., 2009, Improvement of soil properties using compost for optimum parsley production in sandy soils. *Scientia Horticulturae.*, **120**(3): 426-430.
- NEGA, Y. Y., 2000, Dynamics of suplur in an *Alfisol* under permanent manuring and fertilizers schedule. *M.Sc. (Agri.) Thesis*, Univ. Agril. Sci., Bangalore.
- OROZCO, F. M., CEGARRA, J., TRUJILLO, L. M. AND ROIG, A., 1996, Vermicomposting of coffee pulp using the earthworm *Eisenia fetida*: Effect on C and N contents and the availability of nutrient. *Biol. Fertil. Soils*, **22**: 162-166.
- PARTHASARATHI, K., 2004, Vermicomposts produced by four species of earthworms from sugar mill wastes (pressmud). *Ind. J. Life Sci.*, **1**: 41-46.
- PARTHASARATHI, K., GUNASEKARAN, G. AND RANGANATHAN, L. S., 2006, Efficiency of mono and polycultured earthworms in humification of organic wastes. *J. Ann. Uni. Sci.*, **42**: 127-134.
- PONNAMPERUMA, F. N., 1972, The chemistry of submerged soils. *Adv. Agron.*, **24**: 29-96.
- PRAKASH, T. R., BADRINATH. AND ALI, M. K., 1994, Relative efficiency of different phosphorus sources as influenced by liming on yield and uptake by rice on *Oxisols*. *J. Indian Soc. Soil Sci.*, **42**(1):192-194.
- PRASAD, B. AND UMAR, S. M., 1993, Direct and residual effect of soil application of zinc sulphate on yield and zinc uptake in rice-wheat rotation. *J. Indian Soc. Soil Sci.*, **41**(1): 192-194.
- PUNITHA, B. C., 2016, Influence of enriched urban solid waste compost on soil properties, yield and

- uptake of nutrients in cereal-pulse cropping systems. *Ph. D Thesis*, Univ. Agril. Sci., Bengaluru (India).
- RAMESH, T., DEVASENAPATHY, P. AND KAVINO, M., 2007, Effect of enriched banana waste compost on performance of hybrid bhendi. *Crop Res.*, **34**(1-3): 130-132.
- RAO, R. B. AND RADHAKRISHNA, D., 2001, Quality improvement of urban solid waste compost with plant growth promoting organisms. *Proc. Nat. Symp. Envi.*, pp.290-292.
- RATHOD, D. D., MEENA, M. C. AND PATEL, K. P., 2012, Evaluation of different zinc enriched organics as source of zinc under wheat- maize (fodder) cropping sequence on zinc-deficient typic. *J. Indian Soc. Soil Sci.*, **60**(1):50-55.
- REDDY, C. M. AND AHMED, R. S., 2009, Influence of organic, inorganic and biological sources in integrated nutrient management practices of sunflower. *Green Farming*, **2**(9): 584- 587.
- REDDY, N. M. AND KRISHNAIAH, K., 1999, Integrated nutrient management for sustainable rice production. *Tech. Bull.*, Directorate of Rice Research (ICAR), Hyderabad-30 (AP).
- REDDY, V. C., 1999, Effect of urban garbage compost on growth and yield of tomato. *Curr. Res.*, **28**: 43-44.
- SAILAJA, M. S. AND USHAKUMARI, K., 2002, Effect of vermicompost enriched with rock phosphate on yield and uptake of nutrients in cowpea (*Vigna unguiculata* L. Walpa). *J. Tropical Agric.*, **40**: 27-30.
- SANTHY, P., JAYASHREE, SHANKAR, S., MUTHUVEL, P. AND SELVI, D., 1998, Long-term fertilizer experiments-status of N, P and K fractions in soil. *J. Indian Soc. Soil Sci.*, **46**: 395-398.
- SHANMUGAM, G. S. AND WARMAN, P. R., 2004, Soil and plant response to organic amendments to three strawberry cultivars. In: *Proc. Int. Humic Subs. Soc.*, pp. 230-232.
- SHANTHAKUMARI, S., 2007, Distribution of secondary and micronutrients in an *Alfisols* subjected to long term fertilizer schedule and continuous cropping. *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore.
- SHARPLEY, A. N. AND SYERS, J. K., 1997, Earthworms: The 'unheralded soldiers of mankind' and 'farmer's friend' working day and night under the soil: Reviving the dreams of Sir Charles Darwin for promoting sustainable agriculture. *Biol. Agric. Hort.*, **10**: 47-52.
- SHIVAKUMAR, 1999, Effect of farmyard manure, urban compost and NPK fertilizers on growth and yield of finger millet (*Eleusine coracana* L.) (Gaertn). *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore.
- SINGH, D., MANNIKAR, N. D. AND SRINIVAS, N. G., 1976, Fertilizer value of indigenous rock phosphates compared with single super phosphate: laboratory incubation studies with farmyard manure. *J. Indian Soc. Soil Sci.*, **24**: 78-80.

- SINGH, L. AND SINGH, M., 1990, Effect of organic matter and urea on the availability of nitrogen and phosphorus. *J. Indian. Soc. Soil Sci.*, **23**: 205-211.
- SOUMARE, M., TACK, F. AND VERLOO, M., 2003, Characterization of Malian and Belgian solid waste composts with respect to fertility and suitability for land application. *Waste Manage.*, **23**: 517-522.
- SUBBIAH, B. V. AND ASIJA, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.*, **25**: 259-260.
- SUTARIA, G. S., AKBARI, K. N., VORA, V. D., HIRPARA. AND PADMANI, D. R., 2010, Response of legume crops to enriched compost and vermicompost on under rainfed agriculture, *Legume Res.*, **33**(2): 128-130.
- TOMATI, U., GALLI, E., GRAPPELLI, A. AND DIHENA, G., 1990, Effect of earthworm casts on protein synthesis in radish (*Raphanus sativum*) and lettuce (*Lactuca sativa*) seedlings. *Biol. Fertil. Soils*, **9**: 288-299.
- WAFAA, M. T. E., GHAZAL, F. M., MAHMOUD, A. A. AND GEHAN, H. Y., 2013, Responses of wheat-rice cropping system to cyanobacteria inoculation and different soil conditioners sources under saline soil. *Nature. Sci.*, **11**(10): 118-129.
- WALKLEY, A. J. AND BLACK, C. A., 1934, An examination method for determination soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.*, **37**: 29-38.
- WARMAN, P. R., 2001. Municipal solid waste compost effects tomato leaf tissue: Essential plant nutrients and trace elements. In: *Proc. 6th Int. Conf. Biogeochem. Trace Elements*, pp.167.
- WARMAN, P. R., MURPHY, C., BURNHAM, J. AND EATON, L., 2004, Soil and plant response to MSW compost applications on low bush blueberry fields in 2000 and 2001. *Small Fruit Rev.*, **3**(1/2): 19-31.
- YU, X., LIU, X., ZHU, T. H, LIU, G. H. AND MAO, C., 2012, Coinoculation with phosphate-solubilizing and nitrogen fixing bacteria on solubilization of rock phosphate and their effect on growth promotion and nutrient uptake by walnut. *European J. Soil Biology*, **50**: 112-117.
- ZAHID, L. AND NIAZI, M. F. K., 2006, Role of ristech material in the reclamation of saline-sodic soils. *Pak. J. Water Resour.*, **10**: 43-49.
- ZAYED, B. A., ELKHOBAY, W. M., SALEM, A. K., CEESAY, M. AND UPHOFF, N. T., 2013, Effect of integrated nitrogen fertilizer on rice productivity and soil fertility under saline soil conditions. *J. Plant Bio. Res.*, **2**(1): 14-24.
- ZHANG, M., HEANEY, D., HENRIQUEZ, B., SOLBERG, E., BITTNER, E., 2006, A four-year study on influence of biosolids or MSW co-compost application in less productive soils in Alberta: nutrient dynamics. *Compost Sci. Util.*, **14**(1): 68-80.

Table 1. Effect of phosphorus enriched composts on pH, EC and organic carbon in soil after harvest of finger millet

Treatment	pH			EC (dS m ⁻¹)			Organic carbon (%)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T ₁	7.06	7.01	7.03	0.23	0.19	0.21	0.45	0.46	0.45
T ₂	6.87	6.97	6.92	0.19	0.20	0.19	0.50	0.53	0.51
T ₃	7.02	7.05	7.04	0.20	0.22	0.21	0.49	0.52	0.50
T ₄	6.98	7.01	6.99	0.21	0.22	0.21	0.53	0.58	0.55
T ₅	6.88	6.95	6.92	0.17	0.21	0.19	0.54	0.59	0.56
T ₆	7.01	7.04	7.03	0.21	0.21	0.21	0.48	0.51	0.49
T ₇	7.00	7.03	7.01	0.20	0.20	0.20	0.51	0.55	0.53
T ₈	6.93	6.97	6.95	0.20	0.22	0.21	0.53	0.58	0.55
T ₉	7.03	7.06	7.05	0.22	0.21	0.21	0.48	0.50	0.49
T ₁₀	7.02	7.05	7.04	0.21	0.19	0.20	0.49	0.53	0.51
T ₁₁	6.98	7.01	7.00	0.20	0.19	0.20	0.50	0.54	0.52
S.Em±	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD at 5%	0.07	0.03	0.04	0.02	NS	NS	0.04	0.03	0.03

Legend:

T ₁ : Absolute control	T ₇ : Recommended N & K + 50 % P supplied through enriched vermicompost
T ₂ : POP (100 % NPK + FYM @ 10 t ha ⁻¹)	T ₈ : Recommended N & K + 75 % P supplied through enriched vermicompost
T ₃ : Recommended N & K + 25 % P supplied through enriched USWC	T ₉ : Recommended N & K + 25 % P supplied through enriched FYM
T ₄ : Recommended N & K + 50 % P supplied through enriched USWC	T ₁₀ : Recommended N & K + 50 % P supplied through enriched FYM
T ₅ : Recommended N & K + 75 % P supplied through enriched USWC	T ₁₁ : Recommended N & K + 75 % P supplied through enriched FYM
T ₆ : Recommended N & K + 25 % P supplied through enriched vermicompost	

Table 2. Effect of phosphorus enriched composts on available macro nutrients in soil after harvest of finger millet

Treatment	N (kg ha ⁻¹)			P ₂ O ₅ (kg ha ⁻¹)			K ₂ O (kg ha ⁻¹)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T₁	167.80	163.29	165.55	122.47	121.67	122.07	111.53	115.71	113.62
T₂	231.87	232.94	232.41	137.94	133.84	135.89	149.53	153.13	151.33
T₃	203.33	204.35	203.84	131.97	135.31	133.64	131.67	136.46	134.06
T₄	217.47	218.49	217.98	136.55	137.70	137.13	142.13	147.23	144.68
T₅	241.43	242.45	241.94	139.23	138.16	138.69	151.23	156.60	153.92
T₆	204.23	205.25	204.74	128.41	129.34	128.88	128.57	133.26	130.91
T₇	211.33	212.35	211.84	136.28	137.90	137.09	144.33	149.49	146.91
T₈	231.57	232.59	232.08	137.81	138.80	138.31	151.40	156.78	154.09
T₉	202.20	203.22	202.71	123.19	124.27	123.73	120.57	125.02	122.79
T₁₀	213.10	213.82	213.46	129.16	130.46	129.81	124.80	129.38	127.09
T₁₁	220.60	221.62	221.11	135.24	136.03	135.64	142.53	147.64	145.09
S.Em±	11.59	2.72	5.81	2.28	2.52	1.37	7.16	6.98	4.84
CD at 5%	34.19	8.03	17.15	6.72	7.45	4.04	21.11	20.60	14.26

Legend:

T ₁ : Absolute control	T ₇ : Recommended N & K + 50 % P supplied through enriched vermicompost
T ₂ : POP (100 % NPK + FYM @ 10 t ha ⁻¹)	T ₈ : Recommended N & K + 75 % P supplied through enriched vermicompost
T ₃ : Recommended N & K + 25 % P supplied through enriched USWC	T ₉ : Recommended N & K + 25 % P supplied through enriched FYM
T ₄ : Recommended N & K + 50 % P supplied through enriched USWC	T ₁₀ : Recommended N & K + 50 % P supplied through enriched FYM
T ₅ : Recommended N & K + 75 % P supplied through enriched USWC	T ₁₁ : Recommended N & K + 75 % P supplied through enriched FYM
T ₆ : Recommended N & K + 25 % P supplied through enriched vermicompost	

Table 3. Effect of phosphorus enriched composts on available secondary nutrients in soil after harvest of finger millet

Treatment	Ca (cmol (P ⁺) kg ⁻¹)			Mg (cmol (P ⁺) kg ⁻¹)			S (mg kg ⁻¹)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T₁	2.42	2.39	2.41	1.04	1.07	1.06	8.78	8.66	8.72
T₂	3.32	3.40	3.36	1.37	1.38	1.38	9.88	10.01	9.95
T₃	2.95	3.01	2.98	1.45	1.48	1.46	10.11	10.24	10.17
T₄	3.23	3.35	3.29	1.86	1.89	1.88	10.88	11.02	10.95
T₅	3.97	4.10	4.03	2.04	2.10	2.07	11.06	11.21	11.13
T₆	3.44	3.51	3.47	2.00	2.03	2.02	9.14	9.27	9.20
T₇	3.97	4.05	4.01	2.07	2.09	2.08	10.25	10.39	10.32
T₈	4.11	4.19	4.15	2.14	2.18	2.16	10.91	11.05	10.98
T₉	2.94	3.03	2.99	1.87	1.88	1.88	9.08	9.20	9.14
T₁₀	3.13	3.19	3.16	2.01	2.01	2.01	9.59	9.72	9.66
T₁₁	3.21	3.33	3.27	2.05	2.10	2.07	9.92	10.05	9.99
S.Em±	0.06	0.08	0.05	0.04	0.11	0.06	0.17	0.08	0.07
CD at 5%	0.19	0.23	0.14	0.12	0.31	0.19	0.50	0.22	0.21

Legend:

T ₁ : Absolute control	T ₇ : Recommended N & K + 50 % P supplied through enriched vermicompost
T ₂ : POP (100 % NPK + FYM @ 10 t ha ⁻¹)	T ₈ : Recommended N & K + 75 % P supplied through enriched vermicompost
T ₃ : Recommended N & K + 25 % P supplied through enriched USWC	T ₉ : Recommended N & K + 25 % P supplied through enriched FYM
T ₄ : Recommended N & K + 50 % P supplied through enriched USWC	T ₁₀ : Recommended N & K + 50 % P supplied through enriched FYM
T ₅ : Recommended N & K + 75 % P supplied through enriched USWC	T ₁₁ : Recommended N & K + 75 % P supplied through enriched FYM
T ₆ : Recommended N & K + 25 % P supplied through enriched vermicompost	

Table 4. Residual effect of phosphorus enriched composts on pH, EC and organic carbon in soil after harvest of cowpea

Treatment	pH			EC (dS m ⁻¹)			Organic carbon (%)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T₁	7.03	7.03	7.03	0.22	0.19	0.21	0.45	0.44	0.45
T₂	6.99	7.02	7.00	0.19	0.19	0.19	0.51	0.55	0.53
T₃	7.07	7.07	7.07	0.21	0.20	0.21	0.51	0.53	0.52
T₄	7.03	7.00	7.02	0.21	0.21	0.21	0.55	0.59	0.57
T₅	6.97	6.98	6.98	0.19	0.20	0.20	0.56	0.61	0.58
T₆	7.06	7.06	7.06	0.20	0.20	0.20	0.49	0.52	0.50
T₇	7.05	7.05	7.05	0.19	0.19	0.19	0.53	0.58	0.55
T₈	6.98	7.00	6.99	0.21	0.21	0.21	0.55	0.60	0.57
T₉	7.08	7.08	7.08	0.20	0.20	0.20	0.49	0.50	0.49
T₁₀	7.07	7.07	7.07	0.20	0.19	0.19	0.51	0.54	0.52
T₁₁	7.03	7.03	7.03	0.19	0.18	0.19	0.51	0.55	0.53
S.Em±	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
CD at 5%	NS	0.04	0.04	NS	NS	NS	0.02	0.01	0.01

Legend:

T ₁ : Absolute control	T ₇ : Recommended N & K + 50 % P supplied through enriched vermicompost
T ₂ : POP (100 % NPK + FYM @ 10 t ha ⁻¹)	T ₈ : Recommended N & K + 75 % P supplied through enriched vermicompost
T ₃ : Recommended N & K + 25 % P supplied through enriched USWC	T ₉ : Recommended N & K + 25 % P supplied through enriched FYM
T ₄ : Recommended N & K + 50 % P supplied through enriched USWC	T ₁₀ : Recommended N & K + 50 % P supplied through enriched FYM
T ₅ : Recommended N & K + 75 % P supplied through enriched USWC	T ₁₁ : Recommended N & K + 75 % P supplied through enriched FYM
T ₆ : Recommended N & K + 25 % P supplied through enriched vermicompost	

Table 5. Residual effect of phosphorus enriched composts on available macro nutrients in soil after harvest of cowpea

Treatment	N (kg ha ⁻¹)			P ₂ O ₅ (kg ha ⁻¹)			K ₂ O (kg ha ⁻¹)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T ₁	147.67	148.14	147.91	101.45	105.55	103.50	95.00	95.23	95.11
T ₂	211.40	213.20	212.30	115.29	117.72	116.51	131.34	131.56	131.45
T ₃	182.86	185.00	183.93	113.43	117.53	115.48	116.48	115.37	115.92
T ₄	197.34	198.81	198.08	115.82	121.58	118.70	125.94	125.83	125.88
T ₅	223.96	225.76	224.86	118.61	123.37	120.99	134.70	135.93	135.31
T ₆	184.10	185.90	185.00	107.46	113.22	110.34	113.71	112.27	112.99
T ₇	190.53	192.33	191.43	114.02	121.78	117.90	129.80	128.03	128.91
T ₈	211.10	212.90	212.00	116.92	122.68	119.80	134.87	135.10	134.98
T ₉	181.40	183.20	182.30	102.47	108.15	105.31	104.04	104.27	104.15
T ₁₀	192.30	194.10	193.20	109.91	114.34	112.13	108.94	108.50	108.72
T ₁₁	200.47	202.27	201.37	114.15	119.91	117.03	126.00	126.23	126.11
S.Em±	5.09	2.67	2.77	2.59	2.47	1.35	2.82	0.57	1.44
CD at 5%	15.01	7.89	8.18	7.64	7.28	3.99	8.31	1.69	4.24

Legend:

T ₁ : Absolute control	T ₇ : Recommended N & K + 50 % P supplied through enriched vermicompost
T ₂ : POP (100 % NPK + FYM @ 10 t ha ⁻¹)	T ₈ : Recommended N & K + 75 % P supplied through enriched vermicompost
T ₃ : Recommended N & K + 25 % P supplied through enriched USWC	T ₉ : Recommended N & K + 25 % P supplied through enriched FYM
T ₄ : Recommended N & K + 50 % P supplied through enriched USWC	T ₁₀ : Recommended N & K + 50 % P supplied through enriched FYM
T ₅ : Recommended N & K + 75 % P supplied through enriched USWC	T ₁₁ : Recommended N & K + 75 % P supplied through enriched FYM
T ₆ : Recommended N & K + 25 % P supplied through enriched vermicompost	

Table 6. Residual effect of phosphorus enriched composts on available secondary nutrients in soil after harvest of cowpea

Treatment	Ca (C mol (P ⁺) kg ⁻¹)			Mg (C mol (P ⁺) kg ⁻¹)			S (mg kg ⁻¹)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T ₁	2.38	2.37	2.38	1.02	1.04	1.03	8.69	8.60	8.64
T ₂	3.23	3.33	3.28	1.31	1.34	1.32	9.82	9.95	9.88
T ₃	2.87	2.94	2.90	1.39	1.41	1.40	10.05	10.18	10.11
T ₄	3.14	3.30	3.22	1.78	1.83	1.80	10.82	10.95	10.88
T ₅	3.86	4.05	3.96	1.95	2.01	1.98	11.00	11.13	11.06
T ₆	3.34	3.43	3.39	1.94	1.95	1.94	9.08	9.20	9.14
T ₇	3.86	3.99	3.93	1.98	2.01	1.99	10.19	10.32	10.25
T ₈	4.00	4.09	4.04	2.02	2.08	2.05	10.85	11.01	10.93
T ₉	2.89	2.95	2.92	1.79	1.81	1.80	9.02	9.14	9.08
T ₁₀	3.04	3.15	3.09	1.93	1.93	1.93	9.53	9.62	9.58
T ₁₁	3.12	3.29	3.21	1.96	2.01	1.99	9.86	9.98	9.92
S.Em±	0.14	0.11	0.09	0.03	0.12	0.06	0.32	0.09	0.17
CD at 5%	0.42	0.33	0.28	0.10	0.34	0.18	0.95	0.28	0.49

Legend:

T ₁ : Absolute control	T ₇ : Recommended N & K + 50 % P supplied through enriched vermicompost
T ₂ : POP (100 % NPK + FYM @ 10 t ha ⁻¹)	T ₈ : Recommended N & K + 75 % P supplied through enriched vermicompost
T ₃ : Recommended N & K + 25 % P supplied through enriched USWC	T ₉ : Recommended N & K + 25 % P supplied through enriched FYM
T ₄ : Recommended N & K + 50 % P supplied through enriched USWC	T ₁₀ : Recommended N & K + 50 % P supplied through enriched FYM
T ₅ : Recommended N & K + 75 % P supplied through enriched USWC	T ₁₁ : Recommended N & K + 75 % P supplied through enriched FYM
T ₆ : Recommended N & K + 25 % P supplied through enriched vermicompost	

Ms_IJPSS_77797