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Characterization of rock phosphate enriched compost and its influence on growth parameters of finger millet-cowpea cropping system in southern dry zone of Karnataka

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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 growth parameters of finger millet-cowpea cropping system. 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 kg ha^{-1}). The results revealed that, the pH had decreased in rock phosphate enriched USWC (8.02) and vermicompost (6.78) compared to unenriched USWC (8.29) and vermicompost (6.84). With respect to phosphorus concentration, enriched USWC (2.87%), vermicompost (2.43%) and FYM (1.16%) were recorded higher than unenriched USWC (0.90%), vermicompost (0.82%) and FYM (0.28%). Similarly, all the major, secondary and micro nutrient concentration had more in enriched than unenriched compost. Treatment which received recommended N and K + 75 per cent P supplied through enriched USWC (T_5) had significantly higher plant height in 30 DAT (37.84 cm), 60 DAT (92.83 cm) and at harvest (112.75 cm) in finger millet and higher plant in 30 DAS (27.00 cm), 60 DAS (67.98 cm) and at harvest (71.20 cm) in residual cowpea in pooled analysis. Similarly, number of tillers hill^{-1} in finger millet and number of branches plant^{-1} in residual cowpea in all the growth stages of the crop were also recorded significantly higher in T_5 treatment.

Keywords: USWC, vermicompost, FYM, rock phosphate, finger millet, cowpea

Introduction
The continuous monocropping and over use of inorganic fertilizers without organic input degrade the soil quality and health of the soil and cause environmental pollution as well (Albiach *et al.,* 2000) [2]. Soil quality could be restored by proper and careful soil management by different manurial practices. The application of organics along with inorganic fertilizers is an important practice in organic farming to improve soil quality, enhance microbial activity and nutrient recycle to produce high-quality crops. Organic manures act not only as a source of nutrients and organic matter, but also increase size, biodiversity and activity of the microbial population in soil, influence structure, nutrients turnover and many other related physical, chemical and biological parameters of the soil (Albiach *et al*., 2000) [2].
Urban solid waste composting (USWC), however, has proved to be a safe and effective way to accelerate the decomposition and stabilization of biodegradable components of bio-waste from USWC, leading to production of compost for soil amendment or as an organic nutrient source (Hargreaves *et al.*, 2008; Herrera *et al*., 2008) [13, 14]. Urban solid waste contains about 50-60 per cent wet waste, which is very useful in agriculture, if it is utilized scientifically through segregation and composting. Conventional organic fertilizers, such as vermicompost and farmyard manure (FYM), are widely recommended for agricultural production as nutrient source and soil conditioner. In recent years, vermicompost has been considered as an alternative to conventional organic fertilizers. 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) [24, 15]. 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. 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) [9]. 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) [11]. 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 objects of effect of varied levels of RP enriched USWC, vermicompost and FYM with N and K fertilizers on yield and yield attributes of finger millet-cowpea cropping system in Cauvery command area, Karnataka.

Material and methods

Preparation of phosphorus enriched compost

Collection of composts

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. USWC was collected from Karnataka Compost Development Corporation Ltd. (KCDC), Bengaluru. Vermicompost and FYM were procured from ZARS, UAS, GKVK, Bengaluru.

Method of preparation

USWC, vermicompost and FYM were mixed with rock phosphate (18.25% P_2O_5) at the rate of 5 per cent in cement tanks. These three composts were allowing to stabilize up to 45 days and 60 per cent moisture was maintained. The materials in the cement tanks were turned at every 5 days' interval.

Site and experimental details

A field experiment was carried out to assess the effect of rock phosphate enriched compost on yield and yield attributes of finger millet-cowpea cropping system in high phosphorus build up soil at ZARS, Mandya in Southern Dry Zone (Zone 6) 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 (*kharif*) 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}), K_2O (130.20 kg ha^{-1}) and high in available P_2O_5 (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, T_1: Absolute control, T_2: Package of practice (100% NPK + FYM @ 10 t ha^{-1}), T_3: Recommended N and K + 25% P supplied through enriched USWC, T_4: Recommended N and K + 50% P supplied through enriched USWC, T_5: Recommended N and K + 75% P supplied through enriched USWC, T_6: Recommended N and K + 25% P supplied through enriched vermicompost, T_7: Recommended N and K + 50% P supplied through enriched vermicompost, T_8: Recommended N and K + 75% P supplied through enriched vermicompost, T_9: Recommended N and K + 25% P supplied through enriched FYM, T_{10}: Recommended N and K + 50% P supplied through enriched FYM and T_{11}: Recommended N and K + 75% P supplied through enriched FYM. FYM @ 10 t ha^{-1} was common for all the treatments except Absolute control (T_1). Recommended dose of fertilizer was 100:50:50 kg of N, P_2O_5 and K_2O per ha and net plot size was 12 m^2.

Characterization of USWC, vermicompost and FYM

The samples were analysed for pH, EC (Jackson, 1973) [16], organic carbon (dry combustion method, Jackson, 1973) [16], total nitrogen (micro kjeldahl digestion and distillation method, Piper, 1966) [26], phosphorus (vanadomolybdic yellow colour spectrophotometry method, Piper, 1966) [26], potassium (flame photometry method, Piper, 1966) [26] and total micronutrients (Cu, Zn, Fe and Mn) (atomic absorption spectrophotometry method, Lindsay and Norvell (1978) [19].

Growth parameters

Plant height

Plant height was measured from five tagged plants in each net plot from base of the plant to the tip of top most leaf and the average plant height was taken and expressed in cm.

Number of tillers per hill (finger millet) and number of branches per plant (cowpea)

At 30, 60 days after transplanting (DAT) and at harvest stages, number of tillers were counted and expressed as average number of tillers per hill (finger millet) (Plate 3). At 30, 60 days after sowing (DAS) and at harvest stages, number of branches were counted and expressed as average number of branches per plant (cowpea).

Results and discussion

Characterization of enriched USWC, vermicompost and FYM with rock phosphate

Three different composts *viz*., USWC, vermicompost and FYM were analyzed before and after enrichment with rock phosphate by using in the field experiment (Table 1).

Table 1: Nutrient composition of different composts used in the study

Parameter	Unenriched			Enriched		
	USWC	Vermicompost	FYM	USWC	Vermicompost	FYM
Colour	Black	Black	Brown	Black	Black	Brown
BD (Mg m^{-3})	0.55	0.52	0.31	0.54	0.50	0.29
pH	8.29	6.84	7.05	8.02	6.78	7.08
EC (dS m^{-1})	0.54	2.60	2.29	1.58	3.35	3.21
OC (%)	24.61	14.67	12.85	22.74	12.63	12.17
C:N ratio	15.09	14.38	17.84	13.29	10.43	14.48
N (%)	1.63	1.02	0.72	1.71	1.21	0.84
P (%)	0.90	0.82	0.28	2.87	2.43	1.16
K (%)	1.24	1.30	0.64	1.46	1.51	0.71
Ca (%)	2.54	6.92	2.66	4.28	8.21	4.15
Mg (%)	0.68	1.92	0.87	1.07	2.20	1.13
S (%)	0.54	0.48	0.08	0.98	0.81	0.21
Cu (mg kg^{-1})	56.42	4.65	3.22	58.06	4.32	3.17
Zn (mg kg^{-1})	291.64	19.87	17.15	309.47	21.70	19.22
Fe (mg kg^{-1})	4604.12	196.08	141.95	4730.26	225.68	150.63
Mn (mg kg^{-1})	364.60	87.90	62.51	381.79	91.45	66.86
Pb (mg kg^{-1})	7.43	0.54	0.22	7.52	0.71	0.28
Cr (mg kg^{-1})	7.69	4.21	ND	7.77	4.24	ND
Cd (mg kg^{-1})	1.08	ND	ND	1.06	ND	ND
Ni (mg kg^{-1})	3.38	5.62	0.15	4.10	5.72	0.17

Colour and bulk density

Before enrichment with rock phosphate, the colour of USWC, vermicompost and FYM were black, black and brown, respectively. After 45 days of enrichment, colour of these composts didn't change. The unenriched and enriched FYM were brown in colour whereas the USWC and vermicompost were black which clearly indicated that FYM was not fully matured compared to USWC and vermicompost. The appearance of black color is indicative of the maturity. Pandharipande *et al*. (2004) [25] reported that the mature compost must be dark brown or black, granular, spongy in feel and smell normally. Bulk density of unenriched USWC, vermicompost and FYM were 0.55, 0.52 and 0.31 Mg m^{-3}, respectively. After enrichment, bulk density of USWC, vermicompost and FYM were 0.54, 0.50 and 0.29 Mg m^{-3}, respectively. The results indicated that, slight decrease in bulk density of enriched composts compared to unenriched. The results are in agreement with findings of Soumare *et al*. (2003) [41] who reported that the enriched municipal solid waste compost contained low bulk density compared to unenriched.

pH and electrical conductivity

The pH of USWC, vermicompost and FYM were 8.29, 6.84 and 7.05, respectively before enrichment with rock phosphate. After enrichment, pH of USWC, vermicompost and FYM were slightly alkaline (8.02), slightly acidic (6.78) and neutral (7.08), respectively. The pH of enriched USWC and vermicompost were decreases compared to unenriched but, enriched FYM was slightly increases compared to unenriched. The decrease in pH may be due to production of organic acids and phenolic compounds during incubation and further, pH increases mainly due to the formation of ammonia. However, pH was stabilized due to buffering nature of humic substances. The findings in the present study, concurred with the results reported by Poincelot (1978) [27] and Snehall *et al*. (2010) [40]. The pH which was within the range of 6.0-8.5 for considering as good quality compost as suggested by Fogarty and Tuovinen (1991) [12]. The salt content of unenriched and enriched USWC, vermicompost and FYM were 0.54, 2.60 and 2.29 dS m^{-1} and 1.58, 3.35 and 3.21 dS m^{-1}, respectively. Increase in EC during incubation of these rock phosphate enriched composts could be due to release of different mineral ions such as phosphate, ammonium, potassium *etc* (Yadav and Garg, 2011) [46]. Further, <1.5 dS m^{-1} of EC is considered to be acceptable for use of compost as soil amendments as reported by Watson (2003). In the present study, enriched USWC had 1.58 dS m^{-1}.

Organic carbon and C: N ratio

The results presented in Table 3 indicated that, all three enriched composts were found to have effect on organic carbon in decreasing its content compared to unenriched. Before enrichment, the OC content of USWC, vermicompost and FYM were 24.61, 14.67 and 12.85 per cent and after enrichment, 22.74, 12.63 and 12.17 per cent, respectively. Generally, during composting there is degradation of complex organic matter into simple ones with the evolution of CO_2 gas and energy (Adani *et al*., 1997) [1], since C is a source of energy for microorganisms to build up cells (Diaz *et al*., 1993) [8]. The results are also in line with Preethu *et al*. (2007) [28] when coffee pulp was blended with organic wastes and rock phosphate. The C: N ratio of unenriched USWC, vermicompost and FYM were 15.09, 14.38 and 17.84, respectively. After 45 days of enrichment, decreased the C: N ratio of USWC (13.29), vermicompost (10.43) and FYM (14.48). Organic carbon content decreased due to loss of carbon in the form of CO_2, and nitrogen content increased due to concentration effect which resulted in decreased C: N ratio (Lee *et al*., 2002) [18].

Macro nutrients (N, P and K)

The nitrogen (N) content of unenriched and enriched USWC, vermicompost and FYM were 1.63, 1.02 and 0.72 per cent and 1.71, 1.21 and 0.84 per cent, respectively. The improved N content could be due to the concentration effect caused by degradation of labile organic carbon compounds which reduce the weight of the composting mass. Further, it is believed that when biomass and organic matter loss is greater than loss of NH_3, N concentration usually increases (Bernal *et al*., 1998 and Maleena, 1998) [20]. The phosphorus (P) content of USWC, vermicompost and FYM were 0.90, 0.82 and 0.28 per cent, respectively before enrichment with rock phosphate. After 45 days of enrichment, P content of USWC, vermicompost and FYM were 2.87, 2.43 and 1.16 per cent, respectively. As expected, in general rock phosphate application had higher P content. Similar results were obtained by composting of agricultural wastes with super phosphate wherein it increases the solubility of phosphorus (Shinde *et al*., 1990 and Snehall *et al*., 2010) [36, 40]. The potassium (K) content of unenriched USWC, vermicompost and FYM were 1.24, 1.30 and 0.64 per cent, respectively. After 45 days of enrichment, increased the K content of USWC (1.46%), vermicompost (1.51%) and FYM (0.71%). Enriched vermicompost had higher amount of K followed by enriched USWC and FYM. Increased K content in all three enriched composts may be due to quick microbial activity leading to decrease in volume of the material. Manjunatha (2011) [22] also observed higher amount of K content in organic and mineral enriched compost.

Secondary nutrients (Ca, Mg and S)

Calcium (Ca) and magnesium (Mg) content of unenriched USWC, vermicompost and FYM were 2.54, 6.92 and 2.66 per cent and 0.68, 1.92 and 0.87 per cent, respectively. After enrichment with rock phosphate, Ca and Mg contents were increased. The Ca and Mg content of enriched USWC, vermicompost and FYM were 4.28, 8.21 and 4.15 per cent and 1.07, 2.20 and 1.13 per cent, respectively. Enriched vermicompost had higher amount of both Ca and Mg contents compared to enriched USWC and FYM. Enrichment with rock phosphate resulted in higher Ca and Mg contents. Calcium and magnesium being a constituent of rock phosphate and it might have resulted in higher Ca and Mg contents in rock phosphate enriched compost. Manjunatha (2011) [22] also observed similar results in Ca and Mg contents during the compost making with superphosphate enrichment. As like Ca and Mg, the sulphur (S) content also observed more in enriched composts compared to unenriched. Sulphur content of unenriched USWC, vermicompost and FYM were 0.54, 0.48 and 0.08 per cent, respectively. After 45 days of enrichment, increased the S content of USWC (0.98%), vermicompost (0.81%) and FYM (0.21%). Enriched USWC had higher amount of S followed by enriched vermicompost and FYM. Higher S concentration of enriched composts mainly due to decomposition of organic matter present in the solid wastes (Anand, 2016) [3].

Micro nutrients (Cu, Zn, Fe and Mn) and heavy metals (Pb, Cr, Cd and Ni)

Enriched USWC, vermicompost and FYM had higher amount of all four micronutrients compared to unenrich except copper (Cu). The Cu content of enriched vermicompost (4.32 mg kg^{-1}) and FYM (3.17 mg kg^{-1}) were slightly decreased than compared to unenriched. Enriched USWC had higher micronutrient contents (58.06, 309.47, 4730.26 and 381.79 mg kg^{-1} of Cu, Zn, Fe and Mn, respectively) followed by enriched vermicompost and FYM. Among the micronutrients, Fe contents had more in all three enriched composts followed by Mn, Zn and Cu. Higher amount of micronutrients in enriched composts due to organically chelation of micronutrients (Dakshinamurthy and Upendra, 2008) [7]. Heavy metal concentrations of all three composts were analyzed. Chromium (Cr) and Cadmium (Cd) had not detected in both unenriched and enriched vermicompost and FYM. The enriched USWC had higher amount of Pb (7.52 mg kg^{-1}), Cr (7.77 mg kg^{-1}), Cd (1.06 mg kg^{-1}) and Ni (4.10 mg kg^{-1}). Heavy metals are sourced from batteries, solder, wine bottle cap, circuit stabilizers in plastics may contain potentially toxic elements (Richard and woodburg, 1992) [31].

Effect of rock phosphate enriched composts on growth parameters of finger millet

Plant height

As expected an increasing trend in plant height was observed at different crop growth stages in all the treatments. The perusal of data presented in Table 2 and Fig. 1 revealed that there was a significant increase in plant height of finger millet at different days after transplanting (DAT) with the application of different phosphorus enriched composts.

At 30 DAT, treatment which received recommended N and K + 75 per cent P supplied through enriched USWC (T_5) noticed significantly higher plant height as evident from pooled means (37.84 cm) and the trend was identical in first season during 2017 (37.83 cm) and second season during 2018 (37.84 cm). This treatment was on par with T_4 (recommended N and K + 50 per cent P supplied through enriched USWC) (35.77 and 35.91 cm), T_7 (recommended N and K + 50 per cent P supplied through enriched vermicompost) (34.90 and 35.02 cm) and T_8 (recommended N and K + 75 per cent P supplied through enriched vermicompost) (36.50 and 36.54 cm) in first (2017) and second (2018) season, respectively. In pooled data, T_5 was on par with T_8 (36.52 cm). Similarly, at 60 DAT, treatment T_5 had significantly higher plant height compared to other treatments in pooled analysis (92.83 cm) and the similar trend was noticed in first (92.73 cm) and second season (92.93 cm). This treatment was on par with T_4 (90.43 and 90.97 cm), T_7 (90.40 and 90.78 cm) and T_8 (89.83 and 91.57 cm) in first and second season, respectively. At harvest, treatment T_5 recorded significantly higher plant height (111.83, 113.66 and 112.75 cm) compared to other treatments but found at par with T_4 (110.13, 111.89 and 111.01 cm) in first, second season and in pooled means, respectively. In second season (2018), T_5 was on par with T_8 (109.33 cm) also.

Maximum plant height was observed in response to the application of 50 and 75 per cent of P enriched USWC and vermicompost. This could be due to enhanced availability and uptake of nutrients in these treatments. The results are in agreement with the findings of Manzoor *et al*. (2006) [23] and Chathurvedi (2005) [6] who attributed to the enhanced leaf area resulting in more dry matter accumulation with increased availability of soil N because N has a significant influence on the vegetative growth of plant (Rojas *et al*.,1983 and Shukla *et al*.,1993) [32, 37]. Similar findings were observed by Shanmugam and Veeraputhran (2000) [35], Sankalpa (2013) [34] and Kumar (2014) [17]. A report of Reddy (1999) [30] confirms that the application of urban compost, sewage sludge and NPK fertilizers resulted in longer internodes in maize.

Among the treatments, the lower plant height was recorded in absolute control (T_1) in pooled analysis (19.79, 58.25 and 78.98 cm) and in first (19.70, 57.37 and 78.07 cm) and second season (19.88, 59.13 and 79.89 cm) at 30, 60 DAT and at harvest, respectively. Reduced plant height in absolute control was due to inadequate supply of required plant nutrients. Significant increase in the plant height was observed in response to the integrated application of enriched composts (Chari, 2011) [5].

Table 2: Effect of phosphorus enriched composts on plant height (cm) of finger millet at different days after transplanting

Treatment	30 DAT			60 DAT			At harvest		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1	19.70	19.88	19.79	57.37	59.13	58.25	78.07	79.89	78.98
T_2	31.83	31.97	31.90	82.77	84.71	83.74	99.50	100.97	100.24
T_3	31.43	31.29	31.36	81.00	82.57	81.78	91.23	92.99	92.11
T_4	35.77	35.91	35.84	90.43	90.97	90.70	110.13	111.89	111.01
T_5	37.83	37.84	37.84	92.73	92.93	92.83	111.83	113.66	112.75
T_6	31.20	31.24	31.22	77.53	78.88	78.21	89.37	90.86	90.11
T_7	34.90	35.02	34.96	90.40	90.78	90.59	105.40	106.53	105.96
T_8	36.50	36.54	36.52	89.83	91.57	90.70	105.23	109.33	107.28
T_9	23.07	23.23	23.15	66.70	68.27	67.49	84.40	85.86	85.13
T_{10}	31.10	31.14	31.12	82.80	84.03	83.42	98.50	100.29	99.40
T_{11}	30.53	30.54	30.54	84.73	86.67	85.70	103.30	105.09	104.20
S. Em±	1.10	1.11	0.64	1.24	1.32	0.66	1.78	1.49	1.05
CD at 5%	3.25	3.29	1.90	3.65	3.91	1.96	5.26	4.39	3.08

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	

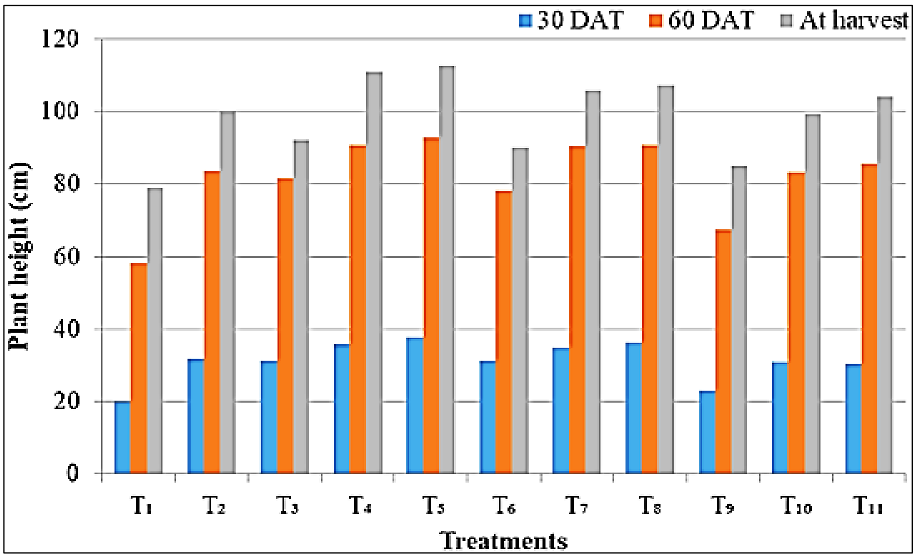

Fig 1: Effect of rock phosphate enriched composts on plant height of finger millet at different days after transplanting

Number of tillers hill^{-1}

Significant difference was observed among the treatments with respect to total number of tillers hill^{-1} of finger millet at different days of transplanting with the application of different phosphorus enriched composts (Table 3).

At 30 DAT, treatment which received recommended N and K + 75 per cent P supplied through enriched USWC (T_5) had significantly higher number of tillers hill^{-1} compared to rest of the treatments in pooled data (1.74) and the similar trend was noticed in first season (1.73) and also in second season (1.74).

At 60 DAT, treatment which received recommended N and K + 75 per cent P supplied through enriched USWC (T_5) (3.73) recorded significantly higher number of tillers hill^{-1} compared to other treatments in pooled analysis and at par with recommended N and K + 50 per cent P supplied through enriched USWC (T_4) (3.53) and recommended N and K + 75 per cent P supplied through enriched vermicompost (T_8) (3.57). Similarly, during 2017, T_5 (3.67) registered significantly higher number of tillers hill^{-1} compared to other treatments but was on par with T_4 (3.47) and T_8 (3.47). In 2018 season, T_5 (3.80) had significantly higher number of tillers hill^{-1} compared to other treatments but was on par with T_4 (3.60), T_7 (recommended N and K + 50 per cent P supplied through enriched vermicompost) (3.46) and T_8 (3.67).

At harvest, in pooled data, treatment T_5 (recommended N and K + 75 per cent P supplied through enriched USWC) (3.75) recorded significantly higher number of tillers hill^{-1} compared to rest of the treatments but at par with T_4 (recommended N and K + 50 per cent P supplied through enriched USWC) (3.52). In first season, only T_5 (3.73) registered significantly higher number of tillers hill^{-1} compared to rest of the treatments and in second season, T_5 (3.77) recorded significantly higher number of tillers $hill^{-1}$ compared to rest of the treatments and was on par with T_4 (3.57) and T_8 (recommended N and K + 75 per cent P supplied through enriched vermicompost) (3.72).

Availability of required quantity of N for long period was probably responsible for producing more number of effective tillers as in the case of treatment applied with higher N (Wijebandara, 2007) [45]. Further, Veeranagappa *et al*. (2010) [43] reported that $ZnSO_4$ application with paddy straw compost or enriched with Zn and NPK had better number of tillers compared to without enrichment. Singh (1998) [39] who also reported an application of P-enriched manure (FYM and FYM + biomass) at the rate of 10 t ha^{-1} resulted in significant and consistent increase in number of effective tillers per metre row length.

Irrespective of the treatments, the total number of tillers $hill^{-1}$ were lower in absolute control (T_1) in pooled data (0.55, 1.73 and 1.91) and in first (0.47, 1.67 and 1.73) and second season (0.63, 1.80 and 2.09) at 30, 60 DAT and at harvest, respectively. These plots did not receive any fertilizers resulted in reduced growth and tiller production. The results are in similar line with Singandupe *et al*. (2008) [38].

Table 3: Effect of phosphorus enriched composts on number of tillers $hill^{-1}$ of finger millet at different days after transplanting

Treatment	30 DAT			60 DAT			At harvest		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1	0.47	0.63	0.55	1.67	1.80	1.73	1.73	2.09	1.91
T_2	1.13	1.14	1.14	2.87	3.14	3.00	2.80	3.04	2.92
T_3	0.80	0.84	0.82	2.53	2.60	2.57	2.60	2.67	2.63
T_4	1.53	1.54	1.54	3.47	3.60	3.53	3.47	3.57	3.52
T_5	1.73	1.74	1.74	3.67	3.80	3.73	3.73	3.77	3.75
T_6	0.87	0.94	0.90	2.87	3.00	2.93	2.60	2.86	2.73
T_7	1.27	1.34	1.30	3.13	3.46	3.30	3.07	3.17	3.12
T_8	1.33	1.51	1.42	3.47	3.67	3.57	3.27	3.72	3.49
T_9	0.67	0.74	0.70	2.20	2.36	2.28	2.27	2.37	2.32
T_{10}	1.13	1.14	1.14	2.93	3.00	2.97	2.87	2.93	2.90
T_{11}	0.87	0.97	0.92	2.87	3.13	3.00	2.87	2.97	2.92
S. Em±	0.05	0.02	0.03	0.07	0.12	0.07	0.08	0.13	0.08
CD at 5%	0.16	0.06	0.09	0.21	0.36	0.21	0.23	0.40	0.24

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	

Residual effect of rock phosphate enriched composts on growth parameters of cowpea

Plant height

The perusal of data shown in the Table 4 and Fig. 2 revealed that there was a significant increase in plant height of residual cowpea at different DAS with the application of different phosphorus enriched composts.

At 30 DAS, treatment which received recommended N and K + 75 per cent P supplied through enriched USWC (T_5) had significantly higher plant height (26.87, 27.13 and 27.00 cm) in first season (2018), second season (2019) and in pooled data, respectively. This treatment was on par with T_4 (recommended N and K + 50 per cent P supplied through enriched USWC) (26.47, 26.60 and 26.54 cm), T_7 (recommended N and K + 50 per cent P supplied through enriched vermicompost) (26.30, 26.42 and 26.36 cm) and T_8 (recommended N and K + 75 per cent P supplied through enriched vermicompost) (26.50, 26.63 and 26.57 cm) in first, second season and in pooled data, respectively. Similarly, at 60 DAS, treatment T_5 registered significantly higher plant height (67.50, 68.45 and 67.98 cm) compared to rest of the treatments but at par with T_8 (66.20, 67.35 and 66.78 cm) in first, second season and in pooled means, respectively. At harvest, treatment T_5 noticed significantly higher plant height (70.57, 71.83 and 71.20 cm) and was on par with T_8 (69.33, 70.59 and 69.96 cm) in first, second season and in pooled analysis, respectively. In second season, T_5 was on par with T_4 (69.60 cm) also.

Higher plant height was recorded in the treatment which received recommended N and K + 75 per cent P supplied through enriched USWC. This could be attributed to the fact that organic residues not only releases N but also P and other nutrients essential for plant growth. The N from organic residues regardless of their initial content was probably used by the cowpea for its vegetative growth and development of rooting system. Rooge (1995) [33] and Sukumari (1997) [42] showed higher plant height with combined use of chemical fertilizers, organic manures and P solubilizer inoculation. Mallikarjun *et al*. (2000) [21] noticed an increase in plant height with full dose of enriched FYM only.

Table 4: Residual effect of phosphorus enriched composts on plant height (cm) of cowpea at different days after sowing

Treatment	30 DAS			60 DAS			At harvest		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1	18.77	18.89	18.83	44.17	45.94	45.05	45.47	46.73	46.10
T_2	24.27	24.39	24.33	58.73	60.24	59.49	59.53	60.79	60.16
T_3	22.43	22.56	22.50	60.30	61.25	60.78	62.00	63.26	62.63
T_4	26.47	26.60	26.54	65.30	66.25	65.78	67.67	69.60	68.63
T_5	26.87	27.13	27.00	67.50	68.45	67.98	70.57	71.83	71.20
T_6	23.20	23.32	23.26	62.30	63.25	62.78	64.33	65.59	64.96
T_7	26.30	26.42	26.36	64.17	65.12	64.65	67.50	68.76	68.13
T_8	26.50	26.63	26.57	66.20	67.35	66.78	69.33	70.59	69.96
T_9	21.50	21.61	21.55	56.17	57.12	56.65	57.50	58.76	58.13
T_{10}	21.70	21.81	21.76	59.20	60.15	59.68	61.57	62.83	62.20
T_{11}	24.07	24.20	24.14	62.63	63.10	62.87	65.40	66.66	66.03
S. Em±	0.79	0.69	0.60	0.68	0.74	0.50	0.72	0.89	0.57
CD at 5%	2.33	2.02	1.76	2.02	2.17	1.47	2.12	2.62	1.69

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	

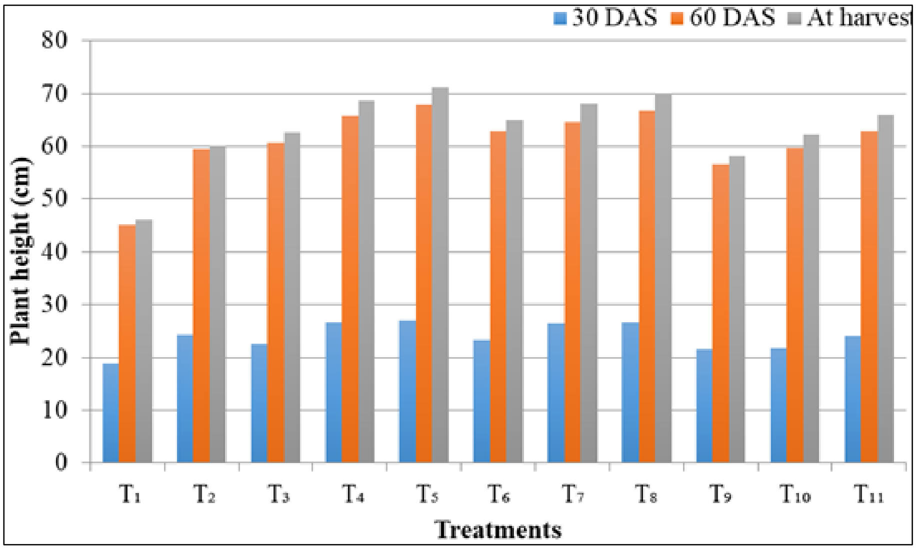

Fig 2: Residual effect of rock phosphate enriched composts on plant height of cowpea at different days after sowing

Number of branches plant^{-1}

Significant difference was observed among the treatments with respect to number of branches plant^{-1} of residual cowpea at different DAS with the application of different phosphorus enriched composts (Table 5).

At 30 DAS, significantly higher number of branches plant^{-1} were recorded in T_5 (recommended N and K + 75 per cent P supplied through enriched USWC) (8.67, 8.83 and 8.75) compared to other treatments but at par with T_8 (recommended N and K + 75 per cent P supplied through enriched vermicompost) (8.33, 8.49 and 8.41) in first, second season and pooled analysis, respectively. Similarly, at 60 DAS, T_5 registered significantly higher number of branches plant^{-1} (13.00, 13.84 and 13.42) in first, second season and pooled analysis, respectively. This treatment was on par with T_8 (12.33 in first season and 13.17 in second season). At harvest, T_5 (13.67, 14.42 and 14.05) recorded significantly higher number of branches plant^{-1} compared to rest of the treatments except T_8 (13.00, 13.75 and 13.38) in first, second season and pooled analysis, respectively.

The number of branches plant^{-1} recorded superior on application of recommended NK along with 75 per cent P through enriched vermicompost and USWC. This could be attributed to increased availability and uptake of major and micronutrients upon mineralization of combined sources of composts. The results are in conformity with the findings of Sukumari (1997) [42], Dubey (1999) [10] and Punitha (2016) [29].

Table 5: Residual effect of phosphorus enriched composts on number of branches plant^{-1} of cowpea at different days after sowing

Treatment	30 DAS			60 DAS			At harvest		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1	4.33	4.49	4.41	7.67	8.51	8.09	8.00	8.75	8.38
T_2	6.33	6.49	6.41	10.67	11.51	11.09	11.00	11.75	11.38
T_3	4.67	4.83	4.75	8.33	9.17	8.75	9.00	9.77	9.38
T_4	7.00	7.33	7.17	11.67	12.51	12.09	12.33	13.08	12.71
T_5	8.67	8.83	8.75	13.00	13.84	13.42	13.67	14.42	14.05
T_6	7.00	7.16	7.08	10.67	11.51	11.09	10.00	10.75	10.38
T_7	6.33	6.49	6.41	11.67	12.51	12.09	11.33	12.08	11.71
T_8	8.33	8.49	8.41	12.33	13.17	12.75	13.00	13.75	13.38
T_9	5.00	5.16	5.08	9.67	10.51	10.09	9.67	10.42	10.05
T_{10}	5.00	5.27	5.14	9.33	10.17	9.75	9.00	9.75	9.38
T_{11}	5.67	5.83	5.75	10.67	11.67	11.17	10.33	11.08	10.71
S. Em±	0.40	0.17	0.19	0.33	0.24	0.19	0.43	0.32	0.29
CD at 5%	1.19	0.50	0.55	0.98	0.71	0.56	1.27	0.94	0.85

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	

Conclusion

Rock phosphate enriched USWC, vermicompost and FYM had higher nutritional status than unenriched compost. 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 higher growth parameters *viz*., plant height, number of tillers hill^{-1} and number of branches plant^{-1} in finger millet-cowpea cropping system compared to control and package of practice.

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