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Organic amendments on soil nutrient balance under mid hills of Meghalaya

R.S. DHIVYA[1], LALA I.P. RAY[1*] AND U.K. BEHERA[2]

[1]*School of Natural Resource Management, College of Postgraduate Studies in Agricultural Sciences, Central Agricultural University-Imphal, Barapani-793103, Meghalaya, India*

[2]*College of Agriculture, Kyrdemkullai, Central Agricultural University-Imphal, Kyrdemkullai-793103, Meghalaya, India*

**lalaipray@rediffmail.com*

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ABSTRACT

To assess the soil nutrient balance under different organic sources, an experiment was conducted during 2018-19 at the experimental farm, College of Agriculture, Kyrdemkullai, Meghalaya. The treatments were in the combination of priming, mulching and manuring. FYM (Farmyard manure), pig manure, poultry manure and maize stover mulch were used as organic inputs. Seed priming was done with liquid washes of manures and water as control. The apparent N and P balance was estimated and was observed that the apparent N balance i.e. N build up at 0-15 cm was higher under T_9 (66.45 kg ha^{-1}) followed by T_8 (61.95 kg ha^{-1}) and at 15-30 cm T_9 (62.23 kg ha^{-1}) followed by T_8 (55.63 kg ha^{-1}). In P balance, the P loss was found under T_{10} (3.51 and 2.25 kg ha^{-1} at 0-15 and 15-30 cm respectively). In all the other treatments, there was gain i.e. no loss in P and was higher under T_9 (12.70 kg ha^{-1}) followed by T_3 (11.19 kg ha^{-1}) at 0-15 cm and at 15-30 cm, T_9 (16.47 kg ha^{-1}) and T_8 (16.01 kg ha^{-1}) had the maximum gain in P. The results revealed that poultry manure had the maximum gain in N and P followed by pig manure and FYM along with mulching and may be preferred over others.

Key words: Black gram, mulching, north-eastern India, nutrient balance, organic agriculture, seed priming

INTRODUCTION

Among various pulses, black gram is one of the important pulse crops grown throughout the country. The protein content of black gram is 26%, which is almost three times that of cereals and other minerals and vitamins (Anon., 2006, Khan et al., 2007). It fixes nitrogen (N) an equivalent of 22.10 kg N ha^{-1}, which has been estimated to supplement of 59,000 tonnes of urea annually (Anon., 2006). In North East Hill (NEH) Region, the average productivity of pulses is 848 kg ha^{-1} is higher than the national average, which is 764 kg ha^{-1}. This shows the pulses production potential of NEH, despite the region is deficit of 82% of its pulses requirement (Das et al., 2016). To meet the protein requirement in the daily diet, the plant protein may be emphasized due to its low cost potential. One of the factors of low crop productivity in North East Region is the nutrient content in the soil and its use efficiency. Therefore, an effective nutrient management needs to be developed to increase the crop productivity in a sustainable manner (Thakuria et al., 2009). It demands in crop residues recycling and efficient nutrient management including the different organic sources. Application of inorganic sources of nutrients will not result in a sustainable soil, as it is not a profitable management strategy. Therefore, organic sources might be the right choice to maintain the soil nutrient balance by incorporating organic manures along with crop residues application.

In this study, we presumed that seed priming with manure leachate, incorporation of organic manures along with application of crop residues, will maintain the soil nutrient balance apart from increasing the crop yield. The application of organic manures improves the nitrogen fixation of black gram by releasing some phyto-chemicals, which is beneficial for root nodulation (Anbuselvi and Rebecca, 2013) and also the soil physical constraints can also be alleviated by the application of organic manures, which improves the soil physiochemical properties and increased the soil available nitrogen and potassium (Pal et al., 2017). Mulching had a positive role in maintaining the soil nutrients, besides maintaining soil temperature and physical properties (Shashidar et al., 2009; Sharma et al., 2010; Kumar et al., 2014). However, the evaluation of soil nutrient balance under different organic sources is limited. Blackgram, being a nitrogen fixing legume, the loss or gain in nutrients needs to be estimated. With this view, the present study has been taken up with the objective of assessing apparent soil nutrient balance of nitrogen and phosphorus and with the hypothesis of soil fertility status may be improved by different sources of organic manuring and mulching by enhancing the soil nutrient status.

MATERIALS AND METHODS

A field experiment was conducted at the College of Agriculture, Kyrdemkulai, Ri-bhoi district, Meghalaya with "*Uttara*" black gram variety during April-July, 2018. The red clay loam soil has initial organic carbon and pH of 1.8% and 5.1, respectively. The available nitrogen (N) and phosphorus (P) at 0-15 cm and 15-30 cm were 227.81 and 16.25 kg ha^{-1} and 202.5 and 14.20 kg ha^{-1}, respectively. Manures were incorporated before sowing. The total N, P and K content of FYM, pig manure, poultry manure and maize stover mulch were 0.47, 0.19 and 0.75%, 0.8, 0.57 and 1.3%, 1.8, 0.61 and 1.2% and 0.5, 0.16 and 1.26% respectively. FYM, pig manure, poultry manure and maize stover mulch were applied at the rate of 10 t ha^{-1}, 8 t ha^{-1}, 1.5 t ha^{-1} and 5 t ha^{-1} respectively (Das et al., 2016). Seed priming was done with the three organic manure leachates and water. Leachates were obtained by soaking the manures in water in the ratio of 1: 10 for 24 hours with intermittent soaking (Kanto et al., 2014). Later the slurries were filtered and seeds were soaked overnight in the respective manure leachates. The seeds were shade dried before sowing. Seed rate and spacing was adopted at 25 kg ha^{-1} and 30 × 10 cm respectively. First irrigation was given after sowing and later on it was followed at flowering and pod filling stages, when required. A total of 12 treatments consisted of seed priming (SP), three organic manures and maize stover application along with control was replicated thrice adopting Randomized Block Design (RBD). The treatments were,

i. T_1 - Farm Yard Manure (FYM)

ii. T_2 - FYM + Mulch

iii. T_3 - FYM + SP (FYM W.) + Mulch

iv. T_4 - Pig manure

v. T_5 - Pig manure + Mulch

vi. T_6 - Pig manure + SP (PM W.) + Mulch

vii. T_7 - Poultry manure

viii. T_8 - Poultry manure + Mulch

ix. T_9 - Poultry manure + SP (PoM W.) + Mulch

x. T_{10} - Control

xi. T_{11} - Control + Mulch

xii. T_{12} - Control + SP (Water) + Mulch

xiii. FYM W. - FYM wash

xiv. PM W. - Pig manure wash

xv. PoM W. - Poultry manure wash

xvi. SP - Seed priming

Soil samples were collected after the harvest at 0-15 cm and 15-30 cm depth and were analysed for the evaluation of apparent nutrient balance by using the following formula given in the equation (1), (2), (3) and (4).

Nitrogen (N) build up in post-harvest soil:

Expected N balance = (initial soil N + applied N) – crop N uptake at harvest … (1)

N build up (kg per ha) = Post harvest soil N status – Expected N balance … (2)

Phosphorous (P) loss in post-harvest soil:

Expected P balance = (initial soil P + applied P) – crop P uptake at harvest … (3)

P loss (kg per ha) = Expected P balance - Post harvest soil P status … (4)

Inputs through manures and mulch were only considered. The nutrient balance indicates the apparent loss or gain in N and P in the post-harvest soil to compare the different nutrient management treatments. The data obtained from various studies during investigation were statistically analysed using the technique of analysis of variance for randomized block design. The difference between the treatment means was tested as for their statistical significance with appropriate critical difference (C.D) value at 5% level of significance as explained by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Organic amendments on nodule number

Black gram is nitrogen fixing legume crop and the amount of nitrogen fixation depends on nodule number in the root. Nodule numbers per plant was significantly influenced by the organic amendments in black gram. The probable reason might be due to that higher nutrients supply from organic manure might have increased the root growth and nodule numbers (Kausale et al., 2009). Apart from soil amendments, indigenous population of soil microorganisms also determine the nodulation response of host plant (Javaid, 2009).

Table 1. Effect of organic amendments on nodule numbers per plant

Sl No	Treatments	Number of nodules per plant
1	T_1 - FYM	40.55
2	T_2 - FYM+ Mulch	44.00
3	T_3 - FYM+ SP (FYM L) + Mulch	48.47
4	T_4 - Pig manure	41.85
5	T_5 - Pig manure + Mulch	44.40
6	T_6 - Pig manure + SP (PM L) + Mulch	50.43
7	T_7 - Poultry Manure	55.80
8	T_8 - Poultry Manure + Mulch	61.37
9	T_9 - Poultry Manure + SP (PoM L) + Mulch	66.54
10	T_{10} – Control	30.87
11	T_{11} - Control + Mulch	32.90
12	T_{12} - Control + SP (Water) + Mulch	38.13
	S.E.(m) ±	2.53
	C.D(P=0.05)	7.41

Crop nutrient uptake and expected nutrient balance

The crop nutrient uptake is one of the parameters for analysing the soil nutrient supplying capacity. As it considers the dry matter, it serves as an indicator of nutrient requirement of crop. Also, the crop response to organic manure will vary and it depends on location, soil type and time of application (Sawyer, 2001). Table 2 shows the N and P uptake by black gram under different treatments. Nitrogen uptake by black gram was higher (61.03 kg ha^{-1}) from T_9 (Poultry manure + SP (PoM W) + Mulch) followed by T_6 (59.88 kg ha^{-1}) which is pig manure incorporated along with mulching and priming. It was observed that P uptake by black gram was higher under T_3 (5.41 kg ha^{-1}) and T_9 (5.22 kg ha^{-1}) which are at par. The crop N and P uptake under all the manure incorporated, seed primed and mulch applied were superior over all the control treatments. As the added manures results in increased availability besides acted as source of nutrients. This is probably due to the incorporation of manure into the soil and improves the soil environment. It allows for better root growth in soil and enhances the nutrient uptake, as supported by Kundu et al. (1996). The continued availability and decreased loss of nutrients during decomposition might have enhanced the N uptake and due to the solubility action of organic acids on native and applied phosphorous which might have enabled the higher P uptake (Rao et al., 2013; Amanullah et al., 2006). Priming strengthened the plants and increased the concentration of nutrient and nutrient uptake (Shah et al., 2012). Umair et al. (2011) reported that priming of seeds improved the nutrient uptake when soil moisture and fertility status are favourable. Apart from manuring and priming, mulching is also one of the factors for increased nutrient uptake which is attributed due to availability of utilizable nutrients and beneficial effects of decomposition of organic material. This was in accordance with the findings of Awopegha et al. (2017). Manuring along with mulching not only resulted in availability of nutrients but also in the more efficient use of nutrients from the soil (Mitra and Mandal, 2012). Sharma and Abraham (2010) also revealed that organic manure increased the adsorptive power of soil for phosphate (cations) and nitrate (anions) and were released slowly throughout the crop growing period.

Post-harvest soil available nitrogen and N build up

The post-harvest soil available nitrogen at 0-15 cm was shown in the Table 2 differed significantly among all the treatments, recorded highest in T_6 (269.99 kg ha^{-1}) followed by T5 (267.89 kg ha^{-1}) and T_4 (265.78 kg ha^{-1}). The treatment under control T_{10} and T_{12} recorded the lowest soil available nitrogen of 213.04 kg ha^{-1}. The post-harvest soil available N noticed at 15-30 cm depth in the Table 3 shows that T_5 (263.67 kg ha^{-1}) and T_4 (255.23 kg ha^{-1}) and followed by T_6 (253.12 kg ha^{-1}) and the treatment T_{12} (189.84 kg ha^{-1}) holds the least.

The data in the Table 2 and 3 described the N build up in the soil, calculated from the post-harvest status of N and expected N balance at 0-15 cm and 15-30 cm depth, respectively was found significant. The N build up indicates the apparent gain or loss of N in the soil. N build up, i.e., positive balance of N at 0-15 cm was noticed highest in T_9 (42.32 kg ha^{-1}) followed by T_6 (35.81 kg ha^{-1}) which is at par with T_8 (35.66 kg ha^{-1}) and the least was in T_{10} (13.74 kg ha^{-1}). At 15-30 cm depth, T_9 (57.09 kg ha^{-1}) gained more N followed by T_8 (48.31 kg ha^{-1}) and T_{10} (17.96 kg ha^{-1}), gained the least amount of N.

Results of the study showed that the apparent balance of N build up under poultry manure was greater than pig manure and FYM. From the Fig. 1, It can be seen that N build up was more at 15-30 cm as compared to 0-15 cm. This positive balance might be attributed to the slower decomposition rate of poultry manure which maintained the continued availability of nitrogen in the soil and met the crop demand in spite of depletion of nutrients by the crop (Rayar, 1984). This was in well agreement with the findings of Bouldin (1988) who reported that even after the completion of the crop; mineralization of N could be continued and added to the soil. This higher availability of nutrients also might be attributed to rate of mineralization of manures, reduction in fixation and complex properties of decomposition of manures (Reddy and Reddy, 1998). The higher mineralization rate of poultry manure was due to low C: N ratio followed by pig manure and FYM, i.e., higher the C: N ratio slower the mineralization rate and this difference influence the nutrient supply from manures. This was supported by Chadwick et al. (2000). Higher nodulation in N gain in manure incorporated treatments was resulted in increased N fixation. Thus, manure incorporation increased the soil available N by mineralization of manure and fixation of N by the crop. This was in relation with the findings of Nimje and Steth (1987).

Table 2. Effect of organic amendments on apparent soil N balance at 0-15 cm

Treatments	Initial soil N + applied N (kg ha^{-1})	Crop N uptake at harvest (kg ha^{-1})	Expected N balance (kg ha^{-1})	Post- harvest soil N status (kg ha^{-1})	N build up (kg ha^{-1})
T_1 - FYM	249.50	50.15	199.34	236.25	36.90
T_2 - FYM+ Mulch	251.75	51.97	199.78	236.25	36.47
T_3 - FYM+ SP (FYM L) + Mulch	251.75	55.87	195.87	236.25	40.37
T_4 - Pig manure	266.50	47.17	219.32	255.23	35.91
T_5 - Pig manure + Mulch	268.75	52.57	216.18	261.56	45.38
T_6 - Pig manure + SP (PM L) + Mulch	268.75	59.88	208.87	255.23	46.36
T_7 - Poultry Manure	229.50	47.42	182.08	227.81	45.73
T_8 - Poultry Manure + Mulch	231.75	52.25	179.49	227.81	48.31
T_9 - Poultry Manure + SP (PoM L) + Mulch	231.75	61.03	170.72	227.81	57.09
T_{10} – Control	202.50	28.50	173.99	191.95	17.96
T_{11} - Control + Mulch	204.75	29.80	174.95	194.06	19.11
T_{12} - Control + SP (Water) + Mulch	204.75	33.68	171.07	191.95	20.88
S.E.(m) ±		2.91	2.91	2.65	3.67
C.D(P=0.05)		8.52	8.52	7.78	10.77

With respect to the control treatment T_{10}, the N build up is only from the N fixation by black gram which was lower. The low N fixation was probably due to the low pH of soil. Nodulation in legumes was restricted when pH of the soil was low. This was supported by Yoshida and Yatazawa (1967). In T_{11} where only application of mulch was done, the N build up is from N fixation by the crop and also from the addition of mulch material which added N in the soil after decomposition. The T_{12} observed greater N build up when compared with T_{10} and T_{11} this might be probably because of seed priming with water which helps in increased nodulation of black gram when compared with non-primed seeds as stated by Umair et al. (2011).

The higher availability of nutrients under T_9 was attributed to the combination of priming, manuring and mulching. N build up was the result of N fixation by black gram, decomposition of residues and mineralization of organic manures. The effect of the interaction of all the three organic amendments was significantly differed with respect to manures. Nitrogen fixation by black gram was enhanced by priming, as it strengthened the root system, increases nodulation and nitrogen fixation. Apart from this, soil nutrient status might have influenced at molecular level and determined the amount of N fixation. This result was in accordance with the findings of Umair et al. (2011). Also, there was a difference in priming treatment in which priming with manure leachates gained more N build up than hydro-priming. Among the washes, poultry manure wash was found to be more effective than other manure washes as it contains more nutrient and hormones. This helps the plant to uptake more nutrient and strengthened the root system and increased the N fixation. The nutrient uptake might be determined by the amount of nutrient in seed priming. This was in correlation with Shah et al. (2012). Mulching also contributed to the N build up in the soil by the decomposition and deposition of organic matter, as supported by Awopegha et al. (2017) .

Table 3. Effect of organic amendments on apparent soil N balance at 15-30 cm

Treatments	Initial soil N + applied N (kg ha^{-1})	Crop N uptake at harvest (kg ha^{-1})	Expected N balance (kg ha^{-1})	Post- harvest soil N status (kg ha^{-1})	N build up (kg ha^{-1})
T_1 - FYM	274.81	50.15	224.65	246.79	22.14
T_2 - FYM+ Mulch	277.06	51.97	225.09	248.90	23.81
T_3 - FYM+ SP (FYM L) + Mulch	277.06	55.87	221.19	251.01	29.82
T_4 - Pig manure	291.81	47.17	244.63	265.78	21.14
T_5 - Pig manure + Mulch	294.06	52.57	241.49	267.89	26.39
T_6 - Pig manure + SP (PM L) + Mulch	294.06	59.88	234.18	269.99	35.81
T_7 - Poultry Manure	254.81	47.42	207.39	240.46	33.07
T_8 - Poultry Manure + Mulch	257.06	52.25	204.81	240.46	35.66
T_9 - Poultry Manure + SP (PoM L) + Mulch	257.06	61.03	196.03	238.35	42.32
T_{10} – Control	227.81	28.50	199.30	213.04	13.74
T_{11} - Control + Mulch	230.06	29.80	200.26	215.15	14.89
T_{12} - Control + SP (Water) + Mulch	230.06	33.68	196.38	213.04	16.66
S.E.(m) ±		2.91	2.91	1.46	3.12
C.D(P=0.05)		8.52	8.52	2.47	9.16

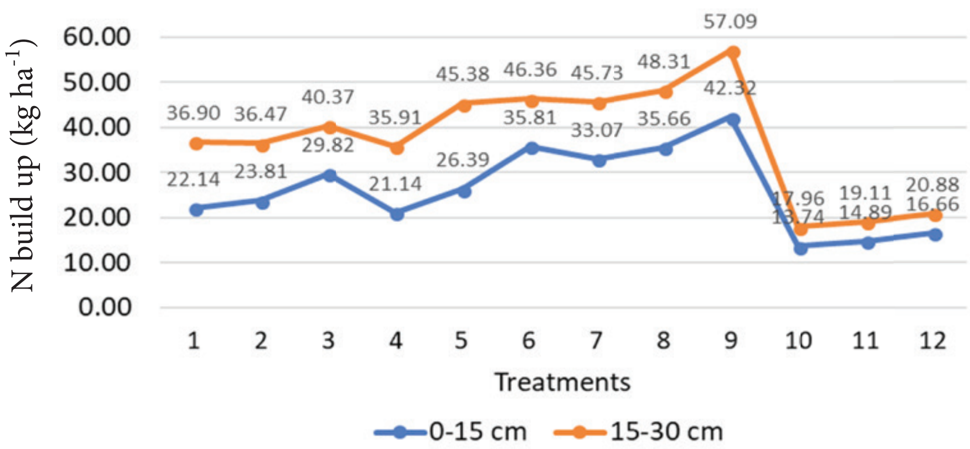

Fig. 1. Comparison of apparent N build up at two different depths in post-harvest soil

Post-harvest soil available phosphorus and P loss

The post-harvest soil available phosphorus at 0-15 cm was shown in the Table 4 differed significantly among all the treatments, recorded the highest in T_6 (69.63 kg ha^{-1}) and T_5 (68.22 kg ha^{-1}) which are at par followed by T_4 (66.29 kg ha^{-1}). The treatment under control recorded the lowest soil available phosphorus of 11.17 kg ha^{-1}. The post-harvest soil available P noticed at 15-30 cm depth was shown in the Table 5 shows that T_6 (69.68 kg ha^{-1}) and T_5 (69.13 kg ha^{-1}) and followed by T_4 (67.76 kg ha^{-1}) and the treatment T_{10} (10.38 kg ha^{-1}) holds the least. The data in the Table 4 and 5 stated the P loss from the soil, calculated from the post-harvest status of P and expected P balance at 0-15 cm and 15-30 cm depth respectively was found significant.

Table 4. Effect of organic amendments on apparent soil P balance at 0-15 cm

Treatments	Initial soil P + applied P (kg ha^{-1})	Crop P uptake at harvest (kg ha^{-1})	Expected P balance (kg ha^{-1})	Post- harvest soil P status (kg ha^{-1})	P loss (kg ha^{-1})
T_1 - FYM	35.25	4.20	31.05	38.74	-7.69
T_2 - FYM+ Mulch	36.15	4.22	31.93	40.80	-8.87
T_3 - FYM+ SP (FYM L) + Mulch	36.15	5.41	30.74	43.14	-12.40
T_4 - Pig manure	61.85	4.25	57.60	66.29	-8.70
T_5 - Pig manure + Mulch	62.75	4.43	58.32	68.22	-9.90
T_6 - Pig manure + SP (PM L) + Mulch	62.75	4.52	58.23	69.63	-11.40
T_7 - Poultry Manure	25.40	4.43	20.97	30.00	-9.03
T_8 - Poultry Manure + Mulch	26.30	4.66	21.64	33.28	-11.64
T_9 - Poultry Manure + SP (PoM L) + Mulch	26.30	5.22	21.08	34.72	-13.64
T_{10} – Control	16.25	2.19	14.06	11.17	2.90
T_{11} - Control + Mulch	17.15	2.50	14.65	14.77	-0.12
T_{12} - Control + SP (Water) + Mulch	17.15	3.11	14.04	14.47	-0.43
S.E.(m) ±		0.38	0.38	0.34	0.54
C.D(P=0.05)		1.11	1.11	1.00	1.58

With respect to P loss, surprisingly there was a gain in P in all the treatments except T_{10} control. The loss in T_{10} was 2.90 kg ha^{-1} at 0-15 cm and 1.63 kg ha^{-1} at 15-30 cm. The gain in P was more under T_9 at 0-15 cm (13.64 kg ha^{-1}) and 15-30 cm (17.41 kg ha^{-1}) followed by T_8. The loss in post-harvest soil available P in control was due to the crop uptake and no addition of any external sources. The role of priming may be negligible because there were no significant results in P status under priming. The increase in P might be in lesser quantity (Gohil et al., 2017). The apparent positive balance of P in mulched treatments was more than the unmulched treatments. The reason might be during the decomposition of organic materials, the production of organic acids reduced the fixation or adsorption of phosphorus by soil or the rate of desorption of phosphate has been increased and it increased the P in soil. This was similar to the report of Othieno (1973) and Nziguheba et al. (1998).

Table 5. Effect of organic amendments on apparent soil P balance at 15-30 cm

Treatments	Initial soil P + applied P (kg ha^{-1})	Crop P uptake at harvest (kg ha^{-1})	Expected P balance (kg ha^{-1})	Post- harvest soil P status (kg ha^{-1})	P loss (kg ha^{-1})
T_1 - FYM	33.20	4.20	29.00	39.83	-10.83
T_2 - FYM+ Mulch	34.10	4.22	29.88	42.32	-12.44
T_3 - FYM+ SP (FYM L) + Mulch	34.10	5.41	28.69	43.14	-14.45
T_4 - Pig manure	59.80	4.25	55.55	67.76	-12.22
T_5 - Pig manure + Mulch	60.70	4.43	56.27	69.13	-12.86
T_6 - Pig manure + SP (PM L) + Mulch	60.70	4.52	56.18	69.68	-13.50
T_7 - Poultry Manure	23.35	4.43	18.92	34.19	-15.27
T_8 - Poultry Manure + Mulch	24.25	4.66	19.59	36.08	-16.49
T_9 - Poultry Manure + SP (PoM L) + Mulch	24.25	5.22	19.03	36.44	-17.41
T_{10} – Control	14.20	2.19	12.01	10.38	1.63
T11 - Control + Mulch	15.10	2.50	12.60	13.86	-1.26
T_{12} - Control + SP (Water) + Mulch	15.10	3.11	11.99	14.08	-2.08
S.E.(m) ±		0.38	0.38	0.54	0.68
C.D(P=0.05)		1.11	1.11	1.58	1.98

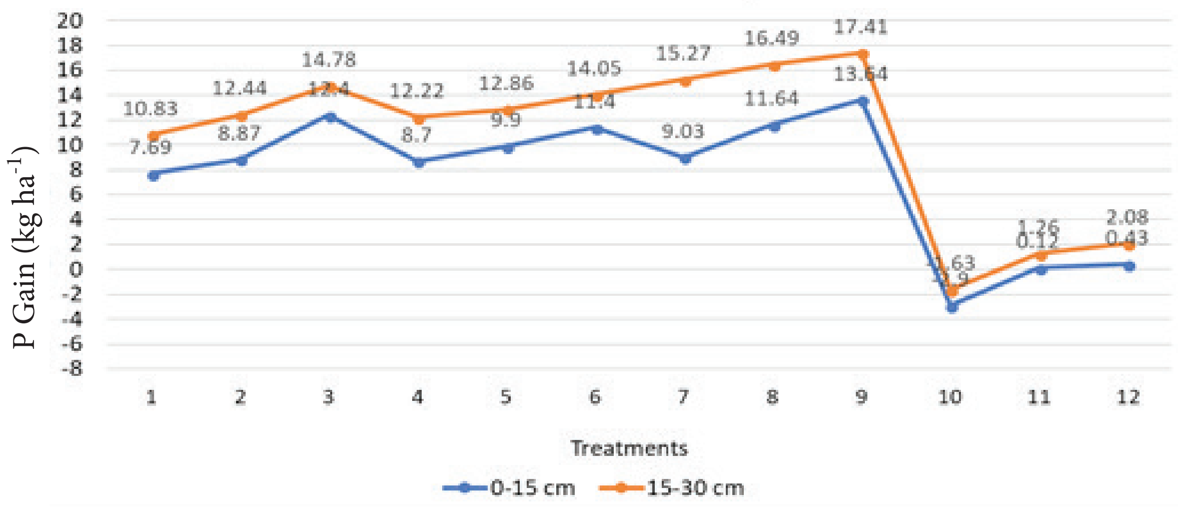

Fig. 2. Comparison of apparent P balance at two different depths under different treatments

The study showed that there was no loss in phosphorus and the positive balance of phosphorus i.e. gain in P was noticed higher under poultry manure incorporated treatments followed by pig manure and FYM. Fig. 2 shows that the apparent P balance was found to be higher at 15-30 cm, as compared to 0-15 cm. This might be due to the supremacy of poultry manure as it can supply soluble nutrients for longer period of time by not allowing the entire nutrients into soil solution, thereby reducing the precipitation and fixation of phosphorus. The release of hydroxyl ions from the organic acid production during decomposition acted as chelates and also stabilized the insoluble native P and made available for longer period of time by mobilizing the native P. Similar results were observed by Sangeetha (2013) and Pazhanivelan et al. (2006). The rate of mineralization was determined by C: P ratio of the organic manures which was in the descending order of FYM, pig manure and poultry manure. The result was in accordance with Pal et al. (2018).

CONCLUSION

The apparent N and P balance was estimated to assess the influence of organic amendments on soil nutrient status. It was observed that the apparent N balance, i.e., gain in N, N build up at 0-15 cm was higher under T_9 followed by T_8 and at 15-30 cm T_9 followed by T_8. In P balance, the P loss was found under T_{10}. In all the other treatments there was gain i.e. no loss in P and was higher under T_9 followed by T_3 at 0-15 cm and at 15-30 cm, T_9 and T_8 had the maximum gain in P. It may be concluded that organic amendments improved the crop growth by increasing the nutrient uptake and soil available nutrients were increased by maintaining the apparent nutrient balance. The study showed that poultry manure had the maximum gain in N and P followed by pig manure and FYM along with mulching. Therefore, poultry manure may be preferred over the other treatments.

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