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Nutrient Release Characteristic of Multinutrient Pellet for Organic Farming in Rice (*Oryza sativa* L) for Acid Sulphate Soils

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To develop a multinutrient pellet for organic farming in rice and investigation on the nutrient release characteristics of pellet in acid sulphate soils of Kuttanad.
Study Design: This experiment was conducted through completely randomized design with 8 treatments and 3 replications.
Place and Duration of Study: The research was appraised at the Department of Soil Science, College of Agriculture Vellayani, between July 2022 - September 2022.

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Methods: Pellets were prepared using organic nutrient sources permitted in NPOP and a 60 day laboratory incubation experiment was performed to evaluate the nutrient release pattern of pellets. Standard procedures were used to analyze the nutrient content in pellets and quantity of nutrients in soil samples drawn from incubation experiment.

Results: Nutrient availability increased from the 15th to the 60th day, and the maximum was observed on 60thday. The soil pH, EC, dehydrogenase activity, and humic acid content increased throughout the incubation period, while organic carbon and fulvic acid content declined.

Conclusion: The gross nutrient release was found to be the highest in pellet containing bloodmeal, rockphosphate and potassium sulphate.

Keywords: Acid sulphate soils; pellets; bloodmeal; rockphosphate; potassium sulphate.

1. INTRODUCTION

Kuttanad is the rice bowl of Kerala lying below mean sea level and soils are acid sulphate in nature [1]. Pyrite levels are significant in this poorly drained potential acid sulphate soils [2]. Hence these soils are classified under the order Entisols, suborder Aquents, great group Sulfaquents and sub group Typic Sulfaquents [3]. Fe and Al toxicity is widespread resulting in yield losses upto 70% [4]. In addition, low inflow of water into Kuttanad during the summer months (February-May) raises the salinity, acidity, and a shortage of water [5].

Amelioration of soil acidity, regulation of nutrients, lime and fertilizer application has been carried out over the years. Practice of liming can enhance the physical, chemical and biological properties of acid sulphate soils in Kuttanad [6]. Increased use of chemical fertilizers has been observed in this region and its application resulted in the negative impact on Atterberg limits and compressive strength of clay, besides excessive accumulation of agrochemical residues were reported [7,8].

In acid sulphate soils, organic matter has a greater alkalizing impact than inorganic salts (e.g. Ca_2SO_4). Organic matter oxidation is widely recognized for producing carbonic and other organic acids. Plant leftovers are a common source of organic matter because they may regulate moisture levels, recycle nutrients, and increase soil fertility [8,9,10].

Plethora of studies regarding organic nutrient sources as pellets highlight the importance of utilization of organic multinutrient pellets in crop production. Pellets are better for long-distance transportation, durable enough without disintegration and produce less of the dust [11]. Also Pellets are convenient to store, handle, transport, and uncomplicated to use in the field [12]. Jeng et al. [13] developed a manure pellet for the cereals in Norway, which was prepared by concentrated organic manure that can supply large amount of nitrogen, phosphorous and calcium to the soil. The development and productivity of rice are further impacted by the nitrogen shift that organic manure caused in the soil, combined with changes to the microbial populations in the rice field [14]. The research work of Conner [15] depicts that application of organic manure with blood meal could accord high bulky carbon to the soil that could improve the soil structure and microbial biomass. Organic manure provides several advantages, including a balanced supply of nutrients, higher soil nutrient availability owing to increased soil microbial activity, the breakdown of hazardous components, soil structure improvements and root growth, and improved soil water availability [16].

Blood meal has the potential to improve the physical and biological qualities of soil [17]. According to Bhattacharyya and Bhupal [18], rock phosphate was more slowly accessible but not as fast fixed in the soil as other soluble forms of phosphate. Since acidic soils have high amounts of Fe and Al, as well as strong activity of $Al_2 O_3$ and $Fe_2 O_3$, soluble forms of phosphate fertilizers are transformed into less soluble aluminum phosphate (Al-P) and iron phosphate (Fe-P) when applied to such soils. Potassium sulphate did not limit nitrification at higher pH levels, but it did encourage nitrogen buildup in the soil and increased EC content. It also inhibited nitrification in acidic soil, which decreased nitrogen losses [19]. Day et al. [20] discovered that langbeinite translocate sodium in high concentrations while also contributing magnesium and potassium at an effective rate. Solubilized langbeinite, which contains Mg and K ions that promote flocculation, kept electrolyte concentrations high [21].

This study delved into the development of multinutrient pellets for organic farming in rice and evaluation on its applicability in acid sulphate soil through a laboratory incubation study conducted in a controlled condition.

2. MATERIALS AND METHODS

2.1 Organic Multinutrient Pellet Preparation

For the preparation of organic multi nutrient pellets, nutrient sources approved under the National Programme for Organic Production (NPOP) were selected and 8 different pellets were prepared using a pelletizing machine, which can produce cylindrical pellets with 1.2cm diameter and 2cm length, by combining different N, P and K nutrient sources with proper moisture to keep the shape, taking into account the nutritional requirement of rice (N : P_2O_5 : K_2O – 90 : 45 : 45) and the fertility status of the experimental soil. The pellets are P1 (Blood meal +Rock phosphate +Potassium sulphate), P2 (Blood meal +Rock phosphate +Langbeinite), P3 (Blood meal +Steamed bone meal +Potassium sulphate), P4 (Blood meal +Steamed bone meal +Langbeinite), P5 (Groundnut cake +Rock phosphate +Potassium sulphate), P6 (Groundnut cake +Rock phosphate +Langbeinite), P7 (Groundnut cake +Steamed bone meal +Potassium sulphate), and P8 (Groundnut cake +Steamed bone meal +Langbeinite).Bentonite clay and humic acid were used as binding agents.

2.2 Pellet Characterization

Physical properties such as bulk density (Volume and weight method [22], water holding capacity (Centrifugation method [23]), stability on storage (simple finger test [24]) and disintegration in water (distilled water method [24]) and chemical properties such as pH and EC (Potentiometry Conductometry [25]) organic carbon (Walkley and Black rapid titration method [26]), total N (Macrokjeldahl distillation and titrimetry after extraction with 2 M KCl [27]), P and K (Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using spectrophotometer for P and flame photometer for K, [28]), Ca and Mg (Diacid (HN O_3:HCl O_4 in the ratio 9:4) digestion and estimation using versanate titration method [27]), S (Diacid (HN O_3:HCl O_4 in the ratio 9:4) digestion and turbidimetry [29]), Fe, Mn, Zn, Cu (Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using atomic absorption spectrometry [28]) and B (Spectrophotometry - Azomethine-H method [30]) along with organic acids such as humic acid and fulvic acid (0.1N sodium hydroxide and concentrated HCL method [28]) were estimated.

2.3 Incubation Pot Preparation

A laboratory incubation experiment was carried out to investigate the nutrient release pattern of the pellets after addition to soil. Five kilograms of acid sulphate soil from Kuttanad were placed in pots. The organic multi nutrient pellets were added into the pots depending on the weight of soil taken and the nutritional requirement of rice. The pots were maintained at saturated condition.

2.4 Nutrient Release Characterization

Samples were drawn at 15^{th}, 30^{th}, 45^{th}, and 60^{th}day of incubation, and analysis was done for the following parameters. Chemical parameters such as pH, EC (Potentiometry Conductometry by [25]), organic carbon (Walkley and Black rapid titration method [26]), Available N (Alkaline potassium permanganate method [31]), Available P (Bray No.1 extraction and estimation using spectrophotometer [32]), Available K (Neutral normal ammonium acetate extraction and estimation using flame photometry by [28]), Exchangeable Ca and Mg (Versanate titration method [27]), available S ($CaCl_2$ extraction and estimation using spectrophotometer [30]), B (Spectrophotometry - Azomethine-H method [30]), available Fe, Mn, Cu, and Zn (0.1 N HCl extraction and estimation using atomic absorption spectrometry [33]), dehydrogenase activity (Colorimetric determination using 2,3,5-triphenyl formazan (TPF) [34]) and humic acid and fulvic acid content (Using 0.1N sodium hydroxide and concentrated HCL method [28]).

3. RESULTS AND DISCUSSION

3.1 Pellet Characterization

3.1.1 Physical characters of pellets

Physical attributes of organic multinutrient pellets (Table 1) clearly specified that the bulk density of pellet P_6 (3.21 Mg m^{-3}) was highest whilst P_4 (2.23 Mg m^{-3}) gave the lowest value and the pellets P_8 (3.15 Mg m^{-3}) and P_5 (3.12 Mg m^{-3}) were on par with P_6. This might be due the moisture content and peanut material used for pellet preparation [35]. Water holding capacity of pellets expressed that P_5 (29.12%) had higher

WHC than other treatments and it was followed by P_1 (28.32%) and P_6 (28.32%) with equal capacity to hold water. This may be due the presence of finer particles and porosity of pellets. All the pellets are found to be stable along the storage period without exhibiting any kind of variations in the shape, structure and texture. The pellets are able to sustain at least 2 hours in water without disintegration. Pellets P_5, P_6, P_7 and P_8 prolonged for more than 2.5hrs without disintegration. This might be due to the high compactness and compressibility of pellets and due to the potential of binding agents.

3.1.2 Physio-chemical properties of pellets

pH, EC and organic carbon concentrations of pellets are represented in the Table 2. pH of P_1 (5.98), P_3 (5.87), P_6 (5.82), P_2 (5.77), P_7 (5.71) and P_4 (5.65) were slightly acidic. The hexacoordinated Fe (III) present in blood meal can be coordinated by OH^- ion and by a Cl^- ion; hence pH may have increased. In addition, the application of organic compounds with blood meal would have increased the pH [36,37]. The Electrical conductivity of pellets exhibited slight variations where P_6 had the highest EC followed by P_8, P_5 and P_2. It is because of the release of mineral salts from potassium langbeinite. All those pellets were blazoned high organic carbon content within a range of 17.5% - 23.5%. P_1 (23.13 %) and P_2 (20.94 %) had higher OC content above 20%. The presence of blood meal in pellet contributed high organic matter content in pellet [36].

3.1.3 Nutrient content of pellets

Nutrient concentrations in the pellets are depicted in the Table 2. P_3 (8.47%), P_1 (8.23%), P_2 (7.61%) and P_4 (7.56%) had the highest concentration of nitrogen than P_5, P_6, P_7 and P_8. It is because they contain blood meal which contains 10-12% N. The nitrogen content in blood meal is easily mineralizable so that it is easily available to plants [36-39]. The phosphorous and potassium contents of pellets were closer to the trend of nitrogen. P_1 exhibited larger concentration of phosphorous (4.24%) and potassium (4.21%). Rock phosphate contains high total phosphate content and on application, it increases the reserve P and available P concentration in soil. It is more suitable for acid soil [40,41]. Sulphate of potash has high quantity of K in available form, which can be applied in acid soils with leaching problem [42].

P_1 (5.08%) reported higher Ca concentration and P_8 (1.10%) least Ca content. Ca content is high in rock phosphate. This leads to a higher Ca content rock phosphate containing pellets. Higher magnesium content was observed in P_2, P_4, P_6 and P_8. It may be because of the presence of Mg in langbeinite used in these pellets [20]. Regarding sulphur, highest concentration was observed in P_2 (4.18%) followed by P_4 (3.87%), because of the presence of sulphate in langbeinite used in these pellets [20].

Micro nutrient content in the eight different pellets are represented in Table 4. The boron content of pellets was in the range of 1.9 mg kg^{-1} – 1.06 mg kg^{-1}, where P_8 had the highest B content. Fe content was found highest in P_3 with 350.53 mg kg^{-1} followed by P_5 (312.86 mg kg^{-1}). Fe content was higher in these treatments because of the presence of Fe in blood meal [43,44]. Mn content of pellets were in an order of P_5 (40.60 mg kg^{-1}) > P_1 (35.93 mg kg^{-1}) > P_8 (34.13 mg kg^{-1}) > P_7 (34.00 mg kg^{-1}) > P_3 (31.56 mg kg^{-1}) > P_2 (31.23 mg kg^{-1}) > P_4 (18.50 mg kg^{-1}) > P_6 (17.13 mg kg^{-1}). Zn content in pellets occurred in the range of 24.73 mg kg^{-1} (P_7) to 15.57 mg kg^{-1} (P_3). Cu content was found in the range of 5.62 mg kg^{-1} (P_6) - 2.57 mg kg^{-1} (P_5). This might be due to ability of slow release organic fertilizers to provide micro nutrients [44].

Table 1. Physical characteristics of organic multinutrient pellet

Pellets	Bulk density ($Mg\ m^{-3}$)	WHC (%)	Stability on Storage	Disintegration in water (minutes)
P_1	2.96	28.32	Stable	160
P_2	2.99	28.06	Stable	150
P_3	2.23	27.12	Stable	120
P_4	2.39	26.77	Stable	120
P_5	3.12	29.12	Stable	170
P_6	3.21	28.32	Stable	165
P_7	2.54	27.71	Stable	170
P_8	3.15	26.35	Stable	180

Table 2. Chemical characterization of organic multi nutrient pellets

Pellets	pH	EC (dSm^{-1})	OC (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B ($mgkg^{-1}$)	Fe ($mgkg^{-1}$)	Mn ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)	Cu ($mgkg^{-1}$)
P_1	5.98	1.44	23.13	8.23	4.24	4.21	5.08	1.02	2.74	1.17	244.26	35.93	22.71	4.21
P_2	5.77	1.64	20.94	7.61	3.64	3.58	4.55	2.65	4.18	1.08	312.86	31.23	18.97	3.53
P_3	5.87	1.35	20.19	8.47	4.06	4.09	2.04	0.12	0.59	1.06	350.53	31.56	15.57	3.26
P_4	5.65	1.60	20.38	7.56	3.78	3.66	1.82	1.88	3.87	1.17	255.60	18.50	17.85	4.13
P_5	5.28	1.69	19.19	4.77	2.74	2.49	2.98	0.60	0.65	1.11	183.43	40.60	22.34	2.57
P_6	5.82	1.89	19.32	4.46	2.46	2.25	2.78	1.62	2.57	1.09	169.23	17.13	21.91	5.62
P_7	5.71	1.23	18.71	4.89	2.49	2.41	1.17	0.10	0.34	1.82	203.50	34.00	24.73	3.62
P_8	5.39	1.79	19.38	4.57	2.21	2.28	1.10	1.14	2.34	1.90	185.40	34.13	21.95	4.27

**P1 (Blood meal +Rock phosphate +Potassium sulphate), P2 (Blood meal +Rock phosphate +Langbeinite), P3 (Blood meal +Steamed bone meal +Potassium sulphate), P4 (Blood meal +Steamed bone meal +Langbeinite), P5 (Groundnut cake +Rock phosphate +Potassium sulphate), P6 (Groundnut cake +Rock phosphate +Langbeinite), P7 (Groundnut cake +Steamed bone meal +Potassium sulphate), P8 (Groundnut cake +Steamed bone meal +Langbeinite).Bentonite clay and humic acid were used as binding agents*

3.1.4 Organic acid content in the pellets

Humic acid (3.05%) and fulvic acid (3.23%) contents (Table 3) revealed that both organic acids were found highest in P_1 and lower values were obtained by P_7 and P_8. This might be due to the presence of higher organic carbon in this pellet. A variety of organic molecules, including proteins, lipids, carbohydrates and pigments, are present in biodegrading organic wastes. These molecules eventually appear to produce complex organics, including humic acids (HA), fulvic acids (FA), and other substances [45].

Table 3. Organic acid content in multi nutrient pellets

Combination	Humic acid (%)	Fulvic acid (%)
P_1	3.05	3.23
P_2	2.59	2.41
P_3	2.74	2.55
P_4	2.36	2.64
P_5	2.10	2.25
P_6	1.92	2.35
P_7	1.88	2.02
P_8	1.33	2.28

3.2 Nutrient Release Characteristics of Pellets

3.2.1 Initial soil analysis

Table 2 delineates the initial physio-chemical and chemical properties of the soils used for the field experiment. It conveyed that the soil was strongly acidic (4.66) and the EC was found low (0.06 dS m^{-1}). The soil had high OC content of 3.34% and medium content of available N, P and K which was 362.5 Kg ha^{-1}, 24.8 Kg ha^{-1} and 185.6 Kg ha^{-1} respectively. Availability of secondary nutrients such as Ca, Mg and S were found excess in the soil. In case of micronutrients Fe was found in higher concentration while Mn, Zn, Cu and B were in sufficient level.

3.2.2 Soil pH

Soil pH was found to increase during the incubation days (Table 5). P_1 was able to reduce more acidity on comparing with others. P_2 and P_6 also exhibited a tendency to reduce pH. Application of combined organic compounds increases soil pH along incubation period in acid soils, which is thought to be associated with the basic cation concentration availability in pellets and its slow release characters which is found consistent with other studies [46-48]. In addition the organic acid content of the manure could raise soil pH [10].

Table 4. Characterization of initial soil

OC	4.66
EC (dS m^{-1})	0.06
OC (%)	3.34
N (Kg ha^{-1})	362.5
P (Kg ha^{-1})	24.8
K (Kg ha^{-1})	185.6
Ca (mg Kg^{-1})	480
Mg (mg Kg^{-1})	165
S (mg Kg^{-1})	16.2
B (mg Kg^{-1})	0.52
Fe (mg Kg^{-1})	280
Mn (mg Kg^{-1})	2.75
Zn (mg Kg^{-1})	1.55
Cu (mg Kg^{-1})	1.20

3.2.3 Soil EC

Application of multinutrient pellets did not significantly influence electrical conductivity until the 45^{th} day of incubation (Table 5). P_1 (0.167 dSm^{-1}) was able to create an influence on EC on the 60^{th} day and it was followed by P4 (0.136). This might be due to the higher concentration of dissolved solutes in an organically improvised soil [49]. Conner [15] reported that application of blood meal can influence the electrical conductivity of soil due to the presence of inorganic nitrogen. Similar increasing trend in EC has observed by Fernandez-Sanjurjo et al. [50] in a study with NPK fertilizer tablets.

3.2.4 Soil organic carbon

Organic carbon content of soil was found non-significant by the application of organic multinutrient pellets up to 45^{th} day (Table 5). A minor fall in OC content was observed on 60^{th} day, within a scale of 3.79% (P_1) to 3.59% (P_6). Applications of manure along with blood meal can contribute in soil C due to increased concentration of water soluble carbon with days [15,51]. Similar increasing OC content were observed from the study of Ciavatta et al. [38].

3.2.5 Soil available nitrogen

The influence of treatments on available nitrogen content of soil is presented in Table 6. Significant contribution of nitrogen content was observed with an increase in nitrogen content from the 15^{th} day to the 60^{th} day (Fig. 1). The range of nitrogen obtained on 15^{th} day was 397.33 kg ha^{-1} (P_1) to 357.01 kg ha^{-1} (P_5). P_2 (396.37 kg ha^{-1}) and P_4 (388.21 kg ha^{-1}) were on par with P_1. Same trend was also recorded on 30^{th} day. On the 45^{th} day the highest N content was reported by P_2 (429.09 kg ha^{-1}) which was on par with P_1 (428.33kg ha^{-1}). Identical tendency has marked on the observation of the 60^{th} day. This might be due to the higher net mineralization rate observed in blood meal [38,52]. As the initial inorganic N concentration was relatively high, the blood meal had the highest total plant available nitrogen percentage. According to Hartz and Johnstone [53], the microbial community accelerated the enzymatic hydrolysis of easily broken down N-compounds during the first 14 days of blood meal mineralization would be slower, but thorough degradation of more intricate organic forms occurred later.

3.2.6 Soil available phosphorous

Available ohosphorous content obtained is detailed in Table 6 (Fig. 2). It is clear that, increase in phosphorous content is seen on the 15^{th} day from the initial reading (24.8 kg ha^{-1}), which exemplifies the significant addition of phosphorous to the soil by the multinutrient pellets. It ranged from 31.98 kg ha^{-1} (P_1) to 25.47 kg ha^{-1} (P_7), where P_2 (32.42 kg ha^{-1}) was on par with P_1. The P availability had been built up peacemeal on 60^{th} day. P_1, P_2 and P_5 reported higher values initially and on the second observation P_2 released more P and it is followed by P_1. In a similar study of Mahawar [54] it was observed that with the application rock phosphate the quantity of P available in soil was high for more than 60 days. The studies of SanthoshKumar [55] and Jalali and Ranjbar [56] also put forward similar results regarding rockphosphate.

3.2.7 Soil available potassium

Potassium concentration in soil is represented in Table 6. Significant contribution to available potassium was observed after the application of pellets (Fig. 3). An increasing trend in potassium content was recorded from the initial soil reading (185.6 kg ha^{-1}) towards the reading on the 60^{th} day. The range of potassium obtained on the 15^{th} day was 198.60 kg ha^{-1}(P_1) to 184.06 kg ha^{-1} (P_8), and P_2, P_3, P_5, P_6 and P_7 were on par with P_1. Highest P content was reported by P_1 (209.06 kg ha^{-1}) on the 45^{th} day of incubation and P_3, P_5 and P_7 were on par with P_1. Similar trend was observed on the observation of 60^{th} day also. The pelletsP$_1$, P_3, P_5 and P_7 which contain sulphate of potash, recorded comparatively higher value of K throughout the incubation period. According to Tian et al. [57], cumulative K release from sulphate of potash was found higher along the incubation period and the available K content in soil was found to be increased with the rate of application. Steady release of K ions in soil through the application of NPK fertilizer gave a positive impact on release rate [50].

3.2.8 Soil exchangeable calcium

Calcium content in soil increased with days (Fig. 4). On the 15^{th} day, the calcium level exhibited a range of 593.33 kg ha^{-1} (P_2) to 480 kg ha^{-1} (P_8) in which P_1 (586.67 kg ha^{-1}), P_5 (583.34 kg ha^{-1}) and P_6 (576.67 kg ha^{-1}) were found on par to P_2 (Table 7). The high value for P_2 was found until 60^{th} day (616.67 Kg ha^{-1}) and it was followed by P_1 (611.34 kg ha^{-1}). The least content was recorded in P_8 from 15^{th} day (480.00 kg ha^{-1}) to 45^{th} day (560.00 kg ha^{-1}). The higher trends in Ca in these treatments may be due to due to the higher content of Ca in rock phosphate [40]. In a similar study of Bloukounon-Goubalan [58], higher quantity of Ca was released slowly in an organic mixture. Olowoake [59] also reported increase in Ca content along the incubation period.

3.2.9 Soil exchangeable magnesium

Magnesium content in soil performed an increasing trend along the incubation period (Fig. 5). P_2 (198.00 kg ha^{-1}) recorded the highest on 15^{th} day (Table 7) which was followed by P_4 (196.00 kg ha^{-1}), P_6 (194.34 kg ha^{-1}) and P_8 (194.00 kg ha^{-1}). On the 60^{th} day the highest Mg value was observed in P_6 (219.34 kg ha^{-1}) and P_1, P_2 P_4 and P_8 were found on par with it and P_7 had the lowest value during incubation days. Broschat [60] reported in his study that the release rate of Mg from Langbeinite was increased from the zeroth day of incubation to the final day of study due to highly mineralized $MgSO_4$ content. Close results were expressed in the study by Broschat and Moore [61].

3.2.10 Soil available Sulphur

Available Sulphur content of soil was found predominant in P_2 (35.50 mg kg^{-1} on 15^{th} day to 36.50 mg kg^{-1} on 60^{th} day) (Table 7). There was an increasing trend during incubation period (Fig. 6). Islam et al. [62] reported that S release increased with incubation and peaked in anaerobic conditions in 45–60 days. These results was concurred with those of Moharana et al. [63], who observed rising net S release levels as the incubation time increased from 30 to 60, irrespective of treatment.

Table 5. Effect of organic multi nutrient pellets on pH, EC and Organic Carbon in soil

Treatment	Days of Incubation											
	pH				EC (dSm^{-1})				Organic Carbon (%)			
	15	30	45	60	15	30	45	60	15	30	45	60
P_1	4.90	5.01	5.13	5.20	0.103	0.143	0.187	0.167	3.70	4.06	3.94	3.79
P_2	4.93	5.07	5.12	5.19	0.123	0.133	0.173	0.153	3.64	4.00	3.88	3.74
P_3	4.86	5.00	5.10	5.18	0.117	0.133	0.173	0.153	3.58	3.94	3.82	3.68
P_4	4.90	5.04	5.10	5.17	0.113	0.147	0.183	0.163	3.63	3.99	3.87	3.73
P_5	4.85	4.99	5.09	5.16	0.113	0.117	0.157	0.127	3.67	4.03	3.91	3.73
P_6	4.94	5.08	5.13	5.17	0.097	0.133	0.173	0.143	3.53	3.89	3.77	3.59
P_7	4.86	5.01	5.09	5.19	0.100	0.123	0.163	0.133	3.57	3.93	3.81	3.63
P_8	4.90	5.04	5.12	5.16	0.103	0.120	0.160	0.130	3.60	3.96	3.84	3.67
SEm (±)	0.015	0.01	0.008	0.008	0.008	0.008	0.008	0.008	0.036	0.035	0.036	0.036
CD (0.05)	0.031	0.029	0.025	0.024	NS	NS	NS	0.023	NS	NS	NS	0.107

**P1 (Blood meal +Rock phosphate +Potassium sulphate), P2 (Blood meal +Rock phosphate +Langbeinite), P3 (Blood meal +Steamed bone meal +Potassium sulphate), P4 (Blood meal +Steamed bone meal +Langbeinite), P5 (Groundnut cake +Rock phosphate +Potassium sulphate), P6 (Groundnut cake +Rock phosphate +Langbeinite), P7 (Groundnut cake +Steamed bone meal +Potassium sulphate), P8 (Groundnut cake +Steamed bone meal +Langbeinite).Bentonite clay and humic acid were used as binding agents*

Table 6. Effect of organic multi nutrient pellets on primary nutrients in soil

Treatment	Days of incubation											
	N ($kg\ ha^{-1}$)				P ($kg\ ha^{-1}$)				K ($kg\ ha^{-1}$)			
	15	30	45	60	15	30	45	60	15	30	45	60
P_1	397.33	408.63	420.13	428.33	31.98	33.37	34.04	35.05	198.73	202.00	209.06	211.27
P_2	396.37	407.67	429.09	437.29	32.42	33.69	34.39	35.07	191.13	192.53	195.67	199.80
P_3	380.45	391.75	411.01	419.21	27.41	28.70	29.72	31.01	195.93	198.20	202.73	205.94
P_4	388.21	399.51	403.25	411.45	26.58	27.76	28.77	29.92	189.53	191.73	193.93	198.14
P_5	357.01	368.31	377.21	388.61	31.32	32.60	31.80	32.54	198.60	200.00	202.80	206.00
P_6	371.35	382.65	390.19	401.59	30.58	31.86	32.52	33.58	192.87	194.26	190.93	195.13
P_7	368.85	380.15	391.22	402.62	25.47	26.67	27.68	28.94	196.86	198.26	201.13	204.34
P_8	366.99	378.76	384.19	395.59	28.06	28.90	29.91	31.17	184.06	185.73	187.93	193.47
SEm (±)	4.16	4.137	4.777	4.776	0.420	0.439	0.403	0.334	2.369	2.687	3.039	3.176
CD (0.05)	12.47	12.40	14.32	14.32	1.26	1.32	1.21	1	7.10	8.06	9.11	9.52

**P1 (Blood meal +Rock phosphate +Potassium sulphate), P2 (Blood meal +Rock phosphate +Langbeinite), P3 (Blood meal +Steamed bone meal +Potassium sulphate), P4 (Blood meal +Steamed bone meal +Langbeinite), P5 (Groundnut cake +Rock phosphate +Potassium sulphate), P6 (Groundnut cake +Rock phosphate +Langbeinite), P7 (Groundnut cake +Steamed bone meal +Potassium sulphate), P8 (Groundnut cake +Steamed bone meal +Langbeinite).Bentonite clay and humic acid were used as binding agents*

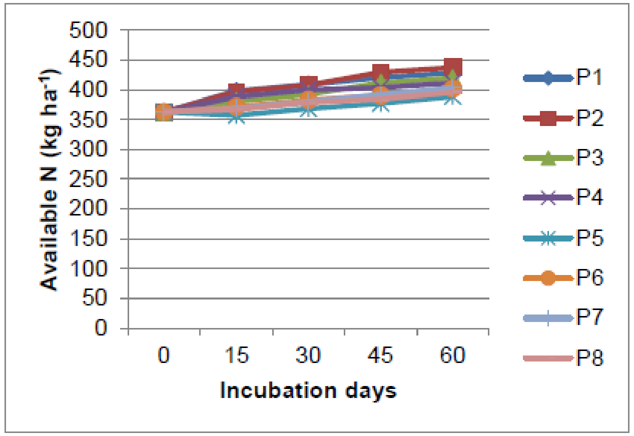

Fig. 1. Effect of organic multinutrient pellets on available N in soil

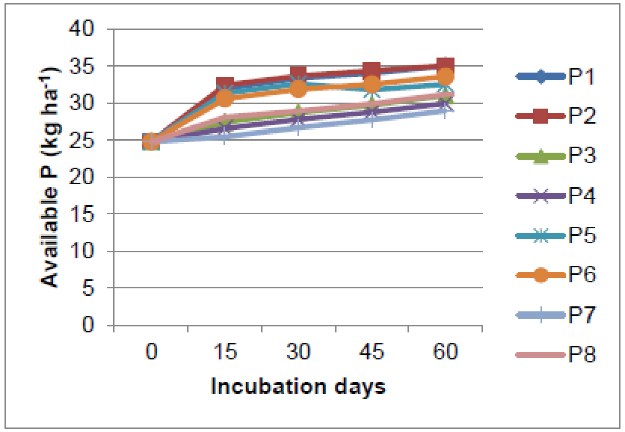

Fig. 2. Effect of organic multinutrient pellets on available P in soil

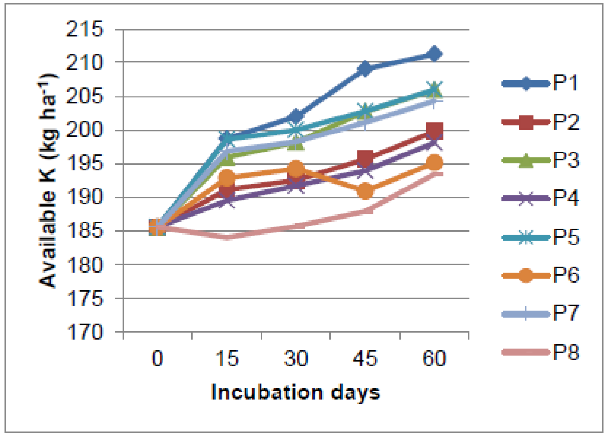

Fig. 3. Effect of organic multinutrient pellets on available K in soil

Table 7. Effect of organic multi nutrient pellets on Calcium, Magnesium, Sulphur and Boron in soil

Treatment	Days of Incubation															
	Ca (mg kg^{-1})				Mg (mg kg^{-1})				S (mg kg^{-1})				B (mg kg^{-1})			
	15	**30**	**45**	**60**	**15**	**30**	**45**	**60**	**15**	**30**	**45**	**60**	**15**	**30**	**45**	**60**
P_1	586.67	600.67	606.67	611.34	182.00	192.67	198.34	213.67	25.75	26.34	27.83	29.17	0.54	0.62	0.67	0.78
P_2	593.33	603.67	609.67	616.67	198.00	204.34	210.67	211.33	35.50	35.67	36.00	36.50	0.52	0.60	0.65	0.76
P_3	543.34	553.00	562.34	583.34	184.00	192.34	199.33	207.00	19.00	21.34	23.16	26.17	0.57	0.65	0.70	0.79
P_4	540.00	563.00	581.34	603.34	196.00	204.00	210.00	216.67	32.25	24.00	24.67	28.34	0.57	0.65	0.70	0.79
P_5	583.34	584.67	601.34	603.34	182.00	190.00	197.00	202.67	23.50	29.00	29.50	30.34	0.55	0.64	0.72	0.80
P_6	576.67	580.00	583.34	593.34	194.34	203.34	210.34	219.34	27.75	28.03	24.00	27.00	0.54	0.62	0.70	0.78
P_7	543.34	557.34	563.34	580.00	174.00	182.34	189.34	200.34	18.00	21.67	28.00	29.00	0.56	0.64	0.74	0.80
P_8	480.00	530.00	560.00	586.67	194.00	202.00	209.00	216.34	20.00	22.17	24.34	26.16	0.61	0.71	0.80	0.85
SEm (±)	12.076	11.961	10.765	7.473	5.018	4.684	4.631	3.665	0.779	0.803	0.932	0.833	0.004	0.003	0.003	0.004
CD (0.05)	36.20	35.87	32.27	22.40	15.04	14.04	13.88	10.99	2.34	2.41	2.80	2.498	0.013	0.01	0.01	0.013

**P1 (Blood meal +Rock phosphate +Potassium sulphate), P2 (Blood meal +Rock phosphate +Langbeinite), P3 (Blood meal +Steamed bone meal +Potassium sulphate), P4 (Blood meal +Steamed bone meal +Langbeinite), P5 (Groundnut cake +Rock phosphate +Potassium sulphate), P6 (Groundnut cake +Rock phosphate +Langbeinite), P7 (Groundnut cake +Steamed bone meal +Potassium sulphate), P8 (Groundnut cake +Steamed bone meal +Langbeinite).Bentonite clay and humic acid were used as binding agents*

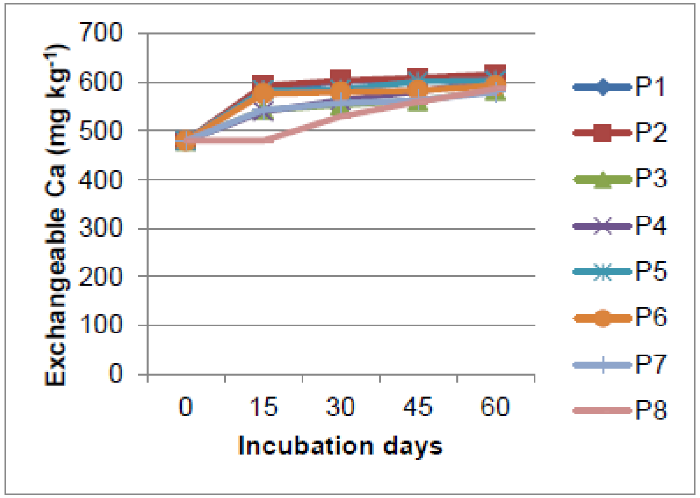

Fig. 4. Effect of organic multinutrient pellets on exchangeable Ca in soil

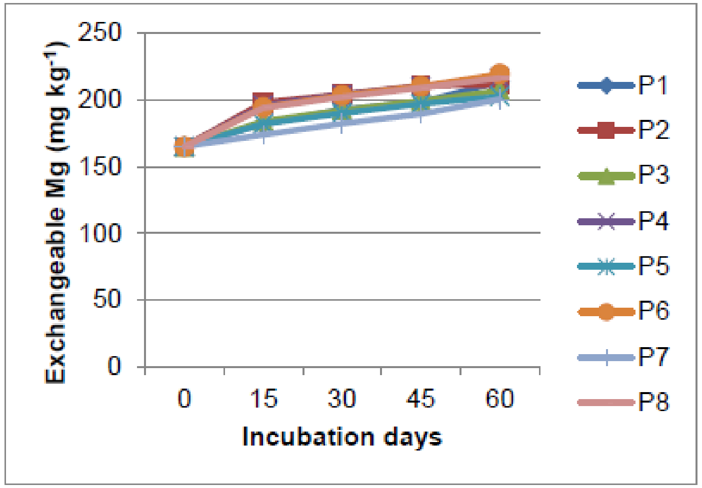

Fig. 5. Effect of organic multinutrient pellets on exchangeable Mg in soil

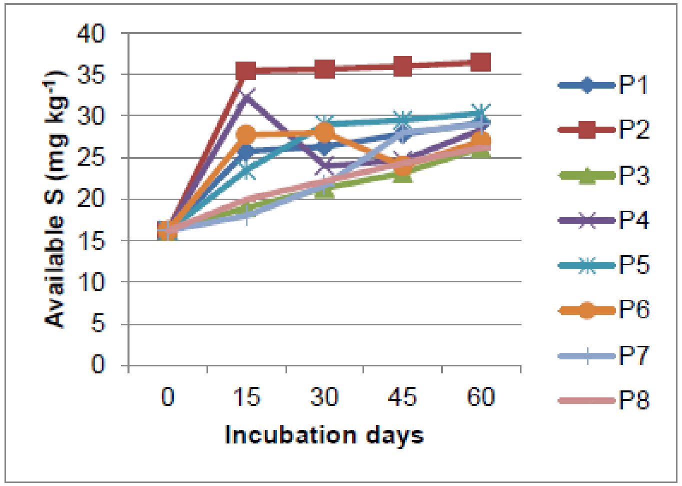

Fig. 6. Effect of organic multinutrient pellets on available S in soil

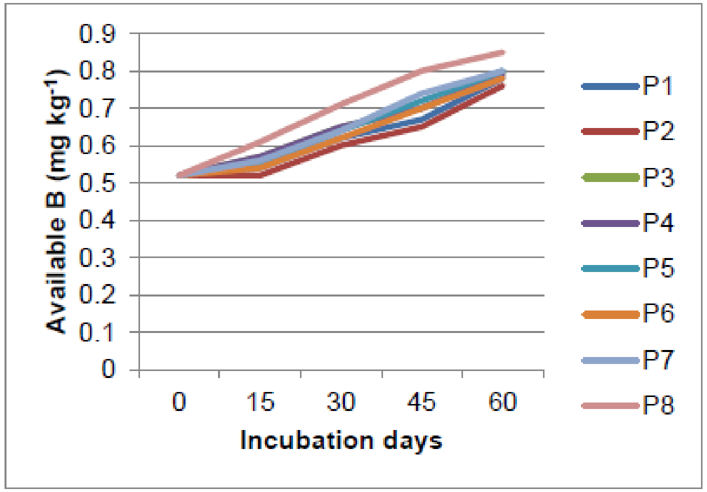

Fig. 7. Effect of organic multinutrient pellets on available B in soil

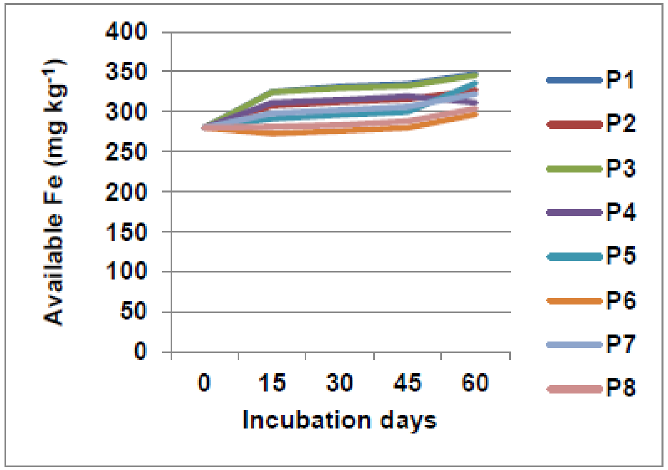

Fig. 8. Effect of organic multinutrient pellets on available Fe in soil

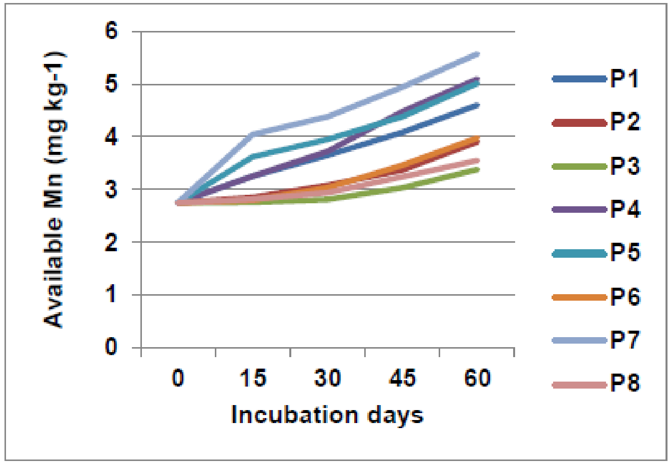

Fig. 9. Effect of organic multinutrient pellets on available Fe in soil

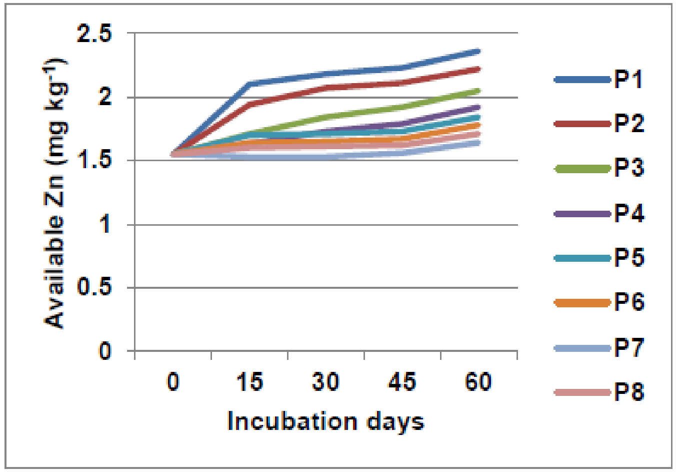

Fig. 10. Effect of organic multinutrient pellets on available Zn in soil

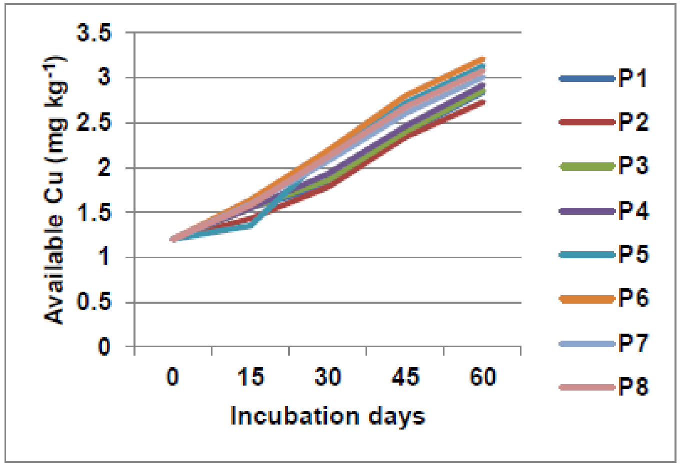

Fig. 11. Effect of organic multinutrient pellets on available Cu in soil

Table 8. Effect of organic multi nutrient pellets on micronutrients in soil

Treatment	Days of Incubation															
	Fe (mg kg^{-1})				Mn (mg kg^{-1})				Zn (mg kg^{-1})				Cu (mg kg^{-1})			
	15	**30**	**45**	**60**	**15**	**30**	**45**	**60**	**15**	**30**	**45**	**60**	**15**	**30**	**45**	**60**
P_1	324.94	331.40	334.40	347.07	3.25	3.65	4.08	4.60	2.10	2.18	2.23	2.36	1.55	1.80	2.38	2.84
P_2	307.40	312.20	315.34	327.27	2.85	3.08	3.37	3.90	1.94	2.07	2.11	2.22	1.43	1.78	2.34	2.73
P_3	324.54	329.33	332.14	345.14	2.76	2.81	3.03	3.38	1.71	1.84	1.92	2.05	1.55	1.86	2.40	2.86
P_4	311.30	314.90	319.50	311.40	3.25	3.72	4.48	5.09	1.63	1.73	1.79	1.92	1.55	1.93	2.46	2.92
P_5	291.10	295.90	299.70	335.50	3.62	3.95	4.38	5.01	1.70	1.71	1.73	1.84	1.35	2.16	2.72	3.13
P_6	272.40	276.00	279.80	296.60	2.80	3.03	3.46	3.98	1.64	1.65	1.67	1.78	1.64	2.19	2.80	3.21
P_7	298.20	301.80	306.37	322.00	4.04	4.38	4.94	5.57	1.53	1.53	1.56	1.64	1.59	2.07	2.60	3.01
P_8	281.00	283.26	288.00	304.00	2.82	2.94	3.24	3.55	1.60	1.61	1.62	1.71	1.58	2.12	2.67	3.08
SEm (±)	1.755	1.988	1.87	1.974	0.152	0.199	0.267	0.29	0.018	0.019	0.02	0.022	0.053	0.012	0.049	0.012
CD (0.05)	5.26	5.96	5.61	5.92	0.46	0.60	0.80	0.87	0.055	0.056	0.059	0.066	0.16	0.035	0.15	0.035

**P1 (Blood meal +Rock phosphate +Potassium sulphate), P2 (Blood meal +Rock phosphate +Langbeinite), P3 (Blood meal +Steamed bone meal +Potassium sulphate), P4 (Blood meal +Steamed bone meal +Langbeinite), P5 (Groundnut cake +Rock phosphate +Potassium sulphate), P6 (Groundnut cake +Rock phosphate +Langbeinite), P7 (Groundnut cake +Steamed bone meal +Potassium sulphate), P8 (Groundnut cake +Steamed bone meal +Langbeinite).Bentonite clay and humic acid were used as binding agents*

Table 9. Effect of organic multi nutrient pellets on dehydrogenase activity, humic and fulvic acid in soil

Treatment	Days of Incubation											
	Dehydrogenase activity in soil, (µg of TPF g^{-1} soil 24 h^{-1})				Humic acid (%)				Fulvic acid ($\%^{1}$)			
	15	**30**	**45**	**60**	**15**	**30**	**45**	**60**	**15**	**30**	**45**	**60**
P_1	18.80	21.75	29.47	34.23	0.210	0.220	0.230	0.260	0.227	0.257	0.387	0.320
P_2	10.77	16.63	23.83	25.61	0.207	0.207	0.223	0.250	0.257	0.293	0.360	0.357
P_3	9.87	19.11	23.32	32.54	0.167	0.210	0.193	0.250	0.133	0.420	0.337	0.117
P_4	9.81	21.56	35.66	44.74	0.210	0.190	0.237	0.263	0.187	0.270	0.380	0.270
P_5	15.97	37.01	48.81	52.91	0.197	0.220	0.197	0.247	0.250	0.410	0.407	0.343
P_6	9.15	14.18	29.97	34.51	0.160	0.187	0.180	0.217	0.170	0.447	0.240	0.260
P_7	10.36	19.51	26.25	27.45	0.160	0.177	0.180	0.210	0.203	0.437	0.453	0.297
P_8	11.44	14.85	19.78	28.38	0.103	0.170	0.120	0.217	0.127	0.363	0.360	0.217
SEm (±)	0.063	2.125	0.203	0.266	0.007	0.002	0.006	0.013	0.008	0.013	0.006	0.007
CD (0.05)	0.189	6.372	1.189	0.678	0.021	0.006	0.019	NS	0.024	0.04	0.018	0.02

**P1 (Blood meal +Rock phosphate +Potassium sulphate), P2 (Blood meal +Rock phosphate +Langbeinite), P3 (Blood meal +Steamed bone meal +Potassium sulphate), P4 (Blood meal +Steamed bone meal +Langbeinite), P5 (Groundnut cake +Rock phosphate +Potassium sulphate), P6 (Groundnut cake +Rock phosphate +Langbeinite), P7 (Groundnut cake +Steamed bone meal +Potassium sulphate), P8 (Groundnut cake +Steamed bone meal +Langbeinite).Bentonite clay and humic acid were used as binding agents*

3.2.11 Soil available micronutrients

Boron content was found increasing with each stage of incubation (Fig. 7). P_8 was having significantly higher value along the incubation period and lowest values were reported by P_2 (Table 7). Boron content exhibited a tendency to increase with the application of organic fertilizer. Readily available B continuously increases for more than 12 weeks [64].

The influence of pellet on Fe, Mn, Zn and Cu content in soil was given in Table 8. Gradual increase in Fe content has noticed during the incubation period (Fig. 8). P_1 reported the higher concentration of Fe from 15th day (324.94 mg kg^{-1}) to 60th day (347.07 mg kg^{-1}). It is clear that blood meal containing pellets released more Fe to soil. Ciavatta et al [37] reported that Fe content was found higher in blood meal containing organic compounds; also, the application of organic fertilizers can increase the Fe content in soil. Mn release was found higher in P_7. It was 4.04 mg kg^{-1} on 15th day and at the end of incubation, it was 5.57 mg kg^{-1} (Fig. 9). P_5 was found close to P_7. In case of Zinc, P_1 had significantly higher values during incubation days and the inferior effect was expressed by P_7 (Fig. 10). From the table it is clear that, on the 15th day available Cu was within a range of 1.64 mg kg^{-1} (P_6) to 1.35 mg kg^{-1} (P_5) which was gradually grown towards the 60th day (Fig. 11). On the application of organic fertilizers the content of Mn, Zn and Cu exhibited gradual increase over time [44,65,66].

3.2.12 Dehydrogenase activity

From the Table 9 it was clear that dehydrogenase activity increased in soil throughout the incubation period. On the 15th day P1 had the higher value, but from 30th day onwards P_5 reported significantly higher value. On 45th day P_8 recorded the lowest value and on 60th day it was lowest in P_2. The increased organic carbon content of soil on addition of pellets would have contributed to the dehydrogenase activity. Wolinska and Stępniewska [67] also reported that dehydrogenase activity increases with increase in total organic carbon in soil. They also recorded an increase in dehydrogenase activity with incubation days. Similar results were obtained by Radhakrishnan and Suja [66].

3.2.13 Humic acid and fulvic acid

Effect of multinutrient pellets on humic and fulvic acid content in soil is represented in Table 9. On 15th day, humic acid recorded the values in a range of 0.210% (P_1 and P_4) to 0.103% (P_8). On the 30th day the values were found within a range of 0.220% (P_4) to 0.170% (P_7) compared to the previous observation. But on 60th day the values were found high even though they were non-significant. In case of fulvic acid the values were higher on 45th and 30th days and lowest value was noticed in the 15th among the observations. Highest value of fulvic acid was recorded on the 45th day for P_6 (0.453%). The lowest value of fulvic acid was reported by P_8 (0.127%) on 15th day. On the th day fulvic acid ranged between 0.357% (P_2) to 0.117% (P_8). P_5 was found on par with P_2. Utomo [68] and Rendana et al. [69] reported the tendency of humic acid and fulvic acid to increase along the incubation study.

4. CONCLUSION

Multinutrient pellets prepared using organic nutrient sources permitted by NPOP for organic farming in rice manifested their capability to supply nutrients to the acid sulphate soil. N content was highest in Pellet 3 (Blood meal +Steamed bone meal +Potassium sulphate) while P & K content were highest in Pellet 1 (Blood meal +Rock phosphate +Potassium sulphate). Soil pH and EC increased with days of incubation while organic carbon decreased. Nutrient availability increased from 15th day to 60th day and the maximum value was observed on 60th day. The dehydrogenase activity of soil and humic acid content increased with days of incubation while fulvic acid content decreased after days of incubation. The blood meal based pellets had the strong propensity to perpetuate and enhance the nutrient release to the soil on comparison with other pellets. The study indicates that Pellet 1 is supreme with respect to nutrient release characteristics, followed by Pellet 2 and Pellet 3. Pellet 1 prepared using blood meal, rock phosphate and potassium sulphate will provide sufficient quantities of all essential nutrients when applied to organically grown rice in acid sulphate soils of Kuttanad.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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