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Effect of Organic Resources on Availability of Some Macronutrients in Soil and its Impact on Agronomic Parameters

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ABSTRACT

The influence of organic matter vis-a-vis humic acids on availability of nutrient status and its impact on cultivation of rice (Variety MTU 1010) followed by mustard (Variety B-9), were studied in Typic *Fluvaquent* soil under Old Alluvial zone of West Bengal, India. Important physical and chemical properties of the soil texture sandy clay loam, bulk density 1.34 Mg m^{-3}, oxidizable organic carbon 1.16 g 100 g^{-1}, pH 6.34, total nitrogen 0.14 g 100 g^{-1}, available phosphorus 25.90 kg ha^{-1}, available potash 127.40 kg ha^{-1}, available sulphate 39.56 kg ha^{-1}, respectively. The C:N ratio of the added FYM, Commercial and FYM extracted humic acid were 32.11, 32.61 and 13.53, respectively. Soils received recommended doses of fertilizers for cultivation of paddy ($N:P_2O_5:K_2O$ :: 60:30:30) followed by mustard ($N:P_2O_5:K_2O$ :: 80:40:40) along with FYM at 5.0 and 2.5 t ha^{-1}, Commercial humic acid at 0.5, 0.25 kg ha^{-1} and FYM extracted humic acid at 0.5 and 0.25 kg ha^{-1}, respectively as per treatment combinations. The experiment was undertaken by following the Randomized Block Design (RBD). Rhizosphere soil (0-15 cm) and plant samples were collected periodically and analysed for C/N ratio, available phosphate, potash and sulphur in soil and total P, K and S in plant with their integral effect on crop growth. At panicle initiation and branching stages of paddy and mustard, highest content of available phosphate, potash and sulphur was recorded and which gradually decrease towards harvesting stage. FYM extracted humic acid resulted highest availability of phosphate, potash and sulphur whereas Commercial humic acid enhanced the content of potash in soil, which signified uptake of phosphorus, potash and sulphur within plants resulted qualitative enrichment through biometric parameters and yield of paddy and mustard.

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INTRODUCTION

The monocotyledonous plant rice is an annual crop, grown mainly in tropical and subtropical climate. Rice is one of the most staple foods for major part of the world. Rice production over the world is being the result of high yielding varieties, chemical fertilizers and improved package of practices. Mustard is designate as one of the world's most spicy crop. Due to its unique properties raises its acceptability in food preparation by different cultures. Yellow sarsoon (*Brassica rapa*) is the most widely spread, rapeseed-mustard group of crops, which is the 2nd most important oilseed crop after ground nut in India (Jha *et al.*, 2012).

Nitrogen is an essential component of all amino acids. These amino acids are the building blocks of all proteins including the enzymes. These amino acids control virtually all biological processes. It is also essential for carbohydrate use within plants. Plants respond quickly to increased nitrogen availability as a result their leaves turn deep green in colour. Nitrogen stimulates plant productivity also (Brady and Weil, 2002).

The essential and primary macronutrient phosphorus, placed in Group VB of Periodic Table is a vital component of genes and chromosomes' building block. Principally it involves in energy transfer and constituents of energy currency - ATP. Adequate supply of P in the form of orthophosphate ($H_2PO_4^-$) and secondary orthophosphate (HPO_4^{-2}) encourages root growth and maturity (Tiwari, 2009). Another essential macronutrient K, supplied in the form of K^+ is required for activation of around 80 enzymes and plays vital role in osmotic and energy regulation, translocation of assimilates, photosynthesis, protein-starch synthesis, metabolic processes for grain/ seed formation, qualitative improvement, imparting resistance to pests and diseases along with adverse climatic condition (Subba Rao and Brar, 2009).

Addition of FYM is the prime source of soil organic matter (SOM), acts as skeleton of holding fertilizer nutrients and provides nutritional benefit to soil for plant. The decomposed portion of SOM *i.e.*, humus has chelating power for chelation of different nutrients especially trace elements (Biswas and Mukherjee, 1987). SOM consists with biological residues of plant and animal to microbial community and macromolecules of mixed aliphatic and aromatic compounds (Chen and Aviad, 1990). The plant growth parameters, cultivated in FYM treated soil also justify the effect of FYM in nutrient absorption and store (Makinde, 2007; Olfati *et al.*, 2008; Jat *et al.*, 2010; Singh *et al.*, 2011).

Humic acid (HA) is the major constituents of humic substances and acts as integral part of SOM and one of the key components of terrestrial ecosystem. It is heterogeneous substance, which include in the same macromolecule, hydrophilic acidic functional groups (made up of carboxylic and phenolic groups) and the hydrophobic groups (made up of aliphatic and aromatic carbon groups) (Stevenson, 1994). FYM with narrow C:N ratio accelerates the formation of humic acid (Muthu Kumar and Ponnuswami, 2013). Humic acid effectively ameliorates leaf interveinal chlorosis as it might be chelating the unavailable nutrients and buffering the soil pH (Pertusatti and Prado, 2007). It may form an enzymatically active complex as a catalyst (Marzadori *et al.*, 2000) that can carry on reactions that are usually assigned to the metabolic activity of living organisms (Serban and Nissenbaum, 1986). HA can partially be used as a supplement to chemical fertilizers based on the properties of base exchange capacity and complexing ability required in soil (Sharif *et al.*, 2005). Application of humic acid with recommended doses of fertilizers (NPK) increases the microbial population as well as biomass (Sellamuthu and Govindaswamy, 2003).

In Ultic *Haplustaff*, during field experiment, Thenmozhi and Natarajan (2007) established a positive change in NPK and secondary nutrient availability with the application of HA to soil. Petronio *et al.* (1982) hypothesized root absorption of HA, its interaction with root cells and subsequent influence on plant physiology and growth through respiratory activity *via* quinine group. The molecular complexicity of HA helps to act as plant growth regulator and shows hormone like activity (Nikbakht *et al.*, 2008). HA is also responsible for increasing the fresh and dry weight of leaves, shoots and roots as well as leaf count and plinth area of leaves (Temz *et al.*, 2009; Vijoyakumari *et al.*, 2012). Study on nutrient use HA also act as a supplementary tool to improve N use efficiency in rapeseed (Jannin *et al.*, 2012).

Keeping above information in view, it is of practical significance to study the role of organic matter vis-a-vis humic acid on improvement of nutrient status in soil and its availability to crops as well as its effect on growth and yield in rice-mustard cropping sequence.

MATERIALS AND METHODS

Site of Field Experiments

Two field experiments was conducted in succession (*Kharif* followed by *Rabi*) at Sub-divisional Adaptive Research Farm, Kandi, Murshidabad, India having longitude and latitude of 23.95° N and 88.03° E respectively, for determining the effect on organic matter vis-a-vis humic acid on changes in available nutrients in soil and its uptake by the growing crops. During the experiment the climate was humid subtropical with a rainfall of 1481 mm and temperature ranges from 34.4 °C (maximum) and 11.0 °C (minimum). Physical and chemical properties of the soil (Typic *Fluvaquent*) of the experimental field are presented in table 1.

Description of Treatments

Humic acids, used as treatment materials in experiments, extracted from FYM by the process of Kononova and Belchikova (1961) and GR grade, commercial humic acid having 8% of ash was purchased from open market. The characteristics of FYM and humic acid used in the experiment are presented in table 2.

Table 1: Physical and Chemical properties of the soils of experiment site

Sl. No.	Parameters		Unit	Field soil
1	Soil Type			Typic *Fluvaquent*
2	Soil texture			Sandy Clay Loam
3	Mechanical analysis	Sand	%	34.8
		Silt	%	20.0
		Clay	%	45.2
4	Bulk Density		Mg m^{-3}	1.34
5	Oxidizable Organic Carbon		g 100 g^{-1}	1.16
6	pH		Soil : water = 1:2.5	6.34
7	Available P_2O_5		kg ha^{-1}	25.90
8	Available K_2O		kg ha^{-1}	127.40
9	Available S		kg ha^{-1}	39.56

The recommended doses of N, P_2O_5 and K_2O at 60, 30 and 30 kg ha^{-1} in the form of urea, SSP and MOP, respectively was applied, irrespective to treatments, to raise the rice crop (Variety MTU-1010) with best management practices during kharif season. 50% of the total fertilizer nitrogen was applied as basal and the rest amount was applied in 2 split doses at tillering and flowering stages of rice. The plot size was 12 (3 × 4) sq. m. The design of the experiment was Randomized Block Design (RBD) with three replications. Mustard (B-9) was cultivated as rabi crop with recommended dose of N, P_2O_5 and K_2O at 80, 40 and 40 kg ha^{-1} in the form of urea, SSP and MOP, respectively in all plots.

The following treatments were adopted in the 1st and 2nd experiments in succession.

Treatments adopted in the 1st experiment with rice,

T_1 = Control.
T_2 = FYM at 5 tons ha^{-1} as basal.
T_3 = Commercial humic acid at 0.5 kg ha^{-1} as basal.
T_4 = Humic acid extracted from FYM at 0.5 kg ha^{-1} as basal.

Table 2: Characteristics of FYM and humic acids of different sources

Sl. No.	Characteristics	FYM	Humic acid extracted from FYM (EHA)	Commercial humic acid (CHA)
1	Oxidizable organic carbon (%)	32.560	29.770	43.360
2	Total Nitrogen (%)	1.014	2.200	1.290
3	C/N ratio	32.016	13.530	33.610
4	Viscosity (measured by Ubelhode viscometer)		133.100	139.000
5	E_4/E_6		3.193	3.410
6	Functional group (measured by Dragunova, 1958) (meq Ba)		6.803	6.803
7	Ash free Carboxylic group (Kononova *et al.*, 1966) (meq)		628.300	415.900

Treatments adopted in the 2nd experiment with mustard,

T_1' = Control.

T_2' = FYM @ 2.5t ha^{-1} as basal.

T_3' = Commercial humic acid at 0.25 kg ha^{-1} as basal.

T_4' = Humic acid extracted from FYM at 0.25 kg ha^{-1} as basal.

Collection and Analysis of Soil and Plant Samples

Rhizosphere soil samples (0-15 cm) were collected from each of the respective treatment plot at tillering, panicle initiation, flowering and harvesting stages of rice followed by branching, flowering and harvesting stages of mustard.

C/N ratio was calculated after estimation of oxidizable organic carbon (Walkley and Black, 1934) and total nitrogen by Kjeldal digestion method. Content of available P_2O_5, K_2O and S were estimated through Olsen method (Olsen *et al.*, 1954), Flame photometer (Jackson, 1973) and turbidimetric procedure using 0.15% $CaCl_2$ extracting solution (Chesnin and Yien, 1951), respectively. Total N in plant sample was estimated by Kjeldahl digestion method (Kjeldahl, 1883). Total P, K, and S in plant sample was determined following full digestion with di-acid mixture ($HClO_4$:H_2SO_4 :: 4:1). Different growth and yield parameters of rice and mustard were recorded as pooled data.

Statistical Analysis

Data of the experiments were analysed statistically for analysis of variance as well as critical difference were calculated at 5% level of significance to test the significance of means for the treatment difference following the procedure as described by Gomez and Gomez (1984) (SEm = Standard Error of mean, CD = Critical Difference, CV = Coefficient of Variation).

RESULTS AND DISCUSSION

Table 3 arranged the calculated C/N ratio of the soil samples, collected from every mentioned steps of paddy followed by mustard cultivation. Irrespective to variation no significant change was found in C/N ratio during the cultivation of paddy. However, specifically at harvesting stage, EHA effectively raised the C/N ratio by 8.4% followed by FYM (6.1%) than that of control in soil. Mustard was cultivated followed by paddy and this will be a reason of significant change in C/N ratio at every step of cultivation period. Irrespective of steps of mustard, EHA resulted highest C/N ratio as compared with control. Also this ratio was gradually decreasing from branching to harvesting stage established that C/N ratio will decrease with increasing rate or degree of humification (Tan, 2014).

Effect of FYM @ 5.0 and 2.5 ton ha^{-1}, commercial and extracted humic acid @ 0.5 and 0.25 kg ha^{-1} on paddy followed by mustard, respectively, on the

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content of available phosphate in soil were tabulated in table 4.

Table 3: Changes in the content of C/N ratio in soil treated with FYM and humic acid in rice-mustard cropping sequence

Treat-ments	Days after transplanting of Rice				Treat-ments	Days after sowing of Mustard		
	Tillering	Panicle initiation	Flower-ing	Harvest-ing		Branch-ing	Flower-ing	Harvest-ing
T_1	12.32	10.71	11.77	12.08	T_1'	7.65	7.77	8.87
T_2	13.12	11.81	11.78	12.81	T_2'	9.23	9.62	8.76
T_3	10.69	8.63	12.19	12.36	T_3'	10.39	8.63	8.21
T_4	11.81	9.61	12.73	13.10	T_4'	11.77	10.63	9.29
SEm (±)	1.3208	0.4701	0.3854	0.2758	SEm (±)	0.5091	0.6378	0.5129
CD (5%)	4.5698 (NS)	1.6264 (NS)	1.3334 (NS)	0.9544	CD (5%)	1.7605	2.2067	1.7744
CV%	19.0852	7.9885	5.5092	3.7957	CV%	9.0340	12.0600	10.1134
SEm (±)	0.4075				SEm (±)	0.5321		
CD (5%)	1.3034 (NS)				CD (5%)	1.8409		

Table 4: Changes in the content of available P_2O_5 (kg ha^{-1}) in soil treated with FYM and humic acid in rice-mustard cropping sequence

Treat-ments	Days after transplanting of Rice				Treat-ments	Days after sowing of Mustard		
	Tillering	Panicle initiation	Flower-ing	Harvest-ing		Branch-ing	Flower-ing	Harvest-ing
T_1	26.393	39.010	32.120	29.070	T_1'	51.76	49.42	31.41
T_2	34.800	56.980	55.100	29.067	T_2'	55.68	43.94	34.50
T_3	26.390	53.163	42.500	35.947	T_3'	68.99	57.25	33.75
T_4	34.040	58.127	47.797	41.690	T_4'	64.30	48.64	45.50
SEm (±)	1.3073	1.3048	0.4622	1.9202	SEm (±)	0.4821	0.2749	0.9868
CD (5%)	4.5233	4.5146	1.5993	6.6437	CD (5%)	1.6679	0.9513	3.4142
CV%	7.4471	4.3613	1.8040	9.7982	CV%	1.3874	0.9560	4.7098
SEm (±)	2.5196				SEm (±)	3.0890		
CD (5%)	8.0594				CD (5%)	10.6877		

Irrespective to treatments, the availability of phosphate was increased upto Panicle initiation (PI) stage and gradually decline towards harvesting stage of paddy. This might be represented the uptake of phosphate within plant body (Table 5 and 6). Highest significant availability of phosphate was recorded with the treatment of EHA (49.0%) at PI stage followed by FYM (46.1%) and CHA (36.3%) despite at tillering stage phosphate availability gradually decline from FYM (31.9%) to EHA (29.0%) and CHA (0.0%) as compared to that of control in soil. This result indicated microbial proliferation of FYM in faster rate than humic substances (Stevenson, 1994) resulting in mineralization of organic phosphate in soil (Lopez-Mtz *et al.*, 2001).

During later stages of incubation period, highest significant availability of phosphate was reflected by EHA at flowering (48.8%) as well as harvesting (43.4%) stage in comparing with control justified the effects of root exudates on microbial activity and nutrient availability in rhizosphere soil (Norton *et al.*, 2009). Irrespective of fertilizer application in recommended doses, the changes for phosphate availability during the incubation period of mustard are not similar. At branching (33.3%) and flowering (15.8%) stages highest phosphate availability was reflected by CHA whereas at harvesting stage EHA showed highest increase of 44.9% as compared to that of control. Significant higher rate of phosphate availability at harvesting stage of paddy, application of fertilizers at basal and organic substances jointly raised the level of phosphate in mustard soil (Wang *et al.*, 1995). CHA showed significant highest availability of phosphate upto flowering stage justified the findings of Tuba arjemend *et al.* (2015), but counteract the results framed by Jones *et al.* (2007). The amount of root exudates during maturity stage and presence of organic substances increased the rate of microbial activity at rhizosphere zone which showed significant increase in available phosphate with EHA (44.9%) followed by FYM (9.8%) and CHA (7.4%) as compared to that of control (Faure *et al.*, 2009).

Table 5: Changes in P content, dry matter yield and P-uptake at different growth stages of rice grown in soil treated with FYM vis-à-vis humic acid in a rice-mustard cropping sequence

Treatments	Panicle initiation			Flowering		
	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1	0.33	216.87	0.72	0.20	445.78	0.88
T_2	0.35	238.84	0.83	0.18	470.07	0.86
T_3	0.33	249.15	0.83	0.27	511.80	1.39
T_4	0.33	267.22	0.87	0.25	528.35	1.34
SEm (±)	54	0.7432	0.0112	0.0003	0.3261	0.0110
CD (5%)	0.0187 (ns)	2.5716	0.0388	0.0010	1.1284	0.0390
CV%	2.7996	0.5297	2.3912	0.2210	0.1155	1.7410

Table 5 Continues ...

Treatments	Harvesting (2011-12) Rice					
	Straw			Grain		
	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1	0.08	4612.50	3.69	0.36	3123.00	11.30
T_2	0.10	4923.00	4.92	0.43	3240.00	14.00
T_3	0.11	5251.50	5.77	0.37	3636.00	13.40
T_4	0.16	5503.50	8.81	0.41	3672.00	15.09
SEm (±)	0.0087	31.1435	0.4524	0.0086	19.0693	0.3022
CD (5%)	0.0300	107.7544	1.5653	0.0296	65.9786	1.0457
CV%	13.3333	1.0634	13.5140	3.7725	0.9664	3.8924

Table 6: Changes in P content, dry matter yield and P-uptake at different growth stages of mustard grown in soil treated with FYM vis-à-vis humic acid in a rice-mustard cropping sequence

Treatment (Mustard)	Branching			Flowering		
	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1'	0.13	498.00	0.52	0.15	996.00	1.82
T_2'	0.15	522.90	0.57	0.12	1643.40	3.43
T_3'	0.13	510.45	0.61	0.16	1776.10	3.88
T_4'	0.13	547.80	0.68	0.12	1444.20	3.48
SEm (±)	0.0037	7.8102	0.0267	0.0034	10.3372	0.0435
CD (5%)	0.0128	27.0229	0.0924	0.0118	35.7662	0.1505
CV%	4.6738	2.6026	7.7918	4.2638	1.2222	2.3883

Table 6 Continues ...

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Treatment (Mustard)	Mustard (2011-12)					
	Stover			Seed		
	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1'	0.15	3036.56	3.79	0.16	915.08	1.34
T_2'	0.15	3802.23	5.16	0.16	1538.82	2.40
T_3'	0.15	2849.81	3.65	0.17	892.67	1.35
T_4'	0.15	3036.56	3.89	0.16	1568.70	2.34
SEm (±)	0.0022	35.2936	0.1786	0.0026	14.4328	0.0184
CD (5%)	0.0077 (ns)	122.1135	0.6181	0.0091	49.9365	0.0637
CV%	2.6125	1.9216	7.5093	2.8495	2.0343	1.7194

During paddy cultivation, irrespective to treatment, the changes in Phosphorus (P) concentration gradually declined from PI stage to flowering stage but inclined upto harvesting stage with maximum concentration at grains (Malhi *et al.*, 2006). However, concentration of P in mustard was gradually uplifted towards stover and seed production resembled the findings of Virgine Tenshia and Singaram (2012). Considering the dry weight at every stages of plant growth, established the fact of gradual increase of phosphorus uptake from PI and branching stage to harvesting stage of paddy and mustard, respectively (Table 5 and 6). In all stages of paddy cultivation, except in grains, EHA resulted significantly highest increase of P uptake and CHA kept the 2nd position as compared with control in plant (Rajpar *et al.*, 2011). More than one fold and 36.0% increase of P uptake by EHA in straw and stover, respectively, with significant rise of 33.5% by EHA following FYM (23.9%) and CHA (18.5%) in grains of paddy and similar effects of FYM and EHA on mustard seed established the facts of qualitative changes in paddy and mustard, as described by Motaghi and Nejad (2014) for cowpea. Use of this enriched straw as cattle feed may bring qualitative enrichment within miltch cow (Sarnklong *et al.*, 2010).

Table 7: Changes in available K_2O (kg ha^{-1}) in soil treated with FYM and humic acid in rice-mustard cropping sequence

Treat-ments	Days after transplanting of Rice				Treat-ments	Days after sowing of Mustard		
	Tiller-ing	Panicle initiation	Flower-ing	Harvest-ing		Branch-ing	Flower-ing	Harvest-ing
T_1	130.52	120.95	86.02	86.02	T_1'	112.90	80.67	75.26
T_2	176.42	115.58	86.02	64.51	T_2'	118.27	86.00	86.02
T_3	182.77	142.50	91.38	80.65	T_3'	107.52	83.33	72.57
T_4	175.72	131.71	86.02	75.25	T_4'	118.27	86.02	80.64
SEm (±)	0.7606	0.3791	0.6956	1.9125	SEm (±)	1.4729	0.9026	1.1382
CD (5%)	2.6317	1.3116	2.4067	6.6172	CD (5%)	5.0961	3.1230	3.9380
CV%	0.7919	0.5142	1.3791	4.3241	CV%	2.2331	1.8611	2.5073
SEm (±)	6.8168				SEm (±)	1.5318		
CD (5%)	21.8049				CD (5%)	5.3000		

Irrespective of treatments, application of MOP at recommended dose to paddy followed by mustard is the main source of available potash in soil but its availability depends on soil borne factors according to applied treatments. Table 7 reflected gradual declining trend towards harvesting stages of paddy and mustard. During the cultivation period, rate of declination in potash availability at harvesting stage, was highest in FYM, followed by EHA and CHA resulting in highest significant increase with CHA at all stages of paddy cultivation. This might be due to presence of 8% potash in leonardite originated CHA (Table 2; Sokolov *et al.*, 2005) along with its positive effect on nutrient availability (Chan *et al.*, 2010). FYM (25.0%) followed by EHA (12.5%) enumerated excessive utilization of available potash from applied even original soil source at harvesting stage of paddy in comparison with control. This established the facts of better microbial activities in FYM and EHA treated soil (Stevenson, 1994). Despite application of fertilizers at recommended doses along with treatments of FYM, EHA and CHA, the result of paddy cultivation was reflected on mustard. The significant change in available potash during mustard cultivation was very much differed with paddy established the findings of Thenmozhi and Natarajan (2007). FYM and EHA resulted similar pattern of potash availability at branching (4.8%) and flowering (6.6%) stages of mustard cultivation as compared to that of control.

Table 8: Changes in K content, dry matter yield and K-uptake at different growth stages of rice grown in soil treated with FYM vis-à-vis humic acid in a rice-mustard cropping sequence

Treatments	Panicle initiation			Flowering		
	K%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	K%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1	1.46	216.87	3.16	1.10	445.78	4.90
T_2	1.4	238.84	3.34	0.74	470.07	3.48
T_3	1.58	249.15	3.94	1.32	511.80	6.76
T_4	1.28	267.22	3.42	1.22	528.35	6.45
SEm (±)	0.0279	0.7432	0.0545	0.0895	0.3261	0.4389
CD (5%)	0.0966	2.5716	0.1885	0.3096	1.1284	1.5185
CV%	3.3854	0.5297	2.7247	14.1553	0.1155	14.0868

Table 8 Continues ...

Treatments	Harvesting (2011-12) Rice					
	Straw			Grain		
	K%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	K%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1	0.76	4612.50	34.82	1.20	3123.00	37.47
T_2	1.38	4923.00	67.73	1.80	3240.00	58.35
T_3	1.35	5251.50	70.81	1.60	3636.00	58.15
T_4	1.32	5503.50	72.65	1.80	3672.00	66.11
SEm (±)	0.0679	31.1435	3.2773	0.0456	19.0693	1.5581
CD (5%)	0.2350	107.7544	11.3391	0.1576	65.9786	5.3911
CV%	9.8042	1.0634	9.2293	4.9312	0.9664	4.9051

However, at harvesting of mustard, highest significant availability of potash was reflected with FYM (14.3%) followed by EHA (7.1%) as compared to that of control in soil. The fertilizer recommended dose of paddy and mustard was 60:30:30 and 80:40:40, respectively, along with microbial feedback in soil during their cultivation period might be the reason of reflected results at their harvesting stages. The findings of Olk and Cassman (1993), Swarup and Yaduvanshi (2000), Singh *et al.* (2001), Khoshgoftarmanesh and Kalbasi (2002), Singh *et al.* (2002) and Verma *et al.* (2005) have similarities with this.

Uptake of potassium (K) in paddy and mustard was tabulated in table 8 and 9. Irrespective of treatments the uptake within plant body was gradually inclining towards harvesting stage justified the declining trend found in table 7 (Barison, 2002). In paddy, irrespective to treatments and stages of plant growth highest significant concentration of K was recorded in grains treated with FYM and EHA (50.0%) as compared with control. On the other way, similar

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trend of results were presented by mustard. Considering qualitative point in mind the highest uptake of K in paddy (76.4%) and more than one and half fold uptake in mustard seed, compared with control, re-established the findings of Barison (2002).

Table 9: Changes in K content, dry matter yield and K-uptake at different growth stages of mustard grown in soil treated with FYM vis-à-vis humic acid in a rice-mustard cropping sequence

Treatments	Panicle initiation			Flowering		
	K%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	K%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1'	1.00	498.00	4.99	1.25	996.00	12.46
T_2'	1.10	522.90	5.75	1.38	1643.40	22.60
T_3'	1.34	510.45	6.84	1.30	1776.10	23.10
T_4'	1.40	547.80	7.67	1.40	1444.20	20.21
SEm (±)	0.0446	7.8102	0.2763	0.0473	10.3372	0.4770
CD (5%)	0.1543	27.0229	0.9560	0.1638 (ns)	35.7662	1.6502
CV%	6.3838	2.6026	7.5813	6.1591	1.2222	4.2163

Table 9 Continues ...

Treatments	Harvesting (2011-12) Mustard					
	Stover			Seed		
	K%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	K%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1'	0.35	3036.56	10.61	1.40	915.08	12.82
T_2'	0.38	3802.23	14.28	2.00	1538.82	30.75
T_3'	0.36	2849.81	10.27	1.80	892.67	16.06
T_4'	0.51	3036.56	15.34	2.20	1568.70	34.58
SEm (±)	0.0308	35.2936	0.9235	0.0726	14.4328	1.2127
CD (5%)	0.1064	122.1135	3.1952	0.2513	49.9365	4.1959
CV%	13.3910	1.9216	12.6700	6.7999	2.0343	8.9181

Table 10: Changes in available S (kg ha^{-1}) in soil treated with FYM and humic acid in rice-mustard cropping sequence

Treat-ments	Stages after transplanting of Rice				Treat-ments	Days after sowing of Mustard		
	Tillering	Panicle Initiation	Flower-ing	Harvest-ing		Branch-ing	Flower-ing	Harvest-ing
T_1	39.79	40.50	35.00	33.60	T_1'	30.24	29.40	29.08
T_2	36.66	39.09	37.83	35.84	T_2'	30.80	30.39	28.27
T_3	37.01	39.53	38.64	36.43	T_3'	39.84	50.14	45.36
T_4	37.01	40.87	39.76	39.21	T_4'	35.84	58.50	43.08
SEm (±)	1.8805	0.3380	0.2560	0.2689	SEm (±)	0.7780	0.9043	0.3614
CD(5%)	6.5064 (ns)	1.1696	0.8856	0.9302	CD (5%)	2.6918	3.1287	1.2503
CV%	8.6587	1.4639	1.1725	1.2839	CV%	3.9424	3.7196	1.7173
SEm (±)	0.8644				SEm (±)	3.2666		
CD (5%)	2.7650				CD (5%)	11.3022		

Neither in the recommended fertilizer dose of paddy and mustard nor in the treatments S was added separately. However, according to table 10, the availability of S in paddy field raised upto PI stage and flowering at mustard. Irrespective of stages except tillering, EHA showed highest significant availability of S as compared to that of control in paddy. At flowering of mustard EHA resulted highest S availability (99.0%) followed by CHA (70.6%) as compared to that of control in soil. Similar type of findings was established by Denre *et al.* (2014). Due to presence of marshy environment in rhizosphere zone and higher carboxylic functional group in EHA, the fungal growth and population took lead role in creation of microbial biomass (Hurst *et al.*, 1962) which might be increased the availability of S in soil like other macronutrients (Malik *et al.*, 2013). In mustard field, higher root exudation and microbial activity at flowering stage in rhizosphere zone resulted significant chronological decrement of S availability from EHA, CHA and FYM treated soil as compared with control. Similar type of findings was established by Denre *et al.* (2014).

Table 11: Changes in S content, dry matter yield and S-uptake at different growth stages of rice grown in soil treated with FYM vis-à-vis humic acid in a rice-mustard cropping sequence

Treatments	Panicle initiation			Flowering		
	S%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	S%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1	0.1	216.87	0.22	0.10	445.78	0.44
T_2	0.2	238.84	0.49	0.11	470.07	0.51
T_3	0.14	249.15	0.34	0.11	511.80	0.55
T_4	0.16	267.22	0.42	0.11	528.35	0.58
SEm (±)	0.0041	0.7432	0.0117	0.0025	0.3261	0.0127
CD (5%)	0.0143	2.5716	0.0405	0.0087 (ns)	1.1284	0.0440
CV%	4.7571	0.5297	5.5226	4.1128	0.1155	4.2522

Table 11 Continues ...

Treatments	Harvesting (2011-12) Rice					
	Straw			Grain		
	S%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	S%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1	0.07	4612.50	3.18	0.10	3123.00	3.25
T_2	0.10	4923.00	4.87	0.15	3240.00	4.83
T_3	0.08	5251.50	3.94	0.12	3636.00	4.18
T_4	0.08	5503.50	4.57	0.15	3672.00	5.44
SEm (±)	0.0054	31.1435	0.2524	0.0041	19.0693	0.1229
CD (5%)	0.0186	107.7544	0.8732	0.0143	65.9786	0.4254
CV%	11.4392	1.0634	10.5585	5.5676	0.9664	4.8151

Table 11 and 12 arranged the data of S content, dry matter yield and S-uptake at different growth stages of paddy and mustard. Irrespective to treatments crop uptake of S showed an increasing trend towards harvesting stage. Application of FYM resulted highest S uptake at PI stage (123%) and straw part of harvesting stage (53.1%) (Saha *et al.*, 2014) as well as EHA at grains (67.4%) as weigh against control. Considering mustard seed production at harvesting stage the uptake of S was similar in FYM and EHA treated plots but S uptake in stover was highest at FYM (42.9%) followed by EHA (10.9%) treated plots in comparing with control in plant (Vasudevan *et al.*, 1997). This result emphasized the qualitative parameters of paddy and mustard production and bringing similarity with the established results of Patra and Maity (2007) for paddy and Ray *et al.* (2015) for mustard.

Table 12: Changes in S content, dry matter yield and S-uptake at different growth stages of mustard grown in soil treated with FYM vis-à-vis humic acid in a rice-mustard cropping sequence

Treatments	Panicle initiation			Flowering		
	S%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	S%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1'	0.21	498.00	1.04	0.41	996.00	4.06
T_2'	0.24	522.90	1.24	0.44	1643.40	7.23
T_3'	0.20	510.45	1.01	0.40	1776.10	7.16
T_4'	0.23	547.80	1.24	0.45	1444.20	6.53
SEm (±)	0.0037	7.8102	0.0215	0.0034	10.3372	0.0952
CD (5%)	0.0127	27.0229	0.0743	0.0119	35.7662	0.3295
CV%	2.9320	2.6026	3.2832	1.4011	1.2222	2.6404

Table 11 Continues ...

Treatments	Harvesting (2011-12) Mustard					
	Stover			Seed		
	S%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	S%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})
T_1'	0.09	3036.56	2.82	0.40	915.08	3.69
T_2'	0.11	3802.23	4.03	0.43	1538.82	6.54
T_3'	0.10	2849.81	2.79	0.41	892.67	3.62
T_4'	0.10	3036.56	3.13	0.41	1568.70	6.42
SEm (±)	0.0032	35.2936	0.1001	0.0049	14.4328	0.1000
CD (5%)	0.0109 (ns)	122.1135	0.3462	0.0170 (ns)	49.9365	0.3460
CV%	5.4772	1.9216	5.4284	2.0671	2.0343	3.4199

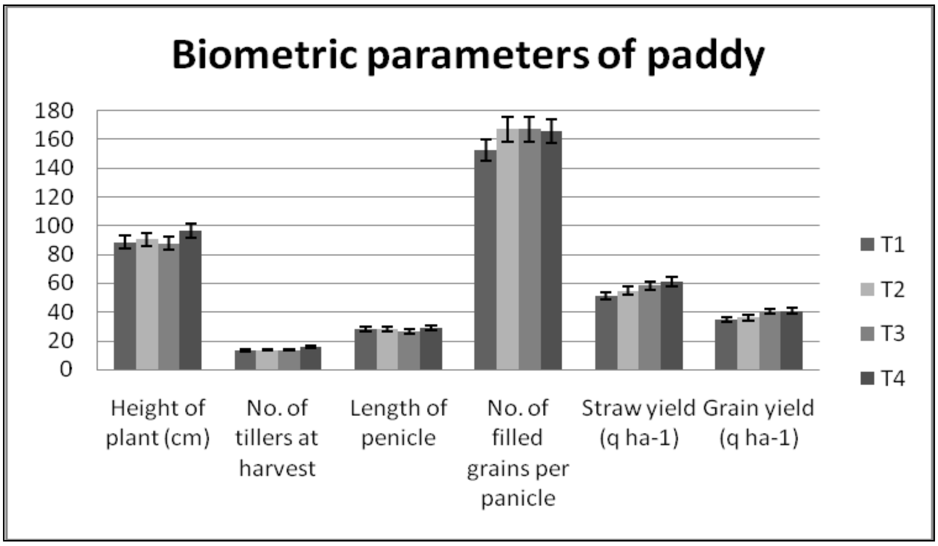

Figure 1: Changes in biometric parameters of paddy treated with FYM and humic acid in rice-mustard cropping sequence

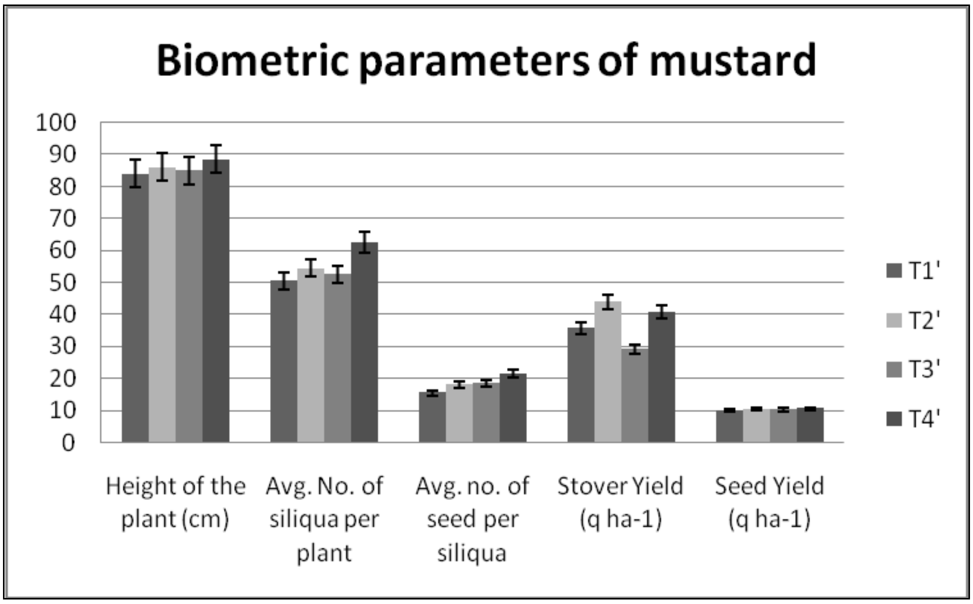

Figure 2: Changes in biometric parameters of mustard treated with FYM and humic acid in rice-mustard cropping sequence

Figure 1 and 2 represented the biometric parameters of paddy and mustard. In respect to treatment, no significant changes were recorded in number of tillers and length of panicle at paddy and yield of mustard. The length of both paddy and mustard plant, at their harvesting stage, reached highest with EHA by 8.9% and 5.36% in comparison to control established the fact of higher metabolic activity within plant body (Nardi *et al.*, 2002). Productivity of paddy was highest with EHA (17.6%) followed by CHA (16.4%) and quantity of stover (13.9%) in mustard as evaluated to their respective control. This result emphasizes the use of HA for productivity of paddy, which is at par with the findings of Sahuran *et al.* (2011).

CONCLUSION

Application of Enriched Humic Acid (EHA) and Compost Humic Acid (CHA), at the basal level collectively, with recommended doses of fertilizers increase availability of phosphate, sulphate and potash in soil, respectively. Residual effect of FYM along with additional dose to mustard resulted highest significant yield of plant biomass; whereas irrespective of treatments the quantitative yield of mustard is similar. EHA is responsible to enrich qualitative parameters through raising the uptake of P, K, S within plant body.

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Conflict of Interest

The authors declare no conflict of interest.

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