International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 10(3): 303-314, June 2017
DOI: 10.5958/2230-732X.2017.00038.9

SOIL SCIENCE

Comparative Study of Organic Matter Vis-a-Vis Humic Acid on Change in Nutrients Availability in Rice-Mustard Cropping Sequence

Niladri Paul*[1], Utpal Giri[2], Ashim Datta[3], Debabrata Dhar[4] and Dipankar Saha[5]

[1]Assistant Professor (SSAC), College of Agriculture, Tripura, Lembucherra, West Tripura, India
[2]Assistant Professor (Agronomy), College of Agriculture, Tripura, Lembucherra, West Tripura, India
[3]Agricultural Research Scientist, Division of Soil and Crop Management, CSSRI, Karnal, Haryana, India
[4]Assistant Professor, Baba Farid Institute of Technology, Bhatinda, Punjab, India
[5]Retd. Professor and Head, Department of Agril. Chem & Soil Science, BCKV, West Bengal, India

*Corresponding author: nilupaul82@gmail.com

Paper No. 583 Received: 13-1-2017 Accepted: 11-5-2017

ABSTRACT

The influence of organic matter vis-a-vis humic acids on the availability of nutrient status and its impact on the cultivation of rice (Variety MTU 1010) followed by mustard (Variety B-9), was studied in Typic *Fluvaquent* soil under Old Alluvial zone of West Bengal, India. Important physical and chemical properties of the soil texture were identified as sandy clay loam, bulk density 1.34 Mg m^{-3}, oxidizable organic carbon 1.16 g $100gm^{-1}$, pH 6.34, total nitrogen 0.14 g $100gm^{-1}$, 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. The soil received recommended doses of fertilizer for the 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, 0.25 kg ha^{-1}, respectively as per the treatments combination. The study selected the Randomized Block Design (RBD). Periodical analysis for the collected rhizosphere soil (0-15 cm) and the plant samples in the C: N ratio was done, along with the available amount of phosphate, potash and sulphur with their integral effect on the crops growth. At the panicle initiation and branching stages of paddy and mustard, the highest content of the available phosphate, potash and sulphur were recorded. This content gradually decreases toward the harvesting stage. FYM extracted humic acid showed the highest availability of phosphate, potash and sulphur whereas Commercial humic acid enhanced the content of potash in soil, which signified the uptake of phosphorus, potash and sulphur within plants, which resulted in the qualitative enrichment through biometric parameters and yield of paddy and mustard.

Highlights

- Humic acid is very much useful for increasing the nutrient availability during growth stages of paddy and mustard.
- Commercial humic acid is leonardite in origin and is rich in potassium.

Keywords: FYM, humic acid, phosphate, potash, sulphate, biometric

The monocotyledonous plant rice is an annual crop, grown mainly in the tropical and subtropical climate. Rice is one of the most staple food for major parts of the world. Rice production over the world is being the result of high yielding varieties, chemical fertilizers and improved packaging practices. Mustard is designated as one of the world's most spicy crop. Its unique properties raise its acceptability in food preparation by different cultures. Yellow sarsoon (*Brassica rapa)* is the most widely spread, rapeseed-mustard group of crop, which is the 2nd most important oilseed crop after groundnut 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. They virtually control all the biological processes. It is also essential within plants for the use of carbohydrate. Plants respond quickly to increased nitrogen availability hence, as a result their leaves turn deep green in colour. Nitrogen also stimulates plant productivity (Brady and Weil, 2002).

The essential and primary macronutrient phosphorus, placed in Group VB of the Periodic Table is a vital component of genes and chromosomes building block. Principally it involves in the transfer of energy and the constituents of energy currency – ATP. An adequate supply of P in the form of orthophosphate ($H_2PO_4^-$) and secondary orthophosphate (HPO_4^{-2}) encourages the growth and maturity of roots (Tiwari, 2009). Another essential macronutrient K, supplied in the form of K^+ is required for the activation of around 80 enzymes and plays a 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 conditions (Subba Rao and Brar, 2009).

The addition of FYM is the prime source of soil organic matter (SOM). It acts as a skeleton of holding fertilizer nutrient and provides nutritional benefit to the soil for the growth of the plant. The decomposed portion of SOM i.e. humus has chelating power for the chelation of different nutrients especially trace elements (Sanghi, 2000). SOM consists of 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 justifies the effect of FYM in nutrient absorption and storage (Singh *et al.,* 2011).

Humic acid (HA) is the major constituent of humic substances and acts as an integral part of SOM and is one of the key components of terrestrial ecosystem. It is a heterogeneous substance, which includes 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 the leaf's interveinal chlorosis as it might be chelating the unavailable nutrients and buffering the soils pH (Pertusatti and Prado, 2007). It may form an enzymatically active complex as a catalyst (Marzadori *et al.,* 2000) that can carry reactions, which are assigned for the metabolic activity of the living organisms (Tikhonov *et al.*, 2010). HA can partially be used as a supplement to chemical fertilizers based on the properties of the base exchange capacity and the complex ability that are required in the soil (Sharif *et al.,* 2005). Application of humic acid with the recommended dose of the fertilizer (NPK) increases the microbial population as well as biomass (Sellamuthu and Govindaswamy, 2003).

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

Keeping the above information in view, it is of practical significance to study the role of organic matter vis-a-vis humic acid on the improvement of the nutrient status in the soil and its availability to crops as well as its effect on growth and the 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 of organic matter vis-a-vis humic acid on changes in the 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 ranged from 34.4°C (maximum) to 11.0°C (minimum). Physical and chemical properties of the soil (Typic *Fluvaquent*) of the experimental field is as mentioned as 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 were purchased from the open market. The characteristics of FYM and humic acid used in the experiment is as presented as in Table 2.

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 were applied, irrespective of the treatments, to raise the rice crop (Variety MTU-1010) with the best management practices during the Kharif season. 50% of the total fertilizer nitrogen was applied as basal and the remaining amount was applied in two split doses at tillering and the flowering stages of rice. The plot size was 12 (3X4) sqm. The design of the experiment was Randomized Block Design (RBD) with three replications. Mustard (B-9) was cultivated as a 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.

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 the estimation of oxidizable organic carbon (Walkley and Black, 1934) and total nitrogen by kjeldal digestion method. The 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, 1950), respectively. Total N in plant samples were estimated by kjeldahl digestion method (Kjeldahl, 1883). Total P, K and S in plant sample were determined by 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 the analysis of variance as well as the critical difference was 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 step of paddy followed by mustard cultivation. Irrespective of variation, no significant changes were found in C/N ratio during the cultivation of paddy. However, at the harvesting stage of paddy, EHA effectively raised the C/N ratio by 8.4% followed by FYM (6.1%) than that of the control in soil signified as the fact of highest enzymatic activity at maturity

(Akmal *et al.*, 2012). Application of EHA raised the rhizosphere microbial activity (Sellamuthu and Govindaswamy, 2003) and auxins, gibberellins content (Trevisan *et al.*, 2010) in mustard, resulting in highest C/N ratio as compared with the control at all stages of mustard cultivation. The ratio that gradually declined towards the harvesting stage justified the increasing rate of humification in soil (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 content of the available phosphate in soil were tabulated in Table 4 and Table 5, Table 6 represents the content and uptake of P during the cultivation of paddy followed by mustard. Irrespective of the treatments, the availability of phosphate increased up to the Panicle initiation (PI) stage and gradually declined towards the harvesting stage of paddy. 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%). At the tillering stage, phosphate availability gradually declined from FYM (31.9%) to EHA (29.0%) and CHA (0.0%) when compared to that of the control in soil. This result indicated microbial proliferation of FYM in the faster rate than humic substances (Stevenson, 1994) resulting in the mineralization of organic phosphate in the soil (Lopez *et al.*, 2001). During later stages of the incubation period, EHA accelerates root exudation, which is responsible for microbial activity and nutrient availability in rhizosphere soil (Norton *et al*, 2009). Irrespective of the application of fertilizer in the recommended doses, the change for phosphate availability during the incubation period of mustard were not similar. At branching (33.3%) and flowering (15.8%) stages, the highest phosphate availability were reflected by CHA whereas at harvesting stage EHA (44.9%) took that position when compared to that of control. CHA that showed the significant availability of phosphate in the flowering stage justifies the findings of Tuba-arjemend *et al.* (2015) but counteracts the result framed by Jones *et al.* (2007).

Considering the dry weight at every stages of plant growth, P concentration and uptake were seen to gradually increase from PI and the branching stage to harvesting stage of paddy and mustard, respectively (Table 5,6). Irrespective of the treatment, the changes in Phosphorus (P) concentration in paddy gradually declined from PI stage to the flowering stage but inclined to harvesting stage with maximum concentration in grains (Malhi *et al.*, 2006). Similarly, in mustard highest P uptake was found in stover and seed (Virginetenshia and Singaram, 2012).

In all the stages, except in grains, EHA followed by CHA resulted in a significant increase in P uptake when compared to the control in paddy. EHA and FYM showed more than one fold and 36.0% increase in P uptake at straw (Paddy) and stover (Mustard), respectively and 33.5% (EHA) increase in grains in paddy. This result established the facts of qualitative changes in paddy and mustard as described by Motaghi and Nejad (2014) for cowpea.

Table 7 reflected the gradually declining trend of available potash towards harvesting stages of paddy and mustard. CHA which resulted in the highest significant increase up to the flowering stage of paddy cultivation might be due to presence of 8% potash in leonardite originated CHA (Table 2 and Sokolov *et al.*, 2005) along with its positive effect on nutrient availability (Chan *et al.*, 2010). At the harvesting stage of paddy, FYM showed highest declination followed by EHA and CHA when compared with control. 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, might be microbial activities in FYM and EHA treated soil (Stevenson, 1994) and this was further reflected on mustard. FYM and EHA resulted in similar patterns of potash availability at branching (4.8%) and flowering (6.6%) stages of mustard as compared to that of control. However, at the harvesting of mustard, highest significant availability of potash was reflected with FYM (14.3%) followed by EHA (7.1%) as compared to that of the control in soil. The significant change in available potash during mustard cultivation differed very much with paddy and established the findings of Thenmozhi and Natarajan 2007.

Irrespective of the treatments, the uptake that was gradually inclining towards the harvesting stage (Table 8, 9) justified the declining trend found in table 7. In paddy, irrespective of the treatments and the stages of plant growth, highest significant concentration of K was recorded in grains that were

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
	Mechanical analysis	Sand	%	34.8
		Silt	%	20.0
		Clay	%	45.2
3	Bulk Density		Mg m^{-3}	1.34
4	Oxidizable Organic Carbon		g $100gm^{-1}$	1.16
5	pH		Soil : water = 1:2.5	6.34
6	Available P_2O_5		Kg ha^{-1}	25.90
7	Available K_2O		Kg ha^{-1}	127.40
8	Available S		Kg ha^{-1}	39.56

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 (%)	32.56	29.77	43.36
2	Total Nitrogen (%)	1.014	2.2	1.29
3	C/N ratio	32.016	13.53	33.61
4	Viscosity (measured by Ubelhode viscometer)		133.1	139.0
5	E_4/E_6		3.193	3.41
6	Functional group (measured by Dragunova, 1958) (meq Ba)		6.803	6.803
7	Ash free Carboxylic group (Kononova *et al.*, 1966) (meq)		628.3	415.9

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

CROP								
Rice					Mustard			
Treatments	Stages after transplanting of rice				Treatments	Stages after sowing of mustard		
	Tillering	Panicle initiation	Flowering	Harvesting		Branching	Flowering	Harvesting
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

CROP								
Rice					Mustard			
Treatments	Stages after transplanting of rice				Treatments	Stages after sowing of mustard		
	Tillering	Panicle initiation	Flowering	Harvesting		Branching	Flowering	Harvesting
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		

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			Harvesting					
							Straw			Grain		
	P%	Dry matter (Kg ha^{-1})	uptake (Kg ha^{-1})	P%	Dry matter (Kg ha^{-1})	uptake (Kg ha^{-1})	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	0.08	4612.50	3.69	0.36	3123.00	11.30
T_2	0.35	238.84	0.83	0.18	470.07	0.86	0.10	4923.00	4.92	0.43	3240.00	14.00
T_3	0.33	249.15	0.83	0.27	511.80	1.39	0.11	5251.50	5.77	0.37	3636.00	13.40
T_4	0.33	267.22	0.87	0.25	528.35	1.34	0.16	5503.50	8.81	0.41	3672.00	15.09
SEm(±)	0.0054	0.7432	0.0112	0.0003	0.3261	0.0110	0.0087	31.1435	0.4524	0.0086	19.0693	0.3022
CD (5%)	0.0187 (ns)	2.5716	0.0388	0.0010	1.1284	0.0390	0.0300	107.7544	1.5653	0.0296	65.9786	1.0457
CV%	2.7996	0.5297	2.3912	0.2210	0.1155	1.7410	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	Branching			Flowering			Harvesting					
							Stover			Seed		
	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	P%	Dry matter (kg ha^{-1})	Uptake (kg ha^{-1})	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	0.15	3036.56	3.79	0.16	915.08	1.34
T_2'	0.15	522.90	0.57	0.12	1643.40	3.43	0.15	3802.23	5.16	0.16	1538.82	2.40
T_3'	0.13	510.45	0.61	0.16	1776.10	3.88	0.15	2849.81	3.65	0.17	892.67	1.35
T_4'	0.13	547.80	0.68	0.12	1444.20	3.48	0.15	3036.56	3.89	0.16	1568.70	2.34
SEm(±)	0.0037	7.8102	0.0267	0.0034	10.3372	0.0435	0.0022	35.2936	0.1786	0.0026	14.4328	0.0184
CD (5%)	0.0128	27.0229	0.0924	0.0118	35.7662	0.1505	0.0077 (ns)	122.1135	0.6181	0.0091	49.9365	0.0637
CV%	4.6738	2.6026	7.7918	4.2638	1.2222	2.3883	2.6125	1.9216	7.5093	2.8495	2.0343	1.7194

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

CROP								
Rice					Mustard			
Treatments	Stages after transplanting of rice				Treatments	Stages after sowing of mustard		
	Tillering	Panicle initiation	Flowering	Harvesting		Branching	Flowering	Harvesting
T_1	130.52	120.95	8602	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		

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			Harvesting					
							Straw			Grain		
	K%	Dry matter (Kg ha^{-1})	uptake (Kg ha^{-1})	K%	Dry matter (Kg ha^{-1})	uptake (Kg ha^{-1})	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	0.76	4612.50	34.82	1.20	3123.00	37.47
T_2	1.4	238.84	3.34	0.74	470.07	3.48	1.38	4923.00	67.73	1.80	3240.00	58.35
T_3	1.58	249.15	3.94	1.32	511.80	6.76	1.35	5251.50	70.81	1.60	3636.00	58.15
T_4	1.28	267.22	3.42	1.22	528.35	6.45	1.32	5503.50	72.65	1.80	3672.00	66.11
SEm(±)	0.0279	0.7432	0.0545	0.0895	0.3261	0.4389	0.0679	31.1435	3.2773	0.0456	19.0693	1.5581
CD (5%)	0.0966	2.5716	0.1885	0.3096	1.1284	1.5185	0.2350	107.7544	11.3391	0.1576	65.9786	5.3911
CV%	3.3854	0.5297	2.7247	14.1553	0.1155	14.0868	9.8042	1.0634	9.2293	4.9312	0.9664	4.9051

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	Branching			Flowering			Harvesting					
							Stover			Seed		
	K%	Dry matter (Kg ha^{-1})	uptake (Kg ha^{-1})	K%	Dry matter (Kg ha^{-1})	uptake (Kg ha^{-1})	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	0.35	3036.56	10.61	1.40	915.08	12.82
T_2'	1.10	522.90	5.75	1.38	1643.40	22.60	0.38	3802.23	14.28	2.00	1538.82	30.75
T_3'	1.34	510.45	6.84	1.30	1776.10	23.10	0.36	2849.81	10.27	1.80	892.67	16.06
T_4'	1.40	547.80	7.67	1.40	1444.20	20.21	0.51	3036.56	15.34	2.20	1568.70	34.58
SEm(±)	0.0446	7.8102	0.2763	0.0473	10.3372	0.4770	0.0308	35.2936	0.9235	0.0726	14.4328	1.2127
CD (5%)	0.1543	27.0229	0.9560	0.1638 (ns)	35.7662	1.6502	0.1064	122.1135	3.1952	0.2513	49.9365	4.1959
CV%	6.3838	2.6026	7.5813	6.1591	1.2222	4.2163	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

CROP								
Paddy					Mustard			
Treatments	Stages after transplanting of rice				Treatments	Stages after sowing of mustard		
	Tillering	Panicle Initiation	Flowering	Harvesting		Branching	Flowering	Harvesting
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	

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			Harvesting					
							Straw			Grain		
	S%	Dry matter (Kg ha^{-1})	Uptake (Kg ha^{-1})	S%	Dry matter (Kg ha^{-1})	Uptake (Kg ha^{-1})	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	0.07	4612.50	3.18	0.10	3123.00	3.25
T_2	0.2	238.84	0.49	0.11	470.07	0.51	0.10	4923.00	4.87	0.15	3240.00	4.83
T_3	0.14	249.15	0.34	0.11	511.80	0.55	0.08	5251.50	3.94	0.12	3636.00	4.18
T_4	0.16	267.22	0.42	0.11	528.35	0.58	0.08	5503.50	4.57	0.15	3672.00	5.44
SEm(±)	0.0041	0.7432	0.0117	0.0025	0.3261	0.0127	0.0054	31.1435	0.2524	0.0041	19.0693	0.1229
CD (5%)	0.0143	2.5716	0.0405	0.0087(ns)	1.1284	0.0440	0.0186	107.7544	0.8732	0.0143	65.9786	0.4254
CV%	4.7571	0.5297	5.5226	4.1128	0.1155	4.2522	11.4392	1.0634	10.5585	5.5676	0.9664	4.8151

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	Branching			Flowering			Harvesting					
							Stover			Seed		
	S%	Dry matter (Kg ha^{-1})	uptake (Kg ha^{-1})	S%	Dry matter (Kg ha^{-1})	uptake (Kg ha^{-1})	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	0.09	3036.56	2.82	0.40	915.08	3.69
T_2'	0.24	522.90	1.24	0.44	1643.40	7.23	0.11	3802.23	4.03	0.43	1538.82	6.54
T_3'	0.20	510.45	1.01	0.40	1776.10	7.16	0.10	2849.81	2.79	0.41	892.67	3.62
T_4'	0.23	547.80	1.24	0.45	1444.20	6.53	0.10	3036.56	3.13	0.41	1568.70	6.42
SEm(±)	0.0037	7.8102	0.0215	0.0034	10.3372	0.0952	0.0032	35.2936	0.1001	0.0049	14.4328	0.1000
CD (5%)	0.0127	27.0229	0.0743	0.0119	35.7662	0.3295	0.0109 (ns)	122.1135	0.3462	0.0170 (ns)	49.9365	0.3460
CV%	2.9320	2.6026	3.2832	1.4011	1.2222	2.6404	5.4772	1.9216	5.4284	2.0671	2.0343	3.4199

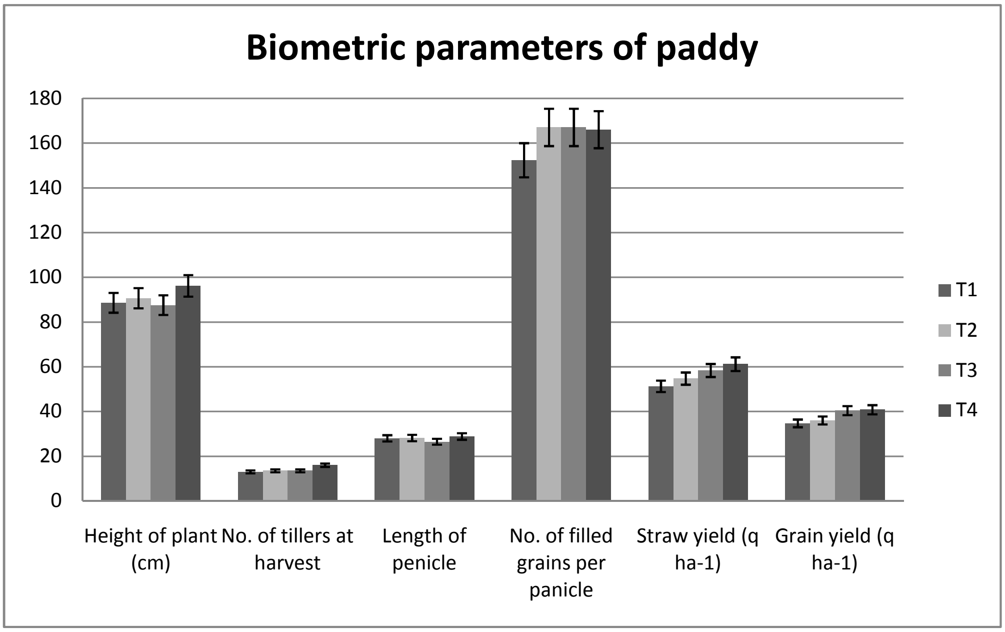

Fig. 1: Changes in biometric parameters of paddy treated with FYM and humic acid in rice-mustard cropping sequence

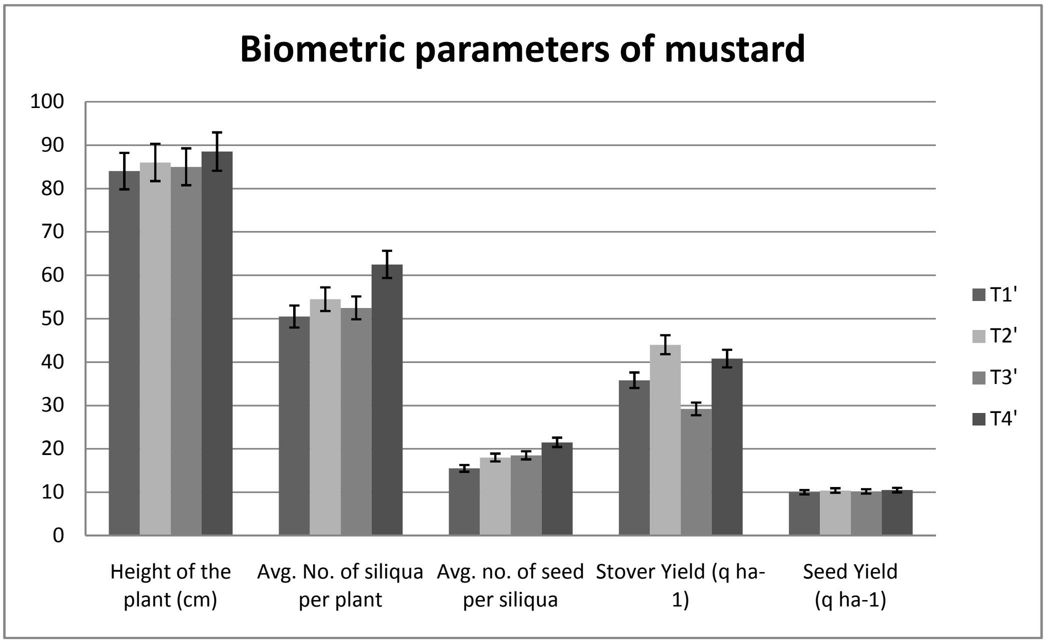

Fig. 2: Changes in biometric parameters of mustard treated with FYM and humic acid in rice-mustard cropping sequence

treated with FYM and EHA (50.0%) as compared with control. On the other way, a similar trend of result was presented by mustard. Considering the qualitative point in mind, the highest uptake of K in paddy (76.4%) and more than one and a half fold uptake in mustard seed, compared with control, re-established the findings of Barison (2002).

Neither in the recommended fertilizer dose of paddy and mustard nor in the treatments was sulphur added separately. According to Table 10, irrespective of the treatments, the availability of sulphur raised up to PI and the flowering of paddy and mustard, respectively. During incubation period except tillering, EHA showed highest significant availability of sulphur when compared to that of control in paddy whereas at flowering EHA resulted highest S availability (99.0%) followed by CHA (70.6%) when again was compared to that of the control in mustard established the findings of Denre *et al.* (2014). Due to the presence of marshy environment in paddy rhizosphere zone and higher carboxylic functional group in EHA, the fungal growth and population took a lead role in the creation of microbial biomass (Strickland and Rousk 2010) which might increase the availability of sulphur in soil like other macronutrients (Malik *et al.*, 2013). In mustard field, higher root exudation and microbial activity at the flowering stage resulted in significant chronological decrement of sulphur availability from EHA, CHA and FYM treated soil as compared with that of control.

Table 11 & 12 arranged the data of sulphur content, dry matter yield, and S-uptake at different growth stages of paddy and mustard. Irrespective of the treatments, crop uptake of sulphur showed an increasing trend towards the harvesting stage. Application of FYM resulted in the highest sulphur 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 they weigh against control. Considering the production of mustard seed, at the 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 on comparing with the control in plant (Rajpar *et al.*, 2011). This result emphasized the qualitative parameters of paddy and mustard production and helped in bringing the similarity with the established results of Patra and Maity, (2007) for paddy and Ray *et al.* (2015) for mustard.

Application of humic acid especially EHA with its resistant characteristics may be absorbed directly by plant roots and would influence the plants metabolic activities like respiration, protein synthesis, enzymatic activity, root hair formation etc. These activities resulting in the secretion of root exudates during the growth period of plant and in exchange of that, the plant absorbs bulk quantity of nutrients were justified in the findings of Table 4,7,10 as reviewed by Trevisan *et al.* (2010). On the other hand, humic acid within the plant body exhibited hormone (auxin) like activities on plasma membrane H^+-ATPase and increased availability of nutrients as well as developed the uptake capacity for phosphate (Karr, 2001), potash and sulphate (Karr, 2001) within the plant body (Table 5,6,8,9, 11,12).

Fig. 1 and 2 represented the biometric parameters of paddy and mustard. With respect to the treatments, no significant change was recorded in the 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 the established fact of higher metabolic activity within the plant body (Nardi *et al.*, 2002). The 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 the productivity of paddy, which is at par with the findings of Sahuran *et al.* (2011).

CONCLUSION

Application of EHA and CHA, at basal, collectively with the recommended dose of fertilizers increase the availability of phosphate, potash and sulphate in soil, respectively. The residual effect of FYM along with additional dose to mustard resulted in highest significant yield of plant biomass whereas it was irrespective of the treatments of the quantitative yield of mustard that is similar. EHA is responsible for enriching the qualitative parameters by raising the uptake of P, K, and S within the plant body.

REFERENCES

Akmal, M., Altaf, M.S., Hayat, R., Hassan, F.U. and Islam, M. 2012. Temporal changes in soil urease, alkaline phosphatise and dehydrogenase activity in rainfed wheat field of Pakistan. *The Journal of Animal and Plant Sciences*, **22**(2): 457-462.

Barison, J. 2002. Nutrient-use efficiency and nutrient uptake in conventional and intensive (SRI) rice cultivation systems in Madagascar. Master's thesis, Crop and Soil Sciences. Department, Cornell University, Ithaca, NY.

Brady, N.C. and Weil, R.R. 2002. The Nature and Properties of soils. Thirteenth Edition. Pearson Education (Singapore) Pte. Ltd, Indian Branch, 482 F.I.E, Patparganj, New Delhi pp. 544-590.

Chan, C.S., Wong, N.C. and Muhammad-Syahren, A. 2010. Performance of formulated nitro humic acid-based rice grain booster. *Journal of Tropical Agriculture and Food Science*, **38**(2): 239-247.

Chen, Y. and Aviad, T. 1990. Effects of Humic Substances on Plant Growth. In P. MacCarthy *et al.* Eds. Humic Substances in Soil and Crop Sciences: Selected Readings. American Society of Agronomy. Madison WI, pp. 161-186.

Chesnin, L. and Yien, C.H. 1950. Turbidimetric determination of available sulphates. *Proceedings of Soil Science Society of America,* **15:** 149-151.

Denre, M., Ghanti, S. and Sarkar, K. 2014. Effect of humic acid application on accumulation of mineral nutrition and pungency in garlic (*Allium sativum* L.). *International Journal of Biotechnology and Molecular Biology Research,* **5**(2): 7-12.

Dragunova, A.F. 1958. A rapid method for determining functional groups in humic acids. Nauch Trudy, Mosk. I in Zh. Chonon Inst. Ser. Khinprioz-vod., Cited by Kononova (1966), pp 544.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for Agricultural Research. John Wiley and sons. New York.

Jackson, M.L. 1973. Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd., New Delhi.

Jannin, L., Arkoun, M., Ourry, A., Laine, P., Goux, D., Garnica, M., Fuentes, M., Francisco, S.S., Baigorri, R., Cruz, F., Houdusse, F., Garcia-Mina, J.M., Yvin, J.C. and Etienne, P. 2012. Microarray analysis of humic acid effects on Brassica napus growth: involvement of N, C and S metabolisms. *Plant and Soil,* **359**(1/2): 297-319.

Jha, G.K., Pal, S., Mathur, V.C., Bisaria, G., Anbukkani, P., Burman, R.R. and Dubey, S.K. 2012. Edible Oilseeds Supply and Demand Scenario in India: Implications for Policy. Division of Agricultural Economics. IARI pp 15.

Jones, C.A., Jacobsen, J.S. and Mugaas, A. 2007. Effect of low-rate commercial humic acid on phosphorus availability, micronutrient uptake, and spring wheat yield. *Communication in Soil Science and Plant Analysis,* **38**(7/8): 921-933.

Karr, M. 2001. Oxidized lignites and extracts from oxidized lignites in Agriculture, *ARCPACS Cent. Prof. Soil Sci.* Pp. 9.

Khaled, H. and Fawy, H.A. 2011. Effect of different levels of humic acids on nutrient content, plant growth and soil properties under conditions of salinity. *Soil and Water Research,* **6:** 21-29.

Kjeldahl, J.Z. 1883. A new method for the determination of nitrogen in organic bodies." *Analytical Chemistry,* 22: 366.

Kononova, M.M. and Belchikova, N.P. 1961. Rapid methods of determining the humus composition of mineral soils. *Ibid.,* **10:** 75.

Kononova, M.M., Nowakowski, T.Z. and Newman, A.C.D. 1966. Soil Organic Matter. Pergamon Press. Ltd. Moscow.

Lopez-Mtz, J.D., Diaz, E.A., Martinez, R.E. and Valdez, C.R.D. 2001. Effect of organic fertilizers on physical-chemical soil properties and corn yield. *Journal of Terramechanics,* **19**(4): 293-299.

Malhi, S.S., Johnston, A.M., Schoenau, J.J., Wang, Z.H. and Vera, C.L. 2006. Seasonal biomass accumulation and nutrient uptake of wheat, barley and oat on a Black Chernozem soil in Saskatchewan. *Canadian Journal of Plant Science,* **86:** 1005-1014.

Malik, M.A., Khan, K.S., Marschner, P., Hassan, F. 2013. Microbial biomass, nutrient availability and nutrient uptake by wheat in two soils with organic amendments. *Journal of Soil Science and Plant Nutrition,* **13**(4): 955-966.

Marzadori, C., Francisco, O. and Ciavatta, C. 2000. Activity and stability of jack bean urease in the presence of peat humic acids obtained using different extrants. *Biology and Fertility of Soils,* **32:** 415-420.

Motaghi, S. and Nejad, T.S. 2014. The effect of different levels of humic acid and potassium fertilizer on physiological indices of growth. *International Journal of Bioscience,* **5**(2): 99-105.

Muthu Kumar, S. and Ponnuswami, V. 2013. Growth, flowering, fruit dimensions and post harvest parameters of Morinda citrifolia as influenced by irrigation regimes and organic manures. *Journal of Medicinal Plants Research,* **7**(36): 2691-2706.

Nardi, S., Pizzeghello, D., Muscolo, A. and Vianello, A. 2002. Physiological effects of humic substances on higher plants. *Soil Biology and Biochemistry,* **34**(11): 1527-1536.

Nikbakht, A., Kafi, M., Babalar, M., Xia, Y.P., Luo, A. and Etemadi, N. 2008. Effect of Humic Acid on Plant Growth, Nutrient Uptake, and Postharvest Life of Gerber. *Journal of Plant Nutrition,* **31**(12): 2155-2167.

Norton, J.M., Firestone, M.K. and Unestam, T. 2009. N dynamics in the rhizosphere of Pinus ponderosa seedlings. *Soil Biology and Biochemistry,* **28**: 351-362.

Olsen, S.R., Cole, C.V., Watnabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *United States Department of Agriculture Circulation* 939.

Patra, T. and Maity, S. 2007. Effect of different sources of sulphur along with or without N, P, K and FYM in rapeseed-mungbean-rice crop sequence in the Gangetic West Bengal. *Journal of Crop and Weed,* **3**(2): 20- 25.

Pertusatti, J. and Prado, A.G. 2007. Buffer capacity of humic acid: thermodynamic approach. *Journal of Colloid Interface Science,* **314**(2): 484-489.

Petronio, P., Vitorovic, D. and Jablanovic, M. 1982. Investigations of the biological effect of humic acid. *Acta Biologica et Medica Expression,* **7:** 21-25.

Rajpar, I., Bhatti, M.B., Zia-ul-Hassan, Shah, A.N. and Tunio, S.D. 2011. Humic acid improves growth, yield and oil content of *Brassica compestris* L. *Pakistan Journal of Agricultiure, Agricultural Engineering, Veterinary Science* **27**(2): 125-133.

Ray, K., Sengupta, K., Pal, A.K. and Banerjee, H. 2015. Effects of sulphur fertilization on yield, S uptake and quality of Indian mustard under varied irrigation regimes. *Plant and Soil Environment,* **61**(1): 6–10.

Saha, R., Saieed, M.A.U., Chowdhury, M.A.K. and Chowdhury, M.A.H. 2014. Influence of humic acid and poultry manure on nutrient content and their uptake by T. aman rice. *Journal of Bangladesh Agricultural University,* **12**(1): 19–24.

Sahuran, V., KuSvuran, A. and Babat, S. 2011. The effect of different humic acid fertilization on yield and yield components performances of common millet (*Panicum miliaceum* L.). *Scientific Research Essays*, **6**(3): 663-669.

Sanghi, R. 2000. What's up with chelates. *Current Science*, **78**(11): 1-5.

Sellamuthu, K.M. and Govindaswamy, M. 2003. Effect of fertiliser and humic acid on rhizosphere microorganisms and soil enzymes at an early stage of sugarcane growth. *Sugar Technology*, **5**(4): 273-277.

Sharif, M., Khattak, R.A., Sarir, M.S. and Wais, A. 2005. Utilization of humic acid in crop production: An overview. (In, D.P. Singh cds). Crop Production in stress Environments: Genetic and Management Options. Feb 9-12, (2005). Agri bios (International).

Singh, C.M., Sharma, P.K., Kishor, P., Mishra, P.K., Singh, A.P., Verma, R. and Raha, P. 2011. Impact of Integrated Nutrient Management on Growth, Yield and Nutrient Uptake by Wheat (*Triticum aestivum* L.). *Asian Journal of Agricultural Research*, **5**(1): 76-82.

Sokolov, G., Michael, I. and Bambalov, N. 2005. Influence of different organic materials on physical properties of desert and cultivated soils. *International Agrophysics*, **19**(4): 337-343.

Stevenson, F.J. 1994. Organic forms of soil nitrogen. In: John Wiley, ed. Humic Chemistry: Genesis, Composition, Reaction, New York, pp 59-95.

Strickland, M.S. and Rousk, J. 2010. Considering fungal: bacterial dominance in soils – methods, controls and ecosystem implications. *Soil Biology and Biochemistry*, **42:** 1385-1395

Subba Rao, A. and Brar, M.S. 2009. Potassium. In: N.N. Goswami, R. K. Rattan, G. Dev, G. Narayanasamy, D.K. Das, S.K. Sanyal, D.K. Pal, D.L.N. Rao, (2nd ed). Fundamentals of Soil Science. Indian Society of Soil Science, New Delhi, India, pp. 431-432.

Tan, H.K. 2014. Humic matter in soil and the environment. Principles and Controversies. 2nd Ed. CRC Press. pp 223.

Temz, M., Karahan, E. and Koca, Y.K. 2009. Effects of humic substances on cotton (*Gossypium hirsutum* L.). *Asian Journal of Chemistry*, **21**(3): 1983-1989.

Thenmozhi, S. and Natarajan, S. 2007. Studies on the influence of humic acid on soil fertility status. *Research on Crops*, **8**(3): 585-588.

Tikhonov, V.V., Yakushev, A.V., Zavgorodnyaya, Y.A., Byzov, B.A. and Demin, V.V. 2010. Effects of humic acids on the growth of bacteria. *Eurasian Soil Science*, **43**(3): 305-313.

Tiwari, K.N. 2009. Phosphorus. In: N.N. Goswami, R. K. Rattan, G. Dev, G. Narayanasamy, D.K. Das, S.K. Sanyal, D.K. Pal, D.L.N. Rao, (2nd ed). Fundamentals of Soil Science. Indian Society of Soil Science, New Delhi, India, pp. 413 – 414.

Trevisan, S., Francisco, O., Quaggiotti, S. and Nardi, S. 2010. Humic substances biological activity at the plant-soil interface from environmental aspects to molecular factors. *Plant Signaling and Behaviour*, **5**(6)**:** 635-643.

Tuba arjemend, M., Abbasi, K. and Rafique, E. 2015. Effect of lignite-derived humic acid on some selected soil properties, growth and nutrient uptake of wheat (*Triticum aestivum* L.) growth under greenhouse conditions. *Pakistan Journal of Botany*, **47**(6): 2231-2238.

Vijoyakumari, B., Yadav, R.H., Gowri, P. and Kandari, L.S. 2012. Effect of panchagavya, humic acid and micro herbal fertilizer on the yield and post harvest soil of soya bean (*Glycine max* L.). *Asian Journal of Plant Science*, **11**(2): 83-86.

Virgine Tenshia, J.S. and Singram, P. 2005. Influence of humic acid application on yield, nutrient availability and iron uptake in tomatoes. *The Madras Agril. J.* **92**: 670-676.

Walkley, A. and Black, I.A. 1934. An examination of wet acid method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, **37:** 29-38.