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Effect of crop residue and fertilizers on humus fractions and rice (*Oryza sativa*) yield

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ABSTRACT

An experiment was conducted during 2019–20 at the Research Farm of Dr. BSKKV, Dapoli, Maharashtra to study the effect of crop residues and fertilizers on humus fractions and rice yield in Alfisols. The study was conducted on *ex situ* incorporation of crop residue along with fertilizers and the results indicated that application of rice straw @2.5 t/ha + Ain leaf residue @2.5 t/ha along with 100% NPK was significantly beneficial for improving the content of soil humin, humic acid, fulvic acid and humic acid : fulvic acid (HA: FA) ratio and yield of rice. Crop residue and fertilizer management significantly improved the soil humin, humic acid, fulvic acid and humic acid: fulvic acid (HA: FA) ratio. Build-up of soil humus was due to the balanced application of crop residue along with fertilizers for developing bio-stability in soil which helps maintain soil health. In contrast, the application of 50%, 75% and 100% NPK alone did not gain optimum humus content in soil and yield of rice because of unbalanced use of fertilizers. Overall improvement in soil humus and yield of rice was observed by the integrated use of crop residue along with fertilizers in Alfisols.

Keywords: Alfisols, Fulvic acid, HA: FA Ratio, Humic acid, Humin, Rice

Soil organic matter is responsible for maintenance of physical conditions of soil and also supplies essential plant nutrients for successful crop production. It is a storehouse of various essential nutrients for plant growth. Besides, humus also exerts a pronounced influence on physical, chemical and biological properties of the soil (Kononova 1966, Meshram *et al.* 2018). Humus is the most important and largest constituent of soil organic matter. Humin, humic acid (HA) and fulvic acid (FA) are formed by decomposition of plant and animal residues by microorganisms. Residue decomposition is a major pathway for providing organic and inorganic elements for the nutrient cycling processes. The impact of decomposing various crop residues *in situ* and *ex situ* in soil is reflected on residual effect of nutrients on soil and productivity of crop. Addition of nutritious residues in soil helps develop soil fertility and subsequently soil carbon, humus, and also improves productivity of the crops/plants (Adams and Angradi 1996). In Konkan region of Maharashtra, people practice “rabbing” which increases harmful heavy metals in the soil. In place of rabbing, residue incorporation in soil with integration of fertilizers improves soil humus, soil fertility and crop productivity. On the basis of farmers’ interest, there is enormous potential of recycling these easily available residues in the crop production systems. Continuous cultivation of rice (*Oryza sativa* L.) in same field without adding any residues heavily depletes the soil nutrient status. Production of 7 t/ha rice removes more than 300 kg/ha N, 30 kg/ha P and 300 kg/ha K from the soil. Another estimate shows that 10 t/ha crop removes 730 kg NPK from the soil that is often not returned to the soils. If this residue is not returned it may cause mining of soil for major nutrients leading to net negative balance and multi-nutrient deficiencies in crops (Mandal *et al.* 2004). This is one of the reasons for the declining soil fertility and crop yield. Thus, the present study was conducted keeping in view the urgent need to manage the residue of crops for sustainability and stabilization of various nutrients in soil.

MATERIALS AND METHODS

The experiment was conducted at Research Farm of Dr. BSKKV, Dapoli, Dist. Ratnagiri, Maharashtra during 2019–20. Dapoli is located in the Konkan region of coastal Maharashtra. The experimental soil was reddish in colour, with lateritic type of Alfisols, particularly Kaolinitic, hyperthermic family of Typic Haplustalf. Initial status of organic matter fractions were humin (0.475 g 100/g soil humus), humic acid (0.350 g 100/g soil humus), fulvic acid (0.142 g 100/g soil humus) and humic acid : fulvic acid (HA:FA) ratio (2.464). The present experiment was

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framed in Strip Plot Design (SPD) with two levels, viz. crop residue [(C_1-Rice straw @5 t/ha, C_2-Ain leaf residues @5t/ha, C_3-Rice straw @2.5 t/ha + Ain leaf residues @2.5 t/ha, C_4-Control (Without residue)] and fertilizers (F_1-100% NPK, F_2-75% NPK, F_3-50% NPK) consisting twelve treatment combinations in three replications. The treatments were: T_1– Rice straw @5 t/ha (C_1) + 100% NPK (F_1), T_2– Rice straw @5 t/ha (C_1) + 75% NPK (F_2), T_3– Rice straw @5 t/ha (C_1) + 50% NPK (F_3), T_4–Ain leaf residues @5 t/ha (C_2) + 100% NPK (F_1), T_5–Ain leaf residues @5 t/ha (C_2) + 75% NPK (F_2), T_6–Ain leaf residues @5 t/ha (C_2) + 50% NPK (F_3), T_7–[Rice straw @2.5 t/ha + Ain leaf residues@ 2.5 t/ha] (C_3) + 100% NPK (F_1), T_8–[Rice straw @2.5 t/ha + Ain leaf residues @2.5 t/ha](C_3) + 75% NPK (F_2), T_9–[Rice straw @2.5 t/ha + Ain leaf residues @2.5 t/ha] (C_3) + 50% NPK (F_3), T_{10}–Without residue (C_4) + 100% NPK (F_1), T_{11}–Without residue (C_4) + 75% NPK (F_2), T_{12}–Without residue (C_4) + 50% NPK (F_3). The residues of selected forest tree species were collected and sun dried. Crop residues were chopped and incorporated in rice field 45 days before transplanting rice. The rice crop (Variety-Ratnagiri-1) was raised during *kharif* (rainy) season using recommended practices. Rice plants were transplanted with 20 cm × 15 cm spacing between rows and plants, respectively. The 100% NPK (100:50:50 kg/ha) recommended dose was applied. Urea, single super phosphate (SSP) and muriate of potash (MOP) were applied as per the treatments. Humus fractions were estimated as outlined by Stevenson (1982). The crop grain and straw yield was calculated by multiplying net plot size, converted on hectare basis as q/ha. The obtained results were statistically analyzed and appropriately intercepted as per the methods described in Statistical Methods for Agricultural Workers (Panse and Sukhaatme 1985).

RESULTS AND DISCUSSION

Humin: Maximum humin content in soil (0.573, 0.560 and 0.551 g 100/g soil humus) at tillering, flowering and harvest stage was recorded by rice straw @2.5 t/ha + Ain leaf residue @2.5 t/ha followed by Ain leaf residue @5 t/ha (0.550 g 100/g soil humus) only at harvest stage of rice which were found to be at par with each other. Whereas, lowest humin (0.499, 0.492 and 0.490 g 100/g soil humus) was noticed in control (no residue) treatment during tillering, flowering and harvest stage of rice. Regarding the fertilizer levels, application of 100% NPK recorded higher humin in soil (0.571, 0.557 and 0.553 g 100/g soil humus) during tillering, flowering and at harvest stage of rice than 75% and 50% NPK. The lowest value (0.531, 0.524 and 0.521 g 100/g soil humus) was noted in 50% NPK treatment during tillering, flowering and at harvest stage of rice than other treatments. Moreover, the interaction effect of crop residue and fertilizer levels was observed statistically non-significant at tillering, flowering stage of rice but it was significantly influenced at harvest stage (Table 1). Addition of organic residue/manure could serve as a source of humus. At the same time, compounds utilized by microorganisms (cellulose, hemicelluloses, mono and disaccharides, glucosides, amino acids etc.) are indirect source of humic substances, being converted in microbial plasma, which then participate in the formation of humic substances (Kononova 1966). Prasad *et al.* (1991), Santhy *et al.* (2001), Banik and Sanyal (2006), Gathala *et al.* (2007) and Salvi, (2007), Bhoye *et al.* (2011), Meshram *et al.* (2016) and Meshram *et al.* (2018) studied that the application of 100% NPK along with organic manure significantly improved humus content in soil than 50% NPK, 75% NPK alone and in control. It may be due to the balanced application of chemical fertilizers along with organic manure or matter for high humus contribution in soil which ultimately reflected as the maximum availability of nutrients in soil for plant.

Humic acid: Maximum humic acid in soil (0.391, 0.377, 0.369 g 100/g soil humus) at tillering, flowering and harvest stage recorded significant differences by rice straw @2.5 t/ha + Ain leaf residue @2.5 t/ha followed by Ain leaf residue @5 t/ha and rice straw @5 t/ha which were at par with each other during flowering and at the harvest of rice. Whereas, lowest humic acid (0.343, 0.323 and 0.309 g 100/g soil humus) was noticed in control (no residue) treatment during tillering, flowering and harvest stage of rice. Regarding the fertilizer levels, application of 100% NPK recorded maximum humic acid in soil (0.390, 0.375 and 0.365 g 100/g soil humus) during tillering, flowering and at harvest stage of rice. The lowest value (0.362, 0.346 and 0.338 g 100/g soil humus) at tillering, flowering and harvest stage was noted in 50% NPK alone. The interaction effect of crop residue and fertilizer levels were statistically non-significant at tillering, flowering stage of rice but it was significantly influenced at harvest stage of rice (Table 1). It may be due to addition of crop residues along with fertilizers leading to higher root formation, residue consequent to higher biomass yield might have produced more amount of humic acid in soil. It might be due to decomposition of added residue to constitute parts such as lignin derived phenolic unit, carbohydrates or amino compounds yield building blocks or substrate for humus formation (Kononova, 1966). Similarly, Prasad *et al.* (1991), Santhy *et al.* (2001), Banik and Sanyal (2006), Gathala *et al.* (2007), Salvi (2007), Bhoye *et al.* (2011), Meshram *et al.* (2016) and Meshram *et al.* (2018) reported under long term experiments, the highest amount of fraction was recorded under integration of organic manure/residue and inorganic fertilizers which could be due to the improved soil organic matter and conductive environment for the formation of humus.

Fulvic acid: The content of humic acid was higher than fulvic acid regardless of treatments. Fulvic acid, although primarily considered to be humic acid precursor, may be humic acid degradation product as well. It is probable that fulvic acid can be absorbed on to clay particles but the size of their molecules suggested that the force of attraction would be less than those for longer humic acid constituents (Anderson 1979). Significantly maximum fulvic acid in soil (0.229, 0.223, 0.219 g 100/g soil humus) at tillering,

Table 1 Effect of crop residues and fertilizers on humin, humic acid, fulvic acid and HA : FA ratio in soil

Treatment	Humin (g 100/g soil humus)			HA (g 100/g soil humus)			FA (g 100/g soil humus)			HA : FA ratio		
	Tillering	Flowering	At harvest	Tillering	Flowering	At harvest	Tillering	Flowering	At harvest	Tillering	Flowering	At harvest
Crop residues level												
C_1 : Rice straw @5 t/ha	0.552	0.543	0.541	0.381	0.366	0.361	0.218	0.213	0.209	1.755	1.724	1.730
C_2 : Ain leaf residue @5 t/ha	0.571	0.559	0.550	0.391	0.376	0.368	0.228	0.223	0.218	1.721	1.694	1.694
C_3 : Rice straw @2.5 t ha + Ain leaf residue @2.5 t/ha	0.573	0.560	0.551	0.391	0.377	0.369	0.229	0.223	0.219	1.714	1.692	1.690
C_4 : Control (No residue)	0.499	0.492	0.490	0.343	0.323	0.309	0.159	0.155	0.140	2.411	2.227	2.215
SE(m) ±	0.017	0.019	0.001	0.014	0.012	0.0007	0.016	0.012	0.001	0.11	0.08	0.007
CD at 5%	-	-	0.003	-	-	0.0025	-	0.038	0.003	0.36	0.26	0.023
F test	NS	NS	Sig	NS	NS	Sig	NS	Sig	Sig	Sig	Sig	Sig
Fertilizer level												
F_1 : 100% NPK	0.571	0.557	0.553	0.390	0.375	0.365	0.228	0.219	0.213	1.734	1.740	1.752
F_2 : 75% NPK	0.545	0.535	0.530	0.377	0.360	0.352	0.213	0.204	0.198	1.947	1.790	1.818
F_3 : 50% NPK	0.531	0.524	0.521	0.362	0.346	0.338	0.185	0.187	0.179	2.020	1.973	1.927
SE(m) ±	0.015	0.016	0.001	0.012	0.009	0.001	0.009	0.009	0.0008	0.13	0.06	0.009
CD at 5%	-	-	0.002	-	-	0.003	-	-	0.0028	-	-	0.033
F test	NS	NS	Sig	NS	NS	Sig	NS	NS	Sig	NS	NS	Sig
Interaction C × F												
SE (m) ±	0.042	0.045	0.002	0.033	0.028	0.002	0.031	0.027	0.002	0.32	0.19	0.02
CD at 5%	-	-	0.005	-	-	0.006	-	-	0.007	-	0.59	0.06
F test	NS	NS	Sig	NS	NS	Sig	NS	NS	Sig	NS	Sig	Sig
Initial value		0.475			0.350			0.142			2.464	

flowering and harvest stage was recorded by rice straw @2.5 t/ha + Ain leaf residue @2.5 t/ha followed by Ain leaf residue @5 t/ha and rice straw @5 t/ha which were found at par with each other during flowering and at harvest of rice than 75% and 50% NPK alone. In case of fertilizer levels, application of 100% NPK recorded maximum fulvic acid in soil (0.228, 0.219, 0.213 g 100/g soil humus) during tillering, flowering and at harvest stage of rice. The lowest value (0.159, 0.155, 0.140 and 0.185, 0.187, 0.179 g 100/g soil humus) at tillering, flowering and harvest stage was noted in 50% NPK alone during both the levels. The interaction effect of crop residue and fertilizer levels were observed statistically non-significant at tillering and flowering stage of rice but it was significantly influenced at harvest stage of rice (Table 1). It seems that the fulvic acids are simpler in nature and more stable, more resistant to coagulating action of electrolyte than humic acid (Kononova 1966). Gathala *et al.* (2007), Meshram *et al.* (2016) and Meshram *et al.* (2018) noticed under long-term experiment that the application of 100% NPK along with organic manure significantly improved fulvic acid content in soil than 50% NPK, 75% NPK alone and absolute control.

Humic acid : Fulvic acid (HA:FA) ratio: Incorporation of crop residues along with chemical fertilizers had statistically significant ($P<0.05$) effect on humic : fulvic acid ratio of soil. Maximum improvement (1.714, 1.692 and 1.690) was reported by the application of rice straw @2.5 t/ha + Ain leaf residue @2.5 t/ha and minimum improvement (2.411, 2.227 and 2.215) was recorded in control (no residue) treatment during tillering, flowering and at harvest stage of rice. In case of fertilizer levels, application of 100% NPK improved humic : fulvic acid ratio of soil (1.734, 1.740 and 1.752) at tillering, flowering and at harvest stage of rice than 75% and 50% NPK. Less improvement (2.020, 1.973 and 1.927) was observed in 50% NPK treatment during tillering, flowering and at harvest stage in rice due to unbalanced use of fertilizers (Table 1). Improvement in the humic acid : fulvic acid ratio may be due to the degradation of fulvic acid which is very high in proportion to humic acid and it also may be the

Table 2 Effect of crop residues and fertilizers on grain and straw yield of rice (q/ha)

Treatment	Grain	Straw
Crop residue level		
C_1 : Rice straw @5 t/ha	46.50	53.49
C_2 : Ain leaf residue @5 t/ha	47.37	55.71
C_3 : Rice straw @2.5 t/ha + Ain leaf residue @2.5 t/ha	47.83	55.13
C_4 : Control (No residue)	27.74	30.99
SE(m) ±	1.05	2.02
CD at 5%	3.63	6.98
F-test	Sig	Sig
Fertilizer level		
F_1 : 100 % NPK	44.77	51.77
F_2 : 75 % NPK	42.86	48.78
F_3 : 50 % NPK	39.45	45.94
SE(m) ±	0.68	0.73
CD at 5%	2.68	2.86
F-test	Sig	Sig
Interaction C × F		
SE(m) ±	3.64	4.41
CD at 5%	11.20	13.60
F-test	Sig	Sig

contribution of organic matter and humus synthesis in soil by the residue and fertilizer application (Kononova1966). Similarly, Santhy *et al.* (2001), and Banik and Sanyal (2006) suggested that naturally occurring humic acid had a more complex structure with an essentially hydrophobic nature as compared to the corresponding fulvic acid and synthetic analogues of humic acid. However, Gathala *et al.* (2007), Meshram *et al.* (2016) and Meshram *et al.* (2018) reported considerable improvement in HA:FA ratio with conjoint use of organic manure and fertilizers.

Grain and straw yield of rice: The maximum grain and straw yield (47.83 and 55.71 q/ha) of rice was recorded by the application of rice straw @2.5 t/ha + Ain leaf residue @2.5 t/ha over control (no residue). It was found to be at par with C_1-rice straw @5 t/ha and C_2-Ain leaf residue @5 t/ha. The lowest rice grain and straw yield (27.74 and 30.99 q/ha) was recorded in control (no residue). In case of fertilizer levels, application of 100% NPK gave significantly higher grain yield and straw yield (44.77 q/ha and 51.77 q/ha) of rice compared to 50% NPK and 75% NPK. The interaction effect of crop residue along with fertilizers was found significant in grain and straw of rice which may be due to balanced integration of organic matter and fertilizers (Table 2). It may be because organics are beneficial in reducing the fixation or precipitation with those of soil components of added or mineralized nutrients and played complementary role to boost the crop grain and straw yield. This could be attributed to the fact that soil fertility and soil productivity of the plots receiving both inorganic and organic source of nutrients were better as compared to control and chemical fertilizer alone (Mandal *et al.* 2004). Singh *et al.* (2019) stated that all the yield attributes were higher with the substitution of crop residue/manure in combination with 50–75% RDF due slow release and continuous supply of balanced quantity of nutrients throughout the various growth stages which enables the rice plants to assimilate sufficient photosynthetic products and thus, increases the dry matter and source capacity, resulting in the production of increased grain and straw yield. Therefore, sustained efforts are needed to improve and maintain the most important natural resource base, the soil, through judicious integration of mineral fertilizers, organic manure and crop residues.

It can be concluded that the application of rice straw @2.5 t/ha + Ain leaf residue @2.5 t/ha along with 100% NPK is most useful for improving humus fractions and getting higher yield of rice in Alfisols. Build-up of soil humus (Humin, humic acid, fulvic acid and humic : fulvic acid ratio) was observed due to balanced application of crop residue along with fertilizer management practices for developing bio-stability in soil which helps maintain soil health.

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