Original Research Article

Effect of different *kharif* paddy straw management options and nitrogen levels on soil organic carbon and soil total carbon and nitrogen

Abstract

A field experiment was conducted during *rabi* 2020-21, at Regional Agricultural Research Station, Polasa, Jagtial, PJTSAU to study the effect of paddy straw burning and incorporation on soil organic carbon, total carbon and nitrogen and soil C:N ratio. The results of the investigation reported that incorporation of paddy straw whose C:N ratio was 71:1 showed that soil organic carbon was significantly higher under paddy straw incorporated treatments. Total carbon content of soil in paddy straw burnt treatments was 1.07 times higher than initial and in paddy straw incorporated treatments 1.51 times higher over initial was observed. Soil total nitrogen decreased with crop duration. At harvest soil total nitrogen was 2606 kg ha^{-1}, 2693 kg ha^{-1} and 1931 kg ha^{-1} in paddy straw burning, paddy straw incorporation without phosphorus, paddy straw incorporation with phosphorus respectively. C:N ratio of soil is not influenced by paddy straw management options, nitrogen levels and the interaction between them.

Introduction

Straw return incorporation is an efficient agronomic practice to improve soil organic matter. Rice is the most residue producing crop. In future with increase in grain production will led to enormous generation of straw. With the intensification of irrigated rice cropping, total crop residue production has increased by 64% over the last 30 years (FAOSTAT, 2009). With one tonne of rice grain produced about 1.35 t of paddy straw will be produced (Kadam *et al*., 2000). Managing rice straw remains a challenge where more rice, and hence, more straw, is grown each year to meet rising demand. Globally, roughly 800 to 1000 Mt per annum of rice straw is produced, with about 600 to 800 Mt per annum produced in Asia (Bhuvaneshwari *et al*., 2019). And due to scarcity of labour and high labour cost involved in its removal from the field and also with little management options burning of paddy straw is adapted and it has been increased dramatically over the last decade. Currently, out of the total straw produced more than 80% is being burnt by farmers in the months of October-November (Singh *et al*., 2010). Though it has some positive effects in managing pests, it also leads to loss of essential soil nutrients – upto 80 % N, 25% P, 21% K and 4-60% S and 13 tonnes per ha of carbondioxide causing loss of soil organic matter (Mandal *et al*., 2004), reduces microbial diversity (Zhang *et al*., 2014). It also causes air pollution by releasing carbon dioxide, carbon monoxide, methane, sulphur and nitrous oxides and particulate matter into the atmosphere (Jain *et al*., 2014). On burning one ton of paddy straw about 1460 kg CO_2, 60 kg CO, 2 kg SO_2 and 199 kg ashes are released into atmosphere which are associated with human respiratory problems Lohan *et al*. (2018). This has led to bans on open-field straw burning in most major rice-producing areas. Straw in its dry matter contains 0.5 to 0.8 % N, 0.16 to 0.27 % P, 1.4 to 2.0% K, 0.05 to 0.10% S and 4 to 7% silica (Dobermann and Fairhurst, 2002). As rice crop residues are removed after each harvest, there is less organic matter added from crop residues to the soil in the paddy field, resulting in a lower concentration of soil C in paddy fields compared to the natural ecosystem. (Wang *et al*., 2014a). Paddy soil with lower SOC content than natural soil provides high absorption of additional C when appropriate management measures like use of organic fertilizers, incorporation of crop residues, management of water regimes etc were adopted (Wissing *et al.,* 2011).Crop residues typically contain between 40 and 45 percent carbon. If crop leftovers are returned to the soil, the soil microbes will use the carbon to increase the organic matter in the soil, which will prevent the loss of organic carbon (Fu*et al*., 2021).The biological characteristics of soil are directly influenced by soil organic carbon (Blanco *et al*., 2013 and Vartharajan *et al*., 2022).

The objectives of this study were to investigate the effects of straw incorporation on the total organic carbon and soil total nitrogen concentrations in the paddy field as affected by paddy straw incorporation and different levels of nitrogen.

Material and methods

The experiment was conducted at Regional agricultural research station, Polasa, Jagtial district. It is situated in the Northern Telangana Zone. The experimental site is located between 18º 51' 53'' N latitude and 78º 56'21'' E longitude at an altitude of 243.4 m above mean sea level (MSL). The soil of the experimental site was sandy clay loam, which is medium in organic carbon (0.54%), low in soil available nitrogen 157.6 kg ha^{-1}, high in soil available phosphorus (31.05kg ha^{-1}) and potassium (309.5kg ha^{-1}). The experiment was laid out in Factorial RBD, with 2 factors, factor 1 comprised of 3 levels and factor 2 comprised of 4 levels with a total of 12 treatments and replicated thrice. Paddy straw mulcher was run to chop it and is incorporated 10 days before transplanting. Paddy (variety- JGL-24423) was transplanted with a spacing of 15x15cm. The recommended dose of fertilizer was 150:60:40 kg N, P_2O_5, K_2O ha^{-1}. The entire recommended dose of phosphorus and potassium was applied as basal dose in the form of SSP and MOP respectively. Nitrogen was applied in 3 splits and the excess of RDN was applied at basal in the form of urea.

Estimation of total nitrogen was done by taking 2.0 g of soil in to 500 ml kjeldahl flask, the soil was swirled with 1g of salicylic acid and 20 ml of concentrated H_2SO_4 for 30 minutes at room temperature. Then added 5 g of sodium thiosulphate and 20 g of digestion mixture, allowed the contents for digestion and run the distillation unit by 40% sodium hydroxide, the released ammonia trapped in to 4% boric acid mixed indicator solution and titrated against 0.01 *N*sulphuric acid until bluish green colour turns pink, the used up sulphuric acid gives the titer value for calculating total nitrogen content in soil (Page *et al*., 1972). For estimation of total soil organic carbon by (Nelson and Somner, 1982), 0.5 g of 0.5 mm mesh sieved soil samples were oven dried at 105˚ C overnight, cooled in a desiccator and weighed in digestion tubes and digested with a digestion mixture (0.4 N potassium dichromate and 18 *N* sulphuric acid) under 150°C for 45 minutes in a digestion chamber. After cooling it was titrated against 0.2 *N* ferrous ammonium sulphate using o-phenanthroline, ferrous sulphate indicator. Organic carbon present in soil sample was determined by wet oxidation method given by Walkley and Black (1935).

List 1:Treatment details

T_1	100% RDN + Residue burning
T_2	10% excess N over RDN + Residue burning
T_3	15% excess N over RDN + Residue burning
T_4	20% excess N over RDN + Residue burning
T_5	100% RDN + Residue incorporation without phosphorus
T_6	10% excess N over RDN + Residue incorporation without phosphorus
T_7	15% excess N over RDN + Residue incorporation without phosphorus
T_8	20% excess N over RDN + Residue incorporation without phosphorus
T_9	100% RDN + Residue incorporation with P application through SSP
T_{10}	10% excess N over RDN + Residue incorporation with P application through SSP
T_{11}	15% excess N over RDN + Residue incorporation with P application through SSP
T_{12}	20% excess N over RDN + Residue incorporation with P application through SSP

Result and discussion

Organic carbon content (%) of soil

Incorporation of paddy straw into soil improves soil organic matter, nutrient availability (Chen *et al*., 2006), increases soil microbial biomass and enhancing various enzymatic activities (Tu *et al*., 2006). It is the core of soil quality and is critical for food production and security (Zhao *et al*., 2018). The data on soil organic carbon (%) at different intervals as significantly influenced by residue management options is furnished in table 1. The effect of different nitrogen levels on soil organic carbon was found to be non significant. Similarly, the interaction between paddy straw management and nitrogen levels was also found to be non significant. At 30 DAT Paddy straw incorporation with phosphorus recorded high organic carbon (0.60%), which is on par with paddy straw incorporation without phosphorus (0.56%). Lower values of organic carbon were recorded in burning treatments (0.51%). At 60 DAT, paddy straw incorporation along with phosphorus addition recorded higher organic carbon (0.62%). Though, it is on par with paddy straw incorporation without phosphorus (0.58%), it was significantly superior to that of burning treatments (0.52%). After harvest, the trend in soil available OC is akin to that of 30 and 60 DAT. At all the stages lower values of organic carbon were recorded in burning treatments.

Singh *et al*. (2015) reported that paddy straw retention could enhance the soil organic carbon and nitrogen. Though, paddy straw incorporation with and without P treatments recorded significantly higher soil organic carbon than burning, the increase in soil organic carbon was maximized due to paddy straw incorporation with phosphorus application in the current field investigation. The increase in soil organic carbon with residue incorporation is consistent with Ali and Nabi (2016). Xionghui*et al*. (2012) reported that increase in soil organic carbon due to combined application of crop residue and NPK. It might be due to transformation of residual carbon into microbial carbon during decomposition of incorporated paddy straw (Moran *et al*., 2005). Burning kills the soil beneficial micro flora and fauna and removes large portions of organic matter thereby decreasing organic carbon of the soil (Singh *et al*., 2010, Singh*et al*., 2004).Results reported by Korav*et al*. (2024) also are on the sameline showing increase in soil organic carbon by incorporation of paddy residues and decreases in organic carbon content by burning in rice wheat cropping system. The outcome of the investigation of Gupta *et al*., 2022 revealed that the When various straw management strategies were used over time, there were positive changes in the amounts of organic carbon and its constituents.

Table.1. Change in soil organic carbon (%) at different by intervals of rabi rice as influenced by different kharif paddy straw management options and fertilizer N levels.

Treatments	30 DAT	60 DAT	After Harvest
Paddy straw management			
Residue burning	0.51	0.52	0.56

Incorporation without Phosphorus	0.56	0.58	0.65
Incorporation with P phosphorus	0.60	0.62	0.69
SEm±	0.01	0.01	0.02
CD@ 5%	0.04	0.04	0.05
Nitrogen levels			
100% RDN	0.53	0.55	0.60
110% RDN	0.55	0.56	0.64
115% RDN	0.56	0.58	0.64
120% RDN	0.58	0.60	0.66
SEm±	0.02	0.02	0.02
CD@ 5%	NS	NS	NS
Interactions			
SEm±	0.03	0.03	0.03
CD @ 5%	NS	NS	NS
CV	8.12	8.77	9.29

RB-residue burning, I-P- incorporation without phosphorus, I+P- incorporation with phosphorus, RDN- recommended dose of nitrogen

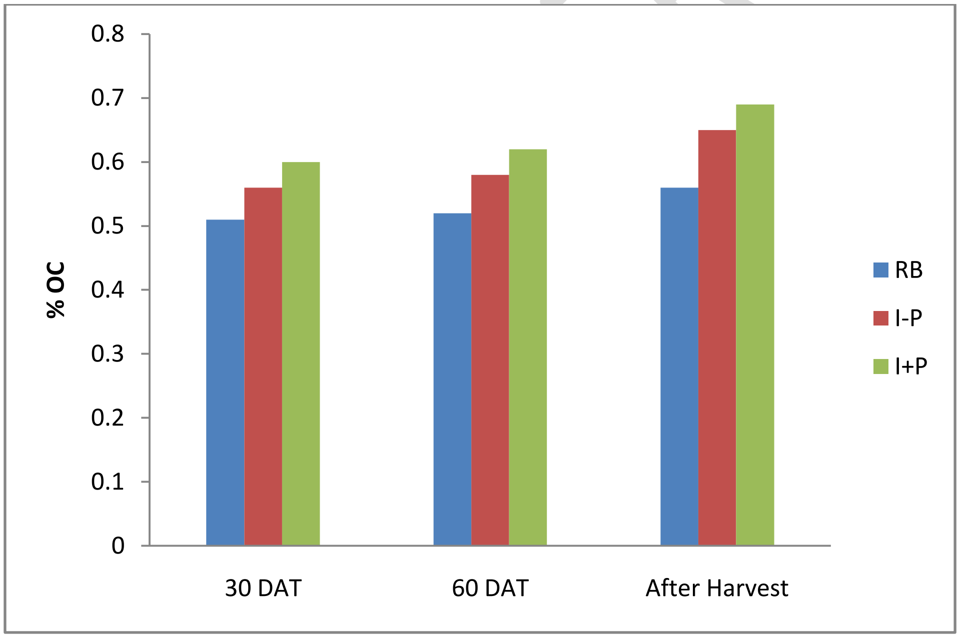

Fig.1. Effect of different *kharif* paddy straw management options on soil organic carbon (%)

Table.2. Effect of different *kharif* paddy straw management options and fertilizer N levels on soil total carbon (%) at different intervals of *rabi* rice

Treatments	7 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	After Harvest
Paddy straw management							
RB	1.06	0.97	0.92	0.91	`0.90	0.88	0.88
I-P	1.44	1.36	1.31	1.30	1.28	1.26	1.24
I+P	1.42	1.37	1.32	1.30	1.28	1.26	1.24
SEm±	0.04	0.04	0.03	0.03	0.03	0.03	0.03
CD@ 5%	0.11	0.11	0.08	0.08	0.08	0.10	0.09
Nitrogen levels							
100% RDN	1.33	1.27	1.21	1.19	1.16	1.13	1.09
110% RDN	1.31	1.24	1.19	1.18	1.16	1.14	1.13
115% RDN	1.30	1.22	1.17	1.16	1.15	1.14	1.14
120% RDN	1.28	1.20	1.16	1.14	1.13	1.13	1.13
SEm±	0.05	0.04	0.03	0.03	0.03	0.03	0.04
CD@ 5%	NS	NS	NS	NS	NS	NS	NS
Interactions							
SEm±	0.08	0.08	0.06	0.06	0.06	0.06	0.06
CD @ 5%	NS	NS	NS	NS	NS	NS	NS
CV	10.58	10.77	8.45	8.26	8.62	9.90	9.94

RB-residue burning, I-P- incorporation without phosphorus, I+P- incorporation with phosphorus, RDN- recommended dose of nitrogen

Effect of paddy straw management practices and nitrogen levels on total carbon content (%) of soil

The data on soil total organic carbon content (%) at different intervals is furnished in Table 2. It was significantly influenced by paddy straw management strategies. However, the graded levels of nitrogen failed to exert significant effect on soil total organic carbon content. Further, the interaction between paddy straw management and nitrogen levels was found to be non significant at all the stages of crop growth.

At 7 DAT, paddy straw incorporation without and with P treatment recorded (1.44% and 1.42%) were at par and both were significantly higher than burning practice (1.06%). The soil total organic carbon content was significantly similar due to combined application of paddy straw and P (1.37%) and (1.36%), but, significantly superior to burning operation (0.97) at 15 DAT. At 30 DAT, paddy straw management showed significant difference in soil total organic carbon content. Paddy straw incorporation with P treatment recorded higher (1.32%) soil total organic carbon content which is on par with paddy straw incorporation without P treatment (1.31%). Lower values were recorded in burning treatment (0.92%). Both paddy straw incorporation with P and without P recorded higher (1.30%) soil total organic carbon content than paddy straw burning treatment (0.91%) at 45 DAT. At 60 DAT, the effect of either paddy straw incorporation with P treatment (1.28%) or without P treatment (1.27%). were same, but, significantly better than burning treatment (0.90%). Paddy straw management showed significant difference in soil total organic carbon content at 75 DAT. Paddy straw incorporation (1.26%) was found to be better and eco-friendly practice than burning (0.88%). With regard to maintenance of soil total organic carbon. At harvest, both paddy straw incorporation with P and without P recorded higher (1.24%) soil total organic carbon content values than paddy straw burning (0.88%).

The amount of total organic carbon (TOC) at all stages of *rabi* rice was statistically similar due to paddy straw incorporation without P fertilizer. Initial total organic carbon content of experimental soil was 0.82%, which has increased upto 1.29% in burnt treatment, 1.75% in incorporation without phosphorous and 1.73% in incorporation with phosphorous at 7 DAT. Lower TOC under burning treatment was due to lower amount of C returned to soil as ash. It is known that burning one ton of paddy straw emits 1460 kg of CO_2, 60 kg CO and 199 kg ash (Lohan *et al*., 2018)release into atmosphere. It means huge amounts of carbon from straw is liberated to atmosphere in the form of gases of particulate matter. However, in the case of paddy straw incorporated treatments 2.5 Mg of C was added through paddy straw. This could be the reason for sudden increase of TOC in incorporated treatments. With time total carbon content was shown to decrease gradually up to harvest in all the treatments. Decrease in TOC might be due to emission of carbon as CH_4 and $CO_{2,}$ which might have released duringmineralization or decomposition of carbon. The anaerobic decomposition of paddy straw under continuously flooded conditions accounts roughly 65% of global CO_2 eq emissions from lowland rice (Allen *et al*., 2020). After harvest, the soil total carbon content in paddy straw burnt treatments was 1.07 times higher than initial and in paddy straw incorporated treatments, it was 1.51 times higher. The higher soil TOC in straw incorporated treatments compared to burnt treatments is due to increased residual carbon input (Malhi *et al*., 2006, Wang *et al*., 2015,Zhu *et al*. 2015, Sharma *et al*., 2020Ghosh *et al*., 2021). Soil total organic carbon decreased with increase in graded levels of nitrogen, and it might be due to induced positive priming effect resulting in a net loss of soil C (Russel *et al*., 2005 andHamer *et al*., 2009,Krishna, 2016). However, our results are in contrast with the findings of Li *et al*. (2019) who observed that soil total organic carbon increased with increased nitrogen levels.

Effect of paddy straw management practices and nitrogen levels on total nitrogen content (%) in soil

The data on soil total nitrogen (kg ha^{-1}) at different intervals is furnished in table 3. The effect of different nitrogen levels on soil total nitrogen content was found to be non-significant. Further, the interactive effect between paddy straw management and nitrogen levels was non-significant.

At all the stages, soil total nitrogen was significantly higher under paddy straw incorporation with and without phosphorus while lower values were recorded under burning practice. After harvest, paddy straw management showed a significant influence on soil total nitrogen. Paddy straw incorporation without phosphorus (2693 kg ha^{-1})being at par with straw incorporation along with phosphorus (2606 kg ha^{-1}) recorded 39.5% higher total nitrogen content over burning practice (1931 kg ha^{-1}).

During final puddling, different grades of nitrogen applied in the form of urea and crop residue were incorporated in respective treatment. This might be the reason for higher levels of total nitrogen at 7 DAT as compared with initial soil total N (1824 kg ha^{-1}). In paddy residue burnt treatments, soil total nitrogen was found to be decreased with time and increased after harvest. The ash left after burning of paddy straw contains high amount of alkali components and contact between applied urea and with straw burnt ash leads to volatilization losses of ammonia resulting in soil lower total nitrogen content (Ma *et al*., 2018) which is expected to show the significant influence on soil properties and many microbial processes. While in paddy straw incorporation with P and without P, the total nitrogen content was decreased gradually upto harvest. The decrease in soil total nitrogen might be due to loss of N, in the form of NO_2during the process of denitrification (Pathak *et al*., 2006) or plant uptake.

Table.3. Effect of different *kharif* paddy straw management options and fertilizer N levels on soil total nitrogen (kg ha^{-1}) at different intervals of *rabi* rice

Treatments	7 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	After Harvest
Paddy straw management							
RB	2149	2034	1978	1974	1951	1921	1931
I-P	2866	2729	2698	2732	2682	2743	2693
I+P	2829	2727	2654	2640	2634	2630	2606
SEm±	61.56	60.34	57.3	58.8	56.98	57.45	58.8
CD@ 5%	180.5	177	168.1	172.6	167.1	168.5	172.4
Nitrogen levels							
100% RDN	2615	2516	2441	2426	2382	2381	2287
110% RDN	2619	2502	2437	2460	2422	2430	2408
115% RDN	2614	2487	2442	2460	2439	2456	2467
120% RDN	2610	2482	2454	2448	2446	2459	2479
SEm±	71.08	69.67	66.17	67.95	65.8	66.94	67.87
CD@ 5%	NS	NS	NS	NS	NS	NS	NS
Interactions							
SEm±	123.1	120.7	114.6	117.7	113.9	114.9	117.6
CD @ 5%	NS	NS	NS	NS	NS	NS	NS
CV	8.15	8.37	8.13	8.32	8.15	8.19	8.45

RB-residue burning, I-P- incorporation without phosphorus, I+P- incorporation with phosphorus, RDN- recommended dose of nitrogen

C:N ratio

The data on soil C:N ratio at different intervals is furnished in Table 4.8. It was not significantly influenced due to either paddy straw management, or nitrogen levels and the interaction between both the practices.

Table 4: Change in C:N ratio of soil at different intervals of *rabi* rice as influenced by different *kharif* paddy straw management options and fertilizer N levels

Treatments	7 DAT	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	After Harvest
Paddy straw management							
RB	11.0	10.77	10.40	10.38	10.29	10.31	10.30
I-P	11.22	11.24	10.93	10.69	10.65	10.35	10.28
I+P	11.28	11.32	11.19	11.05	10.96	10.75	10.68
SEm±	0.16	0.53	0.37	0.42	0.28	0.38	0.32
CD@ 5%	NS	NS	NS	NS	NS	NS	NS
Nitrogen levels							
100% RDN	11.39	11.30	11.13	10.98	10.92	10.69	10.66
110% RDN	11.24	11.18	10.93	10.77	10.72	10.51	10.49
115% RDN	11.11	11.07	10.70	10.59	10.52	10.39	10.33
120% RDN	10.96	10.89	10.60	10.48	10.38	10.29	10.21
SEm±	0.19	0.62	0.43	0.49	0.32	0.44	0.37
CD@ 5%	NS	NS	NS	NS	NS	NS	NS
Interactions							
SEm±	0.32	0.62	0.74	0.84	0.55	0.76	0.65
CD @ 5%	NS	NS	NS	NS	NS	NS	NS
CV	5.00	16.65	11.85	13.65	8.99	12.53	10.77

RB-residue burning, I-P- incorporation without phosphorus, I+P- incorporation with phosphorus, RDN- recommended dose of nitrogen

Conclusion

Paddy straw incorporation with phosphorus recorded 27.8 % higher amount of soil organic carbon followed by paddy straw incorporation without phosphorus (20.4%) and paddy straw burning (3.7%). Soil total organic carbon was increased with crop duration and with the progress of decomposition. After harvest, soil total organic carbon content in paddy straw burnt treatments was 1.07 times higher than initial and in paddy straw incorporated treatments 1.51 times higher soil total organic carbon than initial was observed. Soil total nitrogen decreased with crop duration. AT 7 DAT, soil total nitrogen was increased to 2829, 2866 and 2149 kg ha^{-1} over initial value (1824 kg ha^{-1}) in paddy straw incorporation with phosphorus, paddy straw incorporation without phosphorus and paddy straw burning respectively. Which was decreased to 2606, 2693 and 1931 kg ha^{-1} respectively after harvest. The interactive effect between paddy straw management and nitrogen levels on soil total carbon content and soil total nitrogen was non-significant. C:N ratio of soil is not influenced by paddy straw management, nitrogen levels and the interaction between them.

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