Original Research Article

Influence of crop residue in addition to decomposition enhancers on soil Nitrogen transformation and available macronutrients status during growth of maize

ABSTRACT: A Greenhouse experiment was conducted on loamy sand soils of Agricultural College, Rajendranagar, Hyderabad during *rabi* 2021-2022 to find out the influence of crop residues in addition to decomposition enhancers on soil nitrogen transformation and available macronutrients status during growth of maize. The crop residues were incorporated in soil during sowing of maize either alone or in combination with decomposition enhanceres (microbial consortia and single super phosphate). The nitrogen transformation and macronutrients assayed at different intervals of maize were significantly increased by the application of crop residue along with microbial consortia. At 30 DAI, 60 DAI and 90 DAI among the treatments, the highest ammonical and nitrate nitrogen and macronutrient status of were recorded with T_9 (T_5 + as Microbial consortium @ 1.5 %) and it was on par with the treatment T_{13} (T_5 + as Single Super Phosphate @5%). At 120 DAI among the treatments highest ammonical and nitrate nitrogen and macronutrient status of were recorded with T_8 (T_4+ as Microbial consortium @ 1.5 %,) and it was on par with the T_6 (T_2+ as Microbial consortium @ 1.5 %). At all intervals the lowest ammonical and nitrate nitrogen and macronutrient status were recorded in control (T_1).

Keywords: Crop residues, Microbial consortium, Nitrogen transformation, Macronutrient status

1. INTRODUCTION

In the modern era of Agriculture, with the evolution of agricultural practices which lead to increase in food production as well as crop residues, hence management of crop residue has become important for sustainable agriculture. In India, rice straw is traditionally removed from the fields and used as cattle feed, but with the recent adoption of machine harvesting in some areas, it has become available in large quantities as a farm waste. Currently, the crop residue left in the field in machine-harvested areas is burnt in situ to clear the fields, with the resultant loss of valuable organic matter and nutrients and increased environmental pollution. Here arises the significance of alternative as well as sustainable ways of crop residues management. The technique of ex situ decomposition of crop residues or composting dates back to several decades, however, is still holding its importance in sustainable crop residue recycling. Nevertheless, the in situ or in-field decomposition of crop residue using microbial consortium is rarely studied. It has already been documented that fungi is potent in the degradation of complex lignocellulosic materials present in crop residues (Arcand *et al*. 2016). Earlier studies have reported the potential of lignocellulolytic fungi for ex situ decomposition of crop residues within a short period (Sahu *et al*. 2019). Besides, single microorganism is not capable to secrete all the required enzymes for optimum biodegradation of lignocellulosic substrate. This necessitated the use of microbial consortia developed by a combination of potent strains of fungi which can perform harmoniously for rapid decomposition of crop residues without any chemical pre-treatment (Kumar *et al*. 2008). Returning crop residues to agricultural soils is a management practice with various ecological benefits, such as sustaining soil organic matter contents and nutrient cycling, improving soil physical properties and increasing crop production (Blanco-Canqui 2013).The effects of crop residues on soil properties and nutrient cycling vary with the duration after soil incorporation. The quality of crop residues also has a marked influence on soil properties during the initial decomposition of residues. Nevertheless, inorganic N immobilized during the early stage of crop residue decomposition may be released again during the later stages of decomposition (Nicolardot *et al*. 2001).

2. MATERIALS AND METHODS. – **Soil**: The present investigation was carried out at Professor Jayashankar Telangana State Agricultural University, College of Agriculture, Rajendranagar, which is located in Ranga Reddy district of Telangana state at an altitude of 542.6 m above mean sea level, 78.4237 °E longitude and 17.3142 °N latitude. The mean maximum and mean minimum temperatures of the location are 28.0 °C to 32.6 °C and 10.1 °C to 23.9 °C respectively. The soil required for the present experiment has been collected from B block of Student Farm by following random sampling technique. Bulk soil samples were collected from Student Farm for conducting Pot culture experiment. The collected soil samples from Student Farm were air dried under shade. Later dried samples were ground properly by wooden mortar and pestle and then sieved by using 2 mm sieve.

Crop residues: Rice straw, maize stover, cotton stalks and sunhemp residues were collected from farmers' fields after harvest. Crop residues collected after harvest were shade dried followed by drying in hot air oven at 60°C. Oven dried plant samples were powdered in a stainless-steel grinder then stored in butter paper covers and labeled properly.

Analytical procedures: The pH and EC of soil samples were estimated using pH meter and EC meter (Jackson, 1973). The available N, P and K were determined using the alkaline $KMnO_4$ method (Subbiah and Asija 1956), Olsen extractable P method (Olsen *et al*. 1954) and neutral ammonium acetate method **(**Jackson 1967) respectively. Inorganic nitrogen fraction of soil was analyzed by the procedure described by Keeney and Nelson, 1982. The initial chemical quality of the residues was assessed by determining their lignin, C:N and total phenols contents. Lignin was determined by the acid detergent fibre method (Goering and van Soest, 1970). Total C in crop residues was determined by the weight loss on ignition method (Allen *et al*. 1986) and total N in crop residues was determined by outlined procedure AOAC, 1995. Total phenol content in different crop residues was determined by the Folin-Ciocalteau method (Singleton *et al.* 1999).

Green house study: The 2 mm sieved soil was mixed with crop residue as per the treatments and after mixing of crop residues the pot was filled with soil @ 5 kg pot^{-1}. Decomposer enhancers viz., microbial consortium was applied @1.5 % to crop residues and single super phosphate @ 5 % to crop residues and mixed thoroughly before filling the pots according to treatments. Microbial consortium consists of *Aspergillus nidulus*, *Phanerochaete chrysosporium*, *Trichoderma viridae*, *Aspergillus awanmori*. The test crop used in this experiment was maize (DHM 117). Nitrogen (N), Phosphorous (P_2O_5) and Potassium (K_2O) were applied @ 240-80-80 kg ha^{-1} (72.86 - 32.38 - 32.38 mg pot^{-1}) uniformly to all the treatments including control. The treatments were fixed at the initiation of the experiment (*Rabi 2021-2022*). The details of treatments are T_1: control (No Crop residue), T_2: Rice straw @ 28 per pot, T_3: Cotton stalks @ 28 per pot, T_4: Maize stover @ 28 per pot, T_5: Sunhemp residue @ 28 per pot, T_6: T_2+ + as Microbial consortium @ 1.5 %, T_7: T_3+ as Microbial consortium @ 1.5 %, T_8: T_4+ as Microbial consortium @ 1.5%, T_9: T_5 + as Microbial consortium @ 1.5%, T_{10}: T_2 + as Single Super Phosphate @5%, T_{11}: T_3 + as Single Super Phosphate @5%, T_{12}: T_4 + as Single Super Phosphate @5%, T_{13}: T_5 + as Single Super Phosphate @5%.

3. RESULTS AND DISCUSSION

3.1 Ammonical and nitrate nitrogen

The influence of incorporation of crop residues (rice straw, cotton stalks, maize stover and sunhemp residue) along with microbial consortia and single super phosphate on ammonical and nitrate-N content in soil estimated at 30 days interval in maize was presented in table 3. The data revealed that there was a significant influence of treatments on ammonical and nitrate-N content at all intervals. At 30 DAI the ammonical and nitrate nitrogen contents maximum were observed in all the treatments compared to the 60DAI, 90 DAI and 120 DAI. At 30 DAI and 60 DAI among the treatments significantly highest ammonical and nitrate nitrogen contents were recorded in T_9 and it was on par with T_{13}. At 90 DAI among the treatments highest were recorded in T_9 and it was on par with T_8 and T_6. At 120 DAI highest were recorded in T_8 followed by T_{12} and T_6. At all intervals significantly were recorded in case of in control (T_1)

The significantly higher ammonical and nitrate nitrogen contents were recorded when crop residue was applied along with microbial consortium and crop residue along with single super phosphate when compared to only residues treated treatments. Overall it can be concluded that the ammonical and nitrate nitrogen were immobilized in the soil amended with only crop residues (T_2: rice straw, T_3:cotton stalks and T_4: maize stover) due to high C:N ratio and low N concentration expect T_5: Sunhemp due to lower C:N ratio (18.52) and high N concentration (2.60%) and mineralized in the treatments which received single super phosphate and treatments received crop residue along with microbial consortium due to narrowed the C:N ratio of crop residues and favors the net mineralization of nitrogen. The results were in agreement with Yadvindersingh *et al*. (2004). Adding high quality residues with low C:N resulted in greater releases of residue-N into the mineral N pool and greater fluxes of residue-derived N. Other studies have found low C:N increases residue-N mineralization Khalil *et al*. (2005). Data also indicated high nitrate nitrogen contents than ammonical nitrogen, which could be due to the nitrification under aerobic conditions. The results were agreement with finding of Chen *et al*. (2017), Kaleem *et al*. (2015)

3.2 Available macronutrient status

The influence of incorporation of crop residues (rice straw, cotton stalks, maize stover and sunhemp residue) along with microbial consortia and single super phosphate on the available macronutrient status viz., nitrogen, phosphorus and potassium in soil estimated at 30 days interval in maize was presented in table 4 to 6.

At 30 DAI and 60 DAI among the treatments significantly highest available nitrogen, phosphorus and potassium content were recorded in T_9 which was on par with T_{13} due to sunhemp residue low C: N ratio along with decomposer enhancer. At 90 DAI among the treatments highest available nitrogen, phosphorus and potassium content were recorded in T_8 which was on par with T_6, T_9 and T_7 in case of nitrogen and phosphorus and it was on par with all the crop residue along microbial consortium (T_6, T_7 and T_9) and crop residue along with single super phosphate (T_{10}, T_{11}, T_{12} and T_{13}) in potassium. At 120 DAI among the treatments highest available nitrogen, phosphorus and potassium content were recorded in T_8 which was on par with T_6 in case nitrogen and phosphorus and it was on par with all crop residue along with microbial consortium (T_6 T_7, T_9 and T_{12}) in potassium. At all intervals the lowest available nitrogen, phosphorus and potassium were recorded in case of in control (T_1).

Incorporation of only crop residue (rice straw, maize stover, cotton stalks and sunhemp residue) recorded lowest content of nitrogen when compared to the treatments which received crop residue along with the decomposition enhancer (single super phosphate and microbial consortia). This was elucidated by bare application of crop residue like maize stover, rice straw and cotton stalks are lignocellulosic material which are resistant initially to microbial degradation due to high C:N ratio, high lignin content and high phenol content. The inhibition of decomposition by phenolics can occur via formation of covalent bonds with proteins, decreasing N mineralization and enhancing N limitation to microorganisms. It may result adverse effect on the soil available nutrients due to immobilization of nutrients by the presence of wide C:N ratio residues unaccessible to microbial population present in the soil. On the other hand nitrogen application (RDN) on the residues narrows down the C:N ratio which ultimately becomes easy access for the microbial population and thus decomposition of the residues resulting into increased organic matter and available nutrients. Inoculation of microbial consortia consisting of *Aspergillus nidulans*, *Phanerochaete chrysosporium*, *Aspergillus awanmori* and *Trichoderma* species further accentuated the decomposition process and thus substantially lowering of the C: N ratio. It is likely that a two-step process for degradation would have followed as the primary stage to narrow down C:N ratio of residues by application of urea, hydrolysis of micro-molecules by acid /base reaction of the urea followed by secretion of the extracellular-enzymes for breaking down polymers as well as sequestration of the carbon from the residues resulting into its decomposition .The results were in agreement with Saria *et al*. (2018) and Sharma *et al*. (2012).

In case of phosphorus addition of crop residues adversely affects the availability of nutrients due to immobilization and adsorption. But in the present study improved phosphorus status was due to allotment of sufficient time and the residue was treated with decomposition enhancers (single super phosphate and microbial consortia) which hastened the process of decomposition and release of phosphorus. Further it was attributed that crop residue management leads to the accumulation of more organic matter at the surface soil, which decreases phosphorus sorption by inorganic colloids. Though the added crop residues was not rich in phosphorus however, it improves soil physical properties and at the same time stimulate microbiological activity, which makes available phosphorus in the soil more readily available to plants. Significant increase in the availability of phosphorus in soil was observed by Jalali and Ranjbar (2009) and Yan *et al*. (2019).

In case potassium the present study the benefits of application of crop residues (rice straw, cotton stalks, maize stover and sunhemp residue) were realized in improving the fertility status of soil. This might be due to the N, P and K concentrations in crop residues reached critical levels to enable transition from immobilization to mineralization (Hoorman *et al*., 2010). The increase in available K due to crop residue application might be attributed to the direct addition of potassium to the available pool of the soil besides the reduction of potassium fixation and release of potassium due to the interaction of organic matter with clay (Tandon and Sekhon, 1988). The organic acids released during decomposition of manures mobilize the native or nonexchangeable forms of potassium and charge the soil solution with potassium ions, so that it will be readily available. Significantly lowest potassium content was observed in control plot due to cultivation decreased the water soluble K. Similar improvement in K status with incorporation of crop residues was earlier reported by Yadvinder singh *et al.* (2004). The inverse relationship between C:N ratio and N,P,K contents at all stages of crop growth. This implies that during the decomposition of crop residues slow release of NPK occurs at higher C:N ratio than lower C:N ratios.(Kriauciuniene *et al.*, 2012)

4. CONCLUSIONS

The Nitrogen transformation and macronutrients status were higher in residue treated pots along with microbial consortium. Better soil macronutrient status even at harvest in residue treated soils compared to no residue treated soils as well as initial values indicated a positive influence of organics in sustaining soil health and in turn improving the productivity.

Table 1: **Initial soil properties**

Characteristic	value
Soil pH (1:2.5, soil: water)	7.68
EC (dSm^{-1})	0.48
Available N	130
Available P_2O_5	37
Available K_2O	285
Ammonical N (mg kg^{-1})	26.45
Nitrate N (mg kg^{-1})	35.72

Table.2 **The composition (dry-weight basis) of the crop residues**

Crop residues	Total Carbon (%)	Total N (%)	C:N	Lignin (%)	Total phenols (mg GAE /100g)
Rice straw	44.72	0.73	61.30	19.60	211.75
Cotton stalks	48.10	0.82	58.66	18.50	196.83
Maize stover	48.88	0.77	63.49	21.01	216.65
Sunhemp residues	48.14	2.60	18.52	4.20	103.73

Table 3: Effect of incorporation of crop residue along with microbial consortium and single super phosphate on soil available nitrogen status (kg ha^{-1}) of maize

TREATMENTS	30 DAI	60 DAI	90DAI	120 DAI
T_1:Control(No residue addition)	163	152	148	118
T_2: Rice straw	182	173	151	127
T_3: Cotton stalks	191	186	145	124

T_4: Maize stover	174	165	155	137
T_5: Sunhemp residue	212	203	152	123
T_6: T_2+Microbial consortium @1.5%	223	209	180	146
T_7: T_3+ Microbial consortium @1.5%	233	215	163	133
T_8: T_4+ Microbial consortium @1.5%	211	200	185	153
T_9: T_5+ Microbial consortium @1.5%	256	239	181	129
T_{10}: T_2+ Single super phosphate @5%	209	197	165	135
T_{11}: T_3+ Single super phosphate @5%	216	205	155	128
T_{12}: T_4+ Single super phosphate @5%	202	186	172	144
T_{13}: T_5+ Single super phosphate @5%	240	227	167	126
SEm ±	5.55	5.51	4.47	3.30
CD (P=0.05)	16.15	16.02	13.00	9.60

Table 4: Effect of incorporation of crop residue along with microbial consortium and single super phosphate on soil available phosphorus status (P_2O_5 kg ha^{-1}) of maize

TREATMENTS	**30 DAI**	**60 DAI**	**90DAI**	**120 DAI**
T_1:Control(No residue addition)	72	62	41	34
T_2: Rice straw	84	74	49	39
T_3: Cotton stalks	92	85	46	37
T_4: Maize stover	78	65	50	40
T_5: Sunhemp residue	108	98	48	36
T_6: T_2+Microbial consortium @1.5%	121	99	70	57
T_7: T_3+ Microbial consortium @1.5%	129	110	68	56
T_8: T_4+ Microbial consortium @1.5%	114	89	71	61
T_9: T_5+ Microbial consortium @1.5%	143	126	69	54
T_{10}: T_2+ Single super phosphate @5%	108	87	57	46
T_{11}: T_3+ Single super phosphate @5%	116	98	60	48
T_{12}: T_4+ Single super phosphate @5%	102	78	63	54
T_{13}: T_5+ Single super phosphate @5%	134	116	59	46
SEm ±	3.15	2.30	1.71	1.30
CD (P=0.05)	9.17	6.68	4.96	3.78

Table 5: Effect of incorporation of crop residue along with microbial consortium and single super phosphate on soil available potassium status (K_2O kg ha^{-1}) of maize

TREATMENTS	**30 DAI**	**60 DAI**	**90DAI**	**120 DAI**
T_1:Control(No residue addition)	384	342	316	255
T_2: Rice straw	409	377	331	278
T_3: Cotton stalks	418	386	322	269
T_4: Maize stover	401	365	345	289

T_5: Sunhemp residue	445	413	337	265
T_6: T_2+Microbial consortium @1.5%	465	423	367	314
T_7: T_3+ Microbial consortium @1.5%	477	425	363	313
T_8: T_4+ Microbial consortium @1.5%	457	421	373	332
T_9: T_5+ Microbial consortium @1.5%	512	470	370	310
T_{10}: T_2+ Single super phosphate @5%	446	407	354	294
T_{11}: T_3+ Single super phosphate @5%	458	409	349	291
T_{12}: T_4+ Single super phosphate @5%	442	402	362	321
T_{13}: T_5+ Single super phosphate @5%	496	458	355	289
SEm ±	11.06	11.47	9.57	7.78
CD (P=0.05)	32.15	33.33	27.83	22.62

Table 6: Effect of incorporation of crop residue along with microbial consortium and single super phosphate on soil nitrate and ammonical nitrogen status (mg kg^{-1}) of maize

Treatments	**30DAI**		**60 DAI**		**90 DAI**		**120DAI**	
	NH_4^+	**NO_3^-**	**NH_4^+**	**NO_3^-**	**NH_4^+**	**NO_3^-**	**NH_4^+**	**NO_3^-**
T_1:Control(No residue addition)	59	67	39	47	26	34	21	29
T_2: Rice straw	64	73	44	51	32	39	30	38
T_3: Cotton stalks	67	77	47	56	28	36	25	33
T_4: Maize stover	61	70	42	50	36	43	33	41
T_5: Sunhemp residue	81	91	51	58	40	49	24	32
T_6: T_2+Microbial consortium @1.5%	86	100	66	79	52	64	36	44
T_7: T_3+ Microbial consortium @1.5%	88	103	69	87	50	63	32	40
T_8: T_4+ Microbial consortium @1.5%	83	96	63	78	54	67	40	48
T_9: T_5+ Microbial consortium @1.5%	103	121	93	107	56	69	29	37
T_{10}: T_2+ Single super phosphate @5%	70	81	50	69	47	47	33	41
T_{11}: T_3+ Single super phosphate @5%	77	89	57	76	39	44	30	38
T_{12}: T_4+ Single super phosphate @5%	68	79	48	68	44	58	36	44
T_{13}: T_5+ Single super phosphate @5%	95	110	83	98	49	62	28	36
SEm ±	2.02	2.43	1.67	2.17	1.16	1.22	0.78	1.06
CD (P=0.05)	5.88	7.07	4.860	6.325	3.375	3.570	2.269	3.102

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