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Use of Lignocellulolytic Microbes for In-situ and Ex-situ Wheat Residue Decomposition

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ABSTRACT

Crop residue is one of the various kinds of agricultural waste produced annually. In order to handle the massive amount of crop leftover and have the field ready for the succeeding crop ahead of schedule, farmers choose to burn the residue. In addition to contributing to global warming, crop residue burning has grown to be a serious environmental vis-à-vis soil health concern. Taking into account the abovementioned circumstances, a participatory field trial was carried out during 2021-22 and 2022-23 in Pipariya Kalan and Khairi villages of Shahpura and Patan blocks of Jabalpur district in Madhya Pradesh. Rice-wheat farming, the primary cause of crop residue fires, was the pattern utilized in the trial. The current study aimed to compare three treatments: crop residue removal for ex situ decomposition (ED), in situ decomposition (ID), and residue burning (RB) in field. The pooled data of two years indicated that the ED residue completely decomposed in 52 d after use of lignocellulolytic bacterial and fungal based microbial consortia over traditional decomposition (TD) practices where it took 95 d. Organic carbon (14.88%), nitrogen (0.97%), phosphorus (0.55%), and potassium (0.79%) contents were greater in ED than that of residues decomposed conventionally. Soil samples from in situ decomposition (ID) and the RB fields were taken before onset of monsoon and analyzed for SOC, available N, P and K contents. The results of the in situ decomposition of wheat residue using bacterial and fungal base microbial inoculants and residue burnt (RB) fields showed that the soil organic carbon (SOC), available N, P, and K status decreased by 11.48, 27, 13.62, and 16.55 per cent in the burnt fields, respectively. These values were recorded as 0.61%, 175.66, 18.32, and 231.77 kg/ha in the RB fields, and 0.68%, 223.08, 20.81, and 270.13 kg/ ha in the ID fields respectively.

Key Words: Decomposition, *Ex situ*, *In situ* decomposition, Microbial inoculants, Residue burning.

INTRODUCTION

India produces a large amount of crop residues every year, thirty percent of which contributed by rice and wheat. According to Singh *et al* (2019) rice and wheat contribute to 62% of the crop residue that is burnt, which accounts for 16% of the total quantity. Bhattacharjya *et al* (2019) estimated that 683 million tonnes of crop residue are produced on and off farms by ten key crops grown in India: rice, wheat, sorghum, pearl millet, barley, finger millet, sugarcane, potato tubers, pulses, and oilseeds. When harvesting the crop, combined harvesters leave a lot of standing stubble in the field because they don't remove entire plants. In India, 92 Mt of crop waste are burnt annually as a result of improper disposal practices (Bhuvaneshwari *et al*, 2019). Since burning crop residue is the most economical method of preparing the field for the next crop, farmers choose it as a simple and quick approach to manage the substantial volume of crop residue. One of the main causes of the country's rising agricultural residue burning rates is the replacement of human harvesting methods with mechanical ones through combination harvester harvesting, which is a consequence of a labour shortage. Crop residue burning in the field has been widely used in the states of Punjab, Haryana, Uttar Pradesh, and Uttarakhand after the harvesting of rice and wheat crops using combined harvester (Sarkar *et al*, 2018).

Gupta *et al* (2004) reported that burning crop stubble raises soil temperatures to 33.8–42.2 °C. Along with reducing the bacterial and fungal populations in the top 2.5 cm of the soil, burning

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also causes the soil's nitrogen content to be lost by 27–73%. Additionally, the bacterial population can be reduced by more than 50% by repeated burning. Long-term burning may reduce the amount of total N, C, and possibly mineralized N in the soil's top layer. The intact loss of paddy straw burning has been reported to be around 79.38, 183.71, and 108.86 kg/ha N, P, and K, respectively (Sahu *et al*, 2015). Therefore, continuing to remove and burn it could result in net nutrient losses, which would ultimately raise the cost of nutrient inputs in the short term and, in the long term, lower soil health and productivity. Moreover, burning residue is a primary source of trace gases and finer black carbon particles, which play a major role in the formation of ozone through photochemical reactions between its precursor VOCs and NOx, ultimately increasing radiative forcing into the atmosphere (Romasanta *et al*, 2017). According to a study, burning biomass is a major cause of air pollution in Asian nations, especially in China, India, and Indonesia, where air quality is rapidly declining (Andini *et al*, 2018). According to Gadde *et al* (2009) and IPCC (2013), open burning of residues also increases emissions of greenhouse gases (GHGs), including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Ex situ decomposition, or composting, is a crop waste management practice that has been around for a few decades, but it is still important for sustainable crop residue recycling. However, there is not much research on the in situ or in-field the decomposition of crop residue utilizing microbial inoculums. It is a big challenge to not only achieve complete decomposition but also to increase the rate of in situ decomposition so that farmers can use the land for forthcoming crops. The residue's lignin and cellulose contents are thought to be the main factors controlling how quickly the material degrades. Prior studies (Hosseini and Aziz, 2013; Zhang *et al*, 2011) have employed acid or alkali pre-treatments to quicken the rate of decomposition in ex situ crop residue recycling; however, they are not practicable or cost-effective in in-situ conditions. Therefore, using lignocellulolytic microorganisms to speed up the breakdown of crop residues appears to be the most practical, affordable, and environmentally benign approach. Moreover, the in situ decomposition of crop residue may also increase soil health and productivity and enrich soil carbon (Sahu *et al*, 2015; Zhao *et al*, 2016; Goswami *et al*, 2019). Keeping in view the above, the present study was carried out to access the impact of impact of lignocellulolytic microbes on in-situ and ex-situ wheat residue decomposition.

MATERIALS AND METHODS

In the villages of Pipariya Kalan and Khairi, which are situated in the Shahpura and Patan blocks of the Jabalpur district in Madhya Pradesh, after the wheat harvest, a participatory field trial was conducted in 2021–22 and 2022–23. The region is known for its primarily hot and humid weather. *Typic Haplusterts* are representative soil types of the testing sites; the soils are high in CEC and rich in base. The most common crops cultivated in the Shahpura and Patan blocks of the district are rice, wheat, blackgram, and greengram, as indicated by the cropping pattern (Table 1). Taking into consideration ,five farmer's fields were chosen in each village according to the current cropping pattern, with the local check placed next to trial plots. The objective of the current study was to compare three treatments: the removal of crop residue for ex situ decomposition (ED), in situ decomposition (ID), and residue burning (RB) in the field. For the ex-situ decomposition of wheat residues, 500 ml of bacterial consortia (a multi-blend strain of *Bacillus species*) and fungal consortia (fungi producing lignocellulolytic enzymes) per metric tonne of raw material were used twice at a 10-day interval. For the in-situ decomposition of wheat residues, 2.5 l/ha in the same ratio were used twice in the fields of chosen beneficiaries in both villages. After the wheat was harvested, the bacterial and fungal consortia were sprayed and field ploughed, then again after ten days after ploughing. Just before the monsoon arrived, soil samples were collected from the ID and RB fields. Standard methods given by Jackson (1958), Subbaiah and Asija (1956), Olsen *et al* (1954) and Jackson (1973) were used to analyse the soil samples for soil organic carbon, available nitrogen, phosphorus, and potassium.

Table 1. Pattern of cropping in the study area (2021-22).

Block	Season wise area under crops								
	Kharif			*Rabi*			Summer		
	Crop	Area (ha)	% Area	Crop	Area (ha)	% Area	Crop	Area (ha)	% Area
Shahpura	Rice	13980	35.2	Wheat	28200	47	Blackgram	9935	55.3
	Blackgram	9775	24.6	Garden Pea	18120	30	Greengram	8025	44.7
	Others	15955	40.2	Others	13656	23	Others	--	--
Patan	Rice	32265	74	Wheat	35500	67	Blackgram	6500	50.8
	Blackgram	6030	14	Garden Pea	10000	20	Greengram	6300	49.2
	Others	5315	12	Others	7133	13	Others	--	--

Table 2. Promising indicators of technology under ex situ decomposition of wheat residues (pooled data of two years).

Parameter	Unit	Observation (Pooled data of two years)		
		TD	ED	% increase
Dry matter	Mt /ha	4.42	4.42	--
Decomposition	Days	95	52	(-) 82.7
Compost	Kg/ha	1865	2148	15.17
Organic carbon	%	12.95	14.88	14.9
N content	%	0.89	0.97	8.98
P content	%	0.53	0.55	3.77
K content	%	0.65	0.79	21.54
Net nutrient cost of compost	Rs/ha	3570	4111	15.15

RESULTS AND DISCUSSION

Compared to traditional decomposition (TD) methods, which took 95 d for wheat residue to completely decompose, the pooled data of two years showed that under ED, wheat residue entirely decomposed in 52 d when bacterial and fungal consortiums were used (Table 2). In ED, the decomposition duration was 82.7 per cent shorter than with traditional methods, which improved the decomposition cycle. Eventually, 2148 kg/ha of compost were recorded, 15.17 per cent higher than with traditional decomposition (1865 kg/ha). The residues decomposed utilizing microbial consortia had estimated contents of 14.88, 0.97, 0.55, and 0.79 per cent of organic carbon (OC), N, P, and K. These values were 14.9, 8.98, 3.77, and 21.54 percent higher than those of wheat residues that were decomposed traditionally. The compost produced under ED had a net nutrient cost of Rs.4111/-, which was 15.15% greater than the

Table 3. Nutrient status of soil under in-situ decomposition and residue burnt fields (Pooled data of two years).

Block	Soil organic carbon (%)			Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
	ID	RB	% decline in RB	ID	RB	% decline in RB	ID	RB	% decline in RB	ID	RB	% decline in RB
Shahpura	0.64	0.57	12.28	214.62	170.58	25.82	19.27	16.76	14.98	256.81	218.68	17.44
Patan	0.72	0.65	10.77	231.54	180.73	28.11	22.35	19.87	12.48	283.44	244.85	15.76
Average	0.68	0.61	11.48	223.08	175.66	27.00	20.81	18.32	13.62	270.13	231.77	16.55

compost prepared traditionally, which had a net nutrient cost of Rs.3570/. Sahu *et al* (2019) and Sahu *et al* (2020) have investigated the capacity of consortia of thermophilic and mesophilic microorganisms to degrade residue rapidly. These studies have demonstrated the potential of composting, or the rapid ex situ degradation of wastes, which may hasten the in situ decomposition of crop residue.

According to Table 3, which describes the nutrient status in soils of residue burnt (RB) and in situ wheat residue decomposition (ID) fields, the average SOC was 0.61 per cent in RB fields and 0.68 per cent in ID fields. The mean reduction in SOC as a result of burning residue was 11.48 per cent; however, Shahpura block fields had a higher rate of reduction (12.28%) than Patan sites (10.77%). In the RB fields of Shahpura and Patan blocks, available nitrogen was measured at 170.58 and 180.73 kg/ ha. This was 25.82 and 28.11 per cent less than in the ID fields, where it was determined at 214.62 and 231.54 kg/ha, respectively. Regardless of block, RB fields showed an average reduction in available N of 28%. The mean reduction in available P under RB fields was found to be 13.62 per cent; however, compared to ID fields in Shahpura and Patan blocks, it was 14.98 and 12.48 per cent less, respectively. In ID and RB fields, available K was measured to be 270.13 and 231.77 kg/ha, respectively, regardless of block, with an average decrease of 16.55 per cent in RB fields. Compared to Patan block, where it was estimated to be 15.76 percent, Shahpura block had a greater reduction in available K (17.44 %). Because of residue burning, the rate of reduction was lowest in SOC and greatest in available N. Karwariya *et al* (2014) reported that after residue burning in wheat fields, there was an average reduction of 17.32% in carbon, 12.69% in nitrogen, and 16.23% in potassium; in soybean residue burnt fields, there was a reduction of 9.95, 29.17, and 15.65% in carbon, nitrogen, and potassium. Bhattacharjya *et al* (2021) also reported that a significant amount of nutrients that were also lost as a result of burning residue could be returned to the soil through in situ residue decomposition using lignocellulolytic microbes, replenishing the soil nutrient reserve and lowering the need for fertilizer for the next crop. Additionally, in situ residue the decomposition might enhance soil health by enriching soil organic carbon (SOC), which frequently declines as a result of intensive cropping systems.

CONCLUSION

The current study has shown that instead of burning crop residue, lignocellulolytic bacterial and fungal consortia can be used to decompose the residue both ex situ and in situ. Additionally, it increased the organic carbon (OC), accessible N, P, and K contents in ex situ and in situ decomposition, which in turn decreased the amount of nutrients from inorganic sources and the cultivation cost of the next crop. The compost preparation cycle increased as a result of the residues' quick disintegration by microbial consortia, enabling farmers access to more compost with higher levels of essential and beneficial nutrients.

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