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Assessing the Impact of Rapid Composting Technology on Doubling Farmer's Income in Eastern Uttar Pradesh, India

Vellaichamy Mageshwaran [a*], Birinchi K. Sarma [b], Rudra P Singh [c], Pardeep Kumar [d], Amit Yadav [a], Nagesh Tiwari [a], Pratyush Tripathi [a], Ashish K Vishvakarma [a] and Avadhesh Yadav [a]

[a] Microbial Technology Lab, ICAR-National Bureau of Agriculturally Important Microorganisms, Kushmaur, Mau, U.P. – 275 103, India.
[b] Department of Plant Pathology and Mycology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi,U.P. – 221 005, India.
[c] Krishi Vigyan Kendra, Acharya Narendra Deva University of Agriculture and Technology (ANDUAT) U.P. – 276 207, Azamgarh, India.
[d] Krishi Vigyan Kendra, ANDUAT, Siddharthnagar, U.P. – 272 192, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author VM designed the study, consolidated the data and wrote the first draft of the manuscript. Authors BKS and NT managed the analyses of the study from Varanasi and Chandauli sites. Authors RPS and AY managed the analyses of the study from Azamgarh sites. Authors PT and AY managed the analyses of the study from Mau sites. Authors PK and AKV managed the analyses of the study from Siddharthnagar and Balrampur, respectively. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: mageshbioiari@gmail.com; mageshwaran.v@icar.gov.in;*

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ABSTRACT

The present work aimed to create awareness, conduct demonstrations and train the farmers of Eastern Uttar Pradesh (U.P.) on the adoption of technology on "Rapid Composting of Crop Residues" so as to bring additional income and savings in the cost of cultivation. The districts covered in Eastern U.P. were Mau, Azamgarh, Varanasi, Balrampur, Siddharthnagar, and Chandauli. During the study period (2019 to 2022), 6172 farmers representing 148 villages were reached to create awareness about rapid composting technology for organic matter recycling and livelihood enhancement. The technology was demonstrated to 4976 farmers including women by installation of 2870 composting bags. The number of awareness, demonstration and training conducted were 190, 168 and 21, respectively. By imparting training, 265 master trainers were developed. Out of this, 40 farmer turned entrepreneurs were identified based on successful adoption of this technology in terms of generation of additional income/savings in the cost of production. The farmers were able to produce one quintal of good quality compost from 1.5 quintal of raw material (paddy straw/other crop residue) from each composting bag in each cycle of production. Considering three cycles of production in a year, the farmers can earn a sum of Rs. 6000/- per bag per annum in case of selling the bio-fortified compost at the rate of Rs. 20 per kg. Whereas they save Rs. 3000/- per crop in Kharif on paddy and Rs 1,000 per crop in Rabi on wheat if they use the compost in their own farm as a part of replacement of chemical fertilizers. There is a large demand of organic manure in rural areas, therefore, farmers prefer to use it in their own farm. Some farmers have started selling the compost, which are in excess after application in the farm and earn additional income.

Keywords: Agricultural residues; awareness; biofortification; demonstration; entrepreneurship; rapid composting; training.

1. INTRODUCTION

About 700 million tonnes of agricultural wastes are generated annually in India out of 1,200 million tonnes generated worldwide [1,2]. The rice-wheat cropping system has been predominantly adopted by the farmers of the eastern Uttar Pradesh. During rice and wheat cultivation, plenty of rice straw and wheat straw are generated after their harvest. Most of these wastes are the source of roughage for animal feed and other household applications [3]. In addition, farmers in this region, use straw from the cereals crops for briquette formation by mixing straw with cow dung for energy purposes. Besides, the different usage of cereal straw, the excess material is burnt in the open field which causes pollution to the environment as well as soil eco-system. In the rice-wheat cropping system, there is a short window that exists between rice harvest and wheat sowing [4]. Most of the farmers in this region, however, clear their fields after rice harvest by burning the excess rice stubbles kept in the field. It is estimated that about 20 million tonnes of excess paddy straw/stubbles are available annually in this region [5]. Adoption of rapid composting will help the farmers in these regions as additional source of income on one hand and improve soil health on the other through application of the compost in general and biofortified compost in particular. A rapid composting of cotton stalks was developed so as to prepare the compost within 60 days and the application of biofortified compost improved the cotton yield and quality [6,7]. Although logistics in this kind of study is important, Pandirwar et al. [8] reported a model for logistics of cotton stalks for various value-addition. The application of compost cannot be ignored in the organic farming practices [9]. The use of compost in the crop field could significantly reduce the dependency of chemical fertilizers by 25-30 percent with simultaneous improvement in physical and chemical properties of the soil [10]. The objective of the present study was to establish rapid composting units at the farmer's field of eastern Uttar Pradesh, demonstrate the technology of "rapid composting of agricultural residues" through awareness, demonstration and training programs and develop farmers turned entrepreneurs through adoption of this technology.

2. MATERIALS AND METHODS

The methodology used in the study is outlined in Fig. 1. A well-structured questionnaire was used to collect basic data on socio-economic status of the farmers and also to evaluate the adoption of rapid composting technology by the farmers.

Baseline data collection from the farmers of Mau, Varanasi, Azamgrah, Balrampur, Siddharthnagar and Chandauli districts of Eastern Uttar Pradesh (Sample size, n=600)

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Creating awareness about rapid composting technology

↓

Installation of composting bags

↓

Conducting demonstration

↓

Conducting training at lab and field

↓

Compost production and revenue generation by the farmers

↓

Identification of farmers turned into entrepreneurs

Fig. 1. Methodology used in the study

Fig. 2. Protocol of rapid composting

Agricultural waste primarily paddy straw was collected and shredded into small pieces of 4-5 cm. The other crop residues used in the study were mustard stalks, pulses (chickpea, pea etc.) and tree leaf residues. The protocol for preparation of biofortified compost from agricultural residues is given in Fig. 2. The ratio of 10:1:0.1:0.1 of Agricultural residue: Cow dung:

jaggery: decomposer (Tejas™ manufactured and marketed by M/s Indore Biotech Inputs and Research Pvt. Ltd., Indore) respectively was taken and mixed properly. Initially, Tejas™ was used as decomposer but later on, a microbial consortium developed by ICAR-NBAIM (Kush BioFast) consisting of two hyper lignocellulolytic fungi (*Pleurotus flabellatus* M-1 and *Phanerochaete chrysosporium* V-1) was used as decomposer. The physico-chemical property of the compost prepared using the decomposers (Tejas™ and Kush BioFast) were compared [5]. For application of cow dung and jaggery, a solution was prepared for even mixing and about 50 to 55% moisture was maintained. To understand the moisture in the material under field conditions, the material (agricultural residue) is pressed with fist, the water should not drip while the material contains sufficient moisture. After fine mixing of cow dung, jaggery and decomposer with agricultural residue, they were kept in bioconversion bags (12 x 4 x 2 feet) and covered with thick plastic cover or tarpaulins.

The temperature starts rising in the bio-conversion bags from the next day itself and it reaches up to 70-75 ºC in the large bioconversion unit and about 45-50 ºC in the small polybags. The rise in temperature indicates the process of composting. For every 7 to 10 days, remixing to be done to enhance composting. After 55 to 60 days of composting, dry the compost under sun for 2 to 3 days or till the moisture content reaches 10 to 20% whichever is earlier and sieve them through 6 mm mesh size sieve.

The bio-fortification of compost was done at the end of the composting period usually after 60 days in which the microbial inoculants of ICAR-NBAIM (*Trichoderma viridie*, Bio-NPK, Bio-Zn, Bio-Phos and Bio-Grow) was added at the rate of 0.1 % to the matured compost.

During the study period, the number of awareness, demonstration and training program conducted in the six districts were 190, 168 and 21, respectively. Baseline data was collected from the farmers of Mau, Varanasi, Azamgrah, Balrampur, Siddharthnagar and Chandauli districts of Eastern Uttar Pradesh. The number of farmers from where the baseline data collected was 600 (Sample size, n=600). The awareness programs were conducted by grouping the farmers belong to different villages. While, the demonstration programs were conducted among the farmers of a particular village. The composting bags were installed in units. Each unit consisted of 5 bioconversion bags and thus 2870 bags (574 units) were installed. The trainings were conducted in either institute or village in order to provide hands-on-training to the farmers. The participation of the farmers and their details were noted in a register.

3. RESULTS AND DISCUSSION

Agricultural residues are the annually and abundantly available lignocellulosic biomass [11]. These agro-residues are a good source of raw material for compost preparation as they are rich in organic carbon and mineral nutrients but in unavailable form. The availability of the nutrients is enhanced by composting process. The recycling of these wastes in the farm balances the nutrients in the soil and increase the organic carbon level [7,10]. Globally, the researchers and environmentalists undertake serious efforts to recycle the organic wastes generated in the field for useful purposes. Organic farming is getting momentum globally to overcome the negative impacts created by chemical inputs in agriculture. However, the demand for biological inputs is increasing but the supply is low. The youths in agriculture is being attracted by the organic farming practices owing to the environmental-friendly approach and the premium prices in the market for organic products [12]. In India, Sikkim is the first state to become fully organic and the products obtained from this state has global market [13]. Out of different products and services derived from organic wastes, bio-compost from organic waste received much attention worldwide due to its positive effect on balancing of nutrients in the soil, improving soil health and increasing crop productivity [14]. Thus, the compost is the major option for substitution of chemical fertilizers and bio-inputs in organic farming. The available literature strongly suggests that the use of compost in the crop field could significantly reduce the dependency of chemical fertilizers by 25-30 percent with simultaneous improvement in physical and chemical properties of the soil [10]. The agricultural residues generated after harvesting and threshing of crops should be collected and converted into high quality compost using microbial consortia and then quality upgradation of this compost should be done by fortifying with beneficial microorganisms. By adopting bio-fortified quality compost production, farmers can not only reduce the cost of production but can also increase their income by selling the surplus quantity of the compost. In this way, the farmers also get rid of the problem of burning of agricultural residues by which environmental pollution could be substantially reduced. Simultaneously, the amount of carbon retained in the soil improves the soil health. Apart from this, the core of this study was to create interest among the farmers for the agricultural applications of microorganisms [15]. In this work, rapid composting of agricultural residues technology was disseminated by aggregating farmers of the selected districts including women on a single platform. It is also necessary to make farmers familiar with the economic aspects of these techniques so that small and marginal farmers can be provided with a technology that can help them earn additional income.

3.1 Rapid Composting Technology

Here we present the details of the method of rapid composting of crop residues and uses thereof. The method of preparation of bio-fortified compost using the decomposers, Tejas™ and Kush BioFast was demonstrated among the farmers. It involves a simple process in which the organic wastes are cut into small pieces of 4-5 cm length, kept in HDPE bags/bio-conversion bags, added with microbial consortia Tejas™ /Kush Bio-Fast (supplied by the ICAR-NBAIM), turned on weekly interval to produce the nutrient-rich compost. Normally, 60 days are required for bioconversion of paddy straw/wheat straw/other agro-residue into nutrient-rich compost. It was further, biofortified by mixing microbial inoculants. The bio-fortified compost enhances the nutrient availability (nitrogen, phosphorus, potassium and micronutrients) and protects the plants against disease. In addition, it reduces the dependency of chemical-based fertilizers and pesticides, increase soil fertility and improve soil, plant, environment and human health [15]. Table 1 describes the comparison of physico-chemical properties of bio-compost prepared using Kush BioFast and Tejas™, respectively. It was found that Kush BioFast performed better compared to Tejas™ as it produced better quality of compost with respect to CN ratio and nutrient composition. Therefore, as for as possible Kush BioFast was used as decomposer. The matured compost is the one which has a good aroma, black powdered and total NPK content of more than 2.5 % as set by Fertilizer Control Order (FCO), [16] and the paddy straw compost prepared using the decomposers, Tejas™ and Kush BioFast meets the standards.

3.2 Technology Dissemination

The study area covered six districts of Uttar Pradesh, India and it is depicted in Fig. 3. In this area, we found a biggest scope of rapid composting technology to maintain the soil health. In these aspirational districts, we have seen or found people from various age groups, from young to old age group. This technology benefits various age groups of farmers who have actively adopted it, as shown in. Despite OBC and general category farmers, the scheduled tribes and women farmers were also benefitted from this work. Farmers in this area have a different range of land-holding capacities, ranging from marginal to large. The majority of farmers in these districts have intermediate and graduate levels of education, and some farmers have also done masters and doctorate of philosophy. In the case of family size, it seems that around 56 percent of farmers belong to a medium-sized family, 88 percent of farmers are married and 65 percent of farmers have pucca houses. In the study of the social participation of farmers, we found that majority of the farmers always participate in the training program, village meetings, gram panchayat meetings, and political activities while few farmers sometimes participate in the meetings. Among the different age groups, the youths of the age between 18 to 30 showed high response for the rapid composting technology. Similar findings were observed by Yadav et al. [12] on adoption of organic farming practices by the youths.

Table 1. Physico-chemical properties of bio-compost prepared from paddy straw at 60 days of composting

Microbial Consortium	TN (%)	TP (%)	TK (%)	OC (%)	CN ratio	Iron (ppm)	Zinc (ppm)
Kush Bio-Fast	1.65	0.44	1.63	24.8	15.0	2135	88.3
Tejas™	1.21	0.43	1.46	30.5	25.2	1582	81.5
Control	0.93	0.35	1.32	31.4	33.7	320	72.9

Note: TN- Total Nitrogen; TP- Total Phosphorus; TK- Total Potassium; OC- Organic Carbon; CN- Carbon Nitrogen; Control: Without addition of microbial consortium

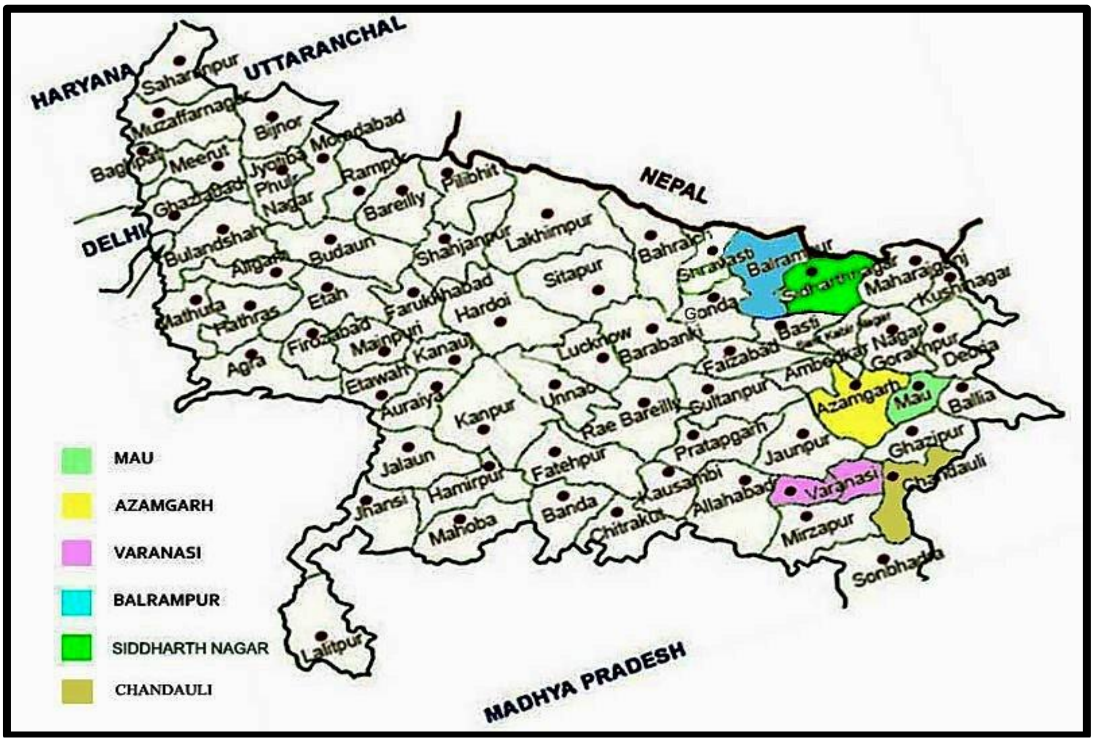
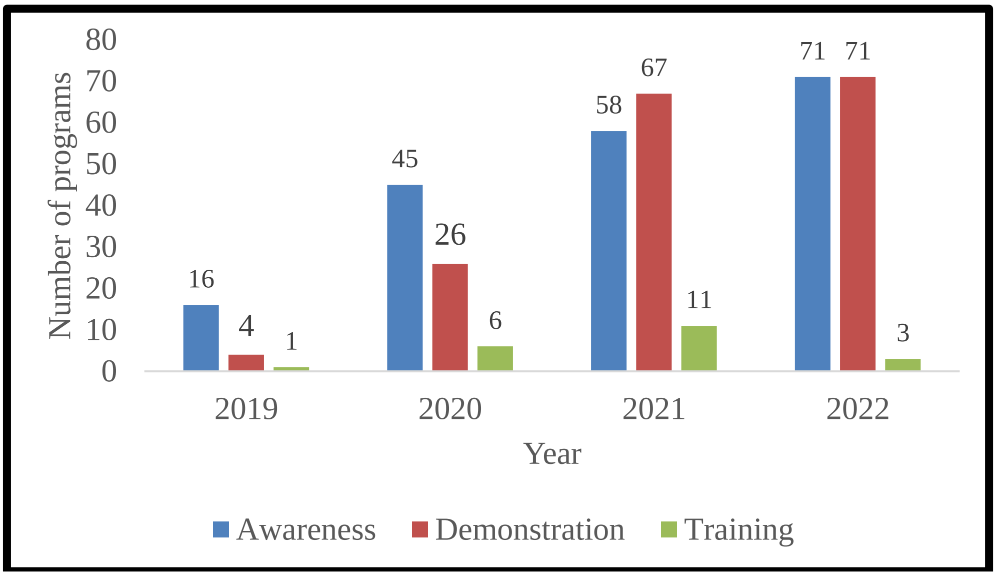


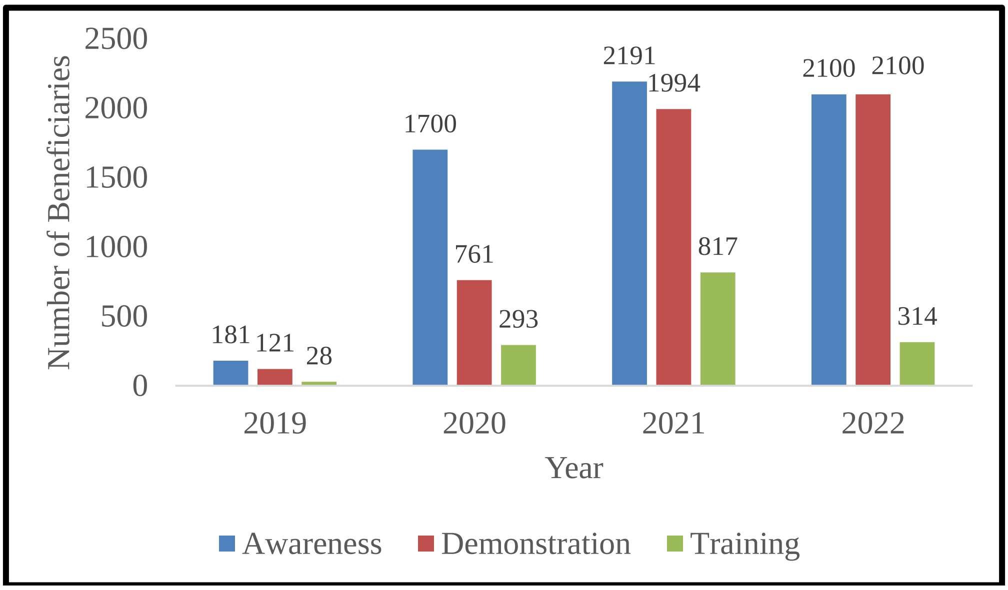
Fig. 3. Districts covered under the study

The present work of the create awareness, conduct demonstration and training among the farmers of Eastern Uttar Pradesh for adoption of technology on “Rapid Composting of Crop Residues” to bring additional income, savings in cost of cultivation and. During the study period (2020 to 2022), consistent efforts were made to reach the farmers in this region, installation of composting units at their site and its demonstration, train the farmers at laboratory despite the hurdle of COVID-19 peaked at this period. The districts associated with the project at eastern U.P. were Mau, Azamgarh, Varanasi, Balrampur, Siddharthnagar and Chandauli.

The number of programs conducted and number of beneficiaries from each program is given in Fig. 4 a and b. During the study period (2019-2022), 6172 farmers representing 148 villages were given awareness about rapid composting technology for organic matter recycling and livelihood enhancement in rural areas. The technology was demonstrated in the villages by installation 2870 composting bags in the villages by which 4976 including women, men and tribal farmers were benefitted. The rural youth, tribal and women showed high response on rapid composting and organic farming technology as they are easy to adopt at farm level [12,17,18]. In a similar study, Katke and Dhurve, [19] reported the participation of women entrepreneurs in bioconversion of garden and kitchen waste into vermicompost and earn additional income. In the present study, the number of awareness and demonstration programs conducted were 190 and 168, respectively. One day and five days training programs were conducted for dissemination and adoption of the technology. The number of training program conducted and beneficiaries were 21 and 1452, respectively. From the project, 265 master trainers were developed who are the motivating agent for the dissemination and adoption of this technology in larger scale. The study showed that training had more impact among the different dissemination methods as they provide hands-on-training to the farmers for enhanced adoption of technology. In a similar study, the impact of training in improving the productivity of vegetable crops has been described [20]. The recent study showed that the farmers have positive attitude towards biotechnology and its application in agriculture [18]. In a similar study, the awareness, demonstration and training programs were conducted for the farmers for adoption of technology on organic farming in soybean and other crops [9,21].



a.



b.

Fig. 4. Technology Dissemination (a. Number of programs; b. Number of beneficiaries)

3.3 Impact of the Study

In this study, 40 farmers turned entrepreneurs were identified based on successful adoption of this rapid composting technology and generate addition savings in the cost of production. Out of 40, 38 and 2, were men and women farmers, respectively. The number of successful entrepreneurs with respect to district they belong is given in Fig. 5. The list of successful entrepreneurs and the date of unit establishment is given in Table 2. The number of cycles of production of compost since the unit establishment was in the range from 1 to 6. The total compost production from each unit during the study period was ranged between 4 and 85 quintals. The compost was applied by the farmers were in the range from 2 to 10 quintals per acre. The compost was applied majorly in the crop's paddy followed wheat. The other crops in which compost applied were sugarcane, onion, mustard, gram, pea and vegetables. The savings in terms of reduction in chemical fertilizers per acre was found in the range between Rs. 1420/- and 26,470/-. Considering the declining cattle population and the poor availability of farm yard manure (FYM), the compost from agro-residues is the promising candidate to substitute FYM in a sustainable farming. In an attempt to develop entrepreneurship among the cotton growers, the farmers were able to substitute the FYM with cotton stalks compost and generate a savings of Rs. 9000/- per acre in cotton farming [22]. In this study, the average annual savings (Rs. per acre) was found to be Rs. 1500/- and 1000/- in male and female farmers, respectively in 2018 (baseline data) while the same has been increased to Rs. 5000/- and 4000/-, respectively in 2022 with the impact of the study (Fig. 6). The farmers were able to produce one quintal of good quality compost from 1.5 quintal of raw material (paddy straw/other crop residue) from each composting bag in each cycle of production. Considering three cycles of production in a year, the farmers can earn a sum of Rs. 6000/- per bag per annum in case of selling the bio-fortified compost at the rate of Rs. 20 per kg. Whereas they save Rs. 3000/- per crop in Kharif on paddy and Rs 1,000 per crop in Rabi on wheat if they use the compost in their own farm as a part of replacement of chemical fertilizers [23,24]. In a similar study, the pattern of farmer's income in Gopalganj district of Bangladesh was analyzed and it was found that 35.12 and 64.88 % of income derived from non-farm and farm sources, respectively [25].

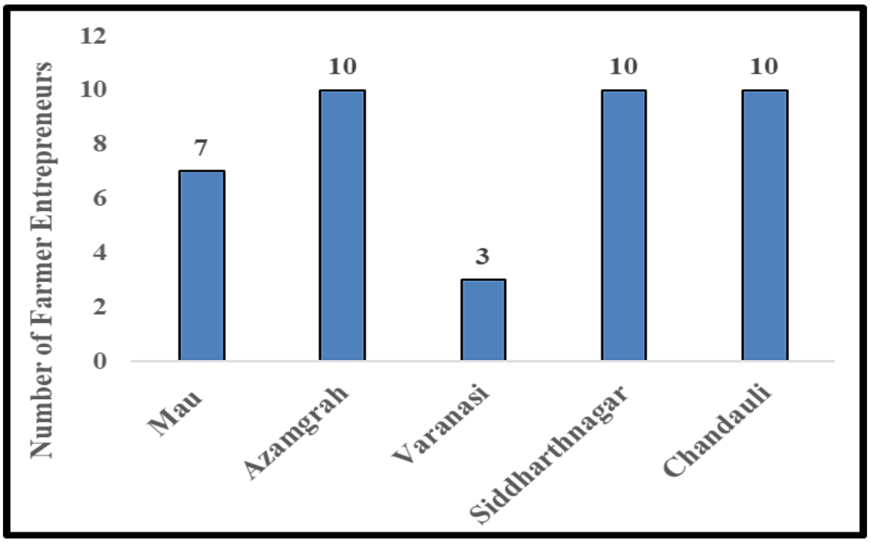


Fig. 5. Number of farmer entrepreneurs- district wise

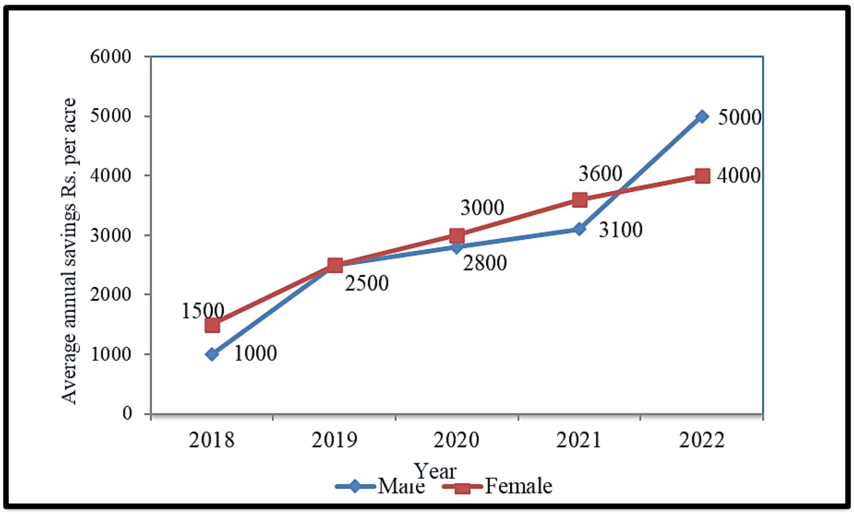


Fig. 6. Average annual savings of the farmers

Table 2. List of farmer entrepreneurs identified in the study

S.N.	Farmer 's Name	Unit Establishment date	No. of cycles of production	Total Production of compost (quintal)	Usage in Field	Benefits in terms of reduction in chemical fertilizer per acre (Rs)
Mau						
1	Shri Chandrapal Chauhan	16/03/2020	03	85	Wheat, Paddy, Sugarcane, Onion	1574/-
2	Shri Nathu Yadav	16/03/2020	03	23	Wheat, Paddy	1640/-
3	Shri Harishankar Prajapati	27/11/2019	03	23	Wheat, Paddy, Vegetable	1918/-
4	Shri Omkar Bharti	23/01/2020	02	21	Wheat, Paddy, Sugarcane	1238/-
5	Shri Shivmurat Prasad	09/11/2020	03	18	Wheat, Paddy	1250/-
6	Shri Devendra Kumar Vishwakarma	17/06/2021	01	10	Wheat, Paddy	1550/-
7	Smt. Leelavati Devi	19/02/2021	01	08	Wheat, Potato, Mustard, Gram, and Paddy	1900/-
Azamgarh						
1	Shri Vipin Bihari	23/10/2020	03	12	Wheat, Paddy, Mushroom	5000/-
2	Shri Ram Avtar Singh	27/10/2020	06	12	Wheat, Paddy, Bottle gourd	3650/-
3	Shri Raj Narayan Singh	09/01/2021	05	09	Paddy	2400/-
4	Shri Sahab Raj Pandey	09/01/2021	05	12	Paddy	2200/-
5	Shri Raj Bahadur Singh	27/10/2020	05	10	Cauliflower	2500/-
6	Shri Kailash Prasad	27/10/2020	05	10	Cauliflower	2352/-
7	Shri Shivashray Singh	02/01/2021	04	09	Garlic	5214/-
8	Shri Ashok Kumar	04/12/2020	05	11	Bitter Gourd	2893/-
9	Shri Sri Ram Singh	27/10/2020	06	11	Pointed Gourd	2100/-
10	Smt. Soni Devi	23/10/2020	02	12	Paddy, Wheat, Pea , Mustard	7857/-
Varanasi						
1	Shri Pawan Tiwari	27/12/2020	02	12	Paddy, Onion	2080/-
2	Shri Dharmendra Kumar	21/02/2021	02	09	Brinjal, Bitter Gourd, Broad Beans	2204/-
3	Shri Ghurenath Singh	15/02/2020	02	16	Bottle Gourd, Sponge Gourd, Pumpkin, Bitter Gourd	2258/-

S.N.	Farmer 's Name	Unit Establishment date	No. of cycles of production	Total Production of compost (quintal)	Usage in Field	Benefits in terms of reduction in chemical fertilizer per acre (Rs)
Siddharth Nagar						
1	Shri Deenanath Singh	22/12/2021	02	10	Paddy, Wheat, Sugarcane and Vegetables	11380/-
2	Shri Bhupendra Singh	12/01/2022	02	10	Paddy, Wheat	14910/-
3	Shri Ajeet Kumar	11/12/2021	02	05	Paddy, Wheat & Vegetables	1420/-
4	Shri Vikram Chaudhary	12/01/2022	02	8	Paddy, Wheat & Vegetables	7450/-
5	Shri Rajkumar Mishra	12/01/2022	01	9	Paddy, Wheat & Vegetables	7900/-
6	Shri Shvinandan Shukla	18/01/2022	02	9	Paddy, Wheat & Vegetables	15430/-
7	Shri Udairaj Bharti	12/01/2022	01	9	Paddy, Wheat & Vegetables	6600/-
8	Shri Narshingh Pathak	11/12/2021	01	10	Paddy, Wheat & Vegetables	26,470/-
9	Shri Chandraprakash Pathak	11/12/2021	02	6	Paddy, Wheat & Vegetables	4510/-
10	Shri Purnamasi Gautam	18/01/2022	02	4	Paddy, Wheat & Vegetables	2342/-
Chandauli						
1	Shri Anish Singh	08/12/2021	02	8	Paddy, Wheat & Mustard	4790/-
2	Shri Avinash Singh	18/02/2022	01	6	Paddy, Wheat & Potato	4100/-
3	Shri Hariom Singh	14/03/2022	01	10	Paddy, Wheat, Brinjal & Cucumber	3500/-
4	Shri Kamlesh Singh	10/12/2021	02	*10*	Paddy, Wheat, Sugarcane & Chickpea	9360/-
5	Shri Praddum Maurya	08/01/2022	02	8	Paddy, Wheat and Sugarcane	10870/-
6	Shri Rajendra Prasad	18/02/2022	01	10	Paddy, Wheat & Onion	2290/-
7	Shri Raju Kumar	14/03/2022	01	7	Paddy &wheat	2600/-
8	Shri Ramshray Kumar	08/01/2022	01	6	Paddy, Wheat and Mustard	2632/-
9	Shri Shiv Poojan Yadav	21/02/2022	01	6	Paddy and Wheat	2380/-
10	Shri Vashudev Singh	17/02/2022	01	7	Paddy and Wheat	2416/-

Since, there is a large demand of organic fertilizers, farmers prefer to use in their own field even though certain farmers have started selling the compost which are excess after application in the field and earn additional income. The impact of this study has resulted in improvement of socio-economic status of the farmers in this region paving the way of achieving Govt. of India ambitious program on "Doubling Farmers Income" [26]. The farmers' fields under the study have increased with soil water holding capacity, soil health, availability of micro-nutrients and crop productivity. We believe that the results of this study will act as ready reckoner for the farmers, academicians, policy workers and social workers for upliftment of livelihood of the farmers of Eastern UP through adoption of technology on rapid composting of agricultural residues.

4. CONCLUSION

In this study, the technology on rapid composting of agricultural residues was disseminated to the farmers of Eastern Uttar Pradesh. Based on analysis of baseline data, it was found that the major problem faced by the farmers in this region was high cost of cultivation due to non-availability of compost and high dependency on chemical fertilizers. The technology on rapid composting of agricultural residues was disseminated through awareness, demonstration and training programs. The total number of beneficiaries were 6172, 4976 and 1452, respectively. In total, 40 entrepreneurs were identified based on the scale of compost production and income generation through sale of compost. Due to the intervention of this technology, the annual savings in cost of production per acre for men and women farmers were ₹5000 and ₹4000, respectively by reduction in use of chemical fertilizer and replacement of farm yard manure with compost. Apart from savings, farmers were benefited by improvement in soil health and product quality. There is a large demand for organic fertilizers, which farmers prefer to use in their own fields, even though certain farmers have started selling compost that is in excess after application in the field to earn additional income. Through this technology intervention, the dependency on chemical fertilizers has been reduced, soil health and livelihood of the farmers has been improved, and the pollution arising due to the burning of crop residues has also been reduced.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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