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Open Access Journal of Waste Management & Xenobiotics
ISSN: 2640-2718

Use of Vermicomposted Fly Ash as an Important Component for Integrated Nutrient Management of Potato

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Research Article

Volume 3 Issue 3

Received Date: August 01, 2020

Published Date: August 25, 2020

DOI: 10.23880/oajwx-16000144

Abstract

Large scale generation of fly ash (FA) from varying kinds of coal fired plants has now emerged as a global environmental threat. To combat the situation, various possibilities of recycling this waste material are being explored. In view of appreciable occurrence of most of the plant nutrients in FA, the possibility of recycling this waste material in agriculture as a source of these nutrients is being envisaged in many countries. However, the major problem associated with supply of plant nutrients through FA is the low bio-availability of most of the nutrients in this material. Under this context, adoption of vermicomposting biotechnology for simultaneous degradation of different organic wastes and FA with the help of some special purpose earthworms is being recommended by a group of workers. Vermicomposting helps in accelerated degradation of various kinds of wastes with the help of gut microorganisms of these earthworms. In view of the encouraging results from various studies on beneficial effects of vermicomposted fly ash (VFA) on soil properties a field study was carried out to assess the potential of VFA as a component of integrated nutrient management for potato cultivation. The on-farm trial revealed the efficiency of VFA in increasing the yield of potato under such nutrient management and the results were comparable to those with farm yard manure and vermicompost.

Keywords: Fly Ash; Recycling In Agriculture; Vermicomposting; Potato Cultivation; Integrated Nutrient Management

Introduction

Coal is the source for energy in different coal-fired power plants which support a large share of the global electricity generation capacity. Large scale generation of fly ash (FA) from these coal fired plants (Figure 1), their adverse impacts on surrounding environments and requirement of huge land areas for their effective disposal have now emerged as serious environmental threats in many countries. To combat the situation, various possibilities of recycling this waste material for productive purposes are being explored at different levels.

During these exercises, use of FA in agriculture as a source of plant nutrients has now appeared as a viable option [1]. Owing to its plant origin, FA usually exhibits almost all the plant nutrients in appreciable concentrations, barring nitrogen and organic carbon [2]. Total occurrences of many of these plant nutrients have been observed to be almost at par with the values commonly observed in agricultural soils [3]. Studies carried out in agriculture sector to assess the effect of FA as a source of plant nutrients have also shown that these ashes have some beneficial properties which can be utilized for agricultural purposes [4-6]. However, in spite of their total occurrence in considerably higher concentrations, poor availability of various plant nutrients in FA forms a major barrier for efficient use of this waste material in agriculture [7]. This behavior has primarily been attributed to inert nature of this burnt material leading to absence of organic matter and consequently very poor microbiological activity in it [8,9]. Under this context, several workers observed simultaneous use of FA and organic matter to be a viable option for improving the efficiency of this material [10-12]. This practice of addition of organic matter amended FA has been considered to be helpful in improving various soil health attributes like buffering of pH, availability of different nutrients, water retention, cation exchange capacity *etc.* In addition, organic matter provides food and energy to different heterotrophic microorganisms [13] and hence such incorporation of organic matter is likely to encourage the microbiological activity in the fly ash amended soils [14]. However, in view of the escalating quantum of FA generation and also restricted availability of conventional organic manures at global levels, the possibility of recycling the huge amount of different kinds of organic wastes is being suggested as an attractive proposition for this purpose [7]. This approach of integrated use of FA along with organic wastes will not only improve the potential of recycling FA in agriculture but will also lead to simultaneous abatement of environmental pollution generated by these waste materials. Since these organic wastes are not advised be used to agricultural fields directly, maximum benefit from such combined use of FA and organic wastes can be achieved through prior co-composting of the organic materials along with FA. This will lead to biological conversion of heterogeneous organic substrates into a hygienic, humus rich, relatively bio-stable product which can improve soil physical conditions and nourish crop plants [15]. In addition, increased microbial activity and also secretion of some organic acids during the composting process will lead to simultaneous degradation of the FA, releasing different plant nutrients into bio-available forms [2].

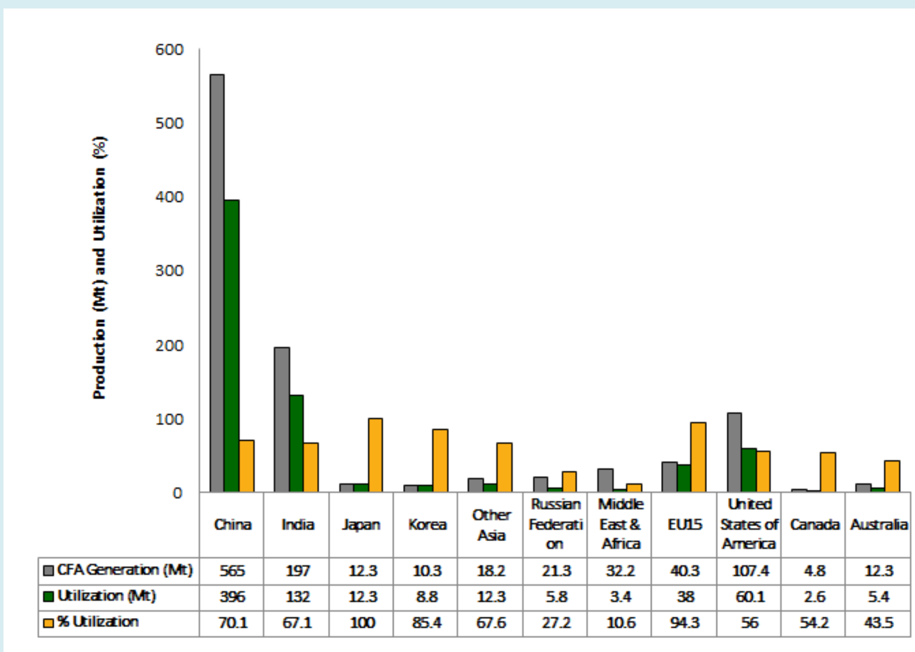

Figure 1: Major Producers of Coal Fly Ash (CFA) and its utilization (Annual Production, Utilization Rates by Country in 2016: Modified from the work of Harris, et al. [16].

Among various processes of composting, vermicomposting is now emerging as a viable biotechnology for recycling various organic wastes into good quality compost [17,18]. The basic principle of vermicomposting involves feeding of different organic wastes by epigeic earthworms and subsequent degradation of the half-digested organic materials excreted by these earthworms by wide array of gut microorganisms under aerobic condition resulting in production of good quality compost in lesser period of time [19]. The possibility of using vermicomposting biotechnology for simultaneous recycling of FA and organic wastes was primarily conceptualized at the soil testing laboratory of Visva-Bharati University, India and first reported by Bhattacharya and Chattopadhyay [20]. Thereafter, the basic technology has been investigated and reviewed by many workers [21-26] All these studies have shown that vermicomposting of fly ash and organic wastes enhances the microbiological activity in the substrates thus facilitating improvement in the availability of three major nutrients viz. N, P and K and also several micro nutrients like Fe, Cu, Mn and Zn in the vermicomposted fly ash. It has also been observed that vermicomposting helps in binding several heavy metals from coal ash in earthworm flesh as organic compound, thus reducing their concentration in this composted product [22]. With all these information, this process has now been established as a proven technology for better utilization of FA in agriculture [7]. However, in spite of all these investigations, elaborate reports from on field studies on potential of vermicomposted fly ash (VFA) in producing agricultural crops have remained limited. In view of this knowledge gap with regard to use of vermicomposted fly ash (VFA) at field levels, we assessed the potential of VFA in producing potato through an on-farm trial. The trial was carried out to study the effect of integrated nutrient management with VFA and varying doses of chemical fertilizers in producing potato and to compare the performance with similar integrations using conventional composts in order to assess the efficiency of VFA as a potential nutrient input in agriculture.

Materials and Methods

The on-farm trial was carried out in a red and lateritic soil zone at Bahadurpur village (23.6662^0 N and 87.6224^0 E) of Birbhum district of West Bengal, India to assess the efficiency of vermicomposted fly ash (VFA) in influencing the production of potato under integrated plant nutrient management in comparison with conventional fertilization practices without and with integration of farm yard manure (FYM) or vermicompost (VC).

Fly ash was collected from Bakreswar Thermal Power Plant of West Bengal Power Development Corporation, India. The material was mixed thoroughly with assorted combination of cow dung and vegetable market waste at 1:1 ratio of FA: organic wastes and vermicomposted with *Eisenia foetida* by following the method described by Chattopadhyay [27]. Conventional vermicompost (VC) was also prepared from the same organic wastes viz. cow dung and vegetable market wastes by following the similar method. Farm yard manure (FYM) was procured from the dairy farm of Institute of Agriculture, Visva-Bharati University, India.

In total, 11 treatments, with three replicates for each, were used for the field trial using different combinations of FYM, VC, VFA and NPK fertilizers under randomized block design. The treatment combinations have been presented in Table 1. Potato (variety- Kufri Jyoti) was cultivated for this on-farm trial using standard cultivation practices.

Composite soil samples were collected from the plots before and after the study. After collection, the soils were air dried, sieved through 80 mesh sieves and analyzed for pH, easily mineralizable organic C and available P and K by following Jackson [28]. Available (easily mineralizable) N status of the soils was determined by following the method of Subbia and Asija [29].

Treatment abbreviations	Treatment combination
T_1	FYM 10 t ha^{-1} + NPK 100%
T_2	VC 10 t ha^{-1} + NPK 100%
T_3	VC 10 t ha^{-1} + NPK 75%
T_4	VC 10 t ha^{-1} + NPK 50%
T_5	VFA 10 t ha^{-1} + NPK 100%
T_6	VFA 10 t ha^{-1} + NPK 75%
T_7	VFA 10 t ha^{-1} + NPK 50%
T_8	NPK 100%
T_9	FYM 10 t ha^{-1}
T_{10}	VC 10 t ha^{-1}
T_{11}	VFA 10 t ha^{-1}

Table 1: Treatment Combinations Used in the Study.
FYM = Farm Yard Manure; VC = Vermicomposting; VFA = Vermicomposted Fly Ash; NPK100%= full recommended fertilizer (N: P_2O_5: K_2O = 150:100: 100 kg ha^{-1}).

Results and Discussion

A low productive soil was selected for the study so that the differences in benefits from application of different inputs can be visualized more distinctly. Initial properties of the soil under cultivation have been shown in Table 2. As observed from the table, the soil was acidic in nature. Availability of all the major nutrients viz. nitrogen, phosphorus and potassium as well as occurrence of easily mineralizable organic C were of low order in the soil .Similar properties of red and lateritic soils have been discussed by Panda, et al. [30].

Soil properties	Unit of expression	Value	Comments
pH		4.64	Acid
Easily mineralizable organic C	%	0.45	Low
Available N	Kg ha^{-1}	172.32	Low
Available P	Kg ha^{-1}	9.23	Low
Available P	Kg ha^{-1}	121.54	Low

Table 2: General Properties of the Soil before Cultivation.

Yield data of potato under different treatments have been presented in Table 3. As observed from the table, lone use of VFA,VC, FYM or NPK fertilizers resulted in significantly lower yields of potato as compared to those obtained through integration with various organic inputs along with different doses of chemical fertilizers .These values remained under a narrow range and did not differ significantly among themselves (Table 2). The results indicate that sole use of these inputs was not sufficient to result in substantial increments in the yield levels of potato in this poorly productive soil. The comparative efficiency of these inputs has been further explained by calculating the percent variations in yield values as compared to the performance under 100%NPK fertilization (Table 3). As observed from there, the mean yield value obtained under sole use of VC @10 t ha-1 was practically at par with conventional fertilizer treatment using 100% recommended NPK fertilizers. On the other hand, FYM and VFA resulted in marginally lower yields. However, the variations in crop yields under these treatments were not found to be statistically significant indicating that the yield producing efficiency of FYM, VC and VFA @ 10 ton ha-1 each was equivalent to use of chemical fertilizers @ 150 :100 :100 kg N :P2O5 :K2O ha-1.

Treatments	Treatment combination	Yield (ton ha^{-1})	Variation(%) over 100 %NPK
T_1	FYM 10 t ha^{-1} + NPK 100%	28.16	66
T_2	VC 10 t ha^{-1} + NPK 100%	32.72	92.9
T_3	VC 10 t ha^{-1} + NPK 75%	30.39	79.2
T_4	VC 10 t ha^{-1} + NPK 50%	27.43	61.7
T_5	VFA 10 t ha^{-1} + NPK 100%	30.64	80.7
T_6	VFA 10 t ha^{-1} + NPK 75%	27.75	63.6
T_7	VFA 10 t ha^{-1} + NPK 50%	24.31	43.3
T_8	NPK 100%	16.96	--
T_9	FYM 10 t ha^{-1}	15.32	-9.7
T_{10}	VC 10 t ha^{-1}	16.85	-0.59
T_{11}	VFA 10 t ha^{-1}	14.88	-12.3
	S. Em (±)	0.88	
	CD (P=0.05)	2.59	
	CV	6.31	

Table 3: Mean Yield Values of Potato Under Different Treatments.

Yield of potato increased significantly under integration of FYM, VC and VFA with different doses of fertilizers. Use of full doses of fertlizers with these inputs resulted in the highest yield values which varied between 28.16 and 32.72 ton ha^{-1}. Among these, integration with VC recorded maximum benefit in terms of numerical increase in crop yield. However, statistically the value was similar to the use of VFA along with recommended fertilization. The mean yield of potato under this integrated treatment using VFA was observed to be statistically similar to that under integrated use of FYM also. The results indicate VFA to be a potential yield boosting input which can be considered as a substitute of these conventional manures and be used in the event of restricted availability of these conventional organic inputs. The yields of potato under different integrated nutrient management practices declined gradually with reduction in the doses of chemical fertilizers. However, even after 50% reduction in fertilizer uses, the yield levels under integrated nutrient management practices with VC and VFA resulted in significantly higher values over application of recommended NPK fertilizers and also the sole uses of the three organically derived inputs. Similar result of VFA application on potato has been reported by Bhattacharya, et al. [27] also.

The residual soil condition after the cultivation has been presented in Table 4. Initial studies showed the soil to be acidic in nature (Table 2). The pH value of the soil remained almost the same under the treatment with sole use of fertilizers while all other treatments using different combinations of FYM, VC and VFA with fertilizers resulted in low to moderate increments in soil pH values. Of these, again, treatments with VFA showed higher range of benefit in terms of increase in soil pH after the cultivation. While buffering action of organic materials are well documented [31], alkaline pH values of common fly ashes have been reported by Chattopadhyay and Bhattacharya [7] also. Amalgamation of these two traits in

VFA helped this input to result in limited increment of the pH of this acid soil when treated with different combination of this input. Amount of easily oxidizable organic carbon (EOOC) was low in this soil. Such low occurrence EOOC is an inherent property of red and lateritic soils [30]. This property recorded marginal increments in the residual soil under most of the treatments. Since it is very difficult to maintain higher status of organic C in tropical soils through use of organic material, these increments may additionally be attributed to increase in biomass in the soils due to the cultivation. It was interesting to observe that the treatments which produced better yields recorded, in general, higher EOOC values in soil. Availability of N, P and K were low in the soil, as are the general property of red and lateritic soils [30]. Integrated uses of different inputs tended to increase the availability of these nutrients at varying levels. This benefit may be due to reduction in leaching loss of water soluble N and K and lowering in fixation of P in acid soils in presence of organic matter [31,32]. Integrated use of VFA, therefore, appeared to be an effective proposition in maintaining better availability of the major plant nutrients in such soil.

Tr. nos.	Treatment Combination	pH	Easily mineralizable organic C (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha-1)	Available K_2O (kg ha-1)
T_1	FYM 10 t ha^{-1}+NPK 100%	4.8	0.6	188.16	12.65	136.54
T_2	VC 10 t ha^{-1} +NPK 100%	4.92	0.66	200.73	14.65	137.65
T_3	VC 10 t ha^{-1} +NPK 75%	4.85	0.61	181.44	13.53	131.21
T_4	VC 10 t ha^{-1} +NPK 50%	4.92	0.61	163.07	13.11	125.21
T_5	VFA 10 t ha^{-1} +NPK 100%	5.06	0.61	181.88	12.24	134.65
T_6	VFA 10 t ha^{-1} +NPK 75%	5.05	0.57	175.62	12.15	130.54
T_7	VFA 10 t ha^{-1} +NPK 50%	5.07	0.55	150.53	12.01	121.24
T_8	NPK 100%	4.72	0.42	112.9	10.21	96.46
T_9	FYM 10 t ha^{-1}	4.92	0.55	75.08	9.25	97.23
T_{10}	VC 10 t ha^{-1}	4.94	0.59	94.08	9.59	98.68
T_{11}	VFA 10 t ha^{-1}	5.08	0.42	75.08	9.36	91.65

Table 4: Residual Soil Condition after Potato Cultivation.

Conclusion

The study showed the that vermicomposted fly ash (VFA) may be considered as a potential input for integrated nutrient management of potato in red and lateritic soils in substitution of conventional organic manures. Integration of VFA with mineral fertilizers not only resulted in resembling improvements in yields of potato in comparison to similar treatments with common organic manures but also maintained the yield benefits even after substantial reduction in the doses of mineral fertilizers. Integrated use of VFA also maintained better soil condition after the cultivation. The benefits achieved from use of VFA in such cultivation can be attributed to its effect on soil pH and also increased availability of different plant nutrients and organic matter content owing to co-composting of fly ash with organic wastes. Large scale adoption of this technology will not only help in recycling of appreciable amount of fly ash in agriculture but will also tend to utilize various organic wastes for such productive purpose.

Acknowledgement

The study was carried out using a grant from Fly Ash Mission of Department of Science and Technology, Govt. of India.

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