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Full Length Research Paper

Rapid agro-waste composting with biogeyser as a by product

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Agro-waste material like crop residues of maize, chickpea, sorghum/barley, mustards, mungbean, sesbania, autumn leaves lawn clippings, and pruned products of trees and field weeds have been chopped and mixed in layers in a pit, pile and above the ground single /multi-bin composters. Garden soil or liquid culture of some selective compost activating fungi (*Trichoderma harzianum*) has been sprayed upon the composting feed as inoculums for rapid composting. The composting material was maintained regularly by periodic forking (fortnightly) and water application to maintain the moisture level of the composting feed at 40%.Temperature of the composting material was regularly monitored with the help of compost thermometer. Compost samples were collected for different analysis including moisture, total carbon, organic carbon, total N, inorganic N, organic N, phosphorus, potash, trace elements and humates content. The prepared compost is being evaluated for its effect on the yield and quality parameters of vegetables (Tomato, Potato, Gobi, Vegetable pea, Onion and Shamla merch), ornamental plants (Araucaria & Palm) and Peach nursery. These studies revealed that 1 % compost application significantly enhanced the yield and quality of all the tested vegetables. Compost applied up to 5% significantly increased the growth parameters of the ornamental plants. During composting of agricultural wastes, a sizeable heat was generated which reached as high as 90^oC within 4-5 days. This heat was utilized for heating of water and such type of energy free facility by the microbial degradation of agricultural waste was termed as a Bio-geyser. This kind of bio-geyser is environment friendly, and provides hot water in winter and also produce quality compost, a slow release organic fertilizer for nurseries and horticultural crops. On experimental basis, a pilot scale modest bio-geyser facility adjacent to NIFA mosque that uses lignocelluloses and an assortment of effective microorganisms has been established. The facility is providing 1000 liters warm water (40-50^oC) to100-150 persons per day for ablution. Since it will be the first ever bio-geyser constructed in the country, therefore, NIFA plans to patent this technology.

Key words: Agro-waste, composting feed, microbial degradation, forking, C/N ratio, Bio-geyser.

INTRODUCTION

Pakistani soils are deficient in organic matter and other essential nutrients which must be applied as fertilizers in order to obtain higher yields. But our farmers are very poor and cannot apply the costly mineral fertilizers in proper ratio and required quantity. It is therefore essential to find out some cheap organic sources of nutrient for enhanced crop production. Compost applications improve soil nitrogen balance (Passoni and Borin, 2009), increase crop yields and improve soil properties (Paul et al., 2009) and also enhance crop productivity under low inputs (Hepperly et al., 2009). Composting is the science of converting organic matter to useful products by the action of various organisms. Decomposition process occurs in nature at various levels. To attain the goal of having quality end products, various modifications have been applied to this natural process with a careful monitoring of the process. The composting process mainly involves a battery of actions carried out by the interplay of various organisms that form a web of life. Composting is generally defined as the biological oxidative decomposition of organic constituents in wastes of almost any nature under controlled conditions (Sharma et al., 1997). Composting is usually successful when the mixture of organic materials consists

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of 20-40 parts of carbon to 1 part of nitrogen. However, as the ratio exceed 30, the rate of composting decreases. Further, as the ratio decreases below 25, excess nitrogen is converted to ammonia. This is released into the atmosphere and results in undesirable odor (Pace et al., 1995).In this process; the organic substances are reduced from large volumes of rapidly decomposable materials to small volumes that continue to decompose slowly. The process brings the ratio of carbon to other elements into a balance, thus providing nutrients to plants in the absorbable state. Significant improvement in composting process was reported by Carmen et al., (2006) when the composting materials like almond shell and rice straw was inoculated by *B. shackletonni* and *U. thermosphaericus.*

Farm waste can be easily composted which can be used as a slow-release organic fertilizing material for enhanced crop productivity and sustainable soil fertility. Agricultural wastes of fields, ornamental plants, lawn clippings, pruned products of trees, and weeds can be chopped, mixed in layers and composted in a pit, pile and above the ground single–bin /multi-bin composters. Garden soil or pure liquid culture of selective compost activating fungi (*Trichoderma harzianum*) can be sprayed upon the composting feed as inoculums for rapid composting. Pit and pile composting can be compared in terms of rate and final product**.** Temperature is an important parameter affecting microbial activity, and variations in temperature affect the various phases of composting (Epstein 1997; McKinley and Vestal. 1984 and McKinley *et al*. 1985). Temperature is produced during the composting process, resulting from the breakdown of organic materials by microbes. The organisms in composting systems can be divided into three classes: cryophiles or psychrophiles (0-25 ^{0}C); mesophiles (25-45 ^{0}C); and thermophiles (>45 ^{0}C). The major microorganisms present in compost are actiomycetes, fungi and bacteria (Palmisano and Bartaz, 1996).

Composting of agricultural wastes releases a sizeable heat which some time reaches up to 90 ^{o}C within 4-5 days. This enormous amount of heat is never used for any beneficial purpose by any person in Pakistan. This heat can be used for some beneficial purpose like water heating in winter and a farm geyser can be prepared for poor farmers to produce hot water by using the farm wastes for compost production at one thousand rupees initial cost with no running expenditure in addition to obtaining a cheap and effective source of soil nutrients i.e. compost. Such type of energy free facility for water heating by the microbial degradation of agricultural waste can be termed as a Bio-geyser. The end product of such type of bio-thermal facility will be agro-waste compost, a slow release organic fertilizer for nurseries and horticultural crops, and the geyser will be a by-product .This dual technology will be environment friendly by utilizing the agricultural wastes of farmer's fields and kitchen wastes with simultaneous additional benefit of creating water heating facility)
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MATERIAL & METHODS

Research Work on the agro-waste compost preparation and its application as a slow release organic fertilizer was conducted at NIFA Peshawar during 2007-2010 (3 years). Chopped stalks of agro-waste material like maize, chickpea, sorghum/barley, mustards, mungbean and green materials like Sesbania green shoot/leaves, field weeds and lawn clippings were used as raw materials for compost preparation. For pile and pit composting, the materials were layered (in 3:1 ratio of brown and green materials) on the smooth and clean platform and a plastic sheet shade was installed to avoid rain water. Also only maize and Sesbania biomass (intercropped on a measured piece of land) was chopped after removing maize cobs and Sesbania seed and was composted in a separate pit to determine the amount of prepared compost per unit mass of composting material. This mix of maize and Sesbania provided a relatively good C/N ratio of the substrate and consistently uniform compost.

Pit and pile composting have been compared in terms of rate and final product. Garden soil and liquid culture of some selective compost activating fungi (*Trichoderma harzianum*) was sprinkled upon the composting feed as inoculums for rapid composting. The compost was being maintained regularly by periodic forking (fortnightly) and water was sprinkled with each turning to maintain the moisture level of the composting feed at 40% (like wronged sponge). Temperature of the composting feed was regularly monitored by compost thermometer inserted in the middle of the pile/pit at half depth. Compost samples were collected on monthly basis for different analyses including moisture and humates content. Stability and maturity of the prepared compost is being determined by seed germination index according to the method of Zucconi, *et.al* (1981). To confirm the stability of finished compost, self-heating test has been performed according to the method of FCQAO (1994). Our experience shows, that within 3 months (after the compost is initially prepared and left for curing without any addition of fresh material and water etc) the material achieves desirable stability depending upon the nature of substrate. Mixture of all available stuff from a setup like our institute ,s (NIFA)lawn clippings, flower plants, fruit tress pruning materials, autumn leaves and field weeds have been utilized in different ratio to get a combination with best C/N ratio. Special emphasis was on the heating potential of different combinations of specific substrates especially maize and Sesbania. This also resulted in a pure/quality compost of a uniform structure and contents that is being utilized as organic fertilizer. Fortification of prepared compost with humic acid, and other nutrients sources was also carried out. Four hundred Kg of finished compost per ton of composting feed was

Table 1. Laboratory anaysis of compost.

Moisture content	20%
pH	8.6
E.C	12 dS/m
Total N	1.8%
NH_4-N	0.28%
P	0.3%
K	2.5%
Organic matter	52%
Ash content	48%
Organic carbon	28%
CN ratio	17

Table 2. Effect of compost levels on seed germination of hybrid tomato.

Treatments	% germination	% increase over control
Control	70%	-
15% compost	70%	-
30% compost	93%	34
50% compost	97%	40

obtained that is being evaluated for its beneficial effects in pot and field experiments using nursery, horticultural and agricultural plants as test crops. One ton Value added quality compost was prepared by spraying 0.5% urea and 0.1% humic acids solution (Pot. humate).

During composting of agricultural waste, a sizeable heat was generated which reached as high as 90^{o}C within 4-5 days. Nobody has used this heat for any beneficial purpose. We utilized this heat for heating of water and such type of energy free facility for hot water production was termed as a Bio-geyser. The end product of such type of bio-thermal facility is agro-waste compost, a slow release organic fertilizer for nurseries and horticultural crops, with simultaneous additional benefit of creating water heating facility (bio-geyser) as a by-product. Four hundred Kg of finished compost per ton of composting feed was obtained that was analyzed in laboratory for different physical and chemical characteristics as summarized in Table1.The prepared compost was being evaluated for its beneficial effects in pot and field experiments using radish, turnip, potato, tomato, cauliflower, vegetable, pea and nursery plants as test crops. In each experiment four treatments i.e. control, recommended NPK, 1% compost and half NPK+0.5 % compost were evaluated to see the effect of agro-waste compost alone and in combination with low dose of NPK fertilizers on the growth and yield parameters of these crops. Each treatment was replicated 3 times in RCB design.. Compost effect on germination of tomato seed was investigated in a pot experiment using 4 levels (0,15,30 and 50%) of compost)

RESULTS AND DISCUSSION

Efficacy studies on agro-waste compost

i). Effect on seed germination of tomato (*Lycopersicon esculentum*) hybrid seed.

In a pot experiment effect of four levels of compost i.e., 0, 15, 30 and 50% compost was investigated on the germination of hybrid tomato (T-1359) seed. The results revealed (Table 2) that seed germination was significantly increased in potting mix with 30% and 50% compost.

ii). Effect of compost and NPK levels on growth/yield of radish (*Raphanus sativus*)

The results of the study revealed that maximum biomass yield (19 kg/plot or 42.2 t/ha) was recorded in treatment receiving half NPK with 0.5% compost followed by 1% compost alone (16.4 kg/plot or 36.4 t/ha) and NPK (14.03 kg/plot or 31.2 t/ha).

iii). Effect of compost and NPK levels on growth of turnip (*Brassica rapa)*

The Study revealed that maximum biomass yield was recorded in treatment receiving 1% compost (11.7 kg/plot or 24 t/ha) followed by treatment receiving ½ NPK along with 0.5% compost (8.9 kg/plot or 19.8 t/ha) and NPK (5.83 kg/plot or 12.9 t/ha). The increase over NPK by 1% compost and 0.5% compost with half NPK was 99% and 52% respectively

iv) . Effect of compost levels on the yield and quality of potato (*Solamum tuberosum*)

The study revealed (Table-3) that maximum and equal potato yield (7.2 t/ha) was observed in treatment receiving

Table 3. Effect of compost application on the yield and quality of potato.

Treatments	Potato yield (t/ha)	No. of potato per plot	A Grade potato (%)
T_1 (Control)	4.45c	44	16.1
T_2 (N_{250} P_{150} K_{250})	7.2 0 a (62)	46	31.1
T_3 (1/2 NPK + 0.5% compost)	7.2 0 a (62)	53	30.1
T_4 (compost 1%)	6.12 b (37.5)	57	22.8

Figures with same letter do not differ significantly at 5 % level.
Figure in brackets are % increase over control

Table 4. Effect of compost application on head cabbage (Brasica *capitata*).

Treatment	Total plant yield(t/ha)	Heads yield (t/ha)	Single head wt. (kg/plant)	Plant fresh wt.(kg/plant)	Root biomass (g/plant)
Control	25.2c	14.9 c	0.427 c	0.72 c	175.8 c
NPK	47.7ab (89%)	27.6 a b	0.790 b (85.01)	1.36 a b	243.0 b (38.2%)
½ NPK+0.5%compost	56.0a (122.2%)	31.5a	0.901 a (111.0)	1.60 a	254 a b (44.48)
1% compost	56.7a (125%)	35.2a	1.007 a (135.8)	1.62 a	278.4 a (58.3)

Figures in brackets are % increase over control

Figures possessing the same letters do not differ significantly.

Table 5. Effect of compost application on different growth parameters of ornamental plants.

Treatments	No. of leave/plant	Plant height (cm)	Stem thickness (diameter in cm)
a. Araucaria			
Control	27.7	69.3	1.26
2% compost	33.0	76.0	1.36
5% compost	34.0 (22.9)	82.3(18.7)	1.38 (9.5)
b. PALM			
Control	17.0	35.33	5.1
2% compost	24.0 (24)	48.0	6.0 (17.0)
5% compost	23.7 (23.9)	56.7 (60.4)	5.4

Each figure is average of 3 replicates.

Figure in brackets are % increase over control

NPK alone and in treatment receiving ½ NPK with 0.5% compost (62% over control). Compost alone produced 6.12 t/ha (37.5% over control). Potato size was also improved by compost application.

v): Effect of compost on the growth parameters of head cabbage (*Brassica oleracea var. capitata*)

In a micro plot (2 m^2) experiment, effect of compost was investigated on the yield and root biomass of cabbage Using 4 treatments (i) Control ii) NPK full dose iii) Half NPK + 0.5% compost and iv) 1.0% compost alone). The study revealed (Table 4) that highest and statistically equal plant biomass yield was recorded in treatment receiving 1% compost (1.62 kg/plant) and treatment receiving 0.5 % compost along with half NPK (1.60 kg/plant). The total plant biomass yield was 56.7 and 56 t/ha respectively and the % increase over control was 122 and 125% respectively.

Figure 1. Residual effect of compost on fruit yield of tomato.

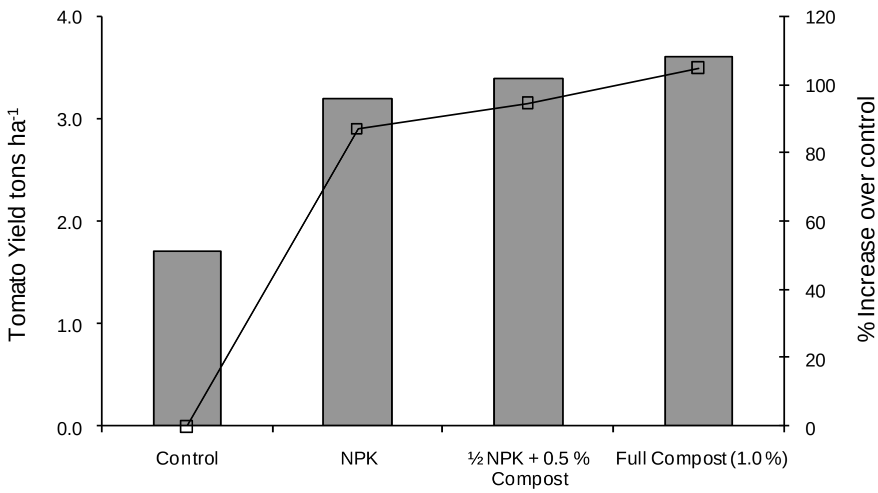

Table 6. Effect of compost application on peach nursery.

Treatment	No. of plants/line	% germination	Plant height (cm)	No. of braches/plant
Control	44 a	14.5	58.6	12.4 b
Compost 25 kg/line(171 ft^2)	88 b (100%)	29.2 (100%)	63.9 (9.0%)	17.5 a (41%)

Each figure is average of 6 replicates. Figures in brackets are % increase over control

vi) : Residual effect of compost on fruit yield of tomato (*Lycopersicon esculentum*)

Residual effect of last season's applied compost (to cabbage) on the fruit yield of tomato was investigated in a micro plot experiment. The data revealed (Figure 1) that maximum and statistically equal tomato fruit yield (3.7 t/ha) was in treatment receiving 1 % compost followed by treatment receiving ½ NPK along with 0.5% compost (3.4t/ha) and treatment receiving full NPK alone (3.1 t/ha). The increase over control by compost was 105 %, by1/2 compost+1/2 NPK was 94.5% and by NPK alone was 87.1% respectively.

vii). Effect of compost application on different growth parameters of ornamental plants.

In a pot experiment effect of two levels of compost (2% and 5%) was investigated on different growth parameters of araucaria (*Araucaria araucana)* and palm (*Borassus flabellate)* plants (one years old seedling). The results (Table 5) are summarized as below:

Number of Leaves : In Araucaria maximum number of leaves/plant (34) were recorded in treatment receiving 5 % compost followed by 2% compost (33) as compared to control (27.6). The increase over control was 17% and 15% respectively. In Palm plants, maximum and statistically equal number of leaves /plant (24) were recorded in treatments receiving 2% and 5% compost (23.7) as compared to control (17). The increase over control was 39%.

Plant height: Compost application increased the plant height in both plant species. In Araucaria the highest plant height was recorded in treatment receiving 5% compost (82.3cm) followed by 2% compost (76 cm) as compared to control (69.3 cm). The % increase over control was 22.9% and 21% respectively. In case of Palm plants, again the highest plant height was recorded in treatment receiving 5% compost (55.7cm) as compared to control (53.3 cm).

Stem diameter: Stem diameter was measured by Varner caliper. Maximum stem thickness was observed in treatment receiving 5% compost in case of Araucaria (1.38 cm) followed by 2% compost (1.36 cm) as compared to control (1.26 cm). In case of Palm plants, maximum stem diameter was recorded in treatment received 2% compost (5.96 cm) as compared to control (5.1 cm).

viii): Effect of compost application on peach (*prunus persica*) nursery.

In a field experiment effect of compost application (1.3 kg/m^2 or 0.7%) was studied on peach nursery. The study revealed (Table 6) that compost application significantly increased seed germination, plant height and number of braches/plant. The increase over control was 100%, 9% and 41% respectively.

Table 7. Effect of compost levels on the pod yield &number of pods of vegetable pea.

Treatments	Pod yield kg/plot	% increase over control	No. of Pods/Plot	% increase over control
Control	0. 8[C] (493.7 kg/ha.)	-	132 [C]	-
Full NPK	1.95 [b] (1218.7kg/ha)	147	219 [b]	65
1% Compost	2.89 [a] (1806.2kg/ha)	266	302 [a]	129
Half NPK +0.5% compost	2.29 [b] (1431.2kg/ha)	190	224 [b]	70

Figures with same letter do not differ significantly at 5 % level.

ix): Effect of compost and NPK on Vegetable pea (*Pisum sativum*)

In a field experiment effect of different levels of compost application and Chemical fertilizer was investigated on the pod yield, pod size and number of pods/plant using the same 4 treatments mentioned in material and method portion. The data revealed (Table 7) that highest pod yield of 2.9 kg/plot(6.42 t/ha) was in case of treatment receiving 1 % compost followed by treatments receiving 0.5 % compost with ½ NPK 2.3kg/ha(5.0 t/ha) and NPK alone 1.95 kg/ha (4.3 t/ha).The % increase over control was 267%,190% and 147% respectively. Similarly the number of pods/plot were also maximum in treatment receiving 1 % compost (302 /plot) followed by 0.5 % compost along with !/2 NPK (224/plot). The increase over control was 129 % and 70 % respectively.

DISCUSSION

The benefit /increase in yield and yield parameters observed in the above mentioned experiments is due to the fact that compost application improve soil nitrogen balance (Passoni and Borin, 2009),and improvement in soil properties (Paul et al., 2009) . Querdraogo et al., 2001 also observed increased crop productivity under low inputs. In this process, the organic substances are reduced from large volumes of rapidly decomposable materials to small volumes that continue to decompose slowly. The process brings the ratio of carbon to other elements into a balance, thus providing nutrients to plants in the absorbable state and improved the plant growth and yield & quality parameters. Compost applications increase soil microbial activity and also improve soil structure. During composting, around 50% of the organic matter will be fully mineralized, producing CO2 and water. Protein, cellulose, and hemicelluloses are easily degradable. Many of these compounds produce organic residues, referred to as humic matter. A great deal of work has been recently conducted on humic matter from various sources. The amount of humic acid increases during the process. Increase in aromatic structures, phenolic structures, and carboxylic structures was also evidenced, whereas decrease in O-alkyl structures, polysaccharides, and amino acids was recorded with no changes in alkyl structures and carbohydrates (Chefetz et al. 1998).

B: Development of bio-thermal technology for heating of water (bio-geyser)

While working on composting / humification at NIFA, it occurred that the heat generated during the process of microbial decomposition of plant residues could be used to heat water. Decomposition of cellulose biomass (consisting mostly of leaves, twigs and other agricultural discard) is an exothermic bioprocess that may elevate the temperature of the material significantly. By maintaining the moisture level and with added insulation, heat generated inside the compost was able to maintain the temperature of the water in a metal (conductive) container up to 55 ^{0}C. The first Bio-Geyser facility was established with NIFA mosque to obtain warm water for the ablution of 100-150 persons daily. A great deal of studies were undertake to optimize the conditions for getting un-interrupted supply of warm water. Turning and supplementation of plant residues was found to help maintain desirable temperatures for extended time periods (up to 4 months). The models developed are being standardized at the University of Engineering and Technology, Peshawar.

This discovery could have an enormous impact on the lives of poor folks in the rural areas without access to electricity. Several functional units of variable sizes (15-1000 liter capacities) have been fabricated for local testing, and the results are astonishing. This technology would be able to provide lukewarm to warm water to rural population, particularly during the winter months, at little or no running cost. The laboratory scale model Bio-geyser won 1st prize in the first “Science Model competition” (June27-28, 2008), and also won 1st prize and Gold Medal in the Grand Final Science Model competition (April 4-5, 2010) organized by Directorate of Science and Technology, Ministry of Science &Technology, Khyber-Pukhtoon Khawa (KPK), province of Pakistan.

Studies were under taken on the heating potential of different composting materials. Maximum heat (65-80 ^{O}C) was recorded by mixing chopped maize stalks mixed with green matter of Sesbania in 3:1 ratio. The heat was maintained for 7 consecutive days after which recharging was found necessary. One kg of composting material produced 18 kilocalories of heat. A series of studies revealed that the thickness of composting material should be at least 12 inches around the water container of 30 cm diameter. In further studies carried out for one month, it was found that 90 litters of water could be heated to 50 ^{0}C every day that is sufficient for a family of four to take daily bath. The study suggested that for 20 ^{0}C rise in temperature of 90 L water, about 1500 kilocalories of heat was supplied by the composting material (18 kilocalories kg^{-1}). Amongst cans of different metals that made of aluminum was found to be most efficient in heat transfer. This Bio-geyser Technology will be popularized among the poor masses of rural and backward arease where electricity and gas is not available and if possible will be also commercialized. Since it will be the first ever bio-geyser constructed in the country, therefore, NIFA will try to patent this technology. The technology will serve as prototype for resource poor segments of the society as well as for saving energy. A case to patent this dual technology has been submitted to IPO, Karachi, Pakistan.

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