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Effect of compost enriched with N and L-tryptophan on soil and maize

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Abstract – Composting provides an excellent way to manage the huge volume of organic waste and convert it into a useful soil amendment. The effectiveness of composted organic waste can be further improved by enriching and blending it with nutrients and biologically active substances. The resulting value-added composts can be used at substantially low rates such as a few hundred kg per ha compared with conventional use of organic wastes in tons per ha. This approach could have practical significance in reducing the use of chemical fertilizer for sustainable agriculture and the environment. L-tryptophan is a precursor of the growth hormone indole acetic acid and is known to stimulate plant growth at extremely low concentrations. Here, we studied the effect of composted fruit and vegetable wastes, enriched with N at 133 g kg^{-1} compost, with or without L-tryptophan at 10 mg kg^{-1} compost, on soil and maize crops. The enriched compost was applied at 300 kg ha^{-1} to a sandy clay loam soil either by mixing with the top 15-cm soil layer in pots or as a band placement along the maize plants grown in the field. The compost was applied alone and in combination with 40 or 80 kg ha^{-1} urea N and compared with a treatment containing 160 kg N ha^{-1}, a full dose of N fertilizer alone, while P and K fertilizers were applied in all the treatments. Our results show that application of the enriched compost to soil increased aggregate stability by up to 24.8% and water retention by up to 43.1% compared with untreated control. A gradual increase in the concentration of indole acetic acid in compost, ranging from 1.02 to 3.34 mg kg^{-1}, was observed when compost was treated with its precursor L-tryptophan. The results of pot and field experiments revealed that compost enriched with N and L-tryptophan in the presence of 80 kg N fertilizer significantly increased cob and grain yields, by up to 19.8 and 21.4%, respectively, compared with a full dose of N fertilizer. These findings suggest that enrichment of composted organic wastes with N and L-tryptophan can change them into a value-added organic product that could be used as a soil amendment at rates as low as 300 kg ha^{-1} to increase crop production on a sustainable basis.

auxins / biologically active substances / maize / nitrogen / organic fertilizer / organic waste / recycling soil aggregate

1. INTRODUCTION

Organic matter is known to improve soil health and availability of plant nutrients (Atagana, 2004; Montemurro et al., 2005; Guillaumes et al., 2006). Organic materials are available in the form of farm waste, sewage sludge, poultry litter and industrial wastes such as food, sugar, cotton and rice industry wastes. Composting is a well-established biological process of recycling these organic wastes and provides an excellent way to manage big volumes of organic wastes in an environmentally sound manner (Millner et al., 1998; Eghball et al., 2004). Compost results in suppression of pathogens and improvement in the C: nutrient ratio, and is easy to handle, store, transport and apply in soil compared with non-composted organic residues (Millner et al., 1998; Eghball and Lesoing, 2000; Hachicha et al., 2006).

Since organic materials, either composted or non-composted, are being used in bulk volume, i.e., at several t ha^{-1} for the improvement of soil health and crop productivity (Wolkowski, 2003; Abera et al., 2005; Elherradi et al., 2005), their availability could be limited and may also not be cost-effective. So there has been renewed interest in compost technology to improve it with respect to the quantity of compost applied and quality of the end product. A wise manipulation of composted material not only can reduce application rates of the compost but could also help achieve a product of desired characteristics. A novel approach to converting composted material into an effective organic product is its value addition through enrichment with certain nutrients and/or with plant growth-promoting substances.

Auxins are a class of plant hormone and indole acetic acid is a principal naturally occurring auxin. Indole acetic acid is involved in a variety of plant growth and development responses (Frankenberger and Arshad, 1995; Khalid et al., 2004a). L-tryptophan is a known physiological precursor of indole acetic acid and its application at appropriate concentrations could have a positive effect on plant growth because

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of slow and gradually continuous release of indole acetic acid from L-tryptophan. It has been demonstrated that application of L-tryptophan had a significant positive effect on growth and yield of crops (Frankenberger and Poth, 1987; Zahir et al., 1997).

In this study, we focused on developing a cost-effective value-added organic fertilizer from fruit and vegetable wastes by using both composting and enrichment technology to reduce the application rates from t ha^{-1} to kg ha^{-1}. The composted organic material was enriched with N and L-tryptophan, and tested for its effects on soil aggregation, water conservation and C mineralization in soil, as well as on growth and yield of maize.

2. MATERIALS AND METHODS

2.1. Preparation of compost

A locally-fabricated mechanical composting unit consisting of drier, crusher/grinder and processor was used for composting fruit and vegetable wastes. The wastes were collected in the month of April from various locations including a local fruit and vegetable market and juice shops of Faisalabad city, situated at longitude 72°0′ and 73°45′ east, and latitude 30°30′ and 32°0', north Pakistan, and air-dried for a couple of days to remove the excessive moisture. The unwanted substances, e.g. pieces of metals, glass and plastic were removed manually from the wastes. The sorted organic material was oven-dried at 65 °C for 24 h and crushed to fine particles of <2.0 mm by passing through an electric grinder. The crushed material was transferred to a vessel of 500 kg capacity for composting. A moisture level of 40% v/w of the compost was maintained during the composting process. Composting was done for 5 days under controlled temperature and aeration, through shaking at 50 rpm. The temperature of the composting unit rose from 30 to 70 °C during the 2nd and 3rd days of the composting process and then reduced gradually to 30 °C after the 4th day. The compost was analyzed for macro- and micro-nutrients (Nelson and Sommers, 1996; Ryan et al., 2001), and C/N, C/P and C/K ratios were determined (Tab. I).

2.2. Enrichment of compost with N and L-tryptophan

The enriched compost was prepared by mixing the finished compost with urea fertilizer purchased from Fauji Fertilizer Company Ltd., Pakistan at 133 g N kg^{-1} compost. Thus, 300 kg compost contained 40 kg N, i.e., 25% of 160 kg ha^{-1} N. Similarly, L-tryptophan obtained from Sigma Chemical Co., St. Louis MO, USA was added to the solution form at 10 mg kg^{-1} compost in one batch of N-enriched compost according to the treatments to release indole acetic acid for plant uptake.

Table I. Analysis of raw and composted fruit and vegetable wastes.

Parameter[a]	Organic waste before composting crushed to <2.0 mm	Composted organic wastes
Carbon (%)	33.5	22.8
Nitrogen (%)	1.39	2.30
Phosphorus (%)	0.36	0.48
Potassium (%)	1.14	1.62
Copper (mg kg^{-1})	1.08	1.24
Zinc (mg kg^{-1})	44.0	51.0
Manganese (mg kg^{-1})	36.0	47.0
Iron (mg kg^{-1})	563	682
C/N ratio	24.1	9.9
C/P ratio	93.1	47.5
C/K ratio	29.4	14.1

2.3. Mineralization rates of raw organic wastes and enriched compost

Mineralized rates of raw organic materials and compost enriched with N and L-tryptophan were determined by using the method described by Anderson (1982). The raw organic waste and enriched compost were added at 1% of the soil weight to vials containing 50 g non-sterilized soil. A moisture level of 15% v/w was maintained in the vials with CO_2-free water. The vials were put in glass jars of 500 mL capacity containing 2.5 N NaOH to trap the CO_2 evolved. The jars were closed with air-tight seals and incubated in triplicate at 30 °C for 21 days. A control treatment consisting of soil without addition of any organic material and a blank treatment consisting of a glass jar without a vial were also included in the study. All the treatments were replicated three times. The CO_2 trapped in NaOH was measured by titrating it with 1.0 N HCl against a phenolphthalein indicator after precipitation with 1.0 N $BaCl_2$.

2.4. Soil aggregate stability

Soil aggregate stability was determined with a nested sieve arrangement using the wet sieving method (Kemper and Rosenau, 1986). The soil was treated either with raw organic waste or enriched compost and incubated for 56 d at 30 °C. There was also an untreated control soil. After 56 days′ incubation, all the crumbled soils were passed through an 8.0-mm sieve to remove large debris-like material. The above sieved soils of <8.0 mm were then wet-sieved in a 1.0-mm sieve in degassed distilled water added at 180 to 250 g water kg^{-1} soil for 5 min. The soil material of >1.0 mm not passed through the sieve openings was weighed and reported as the percent stable aggregate fraction.

2.5. Soil water retention under controlled laboratory conditions

A laboratory study was conducted to determine the water retention in the soil amended either with raw organic wastes or enriched compost applied at 300 kg ha^{-1}. The plastic beakers were filled with 200 g of sieved soil mixed with crushed raw organic wastes or enriched compost. The soil not amended with any organic material was kept as control for comparison. All the soils were saturated by applying an equal volume of water. The saturation percentage of the soil was determined prior to adding measured amounts of water to each soil. The beakers were kept open and incubated at 30 °C for 10 days. The water retained in the soil was monitored periodically. The experiment was conducted with three replications.

2.6. Auxins in the enriched compost

Auxin contents in the N-enriched compost treated with 10 mg L-tryptophan kg^{-1} compost were determined over a period of 10 days according to the method described by Khalid et al. (2004a, b). Similarly, auxin contents were measured in the N-enriched compost treated with synthetic indole acetic acid at 10 mg kg^{-1} compost to test the degradation rate of indole acetic acid in the compost. Amounts of auxins were determined by colorimetry. For this purpose, 3 g of compost treated either with L-tryptophan or indole acetic acid was added to a 50-mL Erlenmeyer flask with 6 mL of 0.2 M phosphate buffer of pH 7. Control consisted of untreated compost. The flasks were covered with Para film and incubated in darkness at 35 °C in an incubator at 100 rpm. The suspension was filtered through Whatman filter paper No. 2 after treating with 2.0 mL of 5% solution of trichloroacetic acid. Auxins expressed as indole acetic acid-equivalents were determined at 535 nm by spectrophotometer (ANA-720W, Tokyo Photoelectric Company Limited, Japan) using Salkowski coloring reagent (Sarwar et al., 1992). All auxin determinations were made in three replications.

2.7. Pot and field trials on maize

Two pot and two field experiments were conducted during the consecutive seasons to assess the effect of compost enriched with N and/or L-tryptophan on growth, yield and nutrient uptake of maize (*Zea mays* L.). A sandy clay loam mixed haplocalcid soil was used for pot trials. The soil was air-dried and sieved with a 40-mesh sieve before filling the pots. Analysis of a composite soil sample revealed a pH of 7.8; electrical conductivity, 2.4 dS m^{-1}; organic matter, 0.60%; total N, 0.04%; available P, 7.6 mg kg^{-1} and extractable K, 130 mg kg^{-1} soil.

Pots of 23 cm diameter and 26.5 cm height were filled with the sieved soil at 12 kg pot^{-1} mixed with P and K fertilizers applied at 120 and 60 kg ha^{-1} as single superphosphate and sulfate of potash, respectively. Nitrogen as urea was applied at 160 kg ha^{-1} according to the treatments. The enriched compost at 300 kg ha^{-1} was applied to each pot by mixing it with the top 15 cm of soil at the time of filling of the pots. The enriched compost was also supplemented with either no N or with 40 and 80 kg N ha^{-1} i.e., 25 and 50% of 160 kg N ha^{-1}, respectively.

Four seeds of hybrid maize cv. Corn-786 were sown in each pot. Plants were thinned to one plant per pot after germination. The pots were arranged randomly in the net house with four replications at ambient light and temperature. The pots were kept moist near field capacity, i.e., 60% of the saturation percentage by using good quality canal water with electrical conductivity of 0.04 dS m^{-1}, a sodium adsorption ratio of 0.3 (mmol L^{-1})$^{1/2}$ and residual sodium carbonate of 0 (Ayers and Westcot, 1985). The aboveground fresh biomass, cob and grain yields and dry root weight were recorded at maturity. Grain and shoot samples of maize plants were analyzed for N, P and K contents and their total uptakes were determined.

Field experiments were conducted in a maize-wheat-maize crop rotation. Hybrid maize, Corn-786, was sown in a sandy clay loam soil in the month of August 2003 in the first year of the experiment and 2004 in the second year of the experiment. The seeds were sown in the field with the help of a dibbler, keeping row to row distance of 60 cm and plant to plant distance of 25 cm, with a plot size of 10 m^2. One seed was sown per hole. The same treatments as described in the pot experiments were used for the field trials. The experiments were laid out in a randomized complete block design with four replications. The whole dose of P and K fertilizers was applied at the time of seed bed preparation in all blocks, while N was applied according to the treatments in two split doses after germination and before tasseling. Air-dried enriched compost was applied at 300 kg ha^{-1} as a band placement along the seeds with a drill according to the treatment plan mentioned above. All the treatments in both experiments were repeated four times. Canal water was used for irrigation. The aboveground fresh biomass, and cob and grain yields were recorded at maturity. Grain and shoot samples were analyzed for N, P and K contents and their total uptakes in maize plant were determined. The data were analyzed statistically at $P < 0.05$, using the MSTATC (Michigan State University, MI, USA) software.

3. RESULTS AND DISCUSSION

This study reports the effects of composted organic wastes enriched with N and L-tryptophan, an organic fertilizer, on soil properties as well as on growth and yield of maize.

3.1. Effect of enriched compost on soil conditioning

The average CO_2 evolved from soil treated with the enriched compost ranged from 48 to 63 mg kg^{-1} day^{-1}, while in the case of soil treated with the raw organic wastes, it ranged from 55 to118 mg kg^{-1} day^{-1} (Tab. II). The highest CO_2 evolution was noted in soil treated with the raw organic wastes after 14 days of incubation. The slow mineralization rate of the composted organic waste in soil implies that organic matter status of a soil might be improved, to some extent, by adding organic fertilizer as a soil amendment. It has been reported that organic matter accumulation in soil was more than double due to compost application than the same amount of raw organic

Table II. Carbon mineralization rate, aggregate stability and water retention in soil treated with raw uncomposted and composted vegetable wastes. The data are an average of three replications.

Treatment	Mineralization rate (mg CO_2 evolved kg^{-1} day^{-1})± S.E.				Aggregate stability (%) ± S.E.	Water retention (%) ± S.E.			
	4 days	9 days	14 days	21 days	(%)	1 day	4 days	7 days	10 days
Untreated soil	31 g* (± 1.39)	34 g (± 1.20)	33 g (± 1.98)	30 g (± 1.24)	21.7 b (± 0.88)	81.6 b (± 1.72)	51.1 de (± 1.38)	35.8 hi (± 0.94)	32.9 i (± 1.03)
Soil treated with raw organic waste	85 c (± 2.98)	106 b (± 3.72)	118 a (± 3.80)	55 e (± 2.50)	23.1 ab (± 0.92)	88.8 a (± 1.90)	56.9 cd (± 1.88)	39.6 gh (± 1.10)	36.7 h (± 1.39)
Soil treated with enriched compost	48 f (± 1.52)	61 de (± 1.77)	63 d (± 2.10)	61 de (± 1.33)	24.8 a (± 1.14)	89.8 a (± 2.10)	60.9 c (± 1.45)	46.6 ef (± 1.22)	43.1 fg (± 1.60)

* Means of each parameter sharing the same letter are statistically not significant at $P < 0.05$ according to Duncan's multiple range test.

material (Food and Fertilizer Technology Centre, 1997). Similarly, Montemurro et al. (2007) reported a significant increase in the organic C contents in soil treated with municipal solid waste compost compared with mineral fertilizer.

A greater amount of stable aggregate fraction of 24.8%, remaining in the 1.0 mm sieve, was found in soil treated with the enriched compost after 56 days of incubation compared with soil treated with the raw organic wastes or untreated soil (Tab. II). Similarly, maximum water retention of 43.1% was recorded in soil treated with the enriched compost, followed by 36.7 and 33.0% water retention in the case of raw organic waste and untreated control soil, respectively. These results show an increase in soil aggregation and water-holding capacity in soils where the enriched compost was applied at 300 kg ha^{-1}. Hanay et al. (2004) reported up to 33% increase in the stable soil aggregate fraction and up to 5.7% increase in the water-holding capacity of soil by the application of compost. Other authors have also reported a strong correlation between soil aggregation and the water-retaining capacity of soil (Canbolat, 1992; Ibrahim et al., 1999).

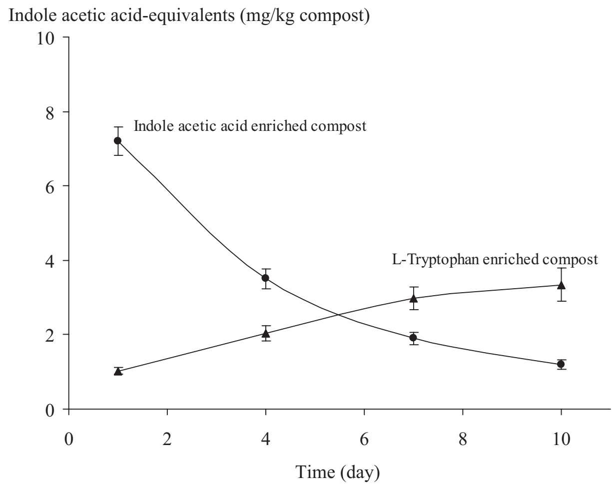

Figure 1. Indole acetic acid in the composted organic wastes treated either with the auxin indole acetic acid or its precursor, L-tryptophan, at 10 mg kg^{-1} compost.

3.2. L-tryptophan-dependent release of auxins in the enriched compost

L-tryptophan-dependent indole acetic acid production was increased gradually, ranging from 1.02 to 3.34 mg kg^{-1}, in the compost as the incubation proceeded up to 10 days (Fig. 1). However, the amount of indole acetic acid detected in the compost treated directly with the synthetic indole acetic acid was sharply reduced from 7.2 to 1.2 mg kg^{-1} compost as the incubation proceeded. This implies that slow and gradual release of indole acetic acid from its precursor, L-tryptophan, could be more stimulatory for plant growth after uptake due to its bioavailability for a longer time than the single application of synthetic indole acetic acid (Frankenberger and Arshad, 1995).

3.3. Effect of enriched compost on growth and yield of maize

The results of two years′ pot experiments indicated that the effect of the compost enriched with N and supplemented with 80 kg N fertilizer on aboveground fresh biomass, cob and grain yields, and root weight was statistically at par to that observed in the case of a full dose of N fertilizer (Tab. III). However, application of the compost enriched with N plus L-tryptophan and supplemented with 80 kg N fertilizer significantly increased the fresh biomass, cob and grain yields, and root weight by up to 12.5, 15.7, 15.1 and 16.5%, respectively, over a full dose of N fertilizer alone. Under field conditions, the maximum increase in fresh biomass, and cob and grain yields in response to N- plus L-tryptophan-enriched compost in the presence of 80 kg N was 12, 15.3 and 16.7% compared with a full dose of N alone (Tab. IV). However, in the second year, the effect of this treatment was more pronounced on cob and grain yields, resulting in increases of 19.8 and 21.4%, respectively, over a full dose of N fertilizer. In general, the compost enriched with N plus L-tryptophan showed more promising results in the presence of 80 kg N fertilizer under both pot and field conditions compared with either a full dose of N alone or N-enriched compost supplemented with a half dose of N fertilizer. There was >25% saving of

Table III. Effect of composted organic wastes enriched with nitrogen and/or L-tryptophan, and supplemented with chemical fertilizer on fresh biomass, cob and grain yields, and root weight of maize, pot experiments. The data are an average of four replications.

Treatment	Fresh biomass (g pot $^{-1}$)		Cob weight (g pot $^{-1}$)		Grain yield (g pot $^{-1}$)		Dry root weight (g pot^{-1})	
	Year-I	Year-II	Year-I	Year-II	Year-I	Year-II	Year-I	Year-II
Urea fertilizer, 160 kg N ha^{-1}	522 b*	550 b	178 b	185 b	125 b	126 b	53.8 b	55.0 b
N-enriched compost, 300 kg ha^{-1}	448 e	455 e	128 d	140 e	87 e	94 e	42.0 d	43.5 d
N-enriched compost supplemented with 40 kg ha^{-1} N	470 d	598 d	156 c	163 d	100 d	108 d	47.2 c	49.0 c
N- & L-tryptophan-enriched compost supplemented with 40 kg ha^{-1} N	503 c	523 c	169 b	174 c	117 c	118 c	52.0 b	52.4 c
N-enriched compost supplemented with 80 kg ha^{-1} N	532 b	568 b	176 b	188 b	128 b	130 b	53.5 b	56.0 b
N- & L-tryptophan-enriched compost supplemented with 80 kg ha^{-1} N	580 a	619 a	195 a	214 a	138 a	145 a	61.5 a	64.1 a

* Means of each parameter sharing the same letter are statistically not significant at $P < 0.05$ according to Duncan's multiple range test.

Table IV. Effect of composted organic wastes material enriched with nitrogen and/or L-tryptophan, and supplemented with chemical fertilizer on fresh biomass, and cob and grain yields of maize, field experiments. The data are an average of four replications.

Treatment	Fresh biomass (t ha^{-1})		Cob yield (t ha^{-1})		Grain yield (t ha^{-1})	
	Year-I	Year-II	Year-I	Year-II	Year-I	Year-II
Urea fertilizer, 160 kg N ha^{-1}	31.6 b*	32.4 b	11.1 b	12.1 b	6.06 b	6.44 b
N-enriched compost, 300 kg ha^{-1}	24.1 d	25.5 d	7.8 e	8.4 e	3.68 e	4.02 e
N-enriched compost supplemented with 40 kg ha^{-1} N	28.7 c	29.4 c	9.2 d	10.8 d	4.75 d	5.41 d
N- & L-tryptophan-enriched compost supplemented with 40 kg ha^{-1} N	30.4 bc	31.1 c	10.2 c	11.6 c	5.41 c	5.98 c
N-enriched compost supplemented with 80 kg ha^{-1} N	32.0 b	33.4 b	11.6 b	12.4 b	6.10 b	6.67 b
N- & L-tryptophan-enriched compost supplemented with 80 kg ha^{-1} N	35.4 a	37.2 a	12.8 a	14.5 a	7.07 a	7.82 a

* Means of each parameter sharing the same letter are statistically not significant at $P < 0.05$ according to Duncan's multiple range test.

N economy with the application of 300 kg ha^{-1} organic fertilizer/enriched compost. Some authors have reported about 20% N saving due to compost (Bajpai et al., 2002); however, they applied compost in t ha^{-1}. Increases in growth and yield of maize could be attributed to enhanced nutrient-use efficiency in the presence of organic fertilizer, it being a source of macro- and micro-nutrients (Tab. I). This premise is supported by the fact that the total N, P and K uptakes in maize (see Tabs. V–VI) were increased significantly in response to combined application of enriched compost and N fertilizer. Previous studies have also shown that composted organic materials enhanced the fertilizer-use efficiency by releasing nutrients slowly and thus reducing the losses, particularly of N (Chang and Janzen, 1996; Paul and Clark, 1996; Nevens and Reheul, 2003). Moreover, an increase in soil aggregation and water retention (Tab. II) might also have affected the nutrient availability to plants. Slow and gradual release of L-tryptophan-dependent indole acetic acid from the composted organic wastes (Fig. 1) could affect root growth directly, and subsequently shoot growth. Studies have indicated that the application of L-tryptophan to the rooting medium improved plant growth (Frankenberger and Arshad, 1991; Arshad et al., 1995; Zahir et al., 1997).

We found that the organic fertilizer applied to the same field during the second year gave a better performance than the first year's application. This reveals that continuous application of composted organic wastes in the field may result in improving the organic matter status of the soil and thus can improve soil health and crop yields on a sustainable basis. We observed slow mineralization rates of the composted organic wastes in the soil (Tab. II), which further supports the above premise.

4. CONCLUSION

The results of our study demonstrate that effectiveness of composted organic waste could be improved by enriching it with N and with little amounts of biologically active substances such as L-tryptophan. Here, we found up to 21% increase in grain yield of maize by the application of just

Table V. Effect of composted organic wastes enriched with nitrogen and/or L-tryptophan, and supplemented with chemical fertilizer on total uptake of nitrogen, phosphorus and potassium by maize, pot experiments. The data are an average of four replications.

Treatment	Total uptake (g pot^{-1})					
	Nitrogen		Phosphorus		Potassium	
	Year-I	Year-II	Year-I	Year-II	Year-I	Year-II
Urea fertilizer, 160 kg N ha^{-1}	1.57 b*	1.60 b	0.59 b	0.60 b	1.39 ab	1.40 b
N-enriched compost, 300 kg ha^{-1}	0.94 e	0.98 d	0.38 e	0.39 d	0.92 e	0.95 e
N-enriched compost supplemented with 40 kg ha^{-1} N	1.22 d	1.42 c	0.45 d	0.47 c	1.12 d	1.16 d
N- & L-tryptophan-enriched compost supplemented with 40 kg ha^{-1} N	1.40 c	1.48 c	0.51 c	0.50 c	1.26 c	1.29 c
N-enriched compost supplemented with 80 kg ha^{-1} N	1.56 b	1.63 b	0.58 b	0.57 b	1.35 b	1.40 b
N- & L-tryptophan-enriched compost supplemented with 80 kg ha^{-1} N	1.69 a	1.82 a	0.65 a	0.69 a	1.44 a	1.50 a

* Means of each parameter sharing the same letter are not significant at $P < 0.05$ according to Duncan's multiple range test.

Table VI. Effect of composted organic wastes enriched with nitrogen and/or L-tryptophan, and supplemented with chemical fertilizer on total uptake of nitrogen, phosphorus and potassium by maize, field experiments. The data are an average of four replications.

Treatment	Total uptake (kg ha^{-1})					
	Nitrogen		Phosphorus		Potassium	
	Year-I	Year-II	Year-I	Year-II	Year-I	Year-II
Urea fertilizer, 160 kg N ha^{-1}	117 b	122 b	54.1 b	56.0 b	109 ab	112 b
N-enriched compost, 300 kg ha^{-1}	72 d	78 e	31.5 e	32.0 e	64 d	66 e
N-enriched compost supplemented with 40 kg ha^{-1} N	95 c	100 d	38.6 d	42.0 d	82 c	85 d
N- & L-tryptophan-enriched compost supplemented with 40 kg ha^{-1} N	101 c	110 c	44.0 c	46.2 c	88 c	96 c
N-enriched compost supplemented with 80 kg ha^{-1} N	119 b	124 b	52.1 b	57.8 b	105 b	110 b
N- & L-tryptophan-enriched compost supplemented with 80 kg ha^{-1} N	130 a	138 a	59.8 a	64.5 a	115 a	123 a

300 kg ha^{-1} of compost enriched with N and 10 mg kg^{-1} L-tryptophan compared with chemical fertilizer alone. This results in a saving of more than 25% N, in addition to improving soil health and the water-retaining capacity of the soil for sustainable crop production. The economic analysis of the enriched compost indicated that this technology is cost-effective, because raw organic wastes are available free of cost in developing countries and application of just 300 kg ha^{-1} of value-added product is quite feasible for the farmers. In this way, use of such organic fertilizers could reduce dependence on chemical fertilizers, to some extent, and would have practical application in sustainable crop production and organic waste management.

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