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EVALUATION OF COMPOSTED ORGANIC WASTE ENRICHED WITH NITROGEN AND L-TRYPTOPHAN FOR IMPROVING GROWTH AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

Organic waste materials are being used in huge amounts (tons ha^{-1}) for improving soil health and crop yields. Recycling of organic wastes enriched with nitrogen and L-tryptophan (L-TRP) could convert organic waste material into a useful soil amendment, which may be effective even when added in substantially small amounts (kg ha^{-1}). Organic waste material of fruits and vegetables was collected and subjected to composting in a locally fabricated mechanical unit. The composted material was enriched with N (120 g kg^{-1} compost) and L-tryptophan (10 mg kg^{-1} compost) to convert it into a value added organic fertilizer. Effectiveness of the compost enriched with N alone and with N plus L-TRP was compared by applying different rates (300, 400 and 500 kg ha^{-1}) to wheat in two year field study. The P and K fertilizers were applied as basal treatment in all plots, thus control consisted of P and K fertilizers only. Results of field experiments revealed that application of N & L-TRP-enriched compost @ 500 kg ha^{-1} was as effective as full dose of N fertilizer in improving growth and yield of wheat, saving 30% N fertilizer. It significantly improved the yield of wheat by 64% during first year and by 73% during second year compared with control. Similarly, N, P & K contents of the wheat plants were significantly improved upon application of N & L-TRP-enriched compost @ 500 kg ha^{-1} compared with control. The technology bears its promise not only to improve crop yield on sustainable basis but also reduce dependence on chemical fertilizer as well as huge piles of organic wastes causing environmental pollution.

Introduction

Organic matter is known to improve soil health and availability of plant nutrients. In agriculture system, recycling of organic waste materials is known to improve soil health and availability of plant nutrients by amending soil physico-chemical and biological properties. Diversified organic wastes like farm wastes, city waste (sewage-sludge), poultry litter and industrial wastes are being accumulated in huge amounts. Most of these organic wastes are either burnt or remain unutilized, especially in developing countries. These practices are not only posing serious threat to the environment, but are causing a loss of useful plant nutrient sources also which can be used for crop production. In urban areas, less than 60 per cent waste is collected. No city in Pakistan has proper waste collection and disposal system (Economic Survey, 2006).

Organic wastes have been used as a source of plant nutrients since centuries; before the advent of chemical fertilizers, organic waste materials were used as a sole nutrient source for crop production. The use of organic waste material in farming has been reduced significantly due to chemical fertilizers being rich and ready source of plant nutrients. High population growth rate, rapid urbanization and mechanization forced the farming community to totally rely on chemical fertilizers. Excessive use of chemical

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fertilizers, however, has created concerns due to energy crises, stagnant yields and soil (physical, chemical and biological properties) health. Integrated approaches which could sustain both agriculture and environment and maintain the long term ecological balance of the soil ecosystem are needed to reduce high cost of production and environmental pollution.

In recent years, land application of organic wastes has emerged as an attractive and cost effective alternate strategy for waste management around the world. However, recycling of these wastes needs to be done in a manner that not only improves soil physical, chemical and biological properties but minimizes environmental risks as well (Pare *et al*., 2000). Composting is a cost effective and environment friendly way of waste recycling (Hoitink & Fahy, 1986; Millner *et al*., 1998). It is a process in which organic waste materials are biologically converted into an amorphous and stable humus like substance (under conditions of optimum temperature, moisture and aeration) that can be handled , stored and applied without any hazardous environmental impacts (Gallardo-Larva & Nogales, 1987; Millner *et al*., 1998). Composted organic waste materials are regarded for their effectiveness to enhance crop yields compared to un-composted/raw ones due to improvement in soil physical, chemical and biological properties and reduced mineralization rate (Ahmad *et al*., 2006).

The composted or un-composted organic waste material is applied in t ha^{-1} in agricultural systems. Adequate storage and transportation facility as well as extensive labor is required for their application. This can be overcome to some extent through improving quality as well as nutrient status of compost so that it may be applied at substantially reduced rates (kg ha^{-1}) than traditional application rates (t ha^{-1}). Enrichment of compost with nitrogen fertilizer (Urea) and its blending with biologically active substance (BAS) *i.e.* L-TRP is a novel approach to convert composted material into a useful soil amendment.

Auxin is one of the principal phytohormones involved in growth regulating processes of plants (Khalid *et al*., 2006). L-tryptophan is a physiological precursor of auxin biosynthesis both in microbes and higher plants. Exogenous application of L-TRP has been reported to improve the growth and yield of various crops (Martens & Frankenberger, 1992; Frankenberger & Arshad, 1995). Similarly, Zahir *et al*. (2000b) has reported that addition of L- TRP substantially increased auxin production by microbes present in soil. The amount of auxins required for better growth may vary with the crop/variety (Zahir *et al*., 2000a).

Although composting is an old technique, but improving its nutritional and quality status by blending it with inorganic N (urea) and biologically active substance (BAS) *i.e.* L-tryptophan is a novel approach. This approach has been tested in this study to improve growth, yield and nutrients uptake of wheat by using N & L-TRP-enriched compost.

Materials and Methods

Two year study was conducted to test the effectiveness of N & L-TRP-enriched compost for improving the growth, yield and nutrients uptake of wheat under field conditions.

Recycling and enrichment of organic waste material: A locally fabricated composter consisting of drier, crusher/grinder and processor was used for recycling of organic waste of fruit and vegetables collected from various locations (local fruit and vegetable market and juice shops etc., of the city. Organic waste material was air dried for couple of days to remove excessive moisture and sorted out to remove unwanted materials (e.g. pieces of metal, glass, polythene bags etc.). The sorted organic waste material was oven dried at 65ºC for 24 h and ground into finer particles with the help of an electric grinder. The ground material was transferred to a composter/processor (500 kg capacity). Composting was done for six days under controlled temperature and aeration (shaking at 50 rpm). Moisture level [40% (v/w) of the compost] and temperature (30-70-30ºC) were maintained during the composting process.

To enhance the quality and nutritional value of the compost, urea fertilizer (Fauji Fertilizer Company Ltd., Pakistan) at the rate of 120 g N kg^{-1} compost was mixed with the finished compost. Thus, 300, 400 and 500 kg batches of compost received 36, 48 and 60 kg N for wheat crop. Similarly, L-TRP (Sigma Chemical Co., St. Louis MO, USA) in the solutions form was added at 10.0 mg kg^{-1} compost in respective batches before sowing according to the treatments for increasing auxin content. During composting the material was converted into an effective organic fertilizer by blending it with inorganic N (Urea) and L-TRP @ 10 mg kg^{-1} compost for wheat crop. The organic material was then incubated at suitable aeration and temperature for six days with constant stirring.

Both raw (non-composted) and composted organic waste materials were analyzed for carbon content (Nelson & Sommers, 1996), and macro- and micro-nutrients (Ryan *et al*., 2001). The C/N, C/P and C/K ratios were also calculated (Table 1).

Field trials: Field experiments on wheat (*Triticum aestivum* L.) were conducted at the Research Area of the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan, during 2003-05, to assess the effect of N & L-TRP-enriched compost on the growth and yield of wheat crop. Soil samples (0-15 cm surface soil layer) were collected randomly from various places of the experimental fields and mixed to make the composite samples. The composite soil sample of experimental field was analyzed for various physical and chemical characteristics. Details of analyses are given in Table 2. Recommended doses of P & K @ 100-60 kg ha^{-1}, as single super phosphate and murate of potash, respectively were applied before sowing while N & L-TRP-enriched compost was applied according to the treatments (Table 3-5). Wheat (*Tritium aestivum* L.) seed (@ 100 kg ha^{-1}) of variety "wattan-93" was sown in plots (size 10 m^2) by drilling method. Enriched compost was applied in bands along the seedlings with hand drill @ 300, 400 and 500 kg ha^{-1} according to the treatments, replicated four times using randomized complete block design (RCBD). Canal water (electrical conductivity = 0.03 dS m^{-1}, sodium adsorption ratio = 0.26 $(mmol\ L^{-1})^{1/2}$, residual sodium carbonate = 0) meeting the irrigation quality criteria for crops (Ayers & Westcot, 1985) was used for irrigation of wheat crop.

Plant height, number of tillers m^{-2} and number of spikelets $spike^{-1}$ were recorded at maturity while grain yield, straw yield and 1000-grain weight was recorded at crop harvest. Grain and shoot samples of plants were analyzed for NPK contents (Ryan *et al*., 2001) and their total uptake were calculated. The data were analyzed statistically according to Steel *et al*. (1997). Means were compared by Duncan`s multiple range test (DMR) at 5 percent probability (Duncan's, 1955). Next year, the experiment was repeated in the same field with similar set of treatments.

Table 1. Analysis of raw and composted organic wastes.

Parameter	Raw organic waste	Composted organic waste
Carbon (%)	32.8±1.2	22.2±0.88
Nitrogen (%)	1.22±0.06	2.18±0.10
Phosphorus (%)	0.28±0.02	0.42±0.03
Potassium (%)	1.10±0.06	1.67±0.10
Copper (mg kg^{-1})	1.05±0.03	1.20±0.05
Zinc (mg kg^{-1})	39.0±2.10	47.0±2.80
Manganese (mg kg^{-1})	40.0±1.88	52.0±2.06
Iron (mg kg^{-1})	495±29.0	708±46.0
Indole acetic acid equivalents (mg kg^{-1} compost)	Traces	6.98±0.35
C/N ratio	26.9±0.68	10.2±0.13
C/P ratio	117.1±8.6	52.9±1.80
C/K ratio	29.8±1.06	13.3±0.15

Average of four repeats ± Standard error

Table 2. Physico-chemical characteristics of soil used for study.

Parameters	Year-I	Year-II
Texture	Sandy clay loam	Sandy clay loam
ECe (dS m^{-1})	2.46	2.42
PH	7.74	7.65
Organic matter (%)	0.69	0.75
Total Nitrogen (%)	0.044	0.05
Available phosphorus (mg kg^{-1})	9.4	10.7
Extractable potassium (mg kg^{-1})	169	186

Table 3. Effect of N & L-TRP-enriched compost on plant height, no. of tillers m^{-2} and no. of spikelets $spike^{-1}$ of wheat (Field experiments, data are average of four repeats)

Treatment	Plant height (cm)		No. of tiller m^{-2}		No. of spikelets $spike^{-1}$	
	Year-I	Year-II	Year-I	Year-II	Year-I	Year-II
Control (P & K only)	70.4 e	75.9 e	340 e	378 e	13.5 f	14.3 d
Urea fertilizer (120 kg N ha^{-1})	94.0 a	96.1 a	466 a	488 ab	18.5 a	19.6 a
N-enriched compost (300 kg ha^{-1}) †	76.3 d	88.7 d	363 d	425 d	14.2 e	16.2 c
N-enriched compost (400 kg ha^{-1}) †	78.3 d	89.6 cd	385 c	445 c	14.9 de	16.8 b
N-enriched compost (500 kg ha^{-1}) †	83.4 c	90.9 cd	418 bc	452 c	15.2 d	17.3 b
N & L-TRP-enriched compost (300 kg ha^{-1}) $	85.5 bc	92.3 bc	421 b	460 c	16.8 c	18.1 b
N & L-TRP-enriched compost (400 kg ha^{-1}) $	89.4 b	94.1 ab	423 b	478 ab	18.3 ab	19.0 a
N & L-TRP-enriched compost (500 kg ha^{-1}) $	91.6 ab	97.4 a	463 a	503 a	19.2 a	20.0 a

Values sharing similar letter (s) in a column are non-significant at $p< 0.05$, according to Duncan's multiple range test.
P and K fertilizers were applied @ 100 & 60 kg ha^{-1}, respectively in all treatments.
†Enriched compost (120 g N kg^{-1} compost). The composition of compost is given in Table 1.
$N-enriched compost was further blended with L-TRP @ 10 mg kg^{-1} compost.

Results

Data regarding the effect of N & L-TRP-enriched compost on plant height, number of tillers m^{-2}, number of spikelets $spike^{-1}$, grain yield, straw yield and 1000-grain weight, and NPK uptake of wheat under field conditions are summarized in Table 2-4 (first year and second year studies, respectively).

Table 4. Effect of N & L-TRP-enriched compost on grain yield, straw yield and 1000-grain weight of wheat (Field experiments, data are average of four repeats).

Treatment	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		1000-grain weight (g)	
	Year-I	Year-II	Year-I	Year-II	Year-I	Year-II
Control (P & K only)	2.85 d[d]	3.25 f	4.5 f	4.9 d	35.9 d	37.9 f
Urea fertilizer (120 kg N ha^{-1})	4.79 a	5.30 ab	8.2 a	8.6 a	46.8 a	48.5 ab
N-enriched compost (300 kg ha^{-1}) †	3.92 c	3.95 e	5.3 e	6.0 c	40.6 c	41.9 e
N-enriched compost (400 kg ha^{-1}) †	3.94 c	4.35 d	6.1 d	7.3 b	41.3 c	43.9 de
N-enriched compost (500 kg ha^{-1}) †	4.50 b	4.72 c	6.8 c	7.5 b	45.7 b	45.1 cd
N & L-TRP-enriched compost (300 kg ha^{-1}) $	4.20 b	4.80 c	7.0 bc	7.6 b	44.5 bc	47.2 bc
N & L-TRP-enriched compost (400 kg ha^{-1}) $	4.56 ab	5.10 ab	7.5 b	8.0 ab	46.0 ab	48.4 ab
N & L-TRP-enriched compost (500 kg ha^{-1}) $	4.68 a	5.62 a	8.0 a	8.5 a	46.8 a	50.1 a

Values sharing similar letter (s) in a column are non-significant at $p < 0.05$, according to Duncan's multiple range test.
P and K fertilizers were applied @ 100 & 60 kg ha^{-1}, respectively in all treatments.
†Enriched compost (120 g N kg^{-1} compost). The composition of compost is given in Table 1.
$N-enriched compost was further blended with L-TRP @ 10 mg kg^{-1} compost.

Table 5. Effect of N & L-TRP-enriched compost on nitrogen (N), phosphorus (P) and potassium (K) uptake of wheat (Field experiments, data are average of four repeats).

Treatment	Total uptake (kg ha^{-1})					
	N		P		K	
	Year-I	Year-II	Year-I	Year-II	Year-I	Year-II
Control (P & K only)	45.6 e	49.8 e	22.6 e	24.2 e	89.6 e	98.4 e
Urea fertilizer (120 kg N ha^{-1})	88.6 a	95.2 a	35.1 ab	37.6 b	144.6 a	156.4 b
N-enriched compost (300 kg ha^{-1}) †	54.8 e	59.7 d	24.7 d	26.9 d	105.5 d	129.2 d
N-enriched compost (400 kg ha^{-1}) †	61.5 d	70.5 cd	25.6 d	29.4 cd	120.5 c	130.6 d
N-enriched compost (500 kg ha^{-1}) †	75.4 c	78.3 c	27.4 c	31.8 c	130.7 b	143.9 c
N & L-TRP-enriched compost (300 kg ha^{-1}) $	75.2 c	75.6 c	30.6 bc	32.2 c	133.2 ab	145.6 c
N & L-TRP-enriched compost (400 kg ha^{-1}) $	81.2 b	91.4 ab	33.3 b	37.4 b	138.3 ab	155.3 b
N & L-TRP-enriched compost (500 kg ha^{-1}) $	84.5 ab	96.5 a	37.4 a	40.2 a	145.2 a	168.4 a

Values sharing similar letter (s) in a column are non-significant at $p < 0.05$, according to Duncan's multiple range test.
P and K fertilizers were applied @ 100 & 60 kg ha^{-1}, respectively in all treatments.
†Enriched compost (120 g N kg^{-1} compost). The composition of compost is given in Table 1.
$N-enriched compost was further blended with L-TRP @ 10 mg kg^{-1} compost.

First year: The data of first year experiment conducted on wheat are given in Table 2-4. N & L-TRP-enriched compost significantly increased the plant height, number of tillers m^{-2} and number of spikelets per spike of wheat (Table 3).

Maximum plant height (33% greater than control) was observed in response to the application of full dose of N fertilizer that was statistically at par with N & L-TRP-enriched compost applied @ 500 kg ha^{-1}. Plant height recorded by N & L-TRP-enriched compost @ 400 kg ha^{-1} differed non-significantly from 500 and 300 kg ha^{-1} compost (with L-TRP). There was a non-significant difference between the effects of N & L-TRP-enriched compost @ 300 kg ha^{-1} and N-enriched compost @ 500 kg ha^{-1} but differed significantly from untreated control. Similarly, plant height produced by N-enriched compost @ 400 and 300 kg ha^{-1} was statistically at par with each other. Maximum number of tillers (37% greater than control) was recorded in the case of full dose of N fertilizer and differed significantly from control; however, it had non-significant difference where N & L-TRP-enriched compost was applied @ 500 kg ha^{-1}. There was a non-significant difference between the effects of N & L-TRP-enriched compost @ 400, 300 kg ha^{-1} and N-enriched compost @ 500 kg ha^{-1} (without L-TRP) but differed significantly from untreated control. The increase observed in number of tillers produced by N-enriched compost @ 500 and 400 kg ha^{-1} was at par with each other but differed significantly from untreated control. As regard the no. of spikelets, maximum increase (42%) was observed in the case of N & L-TRP-enriched compost @ 500 kg ha^{-1} that differed non-significantly from the full dose of N fertilizers and N & L-TRP-enriched compost @ 400 kg ha^{-1}. The increase observed in number of spikelets caused by N & L-TRP-enriched compost @ 300 kg ha^{-1} over control was 24%. It was followed by N-enriched compost @ 500 and 400 kg ha^{-1}, which were at par with each other but differed significantly from untreated control.

The data regarding grain yield, straw yield and 1000-grain weight of wheat are summarized in Table 4. Maximum increase (68%) in grain yield over control was observed in response to application of full dose of N fertilizer that was statistically at par with N & L-TRP-enriched compost applied @ 500 and 400 kg ha^{-1}. Grain yield recorded in case of N & L-TRP-enriched compost @ 400, 300 kg ha^{-1} and N-enriched compost @ 500 kg ha^{-1} were statistically at par with each other but differed significantly from untreated control. N & L-TRP-enriched compost @ 400 and 300 kg ha^{-1} showed statistically similar results with each other. Similarly, maximum increase in straw yield was recorded by full dose of N fertilizer that was 82% more than control and statistically it was at par with N & L-TRP-enriched compost @ 500 kg ha^{-1}. Straw yield observed in case N & L-TRP-enriched compost applied @ 400 and 300 kg ha^{-1} was at par with each other but differed significantly from untreated control. It was followed by N-enriched compost @ 500, 400 and 300 kg ha^{-1}. Likewise, a higher 1000-grain weight (up to 30% increase over control) was observed in response to full dose of N fertilizer and N & L-TRP-enriched compost applied @ 500 kg ha^{-1} that was at par with N & L-TRP-enriched compost @ 400 kg ha^{-1}. Grain weight recorded in case of N-enriched compost @ 500 kg ha^{-1} differed non-significantly from N & L-TRP-enriched compost @ 400 and 300 kg ha^{-1}. Similarly, N-enriched compost @ 400 and 300 kg ha^{-1} showed statistically similar results with N & L-TRP-enriched compost @ 300 kg ha^{-1}.

Data regarding N, P and K uptake depicted that N & L-TRP-enriched compost showed statistically similar results with full dose of N fertilizer (Table 5). Maximum N uptake (94% higher over untreated control) was observed with full dose of N fertilizer that was at par with N & L-TRP-enriched compost @ 500 kg ha^{-1}. It was followed by N & L-TRP-enriched compost applied @ 400 kg ha^{-1}. Nitrogen uptake by N-enriched compost @ 500 kg ha^{-1} was statistically similar with N & L-TRP-enriched compost @ 300 kg ha^{-1} followed by 400 and 300 kg ha^{-1} N-enriched compost. Regarding P uptake, maximum increase 65% over untreated control was observed by N & L-TRP-enriched compost applied @ 500 kg ha^{-1} that was at par with full dose of N fertilizer. Up to 47% increase in P uptake over untreated control was recorded by N & L-TRP-enriched compost @ 400 kg ha^{-1} that was at par with 300 kg ha^{-1}. Similarly, 21% increase in P uptake over control was observed by N-enriched compost @ 500 kg ha^{-1} that was at par with N & L-TRP-enriched compost @ 300 kg ha^{-1} followed by 400 and 300 kg ha^{-1} N-enriched compost. Likewise, a higher uptake of K (up to 62% increase over control) was observed in response to N & L-TRP-enriched compost applied @ 500 kg ha^{-1} that was at par with full dose of N fertilizer and N & L-TRP-enriched compost @ 400 and 300 kg ha^{-1}. Similarly, K uptake by N-enriched compost @ 500 kg ha^{-1} differed non-significantly from N & L-TRP-enriched compost @ 400 and 300 kg ha^{-1} followed by N-enriched compost @ 400 and 300 kg ha^{-1}.

Second year: The data from second year experiment conducted on wheat are given in Table 2-4. N & L-TRP-enriched compost significantly increased the plant height, number of tillers and number of spikelets per spike of wheat (Table 3) compared with untreated control.

Maximum plant height was observed in response to the application of N & L-TRP-enriched compost applied @ 500 kg ha^{-1}, which was 28% greater than control (only PK fertilizers) that was at par with full dose of N fertilizer and N & L-TRP-enriched compost @ 400 kg ha^{-1}. Plant height recorded by N & L-TRP-enriched compost @ 300 kg ha^{-1} differed non-significantly from 400 kg ha^{-1} and N-enriched compost applied @ 500 and 400 kg ha^{-1}, respectively. Maximum number of tillers (33% greater than control) was recorded in the case of 500 kg ha^{-1} N & L-TRP-enriched compost and differed significantly from control; however, it had non-significant difference from full dose of N fertilizer and N & L-TRP-enriched compost applied @ 400 kg ha^{-1}. Statistically similar increase over untreated control was recorded by N & L-TRP-enriched compost applied @ 300 kg ha^{-1} and N-enriched compost applied @ 500 and 400 kg ha^{-1}. As regard the no. of spikelets, maximum increase (40%) was observed in the case of N & L-TRP-enriched compost @ 500 kg ha^{-1} that differed non-significantly from the full dose of N fertilizers and N & L-TRP-enriched compost @ 400 kg ha^{-1}. There was a non-significant difference between the effects of N & L-TRP-enriched compost @ 300 kg ha^{-1} and N-enriched compost @ 500 and 400 kg ha^{-1} (without L-TRP) but differed significantly from untreated control.

The data regarding grain yield, straw yield and 1000-grain weight of wheat during second year are summarized in Table 4. Maximum increase (73%) over control was observed in response to the application of N & L-TRP-enriched compost applied @ 500 kg ha^{-1} that was at par with full dose of N fertilizer and 400 kg ha^{-1} N & L-TRP-enriched compost. Up to 48% increase in grain yield over untreated control was recorded by N & L-TRP-enriched compost @ 300 kg ha^{-1} which differed non-significantly from N-enriched compost @ 500 kg ha^{-1} followed by 400 and 300 kg ha^{-1}. Similarly, maximum increase in straw yield was recorded by full dose of N fertilizer that was 76% more than control and statistically it was at par with N & L-TRP-enriched compost @ 500 and 400 kg ha^{-1}. Straw yield observed by N & L-TRP-enriched compost applied @ 300 kg ha^{-1} was at par with 400 kg ha^{-1} and N-enriched compost @ 500 and 400 kg ha^{-1} followed by N-enriched compost @ 300 kg ha^{-1}. Likewise, a higher weight of 1000-grains (up to 32% increase over control) was observed in response to N & L-TRP-enriched compost applied @ 500 kg ha^{-1} that was at par with full dose of N fertilizer and N & L-TRP-enriched compost @ 400 kg ha^{-1}. Up to 25% increase in 1000-grain weight over control was recorded by N & L-TRP-enriched compost applied @ 300 kg ha^{-1} that differed non-significantly from 400 kg ha^{-1} and N-enriched compost @ 500 kg ha^{-1}.

Data regarding N, P and K uptake during second year are summarized in Table 5. Maximum N uptake (94% over untreated control) was observed by N & L-TRP-enriched compost @ 500 kg ha^{-1} that differed non-significantly from full dose of N fertilizer and 400 kg ha^{-1} N & L-TRP-enriched compost. There was a non-significant difference between the effect of L-TRP-treated N-enriched @ 300 kg ha^{-1} and N-enriched compost @ 500 and 400 kg ha^{-1} followed by N-enriched compost @ 300 kg ha^{-1}. Regarding P uptake, maximum increase 66% over untreated control was observed by N & L-TRP-enriched compost applied @ 500 kg ha^{-1}. Up to 55% increase in P uptake over untreated control was recorded by full dose of N fertilizer that was at par with N & L-TRP-enriched compost @ 400 kg ha^{-1}. Statistically similar increase over untreated control in P uptake was observed by N & L-TRP-enriched compost @ 300 kg ha^{-1} and N-enriched compost @ 500 and 400 kg ha^{-1}. Likewise, a higher uptake of K (up to 71% increase over control) was observed in response to N & L-TRP-enriched compost applied @ 500 kg ha^{-1}. There was a non-significant difference between the effects of full dose of N fertilizer and N & L-TRP-enriched compost @ 400 kg ha^{-1} regarding K uptake. Similarly, K uptake by N-enriched compost @ 400 kg ha^{-1} differed non-significantly from 300 kg ha^{-1} N-enriched compost.

Discussion

Two year-study was conducted to asses the effect of N & L-TRP-enriched compost on growth and yield of wheat under field conditions. Results of first year data revealed that L-TRP-treated (10 mg kg^{-1} compost) N-enriched compost (120 g N kg^{-1} compost) applied @ 500 kg ha^{-1} was comparable to full dose of N fertilizer in improving growth and yield of wheat. However, during second year, more promising results were obtained by application of the same treatment. Overall, there was about 30% saving of N with the application of 500 kg ha^{-1} organic fertilizer/enriched compost. Our findings support the work of other scientists who reported that application of compost could save 20-35% mineral N fertilizer (Bajpai *et al*., 2002; Pooran *et al*., 2002; Nevens & Reheul, 2003; Prabu *et al*., 2003); however, they applied it in tonnage. It is encouraging to observe that N & L-TRP-enriched compost during second year yield up to 6% more when compared with full dose of chemical fertilizer alone. These findings are supported by other researchers who reported an increase of up to 15% in yield by the composted material with nitrogen fertilizer over full dose of chemical fertilizer used alone (Cheuk *et al*., 2003; Guar & Singh, 1993).

It was also observed that the organic fertilizer applied to the same field during second year gave better performance than the first year application. It is highly likely that the continuous use of organic materials (organic fertilizer) in the field may result in improving the organic matter status of soil and thus can improve soil health and crop yields on sustainable basis. This is further supported from the slower mineralization rates of organic fertilizer (prepared from composted organic wastes) than raw organic wastes added to soil. Similar kinds of findings are also reported by Eghball (2004) who stated that residual effect of N- and P-based compost application on corn grain yield and N-uptake lasted at least for one year and on soil properties for several years.

Increases in growth and yield of wheat during the second year in our study could also be attributed to enhanced nutrient use efficiency and physiological response of crops to added L-TRP in the presence of organic fertilizer (as well as residual effect of N & L-TRP-enriched compost) being a source of macro- and micro-nutrients (Table 1). Moreover, total NPK contents in plants (Table 5) increased significantly in response to application of N & L-TRP-enriched compost @ 500 kg ha^{-1}. It is very likely that N losses due to leaching or denitrification might have reduced in soil by mixing N-fertilizer with organic compost, resulting in a better utilization of N by the plant. Previous studies have also shown that composted organic materials enhance fertilizer use efficiency by releasing nutrients slowly and thus reducing the losses, particularly of N (Paul & Clark, 1996; Muneshwar *et al*., 2001; Nevens & Reheul, 2003; Ahmad *et al*., 2006). Since addition of organic fertilizer increases mobilization of P and microbial activities in soil, it might also be a contributing factor in improving nutrition as well as root system. This premise is supported by the fact that the total N, P and K uptake in wheat (see Table 4) were increased significantly in response to 500 kg ha^{-1} application of N & L-TRP-enriched compost. Previous studies have also shown that the composted organic materials enhance N fertilizer use efficiency by releasing it slowly and thus reducing its losses (Muneshwar *et al*., 2001; Nevens & Reheul, 2003; Asghar *et al*., 2006; Zahir *et al*., 2007).

In this study, L-TRP in the compost might also have contributed to growth and yield of wheat. This premise is supported by the data presented in Table 3-5 that N & L-TRP-enriched compost is superior in effectiveness than the compost enriched with N only. Recently, we have reported similar kinds of result (Arshad *et al*., 2004). As L-TRP is considered an efficient physiological precursor for auxin biosynthesis in higher plants and in microbes and it affects physiological processes of plants after uptake directly by the roots in soil or indirectly after converting into IAA in the soil (Frankenberger & Arshad, 1995). It is well established that the effect of L-TRP on plant growth is most likely through its conversion into IAA as evidenced by radio labeled studies (Martens & Frankenberger, 1993). However, application of precursor could be more useful than the one time application of a pure synthetic hormone. Precursor provides continuous supply of a plant hormone and has wide thresholds between the inhibitory and stimulatory levels, thus continuous release of a hormone from a precursor at low concentration (as a result of microbial activity) in the rhizosphere may be more beneficial to modify plant growth in desired direction. Studies have shown that application of L-TRP to the rooting medium improves plant growth (Frankenberger & Arshad, 1991; Arshad *et al*., 1994; Zahir *et al*., 2000a).

The novelty of the approach being used in our study is the application of organic fertilizer just at the rate of 500 kg ha^{-1}, where as previously researchers reported saving of N fertilizer and increase in crop yield by applying raw/ compost organic material in tons ha^{-1} (Bajpai *et al*., 2002; Pooran *et al*., 2002; Cheuk *et al*., 2003; Nevens & Reheul, 2003; Guar & Singh, 1993). Raw organic waste is available free of cost in huge amounts and there is no demand-supply gap expected as application rate of 500 kg ha^{-1} is feasible for the farmers to manage easily. The technology is, therefore cost effective as it reduces dependence on chemical fertilizers, helps in nutrients and water conservation; moreover, it is an economical and safe way for the disposal of organic wastes, so the reduction of huge piling of organic waste is an extra benefit. The use of value-added organic fertilizer to get higher yields is, therefore wise than sole application of either huge amount of low quality raw organic material or adequate amount of chemical fertilizer.

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