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GROWTH AND YIELD RESPONSE OF WHEAT (*TRITICUM AESTIVUM* L.) AND MAIZE (*ZEA MAYS* L.) TO NITROGEN AND L-TRYPTOPHAN ENRICHED COMPOST

RIZWAN AHMAD, SHER M. SHAHZAD, AZEEM KHALID, MUHAMMAD ARSHAD* AND MUHAMMAD H. MAHMOOD

Institute of Soil and Environmental Sciences,
University of Agriculture, Faislabad-38040, Pakistan.

Abstract

Composting is an effective approach for recycling of the organic wastes for agriculture uses. Organic waste material of fruits and vegetables was collected and subjected to composting in a locally fabricated mechanical unit. The compost material was enriched with 25 or 50% of recommended dose of N-fertilizer and L-tryptophan (L-TRP) @ 5 mg kg^{-1} compost. Enriched compost was tested alone as well as in combination with 25 and 50% of an additional dose of N-fertilizer. P and K fertilizers at recommended rates were applied in all the treatments. Results of pot experiments conducted in the net house revealed that application of enriched compost significantly promoted growth and yield of both wheat and maize crops; however, application of enriched compost with 50% N was the most effective in improving grain yield and yield contributing parameters compared with control. Similarly, N, P & K contents of the wheat and maize plants were significantly improved upon application of enriched compost plus N fertilizer. Comparison of enriched compost with chemical N fertilizer indicated the superiority in terms of yield of combined application of enriched compost and N fertilizer over the chemical fertilizer alone. The findings imply that a combined use of compost and chemical fertilizer could be more effective and economical to increase the yield of crop plants on sustainable basis than the chemical fertilizer alone.

Introduction

Management of organic waste in environment-friendly manner is becoming difficult due to rapid increase in population and urbanization. Organic waste materials are available in huge amounts in the form of farm waste, city waste (sewage sludge), poultry litter and the industrial wastes (food, sugar, cotton and rice industry). The continuous accumulation of these materials is becoming a potential source of land, water and air pollution. According to an estimate, 1.2×10^{10} tonnes of organic waste materials are generated daily in Pakistan (Anon., 2004).

Recycling of organic waste is one of the major options, which could be effective for reducing huge piles of organic wastes. Composting is one of the biological processes for recycling of organic waste and can be defined as a method of biological decomposition, where organic material decomposed to a stage that can be handled, stored and applied to land without any environmental impact (Rynk, 1992; Millner *et al*., 1998; Eghball *et al*., 2004). During composting, organic residues are decomposed under controlled conditions (temperature, moisture and aeration). In addition, extensive microbiological and chemical transformations are involved in the composting process. Composted organic material can be used as a source of important nutrients for sustainable crop productivity. The composted organic wastes cannot only act as supplement to chemical fertilizers but may also improve the organic matter status and physico-chemical properties of soil (Harmsen *et al*., 1994).

*Corresponding address: bio@fsd.comsats.net.pk

No doubt, use of chemical fertilizers is essential for nutrition of the crop plants for getting higher yields but during the last couple of years, the yields have become almost static and no more increases in crop yields were obtained even with optimum level of fertilizers. Moreover, chemical fertilizers processes require high cost energy inputs. It is highly likely that the use of composted organic materials along with chemical fertilizers may be an effective alternate approach for further improving levels of the crop yields.

Biologically active substances or plant growth regulators (PGRs) are organic compounds, which have shown far-reaching impacts on growth of plants even at low concentration (Frankenberger & Arshad, 1995; Arshad & Frankenberger, 1998; Khalid *et al*., 2006). L-Tryptophan (L-TRP) is a common precursor of plant hormone auxin, and affects the physiological processes of plants after uptake from soil directly or indirectly after transforming into auxins (IAA) in the soil. It is likely that enrichment of composted material with nutrient (N) and/or PGRs can convert an organic waste material into value-added organic fertilizer, which may increase per acre crop yields. Keeping this in view, a study was planned to recycle fruits and vegetables organic wastes for improving growth and yield of wheat and maize.

Materials and Methods

Pot experiments were conducted in the net house at research area, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, during 2003-2004 to see the effectiveness of enriched compost for improving the growth and yield of wheat and maize.

Preparation of enriched compost: Compost was prepared by using a locally fabricated composter (Compost-Tech, Waseem Mecahnicals, Faisalabad) consisting of drier, crusher/ grinder and a processor. Organic material containing fruit and vegetable wastes was collected from various locations (fruit and juice shops, fruit and vegetable markets, etc.) of Faisalabad city. Collected organic waste material was air-dried for 24 hours to remove the excessive moisture and sorted out to remove all unwanted substances (plastic bags, glass material and stones, etc.) in the organic waste. The organic material was then oven-dried at 65^{o}C for 24 hours and crushed in the crushing unit of composter to convert raw form of waste into finer form (<2 mm). Crushed material was put in the composter (processing unit) to convert organic waste materials into compost. 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 (shaking at 50 rpm). Temperature rose up from 30 to 70^{o}C in the composting unit during 2nd and 3rd day of composting process and then reduced gradually to 30^{o}C after 4th day process.

Composted material was enriched/blended with 25 or 50% of recommended (120 kg ha^{-1}) N fertilizer for wheat in the form of urea. For maize crop, composted material was enriched with 25% of full dose (175 kg ha^{-1}) of N. Thus, 250 kg batch of compost received 30 or 60 kg N for wheat and 44 kg N for maize crop. To make the compost a more value-added organic fertilizer, L-TRP @ 5 mg kg^{-1} compost was sprayed on the compost.

After enrichment, the organic product was passed through a grinder to make granule of the product. The enriched compost was packed in gunny bags prior to use.

Both raw (non-composted) and composted organic waste materials were analyzed (Table 1) 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 determined.

Table 1. Analysis of raw (non-composted) and composted fruit and vegetable wastes.

Parameter	Organic waste before composting (crushed <2.0 mm)	Composted organic waste material
Carbon (%)	36.2	23.4
Nitrogen (%)	1.44	2.26
Phosphorus (%)	0.30	0.48
Potassium (%)	1.22	1.55
Copper (mg kg^{-1})	1.06	1.29
Zinc (mg kg^{-1})	48.0	62.0
Manganese (mg kg^{-1})	40.0	53.0
Iron (mg kg^{-1})	546	655
C/N ratio	25.1	10.4
C/P ratio	121	48.8
C/K ratio	29.7	15.1

Table 2. Effect of nitrogen and L-tryptophan (L-TRP) enriched compost (EC) on plant height, number of tillers and spikelets of wheat.

Treatment	Plant height (cm)	No. of tillers $plant^{-1}$	Spikelets $spike^{-1}$
Control (P & K fertilizer only)	46.5 f[a]	2.2 e	13.3 c
Non-enriched compost (250 kg ha^{-1})	47.5 e	2.5 de	13.4 c
Urea fertilizer (120 kg N ha^{-1})	57.9 b	4.6 a	14.6 b
N (25%) & L-TRP enriched compost (250 kg ha^{-1})	52.9 d	2.8 cd	14.1 bc
N (50%) & L-TRP enriched compost (250 kg ha^{-1})	56.8 c	3.0 c	14.5 b
N (25%) & L-TRP enriched compost (250 kg ha^{-1}) supplemented with 25% N (30 kg N)	56.3 c	4.1 b	15.9 a
N (25%) & L-TRP enriched compost (250 kg ha^{-1}) supplemented with 50% N (60 kg N)	61.8 a	4.3 ab	16.0 a

[a]Values sharing similar letters in a column do not differ significantly at $p<0.05$, according to Duncan's multiple range test.

Pot trials: Pot experiments were conducted in the net house to assess the effect of enriched compost and chemical fertilizers on growth and yield of wheat and maize crops. Soil was collected from a field of Institute of Soil and Environmental Sciences, UAF; air-dried, ground, sieved (2-mm 10-$mesh^{-1}$) and analyzed for physico-chemical properties. The soil was sandy clay loam having a pH of 7.9; ECe, 2.5; organic matter. 0.69%; total N, 0.06%; available P, 6.7 mg kg^{-1} and exchangeable K, 168 mg kg^{-1} soil. This soil was used for pot trials.

Each pot was filled with sieved soil (12 kg pot^{-1}), mixed with recommended P & K fertilizers (@100 and 60 kg ha^{-1}, respectively). Single super phosphate and sulphate of potash were used as a source of P and K. Enriched compost was applied @ 250 kg ha^{-1} by mixing it with top 15 cm soil. A recommended dose of NPK @ 120-100-60 kg ha^{-1} for wheat was kept for comparison. There was also a control consisting of recommended dose of P and K fertilizers alone. Details of the treatments are given in Tables 2-4.

Eight seeds of wheat (*Triticum aestivum* L.) of cultivar Watan-93 were sown in each pot containing 12 kg soil. After germination, four plants were maintained in each pot. The pots were arranged in the net house in a completely randomized design with three replications.

Table 3. Effect of nitrogen and L-tryptophan (L-TRP) enriched compost (EC) on root weight, straw, grain and total dry matter yields and 100-grain weight of wheat.

Treatment	Root weight (g pot^{-1})	Straw yield (g pot^{-1})	Grain yield (g pot^{-1})	Total dry matter yield (g pot^{-1})	100-grain weight (g)
Control (P & K fertilizer only)	7.60 b[a]	13.60 c[a]	10.43 d	31.63 d	4.2 f
Non-enriched compost (250 kg ha^{-1})	7.70 b	13.64 c	10.47 d	31.81 d	4.4 e
Urea fertilizer (120 kg N ha^{-1})	9.30 a	17.80 ab	12.60 b	39.70 ab	5.0 b
N (25%) & L-TRP enriched compost (250 kg ha^{-1})	8.10 b	14.31 c	10.93 d	33.34 cd	4.5 d
N (50%) & L-TRP enriched compost (250 kg ha^{-1})	9.10 a	16.90 b	11.70 c	37.70 b	4.6 c
N (25%) & L-TRP enriched compost (250 kg ha^{-1}) supplemented with 25% N (30 kg N)	9.21 a	17.00 b	11.60 c	37.81 b	4.7 c
N (25%) & L-TRP enriched compost (250 kg ha^{-1}) supplemented with 50% N (60 kg N)	9.80 a	18.80 a	13.63 a	42.23 a	5.3 c

[a]Values sharing similar letters in a column do not differ significantly at $p < 0.05$, according to Duncan's multiple range test.

Table 5. Effect of compost enriched with nitrogen and/or L-tryptophan (L-TRP), and supplemented with chemical fertilizer on growth, yield and nutrients content of maize.

Treatment	Fresh biomass (g pot^{-1})	Cob weight (g pot^{-1})	Grain yield (g pot^{-1})	Dry root weight (g pot^{-1})	N content (g pot^{-1})	P content (g pot^{-1})	K content (g pot^{-1})
Urea fertilizer (175 kg N ha^{-1})	536 b[a]	182 b	125 b	54.0 b	1.59 b[b]	0.59 b	1.34 b
N-enriched compost[b] (250 kg ha^{-1})	452 e	134 d	91 e	43.0 d	0.96 e	0.38 e	0.90 e
N-enriched compost supplemented with 44 kg ha^{-1} N	534 d	160 c	104 d	48 c	1.32 d	0.46 d	1.12 d
N & L-TRP[c] enriched compost supplemented with 44 kg ha^{-1} N	513 c	172 b	119 c	53.0 b	1.44 c	0.51 c	1.25 c
N-enriched compost supplemented with 88 kg ha^{-1} N	550 b	182 b	129 b	54.0 b	1.59 b	0.58 b	1.35 b
N & L-TRP enriched compost supplemented with 88 kg ha^{-1} N	599 a	205 a	142 a	62.5 a	1.75 a	0.66 a	1.44 a

[a]Values sharing similar letter(s) in a column are non-significant at $p < 0.05$, according to Duncan's multiple range test.

Table 4. Effect of nitrogen and L-tryptophan (L-TRP) enriched compost (EC) on nitrogen (N), phosphorus (P) and potassium (K) contents of wheat plant.

Treatment	N content (mg pot^{-1})	P content (mg pot^{-1})	K content (mg pot^{-1})
Control (P & K fertilizer only)	210 d[a]	183 d	192 d
Non-enriched compost (250 kg ha^{-1})	220 d	186 d	199 d
Urea fertilizer (120 kg N ha^{-1})	350 b	263 ab	302 a
N (25%) & L-TRP enriched compost (250 kg ha^{-1})	240 cd	202 c	221 c
N (50%) & L-TRP enriched compost (250 kg ha^{-1})	300 c	227 b	226 c
N (25%) & L-TRP enriched compost (250 kg ha^{-1}) supplemented with 25% N (30 kg N)	310 c	232 b	270 b
N (25%) & L-TRP enriched compost (250 kg ha^{-1}) supplemented with 50% N (60 kg N)	370 a	283 a	313 a

[a]Values sharing similar letters in a column do not differ significantly at p<0.05, according to Duncan's multiple range test.

Additional dose of N fertilizer (25 and 50%) was applied in the form of solution in two split doses. First and second dose was applied after thinning and at grain filling stage. Canal water was used for irrigation. The plants were harvested at maturity and data regarding growth and yield parameters were recorded. The NPK contents in grain and straw were determined (Ryan *et al*., 2001). The total NPK contents of wheat plants were calculated.

In case of maize, N as urea was applied @ 175 kg ha^{-1} according to the treatments. The enriched compost @ 250 kg ha^{-1} was applied to each pot by mixing it with the top 15 cm soil at the time of filling of pots. The enriched compost was also supplemented with either no N or with 44 and 88 kg N ha^{-1} (25 and 50% of 175 kg N ha^{-1} respectively). The whole dose of P and K fertilizers (@ 100 and 60 kg ha^{-1} respectively) was applied by mixing them with soil at the time of pot filling, while N was applied according to the treatments in two split doses (after germination and before tasseling). Detail of the treatments is given in Table 5.

Hybrid maize (cv. Corn-786) was sown (four seeds pot $^{-1}$) as a test crop. 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 above ground fresh biomass, cob and grain yields and root weight were recorded at maturity. Grain and shoot samples of maize plants were analyzed for N, P and K contents (Ryan *et al*., 2001) and their total contents in maize plant were determined.

The data were analyzed by using completely randomized design (Steel & Torrie, 1980). Means were compared by Duncan's Multiple Range Test (Duncan, 1955).

Results

Enriched compost (EC) in combination with N fertilizer significantly increased the plant height, number of tillers and number of spikelets per spike of wheat (Table 2). Maximum plant height was observed in response to the application of compost enriched with 25% N plus L-TRP supplemented with 50% N fertilizer, which was 33% greater than control (only PK fertilizers). There was a non-significant difference between the effect of EC (25% N + L-TRP) supplemented with 25% N and compost enriched with 50% N and L-TRP (without supplementary dose of N). However, combined application of EC supplemented with 50% N had more promising results than full dose of N fertilizer alone. Application of non-enriched compost caused a non-significant improvement in plant height. Maximum number of tillers (109% 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 EC was applied along with 50% N fertilizer. The increase observed in number of tillers caused by EC supplemented with 50% N fertilizer over control was 95.5%. It was followed in descending order by EC (25% N + L-TRP) supplemented with 25% N fertilizer, EC (50% N), EC (25% N + L-TRP) and non-enriched compost. As regard the spikelets, maximum increase (20.3%) was observed in the case of EC plus 50% N fertilizer which differed significantly from control but non-significantly from EC plus 25% N. Application of recommended N fertilizer resulted in a 9.8% increase over control. EC (25% N) supplemented with 25% N fertilizer performed better than compost enriched with 50% N only.

The data regarding root weight, straw, grain and total dry matter yields, and 100-grain weight are summarized in Table 3. Integrated use of EC and chemical fertilizer significantly affected the root weight of wheat and maximum increase (28.9%) over control was observed in response to application of EC supplemented with 50% N fertilizer. EC along with 50% N fertilizer showed superiority (5.4%) over the application of full dose of N fertilizer alone. Similarly, EC in the presence of 50% supplementary dose of N fertilizer caused maximum increases in straw (38.2%), grain (30.7%) and total dry matter yields (33.5%) over control and also showed superiority over full recommended dose of N fertilizer. Non-enriched compost statistically gave similar results as observed in the case of control. Likewise, a higher weight of 100-grains (up to 26.2% increase over control) was observed in response to combined application of enriched compost and chemical fertilizer. In general, grains in the case of enriched compost plus chemical fertilizer were healthy in appearance than that observed in chemical fertilizer alone (Fig. 1).

EC in the presence of 50% N fertilizer caused significant increases in N, P and K contents (76.2, 54.6 and 63%, respectively) over control and also showed superiority (up to 5.7%) over full dose of chemical fertilizer alone (Table 4). Treatments pertaining EC supplemented with 25% N fertilizer and EC (enriched with 25 or 50% N and L-TRP) without any supplementary dose of N fertilizer also improved N, P and K contents and up to 47.6, 26.8 and 40.6% increases over control were observed. However, application of non-enriched compost caused a significant improvement in N uptake but non-significant improvement in P and K uptake in wheat plant.

The data of pot experiment conducted on maize are given in Table 5. Effect of compost enriched with N and supplemented with 50% N fertilizer on above ground fresh biomass, cob weight and grain yield was statistically at par to that observed in case of full dose (175 kg) of N fertilizer. However, application of compost enriched with N and L-TRP in the presence of 50% supplementary dose of N fertilizer significantly increased the fresh biomass (11.8%), cob weight (12.6%) and grain yield (13.6%) compared to full dose of N fertilizer. Similarly, application of enriched compost plus 50% N had significant increasing effect on root weight (15.7% more than the full dose of N fertilizer) of maize plants. In general, N plus L-TRP enriched compost gave better performance than the application of N enriched compost.

There was a significant improvement in N, P and K contents of maize plant in response to application of N and L-TRP enriched compost supplemented with 50% N fertilizer (Table 5). Maximum increases (10.1% N, 11.9% P and 7.5% K) were found in response to combined application of enriched compost and N fertilizer compared to sole application of full dose of N fertilizer. The effect of N enriched (without L-TRP) compost plus 50% N was statistically similar to that observed in case of full dose of N fertilizer alone.

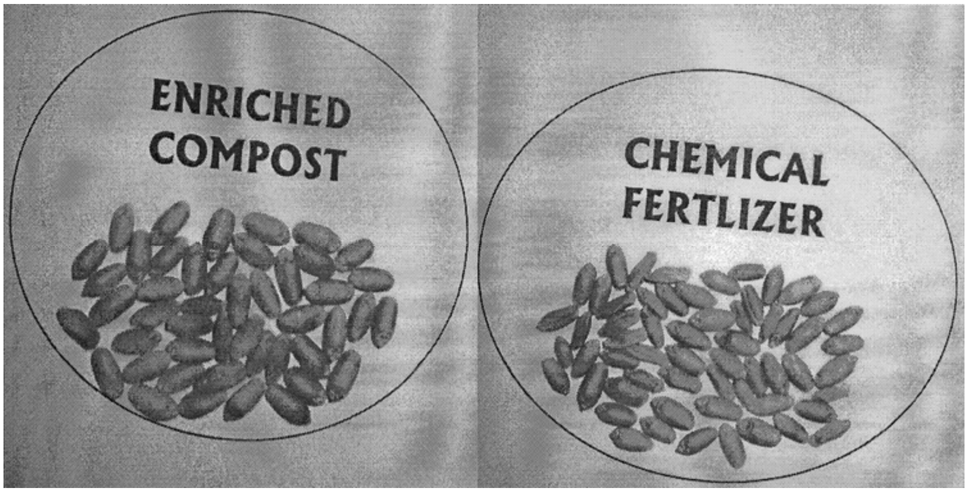

Fig. 1. Effect of enriched compost and chemical fertilizers on the health of wheat grain.

Discussion

This study demonstrated the effectiveness of enriched compost and chemical fertilizer for promoting growth and yield of wheat and maize under net house (pot) conditions. Application of compost (enriched with 25% N and L-TRP) applied @ 250 kg ha^{-1} in the presence of 50% N fertilizer (supplementary dose) significantly increased the growth and yield of both wheat and maize compared to full dose of N fertilizer alone. In case of maize crop, effect of compost enriched with N only and supplemented with 50% N fertilizer was even comparable to full dose of N fertilizer (urea). Overall, there was >25% saving of N with the application of 250 kg ha^{-1} organic fertilizer/enriched compost. Our findings support the results of other scientists who reported ~20% N saving with the application of compost (Bajpai *et al*., 2002; Pooran *et al*., 2002); however, they applied it in tonnage. Increases in growth and yield of wheat and maize in our study could be attributed to enhanced nutrient use efficiency in the presence of organic fertilizer, a good source of macro- and micro-nutrients (Table 1). Moreover, total NPK contents in plants were increased significantly in response to combined application of compost and chemical fertilizer (Tables 4 & 5). 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 (Chang & Janzen, 1996; Paul & Clark, 1996; Muneshwar *et al*., 2001; Nevens & Reheul, 2003). 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.

In this study, L-TRP in the compost might also have contributed to growth of wheat and maize, particularly root growth. This premise is supported by the data presented in Table 5 that compost enriched with both N & L-TRP is superior in effectiveness than the compost enriched with N only. Recently, we have reported similar kind of results (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 less-narrow 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*., 2000).

Effect of compost enriched with 25% N + L-TRP and supplemented with 25% N was significantly greater on number of tillers and spikelets per spike of wheat compared to compost enriched with 50% N + L-TRP without any N supplementation, but it had non-significant effect on grain yield of wheat. This may imply that split application of N either blending in compost or directly in soil could be more effective than one time application of higher dose of N.

The novelty of this approach is that the EC was applied just @ 250 kg ha^{-1} as a soil amendment. Previously, farmers were used to add compost in soil as many tonnes ha^{-1}. The economic analysis of enriched compost indicated that this technology is cost effective if organic material is collected and transported by the Government. So this approach is not only cost effective but also improves soil health, reduces dependence on chemical fertilizer and, most likely, helps in reducing huge piles of organic waste.

In conclusion, organic waste materials can be converted into value-added organic fertilizer by the addition of lower doses of nitrogen as well as biologically active substances. It is possible to get higher yield levels with complimentary use of organic and inorganic (chemical) fertilizers than the application of organic or chemical fertilizers alone. The improvement in soil health and reduction in piling of organic wastes could be extra benefit.

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