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COMPARATIVE EFFICIENCY OF AUXIN AND ITS PRE-CURSOR APPLIED THROUGH COMPOST FOR IMPROVING GROWTH AND YIELD OF MAIZE

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Abstract

In the present study compost was prepared from waste fruit and vegetables and enriched with 25% (44 kg ha^{-1}) of full dose (175 kg ha^{-1}) of N fertilizer for maize. Pure auxin, indole 3-acetic acid (IAA) and L-TRP (precursor) were blended with respective batches @ 10 mg kg^{-1} compost for the value addition of N-enriched compost (NEC). Comparative effectiveness of IAA or L-TRP-blended NEC was studied, in the presence or absence of 50% (88 kg N ha^{-1}) of full dose of N fertilizer, through pot and field trials. Compost was applied @ 300 kg ha^{-1}. Results indicated that IAA-blended NEC supplemented with half dose of N fertilizer was as effective as NEC in improving growth and yield of maize. However, precursor (L-TRP)-blended NEC was found better than pure auxin (IAA)-blended, when both were compared with NEC. It significantly improved growth, yield and nutrient uptakes (up to 8.4, 8.6 and 11% respectively) of maize over NEC in the presence of 88 kg N ha^{-1}. The technology bears its promise not only to improve crop yield on sustainable basis but also reduce huge piles of organic wastes causing environmental pollution.

Introduction

Traditionally, organic wastes (either composted or non-composted) are being used in large amounts (t ha^{-1}) for improving crop productivity (Nevens & Reheul, 2003; Wolkowski, 2003; Loecke *et al*., 2004). Avaliability of organic wastes in bulk, and its transport and application cost is a problem. Consequently, farmers are compelled to opt chemical fertilizer as nutrient source. However, sole use of chemical fertilizer is not sustainable for soil and environment as organic matter (OM) status of arable soil and ultimately physico-chemical properties of soil are declining. Further, it is economic stress on resource poor farmers as fertilizer prices are raising tremendously.

Fortification of composts with suitable amount of chemical fertilizers could enhance fertilizer use efficiency and return back organic matter into soil, restoring soil health and improving crop yield on sustainable basis (Ahmad *et al*., 2008 a). Through composting, heterogeneous organic wastes are biologically converted into an amorphous material and under controlled conditions. The compost product can be handled, stored and applied to land without environmental impacts (Ahmad *et al*., 2007a; Millner *et al*., 1998).

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Very recently, the directive of compost technology is to produce a marketable value-added product rather than a solid waste management strategy (Lassaridi *et al*., 2006). The wise manipulation of composted material with some additives not only reduces its application rates but also helps in achieving product of desired characteristics (Ahmad *et al*., 2007 a). A novel approach is to convert composted material into value-added product through enrichment/blending of the compost with nutrients and plant growth regulators or biologically active substances (BAS).

Auxin, a plant growth regulator, in appropriate concentration, may regulate cell elongation, induction of cambium cell division, formation of adventitious roots, axillary shoot formation, tropisms, callus initiation and growth and induction of embryogenesis (Vandehoff & Dute, 1981). L-tryptophan is a common precursor of auxin, and affects the physiological processes of plants after uptake from soil directly and indirectly after transforming into auxin in the soil. Influence of L-TRP and auxin (IAA) applied through compost on cereal crops have been reported earlier (Ahmad *et al*., 2007a: Ahmad *et al*., 2008 b) but not compared yet.

In this study, waste fruit and vegetables were composted and enriched with urea fertilizer to make nitrogen-enriched compost (NEC). Different batches of NEC were further fortified with IAA and L-TRP, separately. The IAA or L-TRP-treated compost was compared with NEC alone in the absence and presence of lower rate of N fertilizer to increase per unit yield of maize on sustainable basis. The focus was to compare the efficiency of IAA and its precursor (L-TRP)-treated-NEC.

Materials and Methods

Preparation of enriched compost: Compost was prepared by using a locally fabricated composter consisting of drier, crusher/ grinder and a processor. Waste fruit and vegetables were collected from various locations (fruit and juice shops, fruit and vegetable markets, etc.) of the city. Collected organic waste material was air-dried for 24 hours to remove the excess moisture and unwanted substances if any (plastic bags, glass material and stones, etc.) were removed from the organic waste. The organic material was then oven-dried at 55 ^{o}C for 24 hours and ground to 2 mm by electrical grinder. Ground material was put in the composter (processing unit) to convert raw organic waste materials into compost. A moisture level of 40% (v/w) of the material was maintained during composting. Composting was done for 5 days under controlled temperature and aeration (shaking at 50 rpm).

Composted material (300 kg) was enriched/blended with 25% of recommended (175 kg ha^{-1}) N fertilizer in the form of urea. Thus, 300 kg batch of compost received 44 kg N for maize crop. To formulate a value-added organic fertilizer, IAA, and L-TRP were added @ 10 mg kg^{-1} compost to respective batches of N-enriched compost. 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).

Pot trial: Pot experiment was conducted at Agronomy Research Area, Ayub Agriculture Research Institute, Faisalabad during 2005-06, to assess the effect of enriched compost and chemical fertilizers on the growth and yield of maize crop. Soil was collected, air dried, sieved and analyzed for physico-chemical characteristics before sowing the crop.

The soil used was sandy clay loam having pH, 7.7; ECe, 2.7 dS m^{-1}; OM, 0.7 %; total N, 0.048%; available P, 9 mg kg^{-1} and exchangeable K, 175 mg kg^{-1} soil.

Each pot was filled with sieved soil (12 kg pot^{-1}), mixed with recommended P and K fertilizers at 100 and 50 kg ha^{-1}, respectively. Single super phosphate and sulfate of potash were used as a source of P and K. Composts (NEC alone, IAA-treated NEC and L-TRP-treated NEC) were applied on a dry weight basis @ 300 kg ha^{-1} by mixing it with top 15 cm soil before filling the pots.
Details of the treatments are given below:

T1: N-enriched compost
T2: IAA-treated N-enriched compost
T3: L-TRP-treated N-enriched compost
T4: N-enriched compost + 88 kg N fertilizer
T5: IAA-treated N-enriched compost+ 88 kg N fertilizer
T6: L-TRP-treated N-enriched compost + 88 kg N fertilizer

Four seeds of hybrid maize (*Zea mays* L.) cultivar Corn-786 were sown in each pot. After germination, one healthy and uniform plant was maintained in each pot. The pots were arranged in completely randomized design with four replications. An additional amount of N fertilizer 50% of standard rate was applied in solution form as split application twice according to the treatment plan. The first and second applications were applied after germination and before tassaling stage. Canal water meeting the irrigation quality criteria for crops was used for irrigation.

Field trial: Field experiment was conducted to assess the effect of enriched compost and chemical fertilizers on the growth and yield of maize crop. Maize was sown @ 30 kg ha^{-1} keeping row to row distance of 75 cm with a plot size of 10 m^2. The soil had same physico-chemical characteristics as in pot trial. The experiment was laid down in randomized complete block design with four replications. The NPK fertilizers were used @ 175-100-50 kg ha^{-1} as urea, single super phosphate and sulphate of potash, respectively.

Full amounts of P and K fertilizers were applied at the time of sowing as a basal dose in all plots, while N was applied according to the treatments in two split applications i.e., after germination and before tassaling. IAA and L-TRP-treated NEC were applied in the presence and absence of 50% full dose of N fertilizer i.e. 88 kg N ha^{-1}. Compost-based organic fertilizer was applied @ 300 kg ha^{-1} along the plant rows with a drill at the time of first dose of N fertilizer application and was then irrigated with canal water.

The plants were harvested at maturity (both in pot and field trial) and data regarding growth and yield parameters were recorded. Grain and shoot samples of plants were analyzed for N and P contents (Ryan *et al*., 2001) and their total contents were determined. The data were analyzed by using completely randomized design (Steel *et al*., 1997). Means were compared by Duncan's Multiple Range Test (Duncan, 1955).

Results

Pot trial: NEC in combination with N fertilizer increased the yield and yield attributes of maize significantly (Table 2). By comparison with NEC alone, application of L-TRP treated-NEC without N fertilizer caused a significant improvement (10.3%) in total biomass than IAA treated-NEC (5.1%). However, in the presence of 88 kg N fertilizer, the total biomass produced by IAA treated-NEC was no better than NEC. Biomass produced by L-TRP treated-NEC in combination with 88 kg N was significantly higher (6.4%) than NEC with or without IAA.

The maximum cob yield (210 g) was observed where L-TRP treated NEC was applied in the presence of 88 kg N ha^{-1}. It was significantly higher than NEC and IAA treated-NEC applied with same rate of N. Both the latter treatments were no different from each other. Without N fertilizer the treatments followed the order: NEC, IAA-treated NEC and L-TRP-treated NEC. Grain yield the main parameter of concern was also affected significantly by the integrated use of L-TRP and NEC both in the absence (12.5%) and presence (7.6%) of N fertilizer over NEC. In each case, NEC and IAA-treated NEC were non significant with each other.

As expected L-TRP treated NEC in the presence of N fertilizer caused significant increase in N and P contents (Table 3) over un-treated NEC (7.0 and 11.1%, respectively). It showed an increase of 16.6 and 32.5% in N and P contents, respectively where no fertilizer was applied. IAA-treated NEC did not differ significantly with NEC with or without supplementation of N fertilizer.

Field trial: Application of NEC in combination with L-TRP significantly increased the total biomass, cob yield and grain yield (Table 4). The response patterns for most of the parameters followed those observed in the greenhouse experiment. Same results were observed in the case of NEC and IAA-treated NEC in the presence of fertilizer. L-TRP treated NEC increased total biomass and cob yield up to 5.2 and 6.4% over NEC. In the absence of fertilizer, the order of the effects of materials was as follows: NEC, IAA-treated NEC and L-TRP-treated NEC.

Grain yield in response to NEC plus L-TRP without fertilizer was 10.9% more than NEC compared to 9.6% with fertilizer. In each case, NEC and IAA-treated NEC had no difference regarding grain yield. Like field trial, L-TRP treated NEC in the presence of N fertilizer caused significant increase in N and P contents (Table 5) over un-treated NEC (7.0 and 10.9%, respectively). It showed an increase of 16.4 and 26.6% in N and P contents, respectively where no fertilizer was applied followed by IAA-treated NEC. In the presence of fertilizer, IAA-treated NEC showed inconsistent response in N and P uptake.

Discussion

This study demonstrated the comparative effectiveness of NEC treated either with IAA or L-TRP in the presence and absence of N fertilizer. Nitrogen enriched compost and chemical fertilizer promoted growth, yield and nutrient (N and P) uptakes of maize under both net house (pot) and field conditions (Table 2-5). In our previous studies it was confirmed through extensive pot and field experimentation that application of compost (enriched with 25% of standard N) applied @ 300 kg ha^{-1} in the presence of 50% N fertilizer (supplementary dose) increased the growth, yield and nutrient uptakes of cereals comparable to their full doses of N fertilizer (Ahmad *et al*., 2006: Ahmad *et al*., 2007 b: Ahmad *et al*., 2008 b). So, in this study NEC plus 88 kg N ha^{-1} was taken equivalent to full chemical fertilizer.

Table 1: Analysis of raw and composted fruit and vegetable wastes

Parameter	Before composting (raw organic waste)	After composting
Carbon (%)	30.32±1.5*	23.11±0.98
Nitrogen (%)	1.31±0.07	2.47±0.15
Phosphorus (%)	0.22±0.05	0.37±0.09
Potassium (%)	1.20±0.08	1.76±0.15
Copper (mg kg^{-1})	1.12±0.02	1.35±0.07
Zinc (mg kg^{-1})	39.2±3.10	47.4±2.5
Manganese (mg kg^{-1})	42.3±2.98	55.2±3.02
Iron (mg kg^{-1})	351±31	587±49
C/N ratio	23.2±0.65	9.4±0.10
C/P ratio	137.8±9.3	62.5±2.5
C/K ratio	25.3±1.02	13.1±0.15

*Average ± Standard error of three replications

Table 2: Comparative effect of L-TRP/IAA-treated NEC on growth and yield of maize with/without N fertilizer (Pot trial, average of three repeats)

Treatments	Total biomass (g pot^{-1})		Cob yield (g pot^{-1})	
	Without fertilizer	With 88 kg N ha^{-1}	Without fertilizer	With 88 kg N ha^{-1}
NEC	290 d†	418 b	154 d	190 b
NEC+IAA	305 cd	420 b	160 cd	195 b
NEC+L-TRP	320 c	445 a	167 c	210 a
	Grain yield (g pot^{-1})			
NEC	104 d	130 b		
NEC+IAA	109 d	130 b		
NEC+L-TRP	117 c	140 a		

†Means sharing similar letter(s) in a column do not differ significantly at p=0.05

Table 3: Comparative effect of L-TRP/IAA-treated NEC on nitrogen and phosphorus uptake of maize with/without N fertilizer (Pot trial, average of three repeats)

Treatments	N uptake (g pot^{-1})		P uptake (g pot^{-1})	
	Without fertilizer	With 88 kg N ha^{-1}	Without fertilizer	With 88 kg N ha^{-1}
NEC	0.65 d†	1.70 b	0.40 d	0.72 b
NEC+IAA	0.70 d	1.72 b	0.42 d	0.75 b
NEC+L-TRP	0.77 c	1.82 a	0.53 c	0.80 a

†Means sharing similar letter(s) in a column do not differ significantly at p=0.05

Table 4: Comparative effect of L-TRP/IAA-treated NEC on growth and yield of maize with/without N fertilizer (Field trial, average of three repeats)

Treatments	Total biomass (t ha^{-1})		Cob yield (t ha^{-1})	
	Without fertilizer	With 88 kg N ha^{-1}	Without fertilizer	With 88 kg N ha^{-1}
NEC	28.5 d†	36.4 b	12.5 d	15.4 b
NEC+IAA	29.4 cd	36.2 b	12.8 cd	15.5 b
NEC+L-TRP	30.3 c	38.3 a	13.4 c	16.1 a
	Grain yield (t ha^{-1})			
NEC	3.92 d	5.20 b		
NEC+IAA	4.10 d	5.30 b		
NEC+L-TRP	4.35 c	5.70 a		

†Means sharing similar letter(s) in a column do not differ significantly at p=0.05

Table 5: Comparative effect of L-TRP/IAA-treated NEC on nitrogen and phosphorus of maize with/without N fertilizer (Field trial, average of three repeats)

Treatments	**N uptake (kg ha^{-1})**		**P uptake (kg ha^{-1})**	
	Without fertilizer	With 88 kg N ha^{-1}	Without fertilizer	With 88 kg N ha^{-1}
NEC	67 d†	128 b	30 d	55 b
NEC+IAA	72 cd	130 b	34 cd	58 ab
NEC+L-TRP	78 c	137 a	38 c	61 a

†Means sharing similar letter(s) in a column do not differ significantly at p=0.05

In this study, L-TRP-treated NEC showed superiority over untreated NEC either with or without fertilizer in improving growth, yield and nutrient uptake. This supports the results of other scientists who found that application of NEC blended with L-TRP was significant than unblended NEC in improving growth and yield of wheat and maize (Arshad *et al*., 2004; Ahmad *et al*., 2007 b; Zahir *et al*., 2007 a). As L-TRP is considered an efficient physiological precursor for auxin biosynthesis in higher plants and in microbes it affects physiological processes of plants after uptake directly by roots in soil or indirectly after conversion into IAA in the soil (Frankenberger & Arshad, 1995). Studies have shown that application of L-TRP to rooting medium improves plant growth (Frankenberger & Arshad, 1991; Arshad *et al*., 1994; Zahir *et al*., 2000).

Results also showed that IAA-treated NEC was no better than NEC in the presence or absence of N fertilizer in improving growth, yield and nutrient uptake of maize. In our recent study, the effect of IAA, gibberellic acid and kinetin was studied in the presence of enriched compost. It was found that the response of IAA-blended NEC in combination with 50% N fertilizer was non significant with NEC plus 50% fertilizer for cereals (Ahmad *et al*., 2008 b). Zahir *et al*. (2007 b) also reported similar kinds of results for wheat crop.

It is well established that effect of L-TRP on plant growth is due to its conversion into IAA (Martens & Frankenberger, 1993). Application of precursor (L-TRP) of IAA could be more useful than the one time application of pure synthetic hormones. Precursor provides continuous supply of plant hormone and has narrow threshold between inhibitory and stimulatory levels. It is very likely that in this study due to above reasons L-TRP showed more prominent results than pure synthetic IAA. A recent incubation study showed gradual increase in the concentration of IAA-equivalents in compost ranging from 1.02 -3.05 mg kg^{-1} observed when compost was treated with its precursor L-TRP. In contrast to this there was gradual decrease in concentration of IAA-equivalents over a certain time where pure synthetic IAA was applied (Ahmad *et al*., 2008 c).

It is concluded from the study that application of L-TRP treated NEC + 50% N fertilizer is economical than IAA-blended NEC in term of saving of N fertilizer as well as giving significantly higher yield of maize than NEC + 50% N fertilizer (equivalent to full rate of chemical fertilizer). Moreover, the study indicated that this technology is cost effective as collection and transportation of waste organic material is the government's responsibility by law. Raw material is available free of cost and application of just 300 kg ha^{-1} is quite feasible for the farmers to be used as soil amendments and also will not create a demand-supply problem.

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