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EFFECTIVENESS OF IAA, GA_3 AND KINETIN BLENDED WITH RECYCLED ORGANIC WASTE FOR IMPROVING GROWTH AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

Plant hormones play a vital role in coordination of many growth and behavioral processes in the plant life. They regulate the amount, type and direction of plant growth. Organic waste recycling in the form of compost is an effective way of organic waste management, turning it into a high quality and inexpensive soil amendment. In this study, plant growth regulators like IAA, GA_3 and kinetin were blended with composted organic wastes and their bioavailability to affect the growth and yield of wheat was evaluated in a field trial. The compost was prepared from fruit and vegetable waste material and enriched with 25% of full dose of N fertilizer (100 g kg^{-1} compost). Each of indole 3-acetic acid (IAA), gibberellic acid (GA_3) and kinetin were added @ 1.0 mg kg^{-1} compost. Effectiveness of IAA/GA_3 or kinetin-blended N-enriched compost was compared in the presence of 50% of full dose of N fertilizer for improving growth and yield of wheat. Compost was applied @ 300 kg ha^{-1} and full P and K fertilizers (@100-60 kg ha^{-1}) were applied as basal dose to all plots. Full dose of N fertilizer (120 kg ha^{-1}) was used for comparison. Results indicated that IAA-blended N-compost with half dose of N fertilizer was comparable with full dose of N fertilizer for improving growth and yield of wheat, saving 25% N fertilizer. However, application of kinetin blended N-enriched compost increased the grain yield (9.1%) and uptake of nutrients i.e. NPK uptake (5.6, 8.6 and 7%, respectively) over full dose of N fertilizer. The findings also proved that exogenously supplied PGRs may undergo several metabolic processes in the soil resulting in loss of their activity and reduced availability to plants. In this study, such type of behavior was only seen with IAA & GA_3 but not in case of kinetin as its bioavailability to wheat was not affected when blended with compost resulting in improved growth and yield. This study also demonstrated that huge amount of organic waste could be converted into a value-added product for improving growth, yield and nutrient uptake of wheat.

Introduction

Managing balance between vegetative and reproductive growth is a very important part of crop productivity. Plant growth regulators (PGRs) can help to manage this balance (Silvertooth, 2000). The importance of biologically active substances in plants is well documented. Plant growth regulators are natural compounds that have shown far-reaching effects on the growth and development of plants even at low concentration (Arshad & Frankenberger, 1998). Plant growth regulators are known to affect growth, flowering and assimilate translocation in plants (Hayat *et al*., 2001; Naeem *et al*., 2004).

Auxins, gibberillins (GA_3) and kinetin being well known plant growth promoting hormones have shown to be involved in a variety of plant growth and development processes (Frankenberger & Arshad, 1995). Auxins may regulate cell elongation, tissue swelling, cell division, formation of adventitious roots, callus initiation and growth, induction of embryogenesis and promote cell wall loosening at very low concentrations (Vanderhoff & Dute, 1981). Similarly, gibberellic acid (GA_3) facilitates cell elongation

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in different organs and tissues throughout plant growth and development (Karssen *et al*., 1989). Cytokinins regulate cell division and differentiation in certain plant tissues and participate in many developmental processes e.g. senescence, photosynthesis, flower formation and photosynthate partitioning etc. (Frakenberger & Arshad, 1995). Plants have the ability to store excessive amounts of exogenously supplied hormones in the form of reversible conjugates which release active hormone when and where plant needs them during the growth period (Davies, 1987). In almost all the studies reported by now, these PGRs have been tested by applying them in solution form. Present study is perhaps the first one of its type where these PGRs have been applied in the recycled organic waste to investigate if their bioavailability is affected when used with recycled organic waste.

During the recent years, population explosion, urbanization and industrialization has raised many environmental curses including organic waste generation and its accumulation in the environment. Solid waste disposal is a big challenge now-a-days. Operations like burning/incineration, dumping or landfills may be utilized to get rid from this waste but each of them has its own noxious effects on environment quality.

Today, heightened environmental awareness has sparked renewed interest in composting as a mean to prevent or reduce environmental pollution and to manage and recycle waste produced by the society. Waste disposal costs are lowered when organic wastes are composted, instead of trucking off to the local dump. Composting, being the best recycler of wastes is an environment friendly technique used to stabilize huge piles of organic waste. It is a biological process in which microorganisms convert organic material such as manure, leaves, sludge, fruits, paper, vegetables and food waste into soil like material under conditions of optimum temperature, moisture and aeration (Rynk, 1992). Composted organic material is considered as a rich source of nutrients and can also play important role to conserve the soil fertility and to enhance crop production on sustainable basis (Togun *et al*., 2003; Walkowski, 2003). Moreover, this recycled organic waste (compost) has primary value as fertilizer but secondarily provides benefit of improving physical and microbial soil characteristics (Haug, 1993). Application of ample amount of compost leads to soil sustainability (Swift & Woomer, 1993). The addition of chemical N fertilizer and PGRs could convert the compost into a value-added product and its effectiveness could be significantly improved.

The aim of present investigation was to study the effectiveness of IAA, GA_3 and kinetin when blended with recycled organic waste for improving growth and yield of wheat crop.

Materials and Methods

Recycling of organic waste (composting): Fruit and vegetable wastes collected from various locations (local fruit and vegetable market and juice shops etc.) of Faisalabad city were composted in a locally fabricated unit consisting of drier, crusher/grinder and processor. Organic wastes were air-dried for couple of days to remove excessive moisture and sorted out to remove unwanted materials (e.g. pieces of metals, glass, polythene bags etc.). The sorted organic material was oven-dried at 70^{o}C for 24 h and ground into finer particles (<2.0 mm) with the help of an electric grinder. The ground material was transferred to a vessel (500 kg capacity) for composting under controlled temperature and aeration (shaking at 50 rev min^{-1}). A moisture level of 40% (v/w) of the compost was maintained during the composting process. 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. Composting was done for 5 d and composted organic material was analyzed for macro- and micro-nutrients, and C/N, C/P and C/K ratios were also calculated (Table 1).

The finished compost (300 kg) was enriched by mixing it with N-fertilizer (urea, Fuji Fertilizer Company Ltd., Pakistan) @ 100 g N kg^{-1} compost (30 kg N = 25% of 120 kg ha^{-1} N) to enhance the quality and nutritional value of the organic product. Thus, 300 kg batch of compost received 30 kg N for wheat crop. The final product was termed as enriched compost (EC).

Blending of plant growth regulators with enriched compost: Resulting enriched compost was blended with IAA, GA_3 and kinetin @ 1.0 mg kg^{-1} compost according to treatment plan in solution form (Tables 2-4). Before application to soil, bioavailability of IAA, GA_3 and kinetin was determined according to the methods described by Khalid *et al*., (2004), Lienhos & Birnstiel (1989) and Nieto & Frankenberger (1989), respectively. The analysis indicated that the enriched compost had almost same amount of kinetin (0.91 mg kg^{-1} compost) as was added while IAA and GA_3 were significantly reduced to 0.41 and 0.37 mg kg^{-1} compost, respectively.

Field experiment: A field experiment was conducted in the Research Area of the Institute of Soil and Environmental Sciences, at Postgraduate Agriculture Research Station (PARS), University of Agriculture, Faisalabad, Pakistan to assess the effect of enriched compost blended with PGRs on growth and yield of wheat (*Triticum aestivum* L.) during the year 2004. Soil was analyzed for physicochemical properties before experiment. Analyzing composite soil sample revealed that it was sandy clay loam having a pH of 7.6; EC_e, 1.66 dS m^{-1}; organic matter, 0.59%; total nitrogen, 0.04%; available phosphorus, 7.45 mg kg^{-1} and extractable potassium, 117 mg kg^{-1} soil. Recommended doses of NPK @ 120-100-60 kg ha^{-1}, as urea, single super phosphate and murate of potash, respectively were applied. All phosphorus and potassium was applied before sowing while N was applied according to the treatments (Tables 2-4) in two split doses i.e. first dose at 1st irrigation and 2nd dose at grain filling stage. Wheat (*Tritium aestivum* L.) seed (@ 100 kg ha^{-1}) of variety "wattan" was sown in plots (size 10 m^2) by drilling method. Enriched compost was applied in bands along the seeds with hand drill @ 300 kg ha^{-1} according to the treatments, replicated four times using randomized complete block design (RCBD). Canal water was used for irrigation.

Plant height, spike length, number of spikelets $spike^{-1}$ and number of tillers m^{-2} were recorded at maturity. Grain yield, straw weight, total biomass and 1000-grain weight was recorded at crop harvest. Grain and straw samples were dried to a constant weight at 65°C and analyzed for NPK contents using standard methods. The data were analyzed statistically according to Steel & Torrie (1980). Means were compared by Duncan's multiple range test (DMR) at 5 percent probability.

Results

Data regarding the effect of N-enriched compost treated with different BAS in the presence of N fertilizer on growth, yield and N uptake of wheat is presented in Tables 2-4. Maximum plant height was observed where kinetin-blended N-enriched compost was supplemented with 60 kg ha^{-1} N that was statistically similar with indole acetic acid (IAA) blended N enriched compost plus 60 kg ha^{-1} N but differed significantly from full dose of N fertilizer. Application of N-enriched compost with gibberellic acid (GA_3) in combination with 60 kg N produced statistically similar plant height as was produced by full dose of N fertilizer.

Table 1. Analysis of raw and composted fruit and vegetable wastes. (Average of four repeats ± standard error).

Parameter[a]	Before composting (raw organic material)	After composting
Carbon (%)	29.13 ± 1.2	22.11 ± 0.88
Nitrogen (%)	1.41 ± 0.06	2.43 ± 0.10
Phosphorus (%)	0.22 ± 0.02	0.32 ± 0.03
Potassium (%)	1.18 ± 0.06	1.69 ± 0.10
Copper (mg kg^{-1})	1.10 ± 0.03	1.33 ± 0.05
Zinc (mg kg^{-1})	37.5 ± 2.10	45.8 ± 2.8
Manganese (mg kg^{-1})	41.1 ± 1.88	52.8 ± 2.06
Iron (mg kg^{-1})	349 ± 29.0	577 ± 46.0
C/N ratio	26.9 ± 0.68	10.2 ± 0.13
C/P ratio	117.1 ± 8.6	52.9 ± 1.8
C/K ratio	29.8 ± 1.08	13.3 ± 0.14

[a]Carbon content, and macro- and micro-nutrients were determined according to the methods described by Nelson and Sommers (1996) and Ryan *et al*., (2001), respectively.

Table 2. Effect of compost enriched with chemical N fertilizer and plant growth regulators on plant height, no. of tillers m^{-2}, spike length and no. of spikelets $spike^{-1}$ of wheat. (Average of four repeats).

Treatments	Plant height (cm)	Tillers m^{-2}	Spike length (cm)	Spikelets $spike^{-1}$
Urea fertilizer (120 kg ha^{-1} N)	94.7 b	385 b	12.0 a	14.5 b
N-enriched compost + 60 kg ha^{-1} N	91.4 c	355 c	11.3 c	13.9 c
N-enriched compost+IAA+60 kg ha^{-1} N	103.5 a	396 b	11.8 ab	14.4 b
N-enriched compost+KIN+60 kg ha^{-1} N	104.8 a	415 a	12.2 a	14.9 a
N-enriched compost+GA_3+60 kg ha^{-1} N	94.0 b	360 c	11.4 bc	14.2 bc

Means sharing similar letter(s) do not differ significantly at p=0.05
PK @ 100-60 kg ha^{-1} as basal dose to all treatments
IAA, GA_3 and KIN were blended @ 1.0 mg kg^{-1} nitrogen-enriched compost

Table 3. Effect of compost enriched with chemical N fertilizer and plant growth regulators on fresh biomass, grain yield, straw yield and 1000-grain weight of wheat. (Average of four repeats).

Treatments	Fresh biomass (t ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	1000-grain weight (g)
Urea fertilizer (120 kg ha^{-1} N)	9.7 ab	4.5 b	5.2 a	44.0 b
N-enriched compost + 60 kg ha^{-1} N	8.4 c	3.7 c	4.7 b	40.0 d
N-enriched compost+IAA+60 kg ha^{-1} N	9.5 b	4.2 b	5.3 a	42.0 c
N-enriched compost+KIN+60 kg ha^{-1} N	10.0 a	4.8 a	5.2 a	45.0 a
N-enriched compost+GA_3+60 kg ha^{-1} N	8.7 c	3.9 c	4.8 b	40.2 d

Means sharing similar letter(s) do not differ significantly at p=0.05
PK @ 100-60 kg ha^{-1} as basal dose to all treatments
IAA, GA_3 and KIN were blended @ 1.0 mg kg^{-1} nitrogen-enriched compost.

Data regarding no. of tillers m^{-2} (Table 2), revealed that application of kinetin-blended N-enriched compost in the presence of 60 kg N fertilizer was found to be the most effective treatment and increased the number of tillers m^{-2} by 7.8% over full dose of N fertilizer. Enriched compost treated with IAA differed non-significantly with 100% N fertilizer. Enriched compost treated with GA_3 showed non-significant effect on number of tillers m^{-2} when compared with N-enriched compost supplemented with 60 kg ha^{-1} N fertilizer.

Table 4. Effect of compost enriched with chemical N fertilizer and plant growth regulators on NPK uptake of wheat. (Average of four repeats)

Treatments	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)
Urea fertilizer (120 $kg\ ha^{-1}$ N)	96.5 ab	51.2 ab	199.5 b
N-enriched compost + 60 $kg\ ha^{-1}$ N	83.3 c	40.3 c	164.3 d
N-enriched compost+IAA+60 $kg\ ha^{-1}$ N	90.2 bc	47.0 b	177.3 c
N-enriched compost+KIN+60 $kg\ ha^{-1}$ N	102.0 a	55.6 a	213.0 a
N-enriched compost+GA_3+60 $kg\ ha^{-1}$ N	87.8 c	42.0 c	171.5 c

Means sharing similar letter(s) do not differ significantly at p=0.05
PK @ 100-60 $kg\ ha^{-1}$ as basal dose to all treatments
IAA, GA_3 and KIN were blended @ 1.0 $mg\ kg^{-1}$ nitrogen-enriched compost.

Table 2 depicted that maximum spike length (12.20 cm) was recorded in case of kinetin- blended N-enriched compost in the presence of 60 kg ha^{-1} N that differed non significantly from IAA-treated N-enriched compost and full dose of N fertilizer. Minimum spike length was recorded in case of N-enriched compost plus 60 kg N fertilizer (11.3 cm) that was statistically similar with GA_3- treated N-enriched compost.
Similar to spike length, maximum number of spikelets $spike^{-1}$ (Table 2) was also observed in case of kinetin-blended N-enriched compost plus 60 kg ha^{-1} N fertilizer that differed significantly from IAA-treated N-enriched compost plus 60 kg ha^{-1} N and 100% N fertilizer. Application of GA_3- treated N-enriched compost differed non significantly from full dose of N fertilizer and N-enriched compost plus 60 kg ha^{-1} N.

Results regarding fresh biomass are summarized in (Table 3). Application of kinetin-blended N-enriched compost in the presence of 60 kg ha^{-1} N fertilizer produced maximum fresh biomass (10 t ha^{-1}) that was statistically at par with full dose of N fertilizer. However, IAA- treated N-enriched compost plus 60 kg ha^{-1} N fertilizer gave fresh biomass (9.5 t ha^{-1}) that also differed non-significantly from full dose of N fertilizers. Application of GA_3- blended N-enriched compost plus 60 kg N fertilizer produced biomass at par with N-enriched compost plus 60 kg N fertilizer.

There was a significant increase (9.1% over full dose of N fertilizer) in grain yield by the application of kinetin-blended N-enriched compost when supplemented with 60 kg ha^{-1} N fertilizer (Table 3). Application of IAA-treated N-enriched compost plus 60 kg ha^{-1} N fertilizer gave 4.2 t ha^{-1} grain yield that was statistically similar with full dose of N fertilizer (4.4 t ha^{-1}). Next to it was GA_3-treated N-enriched compost in the presence of 60 kg ha^{-1} N which produced statistically similar results (3.9 t ha^{-1}) with N-enriched compost plus 60 kg ha^{-1} N fertilizer.

Data regarding straw yield and 1000-grain weight of wheat are summarized in Table 3. Maximum straw yield (5.3 t ha^{-1}) was recorded in IAA-blended N-enriched compost plus 60 kg ha^{-1} N fertilizer which was at par with kinetin-treated N-enriched compost plus 60 kg ha^{-1} N fertilizer and full dose of N fertilizer. Similarly, 1000-grains weight of wheat was significantly influenced by the application of plant growth regulators-blended N-enriched compost and chemical fertilizers. Application of kinetin-treated N-enriched compost plus 60 kg ha^{-1} N fertilizer produced maximum 1000-grain weight (45g) that differed significantly from full dose of N fertilizer.

Table 4 depicts the statistical behaviour of total N, P and K uptake by wheat plant. Maximum total N uptake (102 kg ha^{-1}) was observed in treatment where kinetin-blended N-enriched compost was applied with 60 kg ha^{-1} N fertilizer that differed non-significantly from full dose of N fertilizer. Similar to N uptake, maximum P uptake was observed in Kinetin-treated N-enriched compost plus 60 kg ha^{-1} N fertilizer (55.6 kg ha^{-1}) that was statistically at par with full dose of N fertilizer. Next to it was IAA-treated N-enriched compost plus 60 kg N fertilizer. Data regarding K uptake (Table 4) revealed that maximum K uptake was observed in case of kinetin-blended N-enriched compost plus 60 kg ha^{-1} N fertilizer that differed significantly from full dose of N fertilizer. However, N-enriched compost treated with IAA or GA_3 showed statistically similar K uptake.

Discussion

This study compared the bioavailability of plant growth regulators for improving growth and yield of wheat crop, when blended with enriched N compost in the presence of chemical N fertilizer. Results revealed that GA_3-blended N-enriched compost showed non significant improvement in the growth and yield of wheat in the presence of 60 kg ha^{-1} of N fertilizer compared to N-enriched compost plus 60 kg ha^{-1} N fertilizer and did not show any improvement than full dose of N fertilizer. The addition of IAA to N-enriched compost showed non-significant improvement in most of the growth and yield parameters of wheat in the presence of 60 kg ha^{-1} of N fertilizer when compared with full dose of N fertilizer. However, blending of kinetin in the N-enriched compost showed more promising results in the presence of 60 kg ha^{-1} N fertilizer, which increased the yield and nutrients (N, P and K) uptake of wheat by 9.1, 5.6, 8.6 and 7%, respectively, over full dose of N fertilizer under field conditions compared with full dose of N fertilizer Our findings are supported by the work of previous researchers who elucidated the effect of plant growth regulators on the growth and development of various crops. Application of IAA at the rate of 10^{-5} M increased grain yield and biological yield in wheat (Arif *et al*., 2001). Similarly, Zahir *et al*., (2000) reported up to 50% increase in fresh biomass of soybean by the application of L-tryptophan (precursor of IAA). Significant increase in 1000-grain weight and protein quality of wheat has been reported in response to kinetin application (Wierzbowska & Nowak, 1998). In a field experiment, ADE + IA (kinetin precursor) application significantly increased the paddy yield and nutrients uptake in grain over control (Zahir *et al*., 2001).

Increases in growth and yield of wheat in our study could also be attributed to enhanced N use efficiency and physiological response of crop to added BAS (kinetin) in the presence of organic fertilizer being a source of macro- and micro-nutrients (Table 1). This premise is supported by the fact that the total N, P and K uptake in wheat (Table 4) were increased significantly in response to combined application of kinetin blended N-enriched compost and N fertilizer. Similar to our work, significant increase in N, P, K concentration in corn by kinetin application was reported by Stoyanov & Drev (1978). Previous studies have also shown that the composted organic materials enhance N fertilizer use efficiency by releasing it slowly and thus reducing its losses (Asghar *et al*., 2006; Nevens & Reheul, 2003).

Comparison among all treatments also reveals that application of kinetin-blended N-enriched compost when supplemented with 60 kg ha^{-1} N fertilizer had more positive effect on growth and yields of wheat than IAA/GA_3- treated N-enriched compost compared to full dose of N fertilizer, saving about 25% of the recommended N fertilizer with out compromising on yield. This was probably due to greater bioavailability of kinetin to plant in the root zone than that of both IAA and GA_3 when mixed with compost (please see material and methods). It is well known through the work of several scientists who reported that PGRs can often under go metabolic processes e.g. hydroxylation, conjugation and catabolism in the soil (Wada *et al*., 1979; Rossi *et al*., 1984; Mahadevan, 1984; Martens & Frankenberger, 1993) resulting in loss of their activity and reduced availability to plants. Significant increase in wheat yield by the application of kinetin-blended N-enriched compost may be due to its greater availability which further implies that kinetin may not have under gone much intense metabolic reactions as compared to IAA and GA_3. This was proven in our compost analysis which showed that the compost had 0.91, 0.41 and 0.37 mg kg^{-1} compost, respectively.

The economic analysis of the BAS-treated enriched compost indicated that instead of IAA or GA_3, the use of kinetin is cost effective. The raw material is available free of cost and application of just 300 kg ha^{-1} is quite feasible for the farmers, and will not create the problem of demand-supply imbalances. Moreover, use of organic fertilizer could reduce dependence on chemical fertilizers to some extent. The improvement in soil health and reduction in piling of organic wastes could be extra benefit.

In conclusion, nutrient availability in the right quantities, ratios and at the time plants need them is important for good crop yields. Kinetin-blended N-enriched compost plus 60 kg N fertilizer was able to provide all nutrients (N, P and K) in adequate quantities, rates and continuous manner to increase crop yields compared with other treatments. Moreover, kinetin- treated N-enriched compost served as a source for continuous supply of this plant growth regulator and nutrients in the root zone. This complimentary use of various nutrient sources and PGRs is advantageous, reducing dependence on chemical fertilizers, helping to maintain both soil health and crop productivity at the same time. Organic waste recycling for the development of a useful organic fertilizer and further it s blending with nutrients and PGRs could be helpful in the sustainability of agriculture industry and our environment cleanliness by reducing huge piles of organic waste. Further research is needed to unlock several horizons like physiochemical transformation of PGRs in the soil, screening efficient and inexpensive precursors of PGRs and agronomic practices which could enhance the stability and bioavailability of PGRs in plant root zone. Judicious use of plant growth regulators (PGRs) could be very helpful for the prosperity of agriculture industry.

References

Arif, M., P. Shah, F. Azam and R. Ahmad. 2001. Effect of auxin on different wheat varieties. *Sarhad J. Agri.,* 17: 33-40.

Arshad, M. and W.T. Frakenberger Jr. 1998. Plant growth regulating substances in the rhizosphere: Microbial production and functions. *Adv. Agron.,* 62: 145-151.

Asghar, H.N., M. Ishaq, Z.A. Zahir, M. Khalid and M. Arshad. 2006. Response of radish to integrated use of nitrogen fertilizer and recycled organic waste. *Pak. J. Bot.,* 38(3): 691-700.

Davies, J.P. 1987. *Plant hormones and their role in plant growth and development*. Martinus Nijhoff, Dordrecht.

Frankenberger Jr., W.T. and M. Arshad. 1995. *Phytohormones in Soil: Microbial Production and Function*. Marcel Dekker, New York.

Haug, R.T. 1993. *The practical hand book of compost engineering*. Lewis pub. Boca Raton, USA.

Hayat, S., A. Ahmad, and M. Mobin. 2001. Carbonic anhydrase, photosynthesis and seed yield in mustard plants treated with phytohormones. *Photosynthetica,* 39: 111-114.

Karssen, C.M., S. Zagorski, J. Kepczynski and S.P.C. Groot. 1989. Key role for endogenous gibberellins in the control of seed germination. *Annals Bot.,* 63: 7180.

Khalid, A., M. Arshad and Z.A. Zahir. 2004. Screenings plant growth-promoting rhizobacteria for improving growth and yield of wheat. *J. Appl. Microbiol.,* 96: 473-480.

Leinhos, V. and H. Birnstiel. 1989. Plant growth substances produced by microorganisms of the rhizosphere and the soil. *J. Basic Microbiol.,* 29: 473-476.
Mahadevan, A. 1984. *Growth regulators, microorganisms and diseased plants*. Oxford and IBH, New Dehli, India, 466pp.
Martens, D.A. and W.T.Jr. Frakenberger. 1993. Metabolism of tryptophan in soil. *Soil Biol. Biochem.,* 25: 1679-1687.
Naeem, M., I. Bhatti, R.H. Ahmad and M.Y. Ashraf. 2004. Effect of some growth hormones (GA_3, IAA and Kinetin) on the morphology and early or delayed initiation of bud of lentil (*Lens Culinaris medik*). *Pak. J. Bot.,* 36(4): 801-809.
Nieto, K.F. and W.T. Frakenberger Jr. 1989. Biosynthesis of cytokinin in soil. *Soil Sci. Soc. A. J.,* 53: 735-740.
Nelson, D.W. and L.E. Sommers. 1996. Total carbon, organic carbon and organic matter. In: *Methods of Soil Analysis*: Part 3-Chemical Methods. (Ed.): J. M. Bigham. Soil Science Society of America, Madison, USA.
Nevens, F. and D. Reheul. 2003. The application of vegetable, fruit and garden waste (VFG) compost in addition to cattle slurry in a silage maize monoculture: nitrogen availability and use. *Europ. J. Agron.,* 19: 189-203.
Rossi, W., A. Grappelli and W. Pietrosanti. 1984. Phytohormones in soil after atrazine application. *Folia Microbiol.,* 29: 325-329.
Ryan, J., G. Estefan and A. Rashid. 2001. *Soil and plant analysis: Laboratory Manual*. ICARDA, Aleppo.
Rynk, R. 1992. *On-farm Composting Handbook*. Northeast Regional Agriculture Engineering Service, coop. Ext., NRAES-54 Ithaca. USA.
Swift, M.J. and P.L. Woomer. 1993. Organic matter and sustainability of agricultural system: Definition and measurement. In: *Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture*. (Eds.): K. Mulongoy and R. Merec. 3-18pp.
Silvertooth, J.C. 2000. Plant Growth Regulator Use. Available at http://cals. arizona.edu/ crops/cotton/comments/comments/june2000cc.html. (Accessed on 10.05.2006).
Steel, R.G.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics*, McGraw-Hill, New York.
Stoyanov, I.G. and T.G.K. Drev. 1978. Maize plant recovery after magnesium starvation with aid of magnesium and kinetin. *Fiziologiya-na- Raste-niya,* 4: 64.
Terrance, D., M. Liebman, A. Cynthia, C.A. Cambardella and L. Richard. 2004. Maize response to composting and time of application of solid swine manure. *Agron. J.,* 96: 214-233.
Togun, A.O., W.B. Akanbi and R. Dris. 2003. Influence of compost and nitrogen fertilizer on growth, nutrient uptake and fruit yield of tomato (*Lycoperscion esculentum*). *Crop Res. Hisar,* 26: 98-105.
Vanderhoff, L.N. and R.R. Dute. 1981. Auxin-regulated wall loosening and sustained growth in elongation. *Plant Physiol.,* 67: 146-149.
Wada, K., T. Imai and K. Shibata. 1979. Microbial production of unnatural gibberellins from (-)-kaurene derivatives in *Gibberrlla fujikuroi. Agri. Biol. Chem.,* 43: 1157-1158.
Walkowski, R.P. 2003. Nitrogen management considerations for land spreading municipal solid waste compost. *J. Environ. Qual.,* 32: 1844-1850.
Wierzbowska, J. and G.A. Nowak. 1998. The effect of cytokinen and auxin on yield and quality of spring wheat grain depending on NPK rates, quality of grain and germination ability. *Biuletyn-Instytutu-Hodowli-i-Aklimatyzacji-Roslin,* 208: 35-42.
Zahir, Z.A., M.A.R. Malik and M. Arshad. 2000. Improving crop yield by the application of an auxin precursor L-TRP. *Pak. J. Biol. Sci.,* 3: 133-135.
Zahir, Z.A., H.N. Asghar and M. Arshad. 2001. Cytokinin and its precursors for improving growth and yield of rice. *Soil Biol. Biochem.,* 33: 405-408.

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