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INTEGRATING N-ENRICHED COMPOST WITH BIOLOGICALLY ACTIVE SUBSTANCES FOR IMPROVING GROWTH AND YIELD OF CEREALS

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Abstract

Value addition of the composted organic waste material through biologically active substances (BAS) is a novel approach to convert composted material into a useful soil amendment. In the present study, compost was prepared from waste fruit and vegetables and enriched with 25% of full dose of N fertilizer for maize and wheat, respectively. Biologically active substances (BAS); indole 3-acetic acid (IAA), gibberellic acid (GA_3) and kinetin, each was added @ 1.0 mg kg^{-1} compost to separate batches of nitrogen enriched compost (NEC). Effectiveness of IAA, GA_3 and kinetin-added NEC was compared in field in the presence of 50% recommended dose of N fertilizer for maize and wheat, respectively. Compost was applied @ 300 kg ha^{-1} to both crops and recommended P and K fertilizers of respective crop were applied as basal dose to all plots. Recommended dose of N fertilizer for respective crop was used for comparison. Results indicated that NEC with or without IAA/GA_3 supplemented with half dose of N fertilizer was as effective as full dose of N fertilizer in improving growth and yield of maize as well as wheat, saving ~ 25% N fertilizer. However, kinetin-added compost was better than IAA/GA_3-added compost when compared with recommended dose of N fertilizer. It significantly improved yield and N uptakes of maize (6.2 and 6.7%, respectively) and wheat (5.9 and 6.1%, respectively) over full dose of N fertilizer. 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

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 (Ahmad *et al*., 2008). 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 also causing a loss of useful plant nutrient sources which can be used for crop production.

Composting is an old technology of recycling organic waste material during which organic residues are bio-chemically decomposed into stabilized humified material under controlled conditions of temperature, moisture and aeration (Ahmad *et al*., 2007a). Interest is renewed in composting for sustaining environment and agriculture side by side. The finished compost product has desirable characteristics regarding odor, weed seed and pathogens. It is most suitable and economical waste management strategy than others as handling, storage and farm application of the composted product is environmentally safe (Ahmad *et al*., 2007a).

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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 substances (BAS) is a novel approach to convert composted material into a useful soil amendment (Zahir *et al*., 2007a, b).

Biologically active substances or PGRs are organic compounds, which have shown far-reaching impacts on plant growth even at low concentration. Auxin, a plant growth regulator, in appropriate concentration, may regulate cell elongation, induction of cambium cell division, formation of adventatitious roots, axillary shoot formation, tropisms, callus initiation and growth and induction of embryogenesis (Vandehoff & Dute, 1981). Similarly, gibberellins (GAs); also a plant growth regulator, promote seed germination, stem elongation, flowering and cone formation. It also facilitates cell elongation of different organs and tissues throughout plant growth and development and retard leaf and fruit senescence (Karssen *et al*., 1989). Kinetin, a cytokinin, when added in appropriate concentrations may regulate cell division and differentiation. They are also associated with senescence of plant organ, apical dominance and stomatal opening (Kabar, 1997). These phytohormones are synthesized in plant bodies, however, their exogenous application has also been reported to leave promising effects (Sarwar & Frankenberger, 1994). Plants have the ability to store the excessive amounts of exogenously applied plant hormones in the form of reversible conjugates which release active hormones when and where plant needs them during the growth period (Davies, 1987).

Although composting is an old technique, but improving its nutritional and quality status by blending it with inorganic N (urea) and BAS *i.e.* IAA, GA_3 and kinetin is a novel approach. Accordingly, this study aimed to improve growth and yield of maize and wheat by integrating BAS-treated NEC and chemical fertilizers.

Materials and Methods

Preparation of enriched compost: Compost was prepared by using a locally fabricated composting unit 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 55ºC 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} for maize and 120 kg ha^{-1} for wheat) N fertilizer in the form of urea. Thus, 300 kg batch of compost received 44 kg N for maize and 30 kg N for wheat crop. To formulate a value-added organic fertilizer, each of IAA, GA_3 and kinetin were added @ 1.0 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).

Field trials: Field experiments were 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 wheat and maize crops. Soil was collected, air dried, sieved and analyzed for physico-chemical characteristics (Table 2) before sowing the crop. Hybrid Corn-786 (maize) and Inqulab-91 (wheat) varieties were sown @ 30 and 100 kg ha^{-1}, respectively. Row to row distance of 75 cm in maize and 25 cm in wheat were maintained with a plot size of 10 m^2. The experiments were laid out in randomized complete block design with four replications as:

T1: Recommended chemical N fertilizer (175 and 120 kg ha^{-1} for respective crops)
T2: N-enriched compost + 50% N fertilizer for respective crops
T3: IAA-treated N-enriched compost + 50% N fertilizer for respective crops
T4: GA_3-treated N-enriched compost + 50% N fertilizer for respective crops
T5: Kinetin-treated N-enriched compost + 50% N fertilizer for respective crops

The NPK fertilizers were used @ 175-100-50 in maize and 120-90-60 kg ha^{-1} in wheat as urea, SSP and SOP, respectively. Full dose of N (175 and 120 kg ha^{-1} for maize and wheat, respectively) was kept for comparison. The whole 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 (Figs. 1-6) in two split applications i.e., after germination and before/at tassaling/tillering. Biologically active substances (BAS)-treated NEC was applied in the presence of 50% full dose of N fertilizer for maize as well as for wheat to compare with the full dose of N fertilizer. 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 it was followed by irrigation immediately. 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 in both crops. The plants were harvested at maturity and data regarding growth and yield parameters were recorded. Grain and shoot samples of plants were analyzed for N content (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

Two field trials on maize and wheat were conducted to test the effectiveness of BAS-treated NEC in the presence of N fertilizer.

Maize trial: Data regarding the effect of NEC treated with different BAS in the presence of N fertilizer on growth, yield and N uptake of maize is presented in Figs. 1-3. Maximum plant height was observed where kinetin-blended NEC was supplemented with 88 kg ha^{-1} N that differed significantly from full dose of N fertilizer (Fig. 1). It was followed by IAA-blended NEC. Application of NEC with or without GA_3 in combination with 88 kg ha^{-1} N produced statistically similar plant height as was produced by full dose of N fertilizer.

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

Parameters	Maize	Wheat
Texture	Sandy clay loam	Sandy clay loam
pH	7.72	7.64
Organic matter (%)	0.69	0.71
Total nitrogen (%)	0.05	0.046
Available phosphorus (mg kg^{-1})	10.0	8.0
Extractable potassium (mg kg^{-1})	182	168

Significantly higher fresh biomass (6%) was produced by kinetin-treated NEC plus 88 kg ha^{-1} N compared to full dose of N fertilizer (Fig. 1). Enriched compost treated with IAA or GA_3 differed non-significantly with each other as well as with kinetin-treated NEC regarding fresh biomass production. There was also non-significant difference between NEC plus 88 kg ha^{-1} N and full dose of N fertilizer.

Like fresh biomass, maximum cob yield was recorded with the application of kinetin-blended NEC plus 88 kg ha^{-1} N and it was 8.2% greater than full dose of N fertilizer (Fig. 2). It was followed by NEC treated either with IAA or GA_3. Similar results were recorded by full dose of N fertilizer and by the treatment where NEC was supplemented with half dose of N fertilizer without any BAS.

Application of kinetin-treated NEC plus 88 kg ha^{-1} N resulted in significantly higher grain yield (6.2%) over full dose of N fertilizer (Fig. 2). Grain yield in response to the application of NEC treated either with IAA or GA_3 was statistically similar but differed significantly with full dose of N fertilizer and N-enriched compost in the presence of half dose of N fertilizer.

In case of 1000-grain weight, effect of BAS-treated /untreated NEC in the presence of 88 kg ha^{-1} N was statistically at par with each other as well as with full dose of N fertilizer (Fig. 3). The maximum 1000-grain weight (312 g), however, was obtained where kinetin-treated NEC was applied in the presence of 88 kg ha^{-1} N fertilizer.

Similarly, significantly higher (6.7%) N uptake was recorded by the application of kinetin-treated NEC plus 88 kg ha^{-1} N compared to full dose of N fertilizer and it was followed by GA_3-treated NEC (Fig. 3). Uptake of N by NEC along with half dose of N fertilizer differed non significantly with full dose of N. However, addition of IAA showed non-significant effect on N uptake over untreated NEC.

Wheat trial: Data regarding the effect of NEC treated with different BAS in the presence of N fertilizer on growth, yield and N uptake of wheat is presented in Figs. 4-6. Significantly higher plant height (4.4%) was observed by the application of kinetin treated NEC plus 60 kg ha^{-1} N over full dose of N fertilizer (Fig. 4). It was followed by NEC treated with IAA. No significant improvement in plant height was recorded by blending GA_3 in NEC supplemented with 60 kg ha^{-1} N compared to unblended compost. Both the treatments also differed non-significantly with full dose of N fertilizer.

Maximum number of tillers m^{-2} (466) were recorded due to the application of kinetin-treated NEC combined with 60 kg ha^{-1} N i.e., 8.3% more than full dose of N fertilizer (Fig. 4). Next was IAA-treated NEC. Enriched compost in the presence of 60 kg ha^{-1} N with or without GA_3 differed non-significantly with full dose of N fertilizer regarding number of tillers m^{-2}.

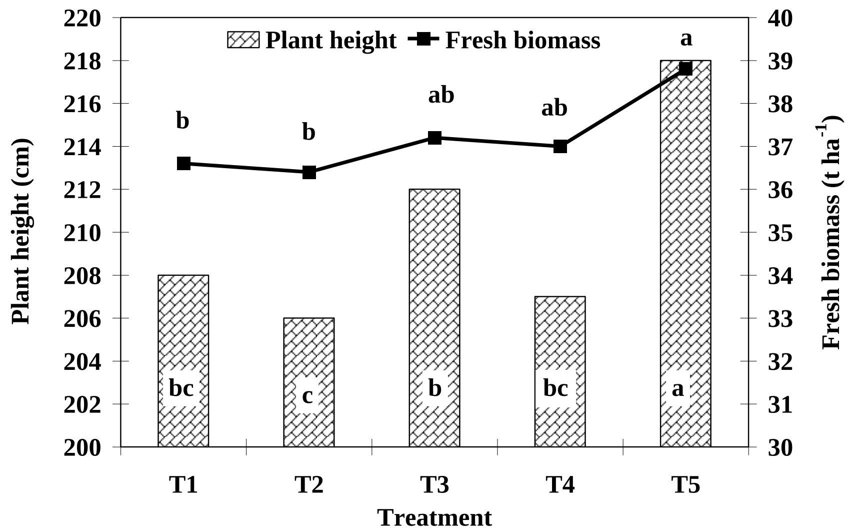


Fig. 1. Effect of compost enriched with different BAS and supplemented with chemical fertilizers on plant height and fresh biomass of maize.
T1, Urea fertilizer 175 kg ha^{-1} N; T2, NEC plus 88 kg ha^{-1} N; T3, IAA-treated NEC plus 88 kg ha^{-1} N; T4, GA_3- treated NEC plus 88 kg ha^{-1} N; T5, Kinetin-treated NEC plus 88 kg ha^{-1} N.

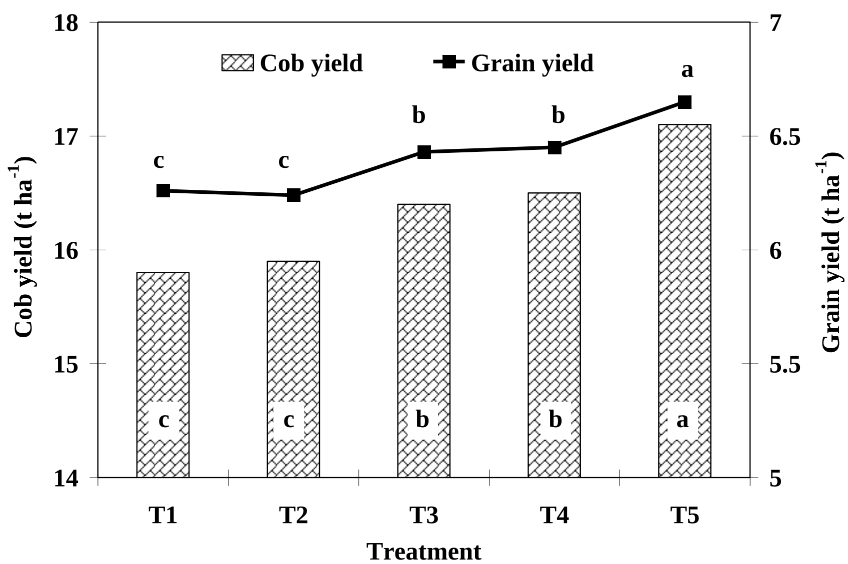
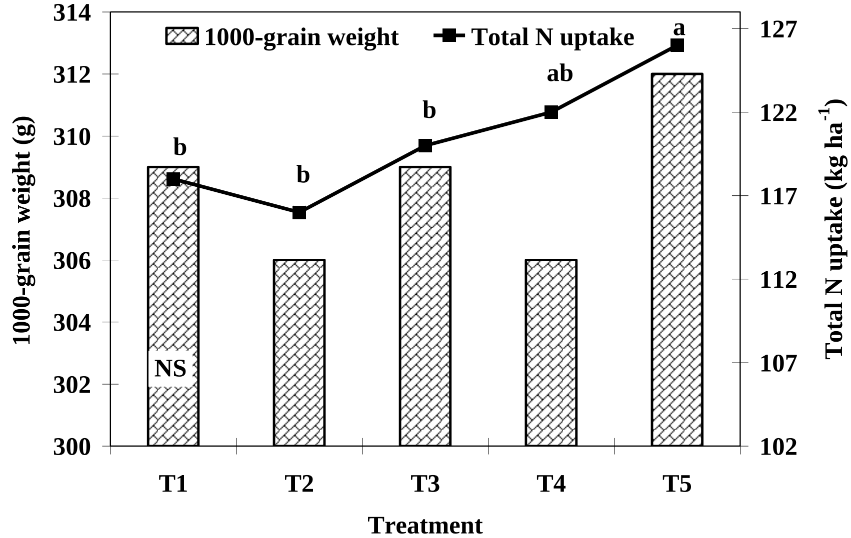


Fig. 2. Effect of compost enriched with different BAS and supplemented with chemical fertilizers on cob and grain yield of maize.
T1, Urea fertilizer 175 kg ha^{-1} N; T2, NEC plus 88 kg ha^{-1} N; T3, IAA-treated NEC plus 88 kg ha^{-1} N; T4, GA_3- treated NEC plus 88 kg ha^{-1} N; T5, Kinetin-treated NEC plus 88 kg ha^{-1} N.



NS: Non-significant

Fig. 3. Effect of compost enriched with different BAS and supplemented with chemical fertilizers on 1000-grain weight and total N uptake of maize.
T1, Urea fertilizer 175 kg ha^{-1} N; T2, NEC plus 88 kg ha^{-1} N; T3, IAA-treated NEC plus 88 kg ha^{-1} N; T4, GA_3- treated NEC plus 88 kg ha^{-1} N; T5, Kinetin-treated NEC plus 88 kg ha^{-1} N.

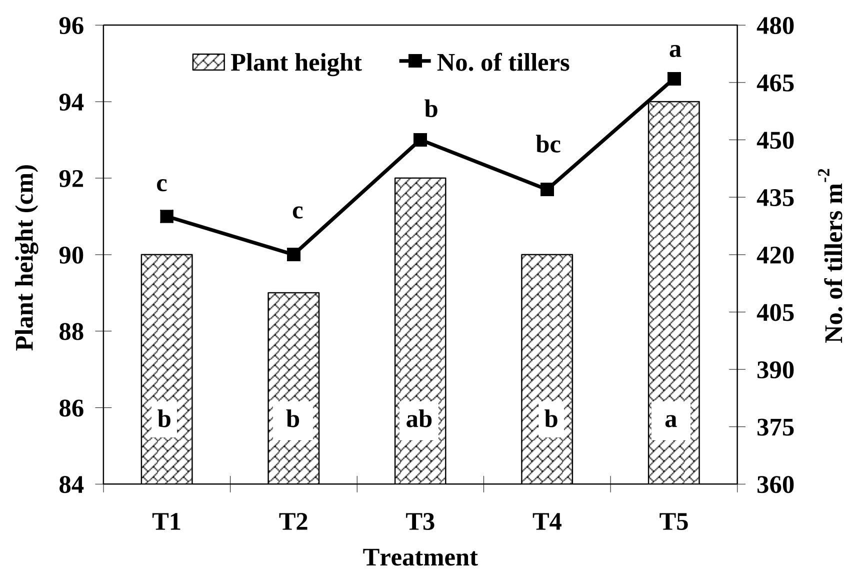


Fig. 4. Effect of compost enriched with different BAS and supplemented with chemical fertilizers on plant height and number of tillers m^{-1} of wheat.
T1, Urea fertilizer 120 kg ha^{-1} N; T2, NEC plus 60 kg ha^{-1} N; T3, IAA-treated NEC plus 60 kg ha^{-1} N; T4, GA_3- treated NEC plus 60 kg ha^{-1} N; T5, Kinetin-treated NEC plus 60 kg ha^{-1} N.

Greater increase (6% over full dose of N) in spike length was produced by NEC treated either with kinetin or IAA along with 60 kg ha^{-1} N that differed significantly with rest of the treatments (Fig. 5). Spike lengths obtained in response to NEC and full dose of N were alike and statistically similar to GA_3 treated NEC.

Likewise, significantly higher (by 5.9%) grain yield resulted in response to kinetin-treated NEC supplemented with 60 kg ha^{-1} N than full dose of N fertilizer (Fig. 5). The grain yield resulted with the application of enriched compost treated either with IAA or GA_3 differed non significantly with each other and with full dose of N fertilizer. The grain yield produced by the integration of NEC and 60 kg ha^{-1} N was statistically at par with the yield produced by full dose of N fertilizer.

Effect of compost treated with different BAS on 1000-grain weight revealed that significantly higher (43.5 g) grain weight was recorded in response to kinetin-treated NEC plus 60 kg ha^{-1} N followed by enriched compost blended with IAA in the presence of same quantity of N (Fig. 6). Non significant (42.2-42.5 g) thousand grain weight was recorded by rest of the treatments.

Like 1000-grain weight, kinetin-treated NEC in conjunction with 60 kg ha^{-1} N resulted in significantly higher N uptake (6.1%) over full dose of N fertilizer (Fig. 6). Statistically similar (88.2-92.3 kg ha^{-1}) N uptakes were observed by rest of the treatments.

Discussion

This study was conducted to asses the effect of NEC treated with different BAS in the presence of chemical N fertilizer on growth and yield of maize and wheat. Results revealed that compost enriched/mixed with 25% of full dose of maize and wheat plus 50% of full dose of N fertilizer of respective crops, applied @ 300 kg ha^{-1} was comparable to full dose of N fertilizer in improving growth and yield of maize and wheat. Addition of the IAA or GA_3 to NEC showed no significant improvement in the growth and yield of both crop in the presence of their half N fertilizer dose when compared with their full dose of N fertilizer. However, enrichment of the compost with kinetin showed more promising results in the presence of half N fertilizer dose and significantly increased growth and yield of both crops under field conditions compared with full dose of N fertilizer. This work indicates that BAS can have an ecological effect in modifying plant growth and development. The mechanism of action of BAS on plant growth may be attributed to direct uptake of these compounds by plant roots, a change in the rhizosphere microflora discouraging root pathogens or by microbial conversion into metabolites resulting in a beneficial rhizosphere for plant growth as reported by other workers (Sarwar & Frankenberger, 1994; Khan *et al*., 2002; Zahir *et al*., 2001, 2007a).

Increases in growth and yield of maize and wheat in our study could also be attributed to enhanced N use efficiency and physiological response of crops to added BAS in the presence of organic fertilizer (Table 1). This premise is supported by the fact that the total N uptake in maize and wheat (Figs. 3 & 6) were increased significantly in response to combined application of enriched compost and N fertilizer. Previous studies have also shown that the composted organic materials enhance N fertilizer use efficiency by releasing it slowly and thus reducing its losses (Paul & Clark, 1996; Muneshwar *et al*., 2001; Nevens & Reheul, 2003). In our earlier reports BAS-added NEC was also found more effective than untreated NEC for wheat, maize and radish (Asghar *et al*., 2006; Zahir *et al*., 2007b; Ahmad *et al*., 2007b). Overall, there was ~ 25% saving of N-economy with the application of 300 kg ha^{-1} organic fertilizer/enriched compost. Researchers have reported ~20% N saving due to the application of compost (Bajpai *et al*., 2002; Pooran *et al*., 2002); however, they applied compost in tons ha^{-1}.

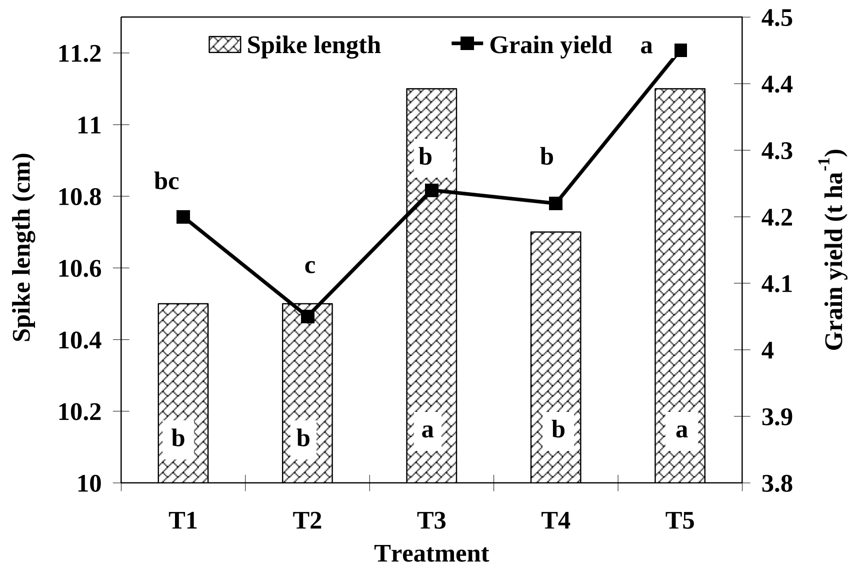


Fig. 5. Effect of compost enriched with different BAS and supplemented with chemical fertilizers on spike length and grain yield of wheat.
T1, Urea fertilizer 120 kg ha^{-1} N; T2, NEC plus 60 kg ha^{-1} N; T3, IAA-treated NEC plus 60 kg ha^{-1} N; T4, GA_3- treated NEC plus 60 kg ha^{-1} N; T5, Kinetin-treated NEC plus 60 kg ha^{-1} N.

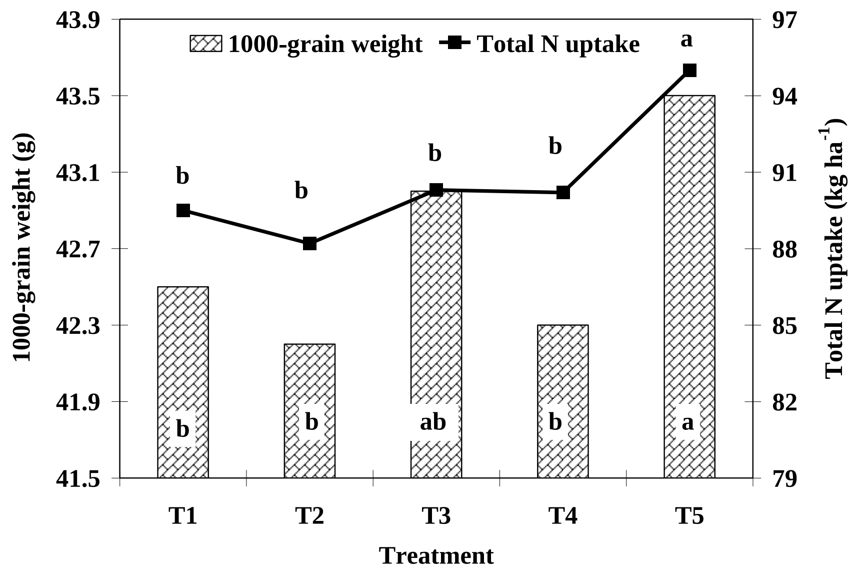


Fig. 6. Effect of compost enriched with different BAS and supplemented with chemical fertilizers on 1000-grain weight and total N uptake of wheat.
T1, Urea fertilizer 120 kg ha^{-1} N; T2, NEC plus 60 kg ha^{-1} N; T3, IAA-treated NEC plus 60 kg ha^{-1} N; T4, GA_3- treated NEC plus 60 kg ha^{-1} N; T5, Kinetin-treated NEC plus 60 kg ha^{-1} N.

The novelty of our approach is that the enriched compost was applied just @ 300 kg ha^{-1}. Previously, researchers investigated the effect of compost/raw organic material by applying it in several tons ha^{-1} (Nevens & Reheul, 2003; Wolkowski, 2003). 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.

Further research is needed to unlock several horizons like physiochemical transformation of BAS in the soil, screening efficient and inexpensive precursors of BAS and agronomic practices which could enhance the stability and bioavailability of BAS in plant root zone. Judicious use of biologically active substances (BAS) could be very helpful for the prosperity of agriculture industry.

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