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QUALITY ASSESSMENT OF ORGANIC AND BIOFERTILIZERS DEVELOPED FROM FRUIT AND VEGETABLE WASTE

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ABSTRACT

Organic wastes play havoc with the environmental health. However, organic and bio-fertilizers can be developed from composted organic wastes for benign environments and low-nutrient input sustainable agriculture. In this study, we utilized fruit and vegetable waste material to develop organic potassium (K) fertilizer and ACC- deaminase rhizobacterial biofertilizers for sustainable maize production. Organic K fertilizer, with L-tryptophan blending, was developed through mechanical composting. This organic material was also used as a carrier to develop two different biofertilizer products by involving selected biotypes of *Pseudomonas fluorescens*. In a series of short laboratory experiments, we assessed the quality of these newly developed fertilizer products against raw form of organic waste. Composting of organic waste material decreased soil carbon to nutrient ratios and increased the macro and micronutrient contents of soil. A continuous gradual release of CO_2 was noted in soil amended with organic and biofertilizers which exhibited greater stability of these fertilizer products over raw form of organic waste. Likewise, soil aggregate stability of these fertilizer products was also higher than raw form of organic waste. Moreover, soil retained comparatively higher moisture when amended with organic and biofertilizer products as compared to raw form of organic waste. These results suggest that organic wastes should not be used in their raw forms and must be transformed into value-added organic and biofertilizers for improving soil health.

Keywords: Biofertilizer, composting, organic fertilizer, organic waste, potassium, rhizobacteria.

INTRODUCTION

Organic sources of nutrients are known to play a vital role in improving soil health due to their versatile benefits on soil properties. Moreover, these sources are also considered rich in plant nutrients. However, in most cases these organic wastes are not properly utilized as nutrient sources in Pakistan agriculture and are either burnt, or remain unutilized (Zia-ul-hassan and Arshad, 2011). This

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results in a great loss to the environments and useful nutrient pool. Pakistan faces volumes of municipal, industrial and fruit/vegetable wastes. The application of these organic wastes to supplement plant nutrition in large amounts has its own issues. Nonetheless, the recent literature suggests that these materials can be composted and effectively utilized as a supplement to chemical fertilizers (Channa *et al*., 2013; Mastoi *et al*., 2013). Composting can be defined as the process of biological decomposition of organic substrates under controlled conditions. The finally produced organic material can be utilized as organic fertilizers and as a carrier for biofertilizers (Zia-ul-hassan and Arshad, 2011).

Organic fertilizers are developed from the composted waste materials to supply essential nutrients to plants. This technology has been emerged as a very useful practice of low-cost plant nutrition (Arshad *et al*., 2007a). Such specially developed fertilizer products are very well known for their being low-cost and environment friendly (Zia-ul-hassan and Arshad, 2011). Value addition of compost through enrichment with chemical fertilizers could lead its application at substantially lower rates and improve nutrient use efficiency by crops (Kubar *et al*., 2013). Further benefits of these composts could be claimed by their blending with biologically active substances (Zia-ul-hassan and Arshad, 2011; Kubar *et al*., 2013). The inoculation of these nutrient-enriched composts with plant growth promoting rhizobacteria further enhances their efficacy and prove very beneficial in terms of improved plant growth, crop yield, nutrient use efficiency (Arshad *et al*., 2007a; Arshad *et al*., 2007b; Zia-ul-hassan and Arshad, 2011).

Hence, the development of nutrient-enriched organic fertilizers from organic waste materials not only reduces environmental pollution but also lowers the input cost of crop production. In addition, application of microbial inoculated nutrient-enriched organic fertilizers can make microbial activities more efficient and active in the rhizosphere of a plant throughout the life cycle (Pooran *et al*., 2002; Cheuk *et al*., 2003; Arshad *et al*., 2007). The rhizobacteria which enhance plant growth under a variety of biotic and abiotic stresses due to their ACC-deaminase activity reduce stress ethylenelevels in plant rhizosphere (Arshad *et al*., 2007; Saleem *et al*., 2007) and hence these can be useful microbial agents for the development of biofertilizers. This study was planned to assess the quality of organic and biological fertilizers developed from fruit and vegetable wastes.

MATERIALS AND METHODS

Development of organic potassium fertilizer from fruit and vegetable waste

Fruit and vegetable organic waste material was collected from concerned markets and shops. This organic waste material was processed for composting using a specially manufactured mechanical composting unit, available at University of Agricutlure, Faisalabad, Pakistan. The composting unit was composed of a grinding unit/crusher, a drying cabin, a fermenter, and a granulator (Compost-Tech, Faisalabad, Pakistan). The composting procedure followed the protocols outlined by Arshad *et al*. (2007a) and followed by Zia-ul-hassan and Arshad (2011). The collected organic waste material was air-dried for 2-days. It was properly sorted-out and all under composable materials were removed (plastic bags, glass material and stones). The material was then ground and the excessive moisture was removed. The material was then placed in a gas-operated oven and dried at 70°C for 2-days. The dried material was then properly crushed to finer particles of <2 mm size in order to increasing the surface area. This fine material was fermented in the composter, i.e. a 0.5 ton vessel to develop a well-rotten compost product. About 40% moisture was maintained during the composting process (40 L water/100 kg organic material). In the fermenter, an oxygen inlet was available to provide aeration for the process of decomposition). The composting process prolonged for 5-days under pre-adjusted aerationlevel (shaking speed was kept 50-rev min^{-1}). The temperature was adjusted between 30-70°C during second and third day of composting. After a perid of 4-days, the temperature was gradually decreased to 30°C (Arshad *et al*., 2007a). During the process of composting, the organic material was enriched with the required amount of the inorganic K fertilizer to develop it into organic K fertilizer.

Value addition of organic fertilizer with plant growth regulator

The auxin precursor L-tryptophan (LTRP) solution of was sprayed onto the organic fertilizer @10-mg LTRP per kg of compost. This value-added material was left for over night drying and then applied to soil. The physico-chemical characteristics of raw and composted organic waste materials were determined in the laboratory following standard procedures. Macro and micro nutrients were analyzed by following the procedures described by Ryan *et al*. (2001). The ratio of carbon to nitrogen, phosphorus and potassium was determined.

Preparation of bio-fertilizers

The bio-fertilizers were formulated by inoculating organic fertilizer (K-enriched compost) with two efficient strains of *Pseudomonas fluorescens* exhibiting maximum growth enhancing activity in field. The inoculum was prepared as we described earlier (Zia-ul-hassan *et al*., 2011). "Selected PGPR *Pseudomonas fluorescens* carrying ACC-deaminase activity were grown in 500-ml flasks containing DF minimal salt medium. The flasks were incubated at 30ºC for 2-days (100 rev min^{-1} shaking). The suspension of selected rhizobacterium [10^8cfuml^{-1}] were mixed with the K-enriched compost (10 ml kg^{-1} compost) and kept for overnight drying at room temperature, before soil application".

Evaluation of the effect of raw organic waste, organic K fertilizers and bio-fertilizer on some important soil quality parameters

Determination of water loss under controlled laboratory conditions

The rate of moisture loss from different types of soils, i.e.with raw organic waste, organic-K fertilizer or bio-fertilizer was evaluated in laboratory as prescribed earlier (Arshad *et al*., 2007a; Zia-ul-hassan and Arshad, 2011). "The beakers were filled with 200 gsieved soil with various amendments, according to treatments. A control was maintained by using the soil without any amendment to compare the effects of various treatments. All the experimental units were given equal amount of water. The beakers were kept open and incubated at 30°C for a period of 10-days and moisture loss was determined at regular intervals".

Determination of mineralization rate of raw and composted organic material

The mineralization rate of two different types of organic materials, i.e. raw and composted organic materials (organic K fertilizer and bio-fertilizer) were determined as suggested earlier (Arshad *et al.,* 2007a; Zia-ul-hassan and Arshad, 2011). "The raw organic waste, raw organic waste + potassium sulphate (equivalent to K present in the organic-/bio-fertilizer), organic K fertilizer and bio-fertilizers were added (1% of the soil weight) to vials containing 50 g non-sterilized soil. Moisture level (15%, v/w) was maintained in the vials with CO_2 free water. The vials were put in glass jars (500 ml capacity) containing 2.5 N NaOH to trap the CO_2 evolved. The jars were closed with air-tight seals and incubated in triplicate at 30 °C for 21 d. A control treatment (soil without addition of any organic material) and a blank treatment (glass jar without vial) were also included in the study. The CO_2 trapped in NaOH was measured by titrating it with 1.0 N HCl against phenolphthalein indicator after precipitation with 1.0 N $BaCl_2$".

Soil aggregate stability

Soil aggregate stability was determined as prescribed by Arshad *et al.* (2007a) and Zia-ul-hassan and Arshad (2011) utilizing a nested-sieve system of 1.0-mm size, following wet-sieving method. Accordingly, "the soils treated either with raw organic waste, organic K fertilizer or bio-fertilizer was incubated for 60 d at 30°C, and wet sieved in degassed distilled water for 5 min. There was also an untreated control soil. All the field moist soils were passed through a sieve (wet sieved in the moist condition, 180 to 250 g water kg^{-1} soil). The soil material not passed through the sieve openings was weighed and reported as the percent stable aggregate fraction".

Data processing

The data were processed by means of line or bar graphs and the treatment means were separated through standard errors using MS-Excel software (Microsoft ®, 2010).

RESULTS

The chemical composition of organic fruits and vegetables wastes was determined before and after composting through laboratory analysis and the ratios of various nutrients to carbon were calculated. The C:N ratio of the raw organic waste material was 27.6 which decreased to 13.9 after 5days of composting process under conducive composting conditions. Likewise, the C:P and C:K ratios of the raw organic waste material were 78.2 and 27.0 which were reduced to 34.6 and 10.8 after composting (Fig. 1A).

The composting increased nutrient content of raw organic waste material. The macronutrient NPK content of raw organic waste materials was 11.8, 4.2 and 12 g kg^{-1}, respectively. The composting of organic waste material increased their N, P and K contents to 15.3, 6.2 and 19.5 g kg^{-1}, respectively (Fig. 1B). Likewise, copper, zinc, manganese and iron content of raw organic waste material, i.e. 1.1, 39.5, 38.7 and 485.0 mg kg^{-1}, respectively, were also elevated to 14.0, 49.8, 54.0 and 630.0 mg kg^{-1}, respectively after the composting process (Fig. 2A).

Laboratory study to determine the rate of mineralization of organic wastes materials, i.e. raw and composted elucidated that the CO_2 released from the unamended soil ranged between 20.8 to 30.5 mg kg^{-1} day^{-1} (Fig. 2B). For soil amended with raw organic waste (un-decomposed) material, the CO_2 release ranged from 32.0 to 109.5 mg kg^{-1} day^{-1}, while the maximum CO_2 release was noted on day-14 of incubation which rapidly decreased afterwards. The integration of chemical K fertilizer as potassium sulphate with raw organic waste material augmented the mineralization process of organic waste material and the highest CO_2 release was observed on day 4 of the incubation process. When raw organic waste material was integrated either with K-enriched organic fertilizer or with ACC-deaminase rhizobacterial strains (ACC_1 & ACC_2) enriched organic fertilizer a continuous gradual release of CO_2 (ranging from 24.5 to 59.0 mg kg^{-1} day^{-1}) was noted which exhibited greater stability of composted organic waste material (specially developed organic fertilizer) over the raw form of organic waste (Fig. 2B).

The results of 60 days laboratory soil incubation study to compare soil aggregation in raw organic waste material v/s organic and biofertilizers developed from fruit and vegetable organic waste materials are highlighted in Fig. 3A. The aggregate stability of unamended soil was 21.5%. The addition of raw organic waste material to the soil increased its aggregate stability to 26.8% (25% more). Further increase in soil aggregate stability, i.e. 32.7% (52% more as compared to unamended soil) and 36.6% (70% more against unamended soil) was noted where the soil was amended with organic-K fertilizer and biofertilizers (effect of ACC_1 or ACC_2 was alike and pooled), respectively. The organic and biofertilizer addition to soil enhanced its stable aggregate up to 22 and 36% against the addition of raw form of the organic waste material.

The water loss from soil treated by raw-organic waste material, organic-K fertilizer and biofertilizer (each added @ 300 kg ha^{-1}) as compared to soil which received no amendment was determined in lab. The results of laboratory study are presented in Fig. 3B. Maximum water loss (68.6%) after 10 days incubation was noted in case of unamended soil. It was followed by the water loss (63.5%) noted for soil treated by raw-orgainc waste. The minimum water loss was observed in case of soil treated by organic-K fertilizer or with biofertilizer containing rhizobacterial strains (effect of ACC_1 and ACC_2 was almost similar and hence pooled). Average water loss during a period of 10 days was highest in case of unamended soil (50%), followed by soil treated with raw-organic waste (45%) and by organic-K fertilizer (40%) or biofertilizer (39%). The later two treatments, thus, resisted water loss from the soil more as compared to former two treatments.

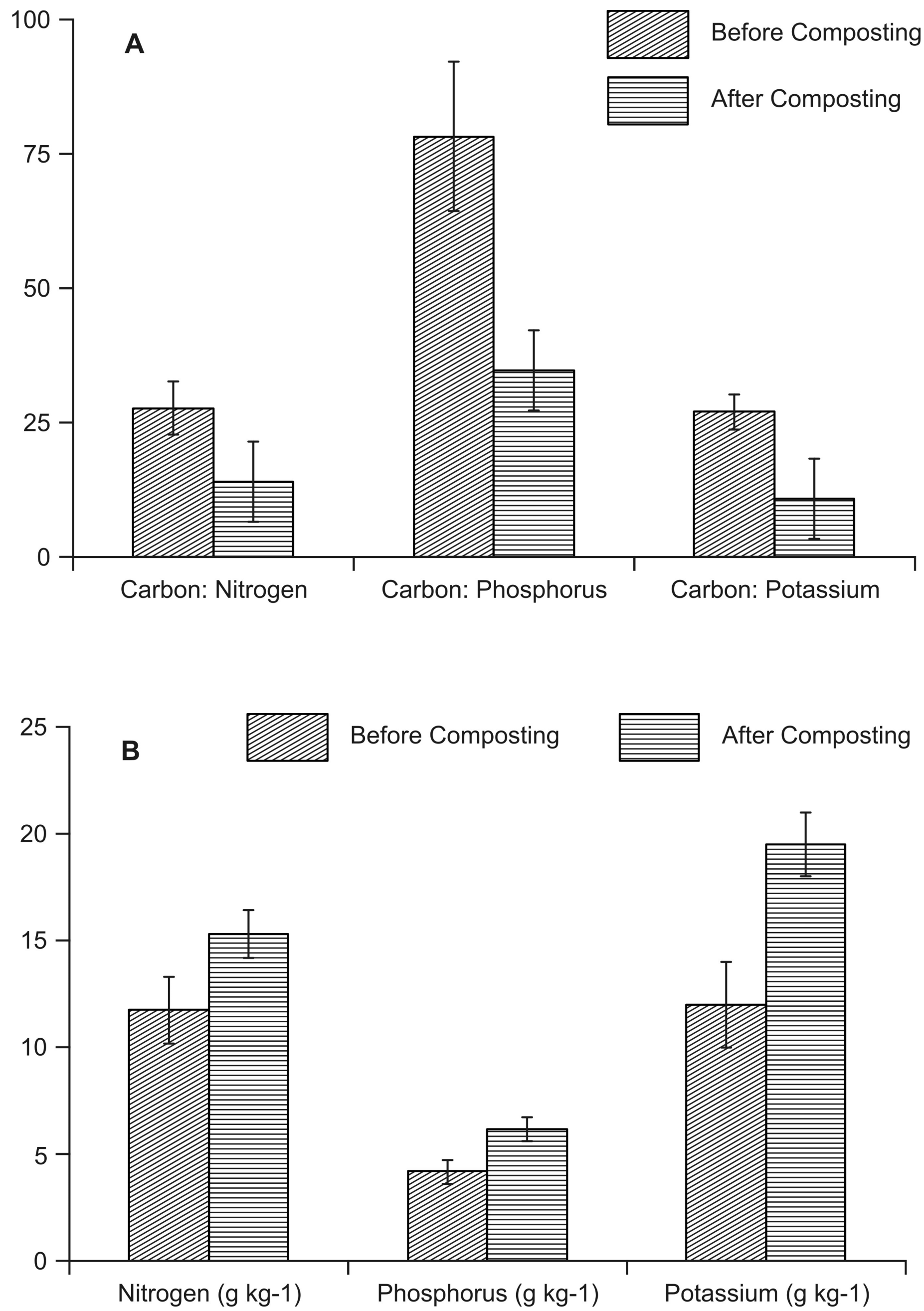

Figure 1. (A) Carbon to nutrient ratios of raw organic waste material before and after composting process (B) Macronutrient content of raw organic fertilizer material before and after composting process.

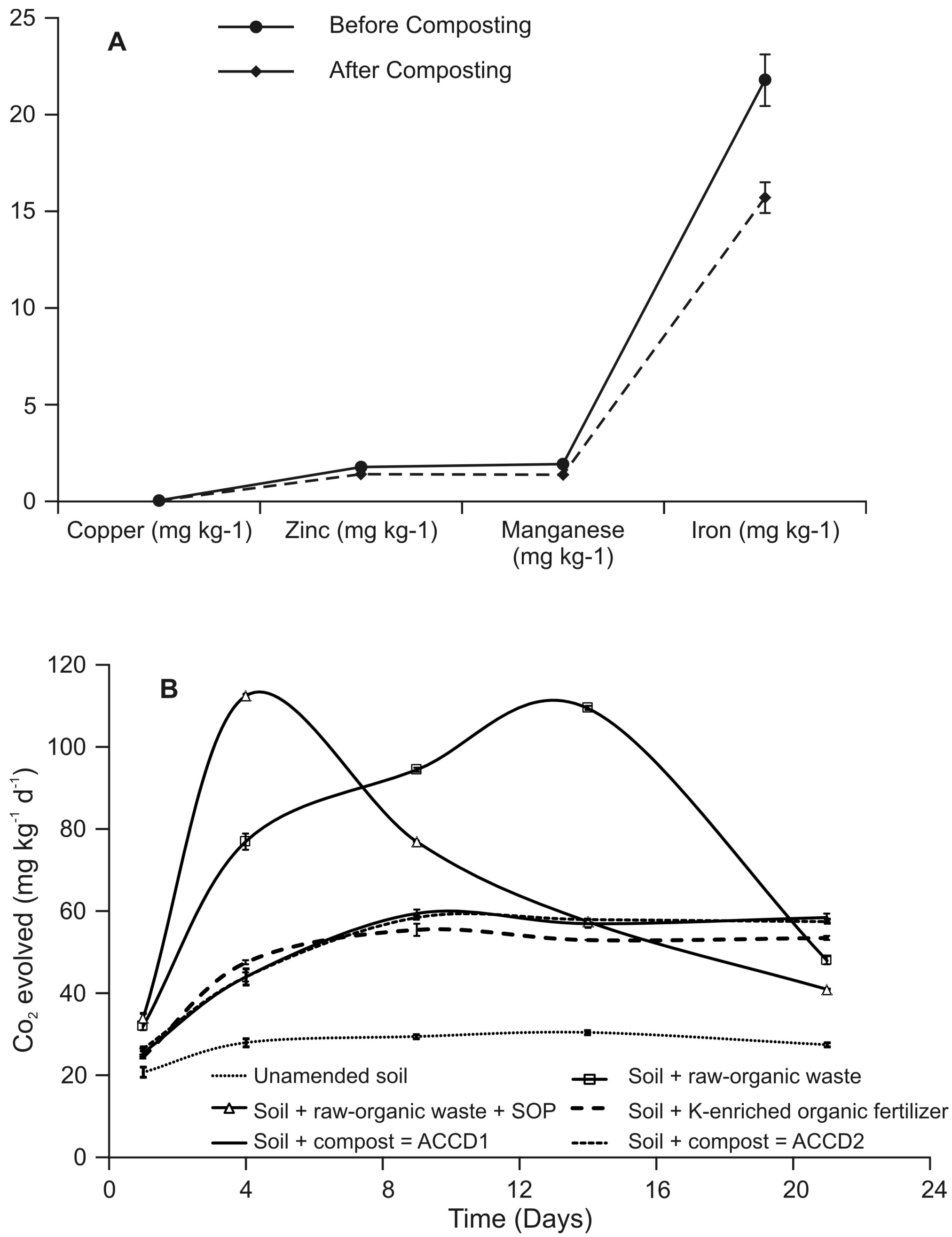

Figure 2. (A) Micronutrient content of raw organic waste material before and after composting process (B) Mineralization rates of raw organic waste with or without organic and biological amendments.

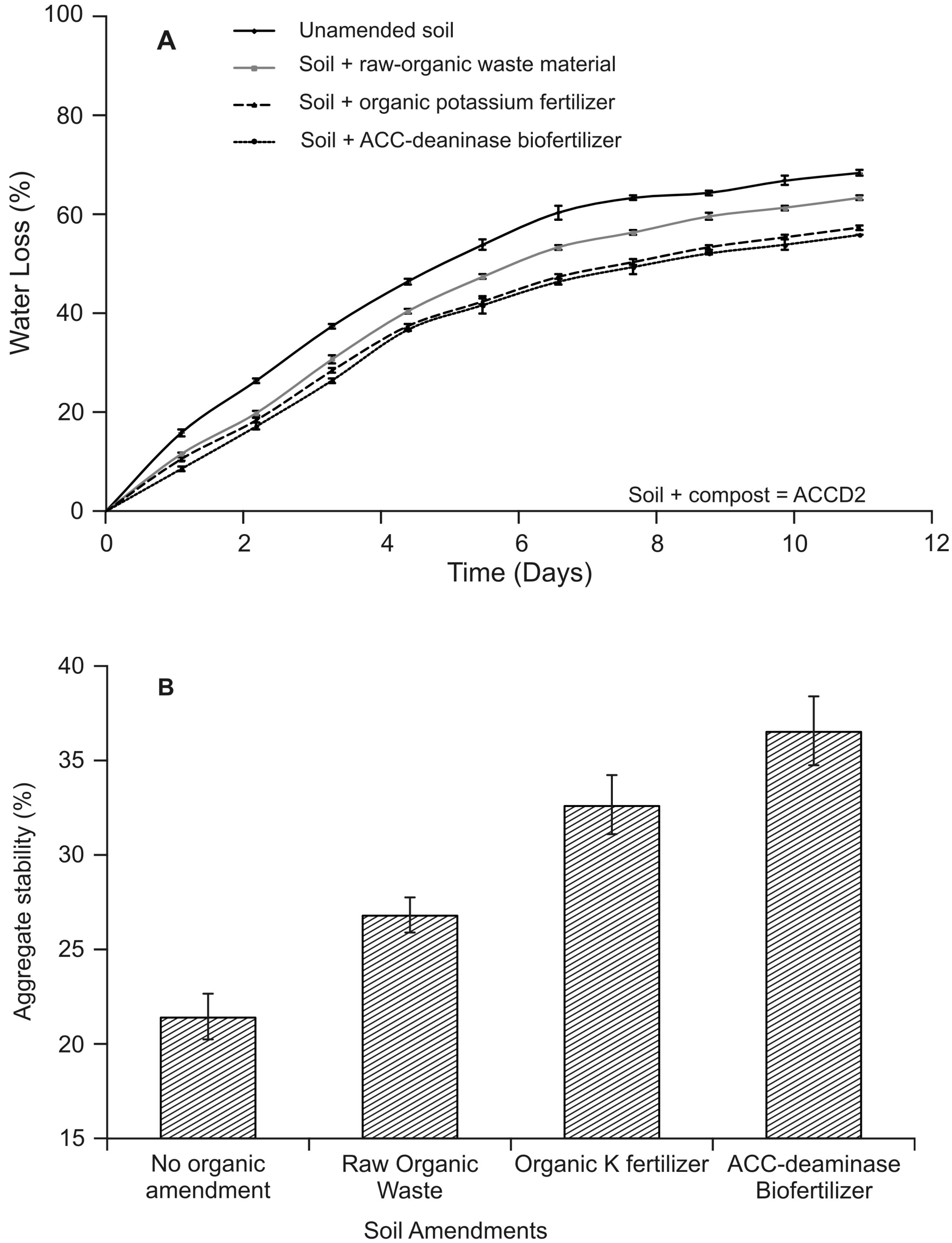

Figure 3. (A) Aggregate stability and (B) water loss of soil amended with raw organic waste material, organic K fertilizer or biofertilizers against unamended soil.

DISCUSSION

The results of laboratory studies to evaluate the effect of raw and composted organic waste materials, either alone or with ACC-deaminase rhizobacterial biofertilizers, generated very encouraging results with regard to improved soil quality parameters. Composted organic materials not only improved carbon to nutrient ratios of soil (Fig. 1A), but also increased the nutrient content of the soil (Fig. 1B and 2A). Moreover, composted organic waste also improved soil mineralization rate (Fig. 2B), aggregate stability (Fig. 3A) and decreased rate of water loss from soil (Fig. 3B). These findings are in-line with the previous research findings highlighting the benefits of composted organic wastes over their raw form (Arshad *et al.,* 2007a; Zia-ul-hassan and Arshad, 2011). In these studies, it was also found that the composted organic wastes are more beneficial in improving soil quality parameters as against raw organic wastes and their enrichment with nutrients or with special purpose rhizobacteria. Earlier too, the beneficial effects of organic K fertilizer have been reported because of their lower carbon to NPK ratios and more nutrient content than the raw organic materials in various crop species, such as brassica (Asghar *et al.,* 2002), radish (Asghar, 2006), tomato (Tahir *et al*., 2006), cotton (Zia-ul-hassan and Arshad, 2011), wheat (Zia-ul-hassan *et al*., 2011), maize (Channa *et al*., 2013; Kubar *et al.,* 2013; Mastoi *et al*., 2013). The impact of these K-enriched composts on soil conditioning has also been studied under controlled laboratory conditions (Ahmad *et al*., 2008; Zia-ul-hassan and Arshad, 2011). The water losses determined from soil treated by organic/bio-fertilizer were substantially less than the soil treated by raw-organic waste or untreated-soil. Average CO_2 evolved from soils treated by organic/bio-fertilizer exhibited more stability over a certain time period as against various other treatments involved in the laboratory study. Organic/bio-fertilizer treated soils registered maximustable soil aggregates (Ahmad *et al*., 2008). The beneficial effects of such especially developed fertilizer products not only enhance plant growth but also increase crop yield, as has reported in many earlier studies (Zia-ul-hassan *et al*., 2011; Channa *et al*., 2013; Kubar *et al*., 2013; Mastoi *et al*., 2013). These results endorse the benefits of specially developed fertilizer products blended with plant growth regulators, such as auxin pre-cursor L-tryptophan (Arshad *et al*., 2007a; Channa *et al*., 2013; Kubar *et al*., 2013; Mastoi *et al*., 2013) and stress-resistant ACC-deaminase rhizobacterial strains (Arshad *et al*., 2007b) for sustainable crop production under various types of environmental stresses.

CONCLUSION

The composting and value-addition of raw organic waste materials through nutrient-enrichement, blending with biologically active substances and Rhizobacterial inoculation improves their quality and exerts beneficial effects on soil health.

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