Research Article

Efficient Utilization of Organic Wastes Effluent for Nitrogen Mineralization and Plant Growth Promotion in Mono-Cropping Soil of China

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Abstract | Mono-cropping agricultural activities and overuses of chemical-based fertilizers result in the deterioration of soil health and considerable economic loss. However, previous studies suggested that organic fertilizers can sustain soil health through improved soil microbial activities. Nevertheless, the effect of poultry compost and poultry fresh manure on P (Phosphatase) and C (β-glycosidase) related enzymes activities, nitrogen mineralization, and fungal biomass in the mono-cropping soil are poorly understood. Though, the efforts were made to reveal how changes in the soil nitrogen mineralization, enzyme activities and fungal biomass influence plant growth. An incubation and pot experiments were carried out to investigate the effect of organic wastes [Poultry compost (PC), Poultry fresh manure (PFM), Chemical fertilizer (CF), and only soil (S)] was used at the quantity of 200 mg N kg^{-1}. We observed that soil amended with PC have produced more phosphatase and β-glycosidase enzyme activities and nitrogen mineralization (36.96 mg kg^{-1}), indicating that it could be contributing to plant growth promotion. The fungal biomass increased after applying poultry compost, it also might be contributing to plant growth promotion. Therefore, poultry compost was a more suitable waste for mono-cropping soil systems than poultry fresh manure in soil enzyme activities, nitrogen mineralization, and fungal biomass. In conclusion, functional organic waste as an additive to conventional fertilization could save chemical fertilizer's contribution and minimize soil deterioration by overuse of chemical fertilizers.

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Keywords | Mono-cropping soil, Poultry compost, Poultry fresh manure, Nitrogen mineralization, Soil enzymes activities

Introduction

Mono-cropping agricultural activities and overuses of chemical-based fertilizers result in the deterioration of soil health and considerable economic loss (Asghar and Kataoka, 2021a). The continuous uses of chemical fertilizers and mono-cropping affecting the soil microbial community and their functions, and ultimately effect on soil nutrient status (Xiong *et al*., 2016). It has been reported that continuous mono-cropping alter the microbial community structure and reduces soil microbial diversity, increasing disease attack, and ultimately affecting the soil health and plant growth (Mo *et al*., 2016; Xiong *et al*., 2016). Poor soil quality is a typical negative effect on plant-soil systems and commonly appears in continuously mono-cropping and due to over use of chemical-based fertilizers (Bozarth *et al*., 2009; Cvačka *et al*., 2012). Therefore, utilization of all available resources with low-input and sustainable ways preserves soil quality in mono-cropping soils.

To increase crop yield on sustainable basis through organic waste and their by-products (Diacono and Montemurro, 2011). In mono-cropping systems, by low inputs of chemical-based fertilizers with a combination of organic waste can meet the crop's nutritional demand. These organic amendments can be collected from industries, agricultural waste and municipal solid waste (Quilty and Cattle, 2011). Furthermore, applications of organic-based amendments are common practices in agricultural systems. These organic-based amendments can enhance long-term soil quality by providing organic matter and plant growth by providing nutrients, and ultimately reducing farmers costs (Mohanty *et al*., 2011b). While Tejada *et al*. (2009) reported that organic-based amendments reclaim and restore the soils health by sustaining soil fertility and providing organic matter for a long time by slow releasing nutrients.

Nitrogen mineralization and releasing of enzymes are biological processes, and usually, it has handled by soil microorganisms. The amount of nitrogen (N) mineralization and release of enzymes depends on the soil microorganisms and biochemical composition of organic matter (Manojlovic *et al*., 2010; Mohanty *et al*., 2011a). Therefore, using organic-based amendments can manage soil fertility and soil microbial activity could improve mono-cropping soil and its quality. Earlier studies already documented that the importance of N mineralization from organic-based amendments in agro-ecosystems (Van Kessel and Reeves, 2002; Kaleem Abbasi *et al*., 2007; Azeez and Van Averbeke, 2010). However, there is no solid evidence against mono-cropping systems, especially releasing of soil enzymes directly or indirectly that responsible for soil nutrients and plant growth promotion. However, little attention has been paid in utilizing organic waste under mono-cropping system for mineral nitrogen availability and the acceleration of soil enzymes and fungal biomass. To date, this study aimed to evaluate the utilization of organic waste in mono-cropping soil and its effects on nitrogen mineralization, accelerating enzymes activities. Furthermore, the effect of organic waste on plant growth promotion and soil fungal biomass was also investigated because rhizosphere fungi are considered the primary decomposers and leads to plant growth promotion.

Materials and Methods

Soil collection and its chemical properties

The mono-cropping soil was collected from the upper layer (0-15 cm) from the Shandong Peanut Research Centre and then carefully transported to the Agriculture University of Beijing (39°54′N 116°24′) Beijing, China. Shandong site has annual average rainfall of 450-900mm, and average temperature of 11-14.5 ºC. Furthermore, the soil was passed via a 2-mm sieve, to remove the solid material, surface litter, and roots, and then kept at room temperature (25 ºC) for further use. The mono-cropping soil pH and EC were 5.58 and 72.09 µs/cm, respectively. However, soil containing organic matter, available N, P, and K were 18.20 g kg^{-1}, 28.1 mg kg^{-1}, 59.60 mg kg^{-1}, and 89.70 mg kg^{-1}, respectively.

Manure collection and its chemical properties analysis

We used two different kinds of organic waste amendments for 60 days laboratory incubation and pots experiment. Organic wastes such as poultry compost and poultry fresh manure were obtained from the Agriculture University of Beijing, Beijing, China for only research purpose. The poultry compost (PC) contained total C, N, P, K (%) were 39.69, 2.87, 3.11, 2.32, whereas poultry fresh manure (PFM) 35.21, 3.42, 2.89, 4.41, respectively. In comparison, C/N % were (10.09) and (14.21) in PC and PFM, respectively. Furthermore, TN and TC were analyzed by CNHS EURO elemental analyzer (Milan, Italy), and TP and TK were analyzed by (Ali *et al*., 2021).

Incubation experiment

The organic wastes were dried at room temperature and crumpled into small pieces with an electric crusher before conducting the incubation experiment. 400 g of air-dried soil was filled into Polyethylene plastic pots. Four scientific treatments were set as followed: poultry compost (PC), poultry fresh manure (PFM), chemical fertilizers, (ammonium sulfate) (CF) and control (S). Organic wastes and chemical fertilizer was used at the quantity of 200 mg N kg^{-1}, which stated the % of nitrogen for both organic amendments already described in those as mentioned above. The experiment was conducted for 60 days in a completely randomized design with three replications. After that, soil moisture content was maintained at 60% water holding capacity with deionized water and monitored once in a week. Pots were covered by aluminum foil and placed into the incubation chamber at 25 ℃. Samplings were done at 0, 10, 20, 30, 40, 50 and the last day of incubation at 60. Samples were carefully collected at each sampling date, and parameters were recorded, including soil enzymes activities (phosphatase and *β* - glycosidase) and soil inorganic nitrogen.

Pot experiment

To analyze the effect of the treatments mentioned above on the plant growth in the mono-cropping soil. A pot experiment was carried out under control environment conditions (25 ºC). A total of 400 g of soil was filled into the pots, and moisture was maintained at 60% water holding capacity with distilled water (DW). The pots were covered with aluminum foil for one week to stabilize the microbial activity. After one week, *Brassica rapa.* var plants were grown with three replications for five weeks and then harvested. Above and below parts of the plants were used to measure the effect of the treatments on plant growth enhancement, and inorganic nitrogen (NH_4^+-N and NO_3^--N), fungal biomass and enzymatic activities were also sought for better justifications.

Fungal abundance (CFUs)

Almost 0.5 g of soil samples were used for the isolation of fungi. Later, 4.5 mL sterilized water was mixed with soil samples and mix through vortexing, and then a series of 10-fold dilutions (10^{-2}, 10^{-3}, and 10^{-4}) were made. After vortexing, 50 μL of the soil suspensions were spread on Martin agar plates (King Jr *et al*., 1979) through a disposable spreader. Then plates were incubated at 24 ºC for seven days.

Measurement of inorganic nitrogen

To measure the inorganic nitrogen, the extracted was taken from collectively 10 g of soil with 50 ml 1 M KCl with shaking for 40 minutes. The extract of soil was filtered via filter paper (MN 616), and then extract was kept at -20 ºC until further analysis. Inorganic nitrogen (NH_4^+-N and NO_3^--N) was measured using flow auto-analyzer (Chemlab System 4, Skalar; The Netherlands).

Measurement of soil enzyme activities

To measure the soil enzyme activities, the P and C related phosphatase and *β*-glycosidase enzymes activities were considered, and 0.5 g of soil sample from each treatment of incubation and pot experiment were used. In brief, 0.5 g soil samples were placed into 15 mL conical tubes, then added 1.5 mL of buffer solution (0.2 M sodium hydrogen phosphate and 0.1 M of citric acid, pH 4.9, for glycosidase and 0.5 M of malic acid and 0.5 M of tris (hydroxymethyl) aminomethane, pH 6.5, for phosphatase), 0.1 mL of toluene, 0.9 mL of distilled water and 0.6 mL of 50 mM p-nitrophenyl-β-glucopyranoside monohydrate or 50 mM p-nitrophenyl phosphate disodium solution and then added into *β*-glycosidase and phosphatase tubes, respectively. After that, enzyme activities were measured according to Asghar and Kataoka (2021a).

Statistically Analysis

One-way ANOVA was applied to determine the significant differences among treatments for each parameter, by Tukey's test at ($P \leq 0.05$) level of significance using Statistix 8.0 (Analytical Software, FL, USA) window version.

Results and Discussion

Incubation experiment

Nitrogen mineralization: The inorganic nitrogen increased after adding organic wastes and chemical fertilizers treatments as compared to untreated pots (control) through the incubation experiment. However, the maximum range was observed from CF treatment 51.99 mg kg^{-1} of soil at the final stage of the incubation experiment, whereas the minimum was observed from CK treatment 3.11 mg kg^{-1} of soil at the initial stage of the incubation experiment. Furthermore, compared to organic waste, maximum inorganic N was observed from PC treatment, and the range was 36.96 mg kg^{-1} of soil at the final stage of the incubation experiment, while 30.45 mg kg^{-1} of

Table 1: *Effect of various treatments on agronomic parameters.*

Treatment	Inorganic N mg kg^{-1}	cfu fungi g of soil (10^4)	SPE ng g^{-1} of soil min^{-1}	SGE ng g^{-1} of soil min^{-1}
PC	1.51±1 ab	29±5 ab	67.31±7.80 a	27.57±2.46 ab
PFM	0.24±0.1 b	19±5 b	44.30±10.92 bc	22.24±0.89 b
CF	5.07±2.0 a	18±4 b	33.28±7.66 c	14.47±0.72 c
CK	-0.67±0.1 b	20±9 b	34.68±1.42 c	12.11±0.42 c

Note: values are shown as means ± SD (n=3). Different letter in the same row indicates significant differences using Tukey's test (P < 0.05). Inorganic N: inorganic nitrogen, cfu fungi: fungal biomass, SPE: soil phosphatase enzymes, SGE: soil glycosidase enzymes.

soil was observed from PFM at the final stage of incubation experiment (Figure 1). Integrated over the incubation period compared to organic waste, PC releases more inorganic nitrogen than PFM, and the highest amount of mineral nitrogen was noted at the final stage of the incubation experiment. The availability of nitrogen is a major problem during plant growth, crop productivity, and development; because this portion is often presented in the soil by adding locally or naturally, which cannot be taken by plants. In this study, the incubation experiment showed that nitrogen mineralization had substantial differences among different organic wastes. Masunga *et al.* (2016) reported that organic wastes with low C/N have a high quality of organic matter and sufficient nitrogen supply to sustain crop growth and soil microbe activity. Interestingly, it was noted that PC contains a lower C/N ratio (10.09) compared with PFM. Therefore, C/N ratio also indicated that nitrogen mineralization was higher with PC treatment and the possible ability to degrade the organic matter and convert it into plant-available nutrients by microbes. Later, pot experiment also revealed that PC contained higher fungal biomass compared to PFM and CF treatments (Table 1). Sani *et al.* (2020) reported that soil microbes such as soil fungi and bacteria enhance nutrient availability in the rhizosphere and uptake as well as assimilation in plants. Furthermore, The increase of fungal biomass, which could be participated in organic matter decomposition and plant nutrient delivery (Asghar and Kataoka, 2022). Asghar and Kataoka (2021b) also reported that inoculation of beneficial fungi enhance the degradation of organic materials, resulting in the release of plant available nutrients. Pot experiment results demonstrated that an increase in fungal biomass may responsible for the nitrogen mineralization with PC treatment. However, the application of organic wastes into the mono-cropping soils cause promising nutrients mineralization, which assists more microbial colonization in the rhizosphere, promotes plant growth, and increases the accessibility of nutrients uptake by plants.

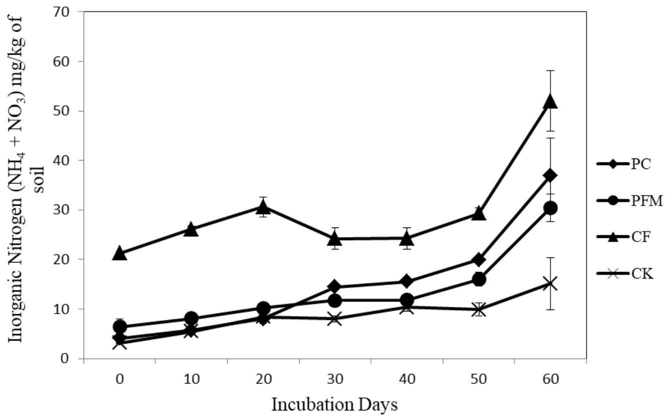

Figure 1: *The nitrogen mineralization from different organic wastes. Poultry compost (PC), poultry fresh manure (PFM), chemical fertilizer (CF), control soil only (CK). The values are means ± standard deviation (n=3).*

Enzymes activities: On the base of soil enzymes importance for soil fertility and quality, soil enzymes activities, including β-glycosidase and phosphatase, were measured during the incubation experiment. Both enzyme activities were lower at the initial stage of the incubation; nevertheless, enzyme activities gradually increase with the incubation period. In terms of β-glycosidase enzyme activity, the highest range was observed from PC treatment 33.10 ng g^{-1} of soil at the final stage of the incubation. However, a second highest range was observed from the PFM treatment of 28.50 ng g^{-1} of soil at the final stage of the incubation. In contrast, β-glycosidase enzyme activity was lower in CF treatment than in organic waste treatments. At the final stage of the incubation period, the highest range of 22.10 ng g^{-1} of soil was observed. β-glycosidase activity was significantly higher in PC treatment than that of PFM and CF treatment (Figure 2).

Regarding phosphatase enzyme activity, the highest range was observed from PC treatment 70.24 ng g^{-1} of soil at the 50 days of the incubation, and the lowest range was observed at the initial stage of the incubation. However, a second highest range was also observed from PC treatment at the final stage of the incubation experiment. In contrast, an almost similar range was also observed from PFM treatment 56.24 ng g^{-1} of soil at the final stage of the incubation. However, phosphatase activity was significantly higher in PC treatment than PFM as compared to CF and CK treatments (Figure 3). In this study, incubation and pot experiment results revealed that the application of organic wastes significantly affects the phosphatase and glycosidase activity compared with CF and control treatment (Table 1), where organic wastes released more enzymes than CF and CK treatments (Figure 2 and 3). In general, the increase of soil enzyme activities and microbiological functions likely influences the application of organic wastes. Through microbiological functions, soil microorganisms degrade organic matter by producing extracellular enzymes after applying the organic-based product and green manure (Tejada *et al*., 2008). In this study, phosphatase and glycosidase enzymes activities were greater in PC treatment when compared with other treatments. The possible mechanism is that C/N ratio of organic wastes. The C/N ratio largely determines the balance between immobilization and mineralization which ultimately reflected in the net nutrient release (Chaves *et al*., 2004). An optimum C/N ratio of the organic waste amendment is ideal for nutrient release into the rhizosphere, where plants uptake nutrients per necessities.

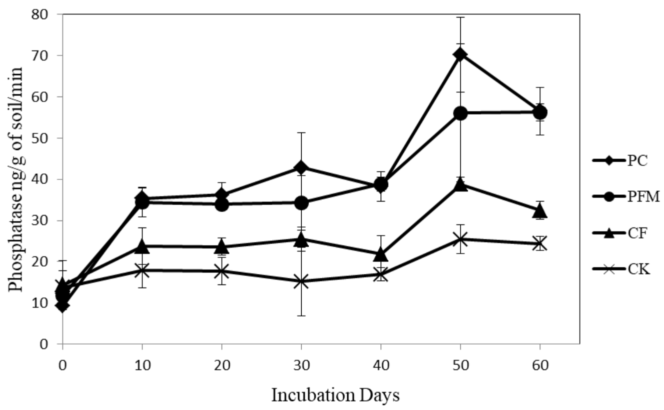

Figure 2: *The dynamics of phosphatase activity in soil with different organic wastes. Poultry compost (PC), poultry fresh manure (PFM), chemical fertilizer (CF), control soil only (CK). The values are means ± standard deviation (n=3).*

Interestingly, it was noted that PC has a lower C/N ratio (10.09) when compared with the PFM C/N ratio (14.21). Thus, compared to PFM, the PC treatment likely increases phosphorus and nitrogen availability in soil and is revealed in greater soil enzyme activities. Besides, Bandick and Dick (1999) reported that soil enzymes could be reflected as soil quality indicators of biological changes and act as catalysts of particular reactions that depend on different factors such as organic amendment and crops types. Therefore, our short data indicated that the application of organic wastes is suitable for accelerating enzyme activities in mono-cropping soil and contributes to improving soil quality and nutrients.

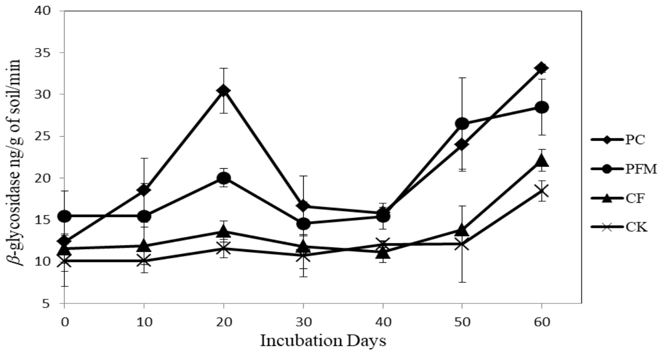

Figure 3: *The dynamics of β-glycosidase activity in soil with different organic wastes. Poultry compost (PC), poultry fresh manure (PFM), chemical fertilizer (CF), control soil only (CK). The values are means ± standard deviation (n=3).*

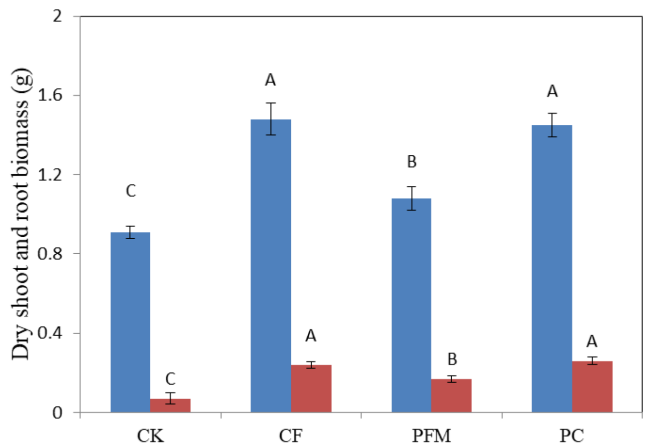

Figure 4: *Pot experiment investigating growth of Brassica rapa. using different organic wastes with mono-cropping soil. Plant biomass was shown as dry weight (a) and fresh weight (b). The blue and red bars shows shoot and root biomass, respectively. The bars show standard deviation among replicates (n=3). Different letters indicates the statistical significance between treatments using Tukey's test (P <0.05).*

Pot experiment

A pot experiment was conducted to better understanding the function and effect of organic waste in mono-cropping soil. Similar treatments were used in the incubation and pot experiment. The dry shoot and root biomass of plants were subjected to assess the effect of different treatments. Regarding to dry shoot weight, the shoot weight was significantly affected by PC and CF (Tukey's P <0.05) treatments compared to PFM and control, respectively. Moreover, similar results were observed from the dry root weight of plants (Figure 4). Postharvest soil showed that no significant differences between PC and CF (Tukey's p <0.05) treatments in terms of inorganic nitrogen, while the lowest range was observed from CK. The fungal biomass was significantly higher with PC treatments as compared to the rest of the treatments (Tukey's P <0.05; Table 1). Moreover, soil enzyme activities were also observed significant by PC treatments compared to PFM, CF, and control (Tukey's P <0.05). Current results revealed that organic waste application alters the postharvest soil nutrients and possible effects on plant growth through the enhancing of soil fungal biomass. Plants grown in PC and CF treatment had greater biomass than control, but there were no significant differences among PC and CF treatment (Tukey's test at P ≤ 0.05). In contrast, PFM treatment had a more splendid shoot and root biomass over control. Based on plant growth promotion, results proposed that N availability, fungal biomass, and enzyme activities influenced plant growth under PC treatment in mono-cropping soil. Notably, postharvest soil showed that fungal biomass and enzyme activities were significant with PC treatment (Table 1), directly or indirectly responsible for plant growth promotion. Input of nutrients such as N and other rich N sources of organic waste might directly affect the plant growth which ultimately affect the crop yield (Hwang *et al*., 2015). Pang *et al*. (2017) also reported that increased nutrient availability could improve plant growth through better root growth, which further assists in microbial colonization of the rhizosphere and increases the accessibility of nutrients for plant uptake. Analysis of soil after plant harvest showed that fungal biomass and enzyme activities significantly increased with the application of PC into soil. To date, the roles of fungal biomass in the application of organic wastes have received more attention; these results suggested that soil fungal biomass degrade the organic matter and release more nutrients in terms of N availability and soil enzymes activities. However, our findings showed that organic waste application results exhibited plant growth promotion, increased fungal biomass, and substantial differences in soil enzyme activities.

Conclusions and Recommendations

Application of poultry compost in mono-cropping soil enhanced biological activities as measured by soil enzymes activities and soil fungal biomass. Although, soil enzymes activities, nitrogen mineralization, and fungal biomass increased after applying poultry compost, its role in determining soil quality and soil health but directly plant growth promotion is still unclear. Results also demonstrated that poultry compost was a suitable medium for the improvement of soil health and quality through the enhancement of soil nutrients and fungal biomass. On the base of incubation experiment findings, long-term field experiments should be conducted to monitor the soil microbial community and enzyme activities for better understand the role of organic wastes in such mono-cropping soil systems. Meanwhile, functional organic wastes as an additive to conventional fertilization could save chemical fertilizer's contribution and minimize soil deterioration due to overuse of chemical fertilizers.

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Novelty Statement

This study for the first time evaluated the utilization of organic waste in mono-cropping soil and its effects on nitrogen mineralization, accelerating enzymes activities, and plant growth promotion.

Author's Contributions

Waleed Asghar and Farhan Iftikhar: Conceptualization.
Farhan Iftikhar and Waleed Ashgar: Wrote original draft, preparation and Methodology.
Ahmad Mahmood, Bushra Ahmad, Rehmat Ullah, Muhammad Bilal and Abdul Latif: Wrote the draft, Reviewed, Edited, and Visualization.
All authors have read and agreed to the published version of the manuscript.

Conflicts of interest
The authors declare no conflict of interest.

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