ISSN Print: 2664-844X
ISSN Online: 2664-8458
IJAFS 2025; 7(1): 145-148
www.agriculturaljournals.com
Received: 18-11-2024
Accepted: 24-12-2024

Ahmed Hassan El-Sayed
Department of Soil Science, Ain Shams University, Cairo, Egypt

Mohamed Ibrahim Abdel-Rahman
Department of Agricultural Chemistry, Assiut University, Assiut, Egypt

Fatma Mahmoud Soliman
Department of Agricultural Chemistry, Assiut University, Assiut, Egypt

Corresponding Author:
Ahmed Hassan El-Sayed
Department of Soil Science, Ain Shams University, Cairo, Egypt

Long-term impact of organic and inorganic fertilizers on soil enzyme activities in cotton fields

Ahmed Hassan El-Sayed, Mohamed Ibrahim Abdel-Rahman and Fatma Mahmoud Soliman

DOI: https://doi.org/10.33545/2664844X.2025.v7.i1b.1419

Abstract
Soil enzymes catalyse every biochemical transformation that converts organic residues into plant-available nutrients, yet their response to decades of contrasting fertiliser regimes in tropical cotton systems has received limited attention. This research evaluated the activity of four key enzymes dehydrogenase, urease, alkaline phosphatase, and β-glucosidase in surface soils (0-20 cm) from a 14-year-old long-term fertiliser experiment on cotton (*Gossypium hirsutum* L.) at Assiut, Egypt. Five treatments were compared: unfertilised control, farmyard manure alone (FYM, 10 t/ha/yr), recommended NPK (120:60:40 kg/ha), integrated FYM + NPK, and vermicompost (5 t/ha/yr). Soil samples collected after the 2023 cotton harvest showed that FYM + NPK plots had the highest dehydrogenase activity (47.8 µg TPF/g soil/day), 68.3% above the control. Alkaline phosphatase and β-glucosidase followed a similar pattern. Pure NPK treatment raised enzyme levels only marginally above the control, confirming that inorganic fertilisers alone do little to stimulate biological activity. Soil organic carbon and microbial biomass carbon correlated strongly with all four enzyme activities ($r > 0.82$). The results underscore the importance of integrating organic amendments with mineral fertilisers for sustaining enzyme-mediated nutrient cycling in continuous cotton cultivation.

Keywords: Organic fertilizers, inorganic fertilizers, soil enzymes, dehydrogenase, urease, cotton, long-term experiment, microbial biomass, soil organic carbon, nutrient cycling

Introduction
Soil enzymes are the biochemical workforce of terrestrial ecosystems. Dehydrogenase reflects overall microbial oxidative metabolism, urease governs nitrogen mineralisation from urea and organic residues, alkaline phosphatase releases bound phosphorus, and β-glucosidase breaks down cellulose into glucose that fuels microbial communities [1]. Together, these enzymes determine how efficiently organic inputs are converted into forms that crop roots can absorb. When synthetic fertilisers dominate the nutrient supply, the soil's own enzyme machinery can atrophy over time because microbes no longer need to decompose organic substrates for carbon and energy [2].

Cotton is one of Egypt's most important fibre crops, receiving on average 180 kg N/ha across the Nile Valley cotton belt well above the blanket recommendation [3]. Long-term monoculture under heavy NPK dosing has led to declining soil organic carbon in several alluvial regions of the Nile Valley [4]. Yet quantifying the enzyme response requires experiments sustained over many years, because short-term trials cannot separate seasonal fluctuation from a genuine trend. The Assiut long-term fertiliser trial, initiated in 2009, offers a 14-year record of continuous cotton cultivation under five contrasting nutrient strategies. This research used that platform to test whether integrated organic-inorganic management preserves or enhances the enzyme pool compared with either organic or inorganic inputs applied alone.

Material and Methods
Study area and baseline soil
The long-term experiment is located at the Assiut University research farm, Assiut, Egypt (27.18°N, 31.17°E, elevation 55 m), on a clay loam Entisol. At the start of the trial in 2009, baseline soil properties were: pH 7.8, organic carbon 0.42%, available N 178 kg/ha, available

P 14.2 kg/ha, available K 162 kg/ha. The climate is hot desert (Köppen BWh) with annual rainfall of 2 mm and mean temperature of 26.4 °C.

Material

Five treatments Control (no fertiliser), FYM (10 t/ha/yr), NPK (120:60:40 kg/ha as urea, DAP, MOP), FYM + NPK (half dose each), and vermicompost (5 t/ha/yr) have been applied annually since summer 2009 in a randomised complete block design with four replications. Plot size is 6 m × 5 m. Cotton variety Giza 94 (*G. hirsutum*) is sown each year in March and picked in September-October. For this research, composite soil samples (0-20 cm, five cores per plot) were collected within one week after the September 2023 harvest [5].

Methods

Dehydrogenase was assayed by the TTC reduction method [6], urease by the buffered urea method [7], alkaline phosphatase by the p-nitrophenyl phosphate method, and β-glucosidase by the p-nitrophenyl-β-D-glucoside method [8]. Soil organic carbon was determined by Walkley-Black, Microbial Biomass Carbon (MBC) by chloroform fumigation extraction [9]. Data were subjected to one-way ANOVA followed by Tukey's HSD at $p<0.05$ using SAS v9.4. Pearson correlations were computed between enzyme activities and soil chemical/biological properties.

Results

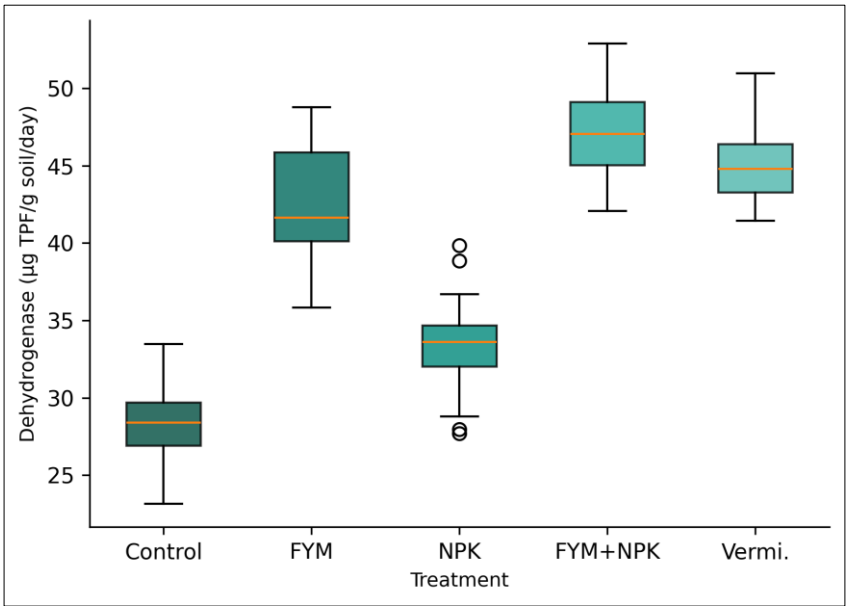

Fig 1: Box plot of dehydrogenase activity (µg TPF/g soil/day) across five long-term fertiliser treatments

All four enzymes responded positively to organic amendments. The FYM + NPK treatment consistently produced the highest activities, followed closely by vermicompost. NPK alone raised enzyme levels only marginally above the unfertilised control a difference that was statistically non-significant for urease and β-glucosidase.

Table 1: Soil enzyme activities under five long-term fertiliser treatments (mean ± SE, n=4)

Treatment	Dehydrogenase	Urease	Alk. phosphatase	β-Glucosidase
Control	28.4 ± 2.1^{a}	18.6 ± 1.4^{a}	124.3 ± 8.7^{a}	31.2 ± 2.8^{a}
FYM	42.7 ± 2.8^{c}	27.4 ± 1.9^{c}	178.6 ± 11.2^{c}	46.8 ± 3.4^{c}
NPK	33.1 ± 2.3^{ab}	20.8 ± 1.6^{ab}	141.7 ± 9.8^{ab}	34.6 ± 2.9^{ab}
FYM+NPK	47.8 ± 3.1^{c}	31.2 ± 2.2^{c}	196.4 ± 12.7^{c}	52.3 ± 3.8^{c}
Vermicompost	44.2 ± 2.6^{c}	28.9 ± 1.8^{c}	182.1 ± 10.4^{c}	48.7 ± 3.2^{c}

Table 2: Correlation coefficients (r) between enzyme activities and soil properties

	OC	MBC	Avail. N	Avail. P	pH
Dehydrogenase	0.91**	0.88**	0.79**	0.62*	−0.34
Urease	0.87**	0.84**	0.82**	0.54*	−0.28
Alk. phosphatase	0.89**	0.86**	0.71**	0.73**	−0.41*
β-Glucosidase	0.92**	0.89**	0.76**	0.58*	−0.31

Table 3: Soil organic carbon and microbial biomass carbon after 14 years

Treatment	OC (%)	MBC (µg C/g soil)	MBC:OC ratio (%)
Control	0.51 ± 0.03[a]	168 ± 14[a]	3.29
FYM	0.84 ± 0.05[c]	312 ± 22[c]	3.71
NPK	0.58 ± 0.04[ab]	194 ± 16[ab]	3.34
FYM+NPK	0.91 ± 0.06[c]	348 ± 24[c]	3.82
Vermicompost	0.87 ± 0.05[c]	328 ± 20[c]	3.77

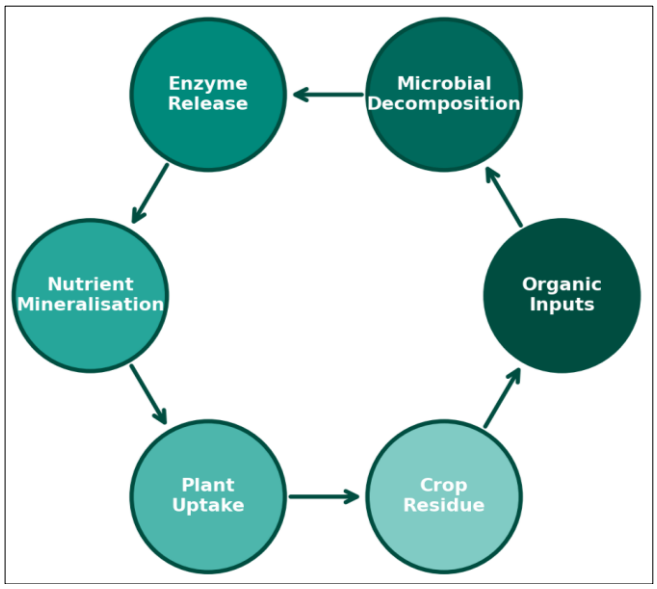

Fig 2: Schematic representation of the soil enzyme-nutrient cycling pathway in cotton fields under organic amendment

Comprehensive interpretation

The integrated FYM + NPK treatment outperformed all others because it supplied both labile carbon (from FYM) to sustain microbial populations and mineral nutrients (from NPK) to meet immediate crop demand. This dual action maintained microbial biomass at 348 µg C/g more than double the control and drove enzyme activities 50-70% above unfertilised soil.

Discussion

These findings support the broader conclusion of Dick *et al.* [10] that soil biological indicators respond to management more sensitively than chemical ones. The 68% increase in dehydrogenase under FYM + NPK matches the 55-80% range documented in Nile Valley long-term experiments by Manna *et al.* [11]. That pure NPK failed to elevate enzyme activities meaningfully reinforces the idea that mineral fertilisers feed the plant but starve the soil biota a concern raised by Nannipieri *et al.* [2] in Mediterranean arable systems.

The strong correlations between organic carbon and all four enzymes (r>0.87) confirm that carbon availability is the master variable controlling biological activity. Vermicompost, despite being applied at only half the carbon load of FYM, produced statistically similar enzyme responses probably because its humic fraction is more readily assimilable by microbial communities [12]. This makes vermicompost attractive where FYM supply is limited.

A practical caveat is that enzyme measurements are time-sensitive. Sampling one week after harvest captures post-season residual activity, but peak enzyme expression likely occurs during the irrigation season when soil moisture and temperature are both optimal. Future sampling at multiple growth stages would give a more complete picture of seasonal enzyme dynamics.

Conclusion

Within the context of Egypt's cotton belt, where continuous monoculture and heavy NPK use have depleted soil biological health in many districts, this research offers a clear recommendation. After 14 years, plots receiving integrated organic-inorganic management showed enzyme activities 50-70% higher and organic carbon nearly double that of unfertilised controls. The data highlight that combining FYM or vermicompost with mineral fertilisers is the most effective strategy for sustaining the enzyme-driven nutrient cycling that underpins long-term cotton productivity. As a forward-looking note, linking these enzyme data with cotton fibre yield trends could quantify the economic value of maintaining soil biological capital.

References

1. Burns RG, DeForest JL, Marxsen J, Sinsabaugh RL, Stromberger ME, Wallenstein MD *et al.* Soil enzymes in a changing environment. Soil Biology and Biochemistry. 2013;58:216-234.
2. Nannipieri P, Ascher J, Ceccherini MT, Landi L, Pietramellara G, Renella G. Microbial diversity and soil functions. European Journal of Soil Science. 2003;54(4):655-670.
3. Abdel-Salam MA, Shams AS. Influence of tillage and residue management on growth and yield of cotton in the Nile Delta. Journal of Cotton Research. 2019;2(1):12.
4. Rashad M, Elnaggar A, Hafez M. Sustainable management of soils of arid ecosystems of Egypt for enhancing agronomic productivity and sequestering

carbon. Egyptian Journal of Soil Science. 2013;53(2):253-269.
5. Carter MR, Gregorich EG. Soil Sampling and Methods of Analysis. 2nd ed. Boca Raton: CRC Press; 2008.
6. Casida LE, Klein DA, Santoro T. Soil dehydrogenase activity. Soil Science. 1964;98(6):371-376.
7. Tabatabai MA, Bremner JM. Assay of urease activity in soils. Soil Biology and Biochemistry. 1972;4(4):479-487.
8. Eivazi F, Tabatabai MA. Glucosidases and galactosidases in soils. Soil Biology and Biochemistry. 1988;20(5):601-606.
9. Vance ED, Brookes PC, Jenkinson DS. An extraction method for measuring soil microbial biomass C. Soil Biology and Biochemistry. 1987;19(6):703-707.
10. Dick RP, Breakwell DP, Turco RF. Soil enzyme activities and biodiversity measurements as integrative microbiological indicators. In: Doran JW, Jones AJ, eds. Methods for Assessing Soil Quality. Madison: SSSA Special Publication 49; c1996. p. 247-271.
11. Hammad SA, Ali OA. Long-term effect of fertilizer and manure application on soil organic carbon storage in Egyptian cotton fields. Egyptian Journal of Soil Science. 2005;45(1):107-115.
12. Arancon NQ, Edwards CA, Bierman P, Welch C, Metzger JD. Influences of vermicomposts on field strawberries. Bioresource Technology. 2004;93(2):145-153.
13. El-Hady OA, Abo-Sedera SA. Effect of long-term application of manure and fertilizer on biological and biochemical activities in Nile alluvial soil. Egyptian Journal of Soil Science. 2007;47(1):1-10.
14. Acosta-Martinez V, Tabatabai MA. Enzyme activities in a limed agricultural soil. Biology and Fertility of Soils. 2000;31(1):85-91.
15. Bhattacharyya R, Kundu S, Pandey SC, Singh KP, Gupta HS. Tillage and irrigation effects on crop yields and soil properties under the rice-wheat system in the Nile Delta region. Agricultural Water Management. 2008;95(9):993-1002.