

Integrating Zero Tillage, Paddy Straw Mulching, and Wastewater Irrigation for Potato Farming in East Kolkata Wetland Silty Clay Soil: A Sustainable Alternative to Synthetic Fertilizer-Dependent Production

Asim Panda

panda1asim@gmail.com

Raidighi College <https://orcid.org/0000-0002-9743-6366>

Mainak Mukhopadhyay

JIS University

Research Article

Keywords: East Kolkata Wetlands, potato, wastewater irrigation, zero tillage, paddy straw mulching, silty clay soil, nutrient substitution, *Pseudomonas fluorescens*, *Trichoderma viride*

Posted Date: May 5th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9510194/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Potato cultivation in West Bengal is usually concentrated in sandy loam and other well-drained soils and is commonly supported by substantial synthetic fertilizer inputs. The present study, conducted between 2021 and 2026, evaluates an alternative production model in the East Kolkata Wetlands, where potato was cultivated on silty clay soil under zero tillage with approximately 11-inch paddy straw mulching and irrigation from a sewage-fed canal. Soil test records, canal-water nutrient analysis, field yield records, and paired temperature measurements from the bed surface and tuber zone have been examined in this study. Across four soil reports, mean values are pH 5.62, organic carbon 0.72%, available nitrogen 437.38 kg/ha, available phosphorus 37.64 kg/ha, and available potassium 456.97 kg/ha. Canal water contained 17.1 mg/L dissolved nitrogen as $\text{NH}_3\text{-N}$, 1.95 mg/L dissolved phosphorus as $\text{PO}_4\text{-P}$, and 4.82 mg/L dissolved potassium; at an assumed seasonal irrigation volume of 6,000 m^3/ha , this corresponds to approximately 102.6 kg N/ha, 11.7 kg P/ha, and 28.9 kg K/ha. Potato productivity under the East Kolkata Wetland silty clay system ranged from 21,525 to 25,830 kg/ha, with a mean of 23,677.5 kg/ha, representing 77.7% to 93.2% of the comparative benchmark yield of 27,720 kg/ha reported for conventional fertilizer-dependent sandy loam potato farming in other parts of West Bengal. Temperature observations showed that the thick straw mulch reduced tuber-zone temperature by an average of 9.25°C relative to the aerial bed temperature, and this paired difference was statistically significant (paired t-test, $p = .033$). Although the small number of yield observations limits formal inference, the results indicate that wastewater irrigation, native soil fertility, and thick paddy straw mulch jointly created a productive potato-growing environment in a soil type that was usually considered less suitable for the crop. The system appears particularly strong in reducing synthetic nitrogen requirement, while phosphorus management remains necessary for balanced crop nutrition in conventional farming so in the zero-tillage model, with the creation of favourable environment of beneficiary microbes the *Pseudomonas fluorescens* 10^8 /gm and *Trichoderma viride* 10^7 /gm are used as Biocontrol and Phosphorus uptake enhancer.

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the major winter crops of India and an economically important crop in West Bengal. The crop is highly responsive to soil condition, irrigation, and nutrient supply, and recommended fertilizer doses for potato farming remain relatively high under conventional sandy loam soil cultivation systems (National Horticulture Board, n.d.).

In West Bengal, potato cultivation is strongly associated with sandy loam and other well-drained alluvial soils because loose structure, better aeration, and lower mechanical resistance favour tuber initiation, enlargement, and marketable tuber quality (Chakraborty & Mistri, 2015; Koco et al., 2020; Molla et al., 2020; Roy et al., 2019). By contrast, heavier clayey and silty clay soils are usually considered less suitable under conventional management because compaction, poor aeration, and excess water retention may restrict tuber development (Koco et al., 2020; Molla et al., 2020; Yang et al., 2023). Soil texture and water

relations, therefore, remain central to potato agronomy in this region (Ahmadi et al., 2010; Koco et al., 2020; Yang et al., 2023).

Nutrient management is another major concern in this context. Conventional potato farming often depends on repeated applications of synthetic fertilizers and pesticides to sustain productivity, especially in established potato-growing belts (Ierna & Distefano, 2024; Jia et al., 2022). Long-term dependence on external inputs may alter soil organic matter dynamics and nutrient cycling, while pesticide residues reported from potato tubers and related products also raise food-quality concerns (Amaral et al., 2023; Danek et al., 2020; Mansour et al., 2008). At the same time, potato is nutritionally important as a source of vitamin C, potassium, and dietary fibre (Camire et al., 1997; Love & Pavék, 2008).

The East Kolkata Wetlands (EKW) area has unique character of sewage canal feed natural recharged soil offer a distinctive agro-ecological potency towards fertilizer independent agriculture. Non toxic Domestic wastewater-fed canals, fisheries, agricultural lands, and biological nutrient recycling are remain closely interconnected in the East Kata Wetland area (Pal et al., 2014; Ray Chaudhuri et al., 2012). Previous studies (Pal et al., 2014; Selim et al., 2022) have shown that agricultural practice in this region depends on surface level fertile EKW soils and canal waters with substantial nutrient loads. In such a unique landscape, irrigation water may function not only as a water source but also as a carrier of dissolved valuable nutrients, thereby partially supporting crop demand through repeated field application.

This possibility becomes especially important when combined with zero tillage and residue retention. Recent work (Dey et al., 2025) from coastal eastern India has shown that potato cultivation under zero tillage and straw mulching can serve as a useful option for crop intensification in moisture-sensitive and fragile agro-ecosystems. In the present study, potato was cultivated on silty clay soil of the East Kolkata Wetlands under zero tillage, with approximately 11-inch paddy straw mulching and irrigation from a sewage-fed canal. The purpose was not to claim that silty clay is intrinsically superior to sandy loam for potato cultivation, but to examine whether a different management of logic based on wastewater nutrient recovery, soil moisture moderation, paddy straw mulching, and Zero tillage can reduce the practical limitations of a heavy soil and approach towards the productivity of conventional fertilizer-dependent systems.

2. Materials and Methods

The study was conducted from 2021 to 2026 in the East Kolkata Wetlands on silty clay soil under a zero-tillage potato production system in which the beds were covered with approximately 11-inch paddy straw mulch and irrigated with wastewater canal water from the Chapramari Canal with other branches. As a local resident of the region, the first author has had ethnographic observations of potato farming in the region for about eight years. Field characterization for this study was based on surface level soil analysis reports from the Vivekananda Institute of Biotechnology, Nimpith Ramkrishna Ashram, Nimpith. The recorded soil values were pH 5.84, 5.15, 6.07, and 5.42; organic carbon 0.74%, 0.76%, 0.68%, and 0.72%;

available nitrogen 446.40, 460.60, 403.80, and 438.70 kg/ha; available phosphorus 27.05, 70.88, 32.73, and 19.92 kg/ha; and available potassium 420.67, 479.80, 458.30, and 469.12 kg/ha. The chemical analysis of canal water on 31st March 2026 indicated dissolved nitrogen as $\text{NH}_3\text{-N}$ at 17.1 mg/L, dissolved phosphorus as $\text{PO}_4\text{-P}$ at 1.95 mg/L, dissolved potassium at 4.82 mg/L, and permanganate demand at 2.8 mg $\text{O}_2\text{/L}$. For practical interpretation of nutrient contribution through irrigation, seasonal water application was considered at 6,000 $\text{m}^3\text{/ha}$, and nutrient addition per hectare was calculated accordingly. Field productivity under the East Kolkata Wetlands system was represented by hectare-scale yield values of 21,525 and 25,830 kg/ha obtained under silty clay soil, zero tillage, thick paddy straw mulch, and canal-water irrigation. For contextual comparison, a conventional fertilizer-dependent sandy loam benchmark yield of kufri Jyoti variety Potato was 27,720 kg/ha from potato-growing area of Hooghly-Tarakeswar and Memari-Bardhaman used as a standard production reference (Das et al., 2024; Roy et al., 2019). Temperature difference between upper Photosynthetic foliar zone and Paddy straw covered tuber growing zone shows a major beneficiary effect of this model. Paddy Straw mulch, paired measurements of aerial bed temperature, and tuber-zone temperature were recorded from four mulched beds. Mean, range, and standard deviation were calculated for soil properties, yield values, and temperature measurements. A paired t-test was used to compare aerial and tuber-zone temperatures under mulch. A one-sample t-test was used to compare the yield values of the East Kolkata Wetlands against the conventional benchmark of 27,720 kg/ha.

3. Results and Discussion

3.1 Soil texture and fertility

The East Kolkata Wetland area has silty clay soil that showed some kind of salinity and acid stress. For statistical analysis and better calculation of the status, mean value was taken. The sampling of the soil was conducted from four Moujas under different panchayet area of the East Kolkata Wetlands. Therefore, the actual value of the studied field needs management as per soil health card number report. In case of academic discussion, the statistical values are considered, as Mean pH was 5.62, mean organic carbon was 0.72%, mean available nitrogen was 437.38 kg/ha, mean available phosphorus was 37.64 kg/ha, and mean available potassium was 456.97 kg/ha. These values indicate a reasonably fertile soil base, particularly with respect to nitrogen and potassium, while phosphorus was comparatively weaker form the soil fertility. The observed pH range also falls within a manageable range for potato cultivation (Ierna & Distefano, 2024; Koco et al., 2020).

Table 1
Descriptive statistics of East Kolkata Wetland soil properties based on four soil-test reports.

Parameter	Observed range	Mean	SD	Interpretation
pH	5.15–6.07	5.62	0.42	Slightly acidic, suitable range
Organic carbon (%)	0.68–0.76	0.72	0.03	Moderate soil organic status
Available N (kg/ha)	403.80–460.60	437.38	24.20	High native nitrogen
Available P (kg/ha)	19.92–70.88	37.64	23.11	Lower and variable phosphorus
Available K (kg/ha)	420.67–479.80	456.97	26.24	High native potassium

3.2 Canal-water nutrient contribution

The canal-water analysis indicates that wastewater irrigation contributed not only water but also plant nutrients. At an assumed seasonal irrigation volume of 6,000 m³/ha, the Chapramari canal water would contribute approximately 102.6 kg N/ha, 11.7 kg P/ha, and 28.9 kg K/ha. Relative to recommended potato fertilizer doses, this represents a substantial nitrogen input through irrigation alone, whereas phosphorus and potassium contributions are supplementary rather than fully sufficient (National Horticulture Board, n.d.).

Table 2
Chemical characteristics and estimated nutrient contribution of Chapramari canal water used for potato irrigation.

Parameter	Laboratory value	Unit	Interpretation	Estimated supply at 6,000 m ³ /ha
Dissolved nitrogen (as NH ₃ -N)	17.1	mg/L	Available nitrogen	102.6 kg/ha
Dissolved phosphorus (as PO ₄ -P)	1.95	mg/L	Available phosphorus	11.7 kg/ha
Dissolved potassium (as K)	4.82	mg/L	Available potassium	28.9 kg/ha
Permanganate demand	2.8	mg O ₂ /L	Low organic load indicator	-

3.3 Combined nutrient support versus conventional fertilizer-dependent potato farming

When the mean soil-test values are viewed together with canal-water nutrient input, the East Kolkata Wetlands system appears particularly strong in nitrogen and potassium support. This comparison is interpretive rather than strictly equivalent because soil-test availability and irrigation-borne nutrients are being viewed alongside recommended fertilizer dose. Even so, the practical point remains clear: the

wetland field was not nutritionally weak, and, in addition, canal-water irrigation substantially strengthened the nitrogen economy of the system.

Table 3
Comparative nutrient support of the East Kolkata Wetland system and conventional fertilizer-dependent potato farming.

Nutrient / parameter	EKW soil mean value	Canal-water supply	Combined support	Conventional recommendation	Interpretation
Nitrogen (kg/ha)	437.38	102.6	539.98	180–240	Strong nitrogen support; synthetic N requirement may be reduced
Phosphorus (kg/ha)	37.64	11.7	49.34	60–90	Moderate support; phosphorus top-up remains necessary
Potassium (kg/ha)	456.97	28.9	485.87	85–130	Strong potassium-supporting system
Soil pH	5.62	-	5.62	About 4.7–6.2	Suitable soil reaction for potato
Organic carbon (%)	0.72	-	0.72	> 0.5 desirable	Favourable for soil health and nutrient retention

3.4 Thermal buffering effect of 11-inch paddy straw mulch

Direct temperature observations showed that the straw mulch created a cooler microenvironment around the tuber zone. Mean aerial bed temperature was 43.25°C, whereas mean tuber-zone temperature was 34.00°C. The mean paired reduction was 9.25°C, with a range of 5-14°C. This paired difference was statistically significant (paired t-test, $t = 3.76$, $df = 3$, $p = .033$), indicating a measurable thermal-buffering effect of the thick mulch despite the small sample size. Such moderation of the near-tuber microclimate may help explain why a heavy wetland soil supported acceptable potato development under non-conventional management (Dey et al., 2025).

Table 4
Temperature difference between aerial zone and tuber region under 11-inch paddy straw mulch.

Sl. no.	Date	Aerial temperature (C)	Tuber-zone temperature (C)	Difference (C)
45	27/03/2022	49	35	14
75	25/03/2022	40	35	5
60	25/03/2022	38	33	5
125	27/03/2022	46	33	13

3.5 Yield performance and comparison with the sandy loam benchmark

In between 2021 and 2026, Jyoti variety Potato productivity under Zero tillage paddy straw mulching model in the East Kolkata Wetlands silty clay system ranged from 21,525 to 25,830 kg/ha, with a mean of 23,677.5 kg/ha. Against the comparative sandy loam benchmark of 27,720 kg/ha, the wetland system attained 77.7% to 93.2% of the benchmark yield, with a mean benchmark attainment of 85.4%. A one-sample t-test comparing the two East Kolkata Wetlands yield values with the benchmark did not show statistical significance ($t = -1.88$, $df = 1$, $p = .311$), but this result should not be overinterpreted because the sample size was too small to provide meaningful statistical power. Agronomically, the more important observation is that the yield range approached the conventional benchmark closely enough to support the practical value of the system.

Table 5
Yield comparison between the East Kolkata Wetland system and the conventional sandy loam benchmark.

System	(Jyoti variety potato) Yield value(s) (kg/ha)	Mean yield (kg/ha)	Benchmark attainment (%)
EKW Zero-tillage Paddy straw Mulching silty clay system	21,525 and 25,830	23,677.5	77.7–93.2
Conventional sandy loam benchmark	27,720	27,720	100

The results suggest that a heavy wetland soil can support substantial potato production when the field system is restructured around nutrient recycling and microclimatic buffering. One mechanism is wastewater fertigation: the canal water contributed a large share of the crop’s likely nitrogen demand. A second mechanism is mulch-mediated thermal moderation: the 11-inch paddy straw layer insulated the tuber zone from excessive surface heat with a secondary environment of beneficiary microbial growth and continuous soil surface level humidity. A third mechanism is the field’s native natural rechargeable fertility, which was already relatively strong for nitrogen and potassium. Together, these factors help explain why the East Kolkata Wetland system approached the performance of conventional sandy loam potato farming despite operating in a soil texture normally treated as unfavourable for the crop.

At the same time, the findings do not justify a claim of complete fertilizer replacement. Phosphorus remains the weaker point in both soil and irrigation water. The canal-water contribution of 11.7 kg P/ha and the lower, more variable soil phosphorus values suggest that the system is best understood as a partial synthetic-fertilizer substitution model, particularly strong for nitrogen substitution but still in need of phosphorus supplementation for balanced nutrition. In this context, beneficial microorganisms such as *Pseudomonas fluorescens* and *Trichoderma viride* have potency to overcome Phosphorus deficiency by enhancement of Phosphorus solubility and uptake capacity with a support of disease management

favourable environment. (Arseneault et al., 2015; Panpatte et al., 2016; Dennis & Webster, 1971; Purwantisari et al., 2020).

4. Conclusion

Potato cultivation on East Kolkata Wetland silty clay soil was technically viable in this study when wastewater canal irrigation was integrated with zero tillage and approximately 11-inch paddy straw mulching. The field showed moderate acidity, moderate organic carbon, high available nitrogen, and high available potassium, whereas phosphorus remained comparatively lower. Canal-water irrigation added about 102.6 kg N/ha, 11.7 kg P/ha, and 28.9 kg K/ha, indicating that the water source functioned as a substantial nitrogen carrier and a supplementary source of phosphorus and potassium. Straw mulch reduced tuber-zone temperature by an average of 9.25°C, and this thermal-buffering effect was statistically significant. Potato yield under the wetland system ranged from 21,525 to 25,830 kg/ha, approaching the conventional sandy loam benchmark closely enough to be agronomically meaningful. The system should therefore be interpreted as a wetland-based, zero tillage paddy straw mulching beneficiary microbial environment dependent fertilizer-substituting potato production model with clear potential to reduce dependence on synthetic nitrogen fertilizer while maintaining acceptable productivity under a non-conventional soil environment.

Declarations

Competing interests.

The authors declare that there are no competing interests.

Ethical approval.

The study was based on field observations and laboratory analytical records and did not involve human or animal experimentation.

Authors' contributions.

Asim Panda designed the study, was directly involved throughout the season of farming in the field and conducted field observations, compiled the analytical records, interpreted the results, and prepared the initial manuscript draft. Dr. Mainak Mukhopadhyay contributed to academic supervision, interpretation of results, and critical revision of the manuscript. Both authors approved the final manuscript.

Acknowledgements.

The authors express their gratitude for the support they received from the Vivekananda Institute of Biotechnology for soil analysis and Good Earth Laboratories for canal water analysis. The authors are thankful to the local farmer and the owner of the potato field for leasing the land for cultivation and for continuing to cooperate with them throughout the study.

References

1. Ahmadi, S. H., Andersen, M. N., Plauborg, F., Poulsen, R. T., Jensen, C. R., Sepaskhah, A. R., & Hansen, S. (2010). Effects of irrigation strategies and soils on field-grown potatoes: Yield and water productivity. *Agricultural Water Management*, 97(11), 1923–1930. <https://doi.org/10.1016/j.agwat.2010.07.007>
2. Amaral, L. R., Zanchin, C. F., Floriano, L., Ues, K., Prestes, O. D., & Zanella, R. (2023). Multiresidue determination of pesticides in potato tuber, peel, and pulp by QuEChERS and UHPLC-MS/MS. *Food Analytical Methods*, 16(4), 771–780. <https://doi.org/10.1007/s12161-023-02471-y>
3. Arseneault, T., Goyer, C., & Filion, M. (2015). *Pseudomonas fluorescens* LBUM223 increases potato yield and reduces common scab symptoms in the field. *Phytopathology*, 105(10), 1311–1317. <https://doi.org/10.1094/PHYTO-12-14-0358-R>
4. Camire, M. E., Violette, D., Dougherty, M. P., & McLaughlin, M. A. (1997). Potato peel dietary fiber composition: Effects of peeling and extrusion cooking processes. *Journal of Agricultural and Food Chemistry*, 45(4), 1404–1408. <https://doi.org/10.1021/jf9604293>
5. Chakraborty, K., & Mistri, B. (2015). Importance of soil texture in sustenance of agriculture: A study in Burdwan-I C. D. Block, Burdwan, West Bengal. *Eastern Geographer*, 21(1), 475–482.
6. Danek, M., Sajdak, M., Płonka, J., & Barchańska, H. (2020). Rapid MSPD-LC-MS/MS procedure for determination of pesticides in potato tubers. *Journal of Chromatographic Science*, 58(9), 831–843. <https://doi.org/10.1093/chromsci/bmaa053>
7. Das, M., Sarkar, B., Sahu, P. K., Othman, A. J., & Ranjan, S. (2024). Potato in India: Its growth, trend and export. *Potato Research*. Advance online publication. <https://doi.org/10.1007/s11540-024-09732-1>
8. Dennis, C., & Webster, J. (1971). Antagonistic properties of species-groups of *Trichoderma*. *Transactions of the British Mycological Society*, 57(1), 25–39. [https://doi.org/10.1016/S0007-1536\(71\)80077-3](https://doi.org/10.1016/S0007-1536(71)80077-3)
9. Dey, S., Sarkar, S., Dhar, A., Brahmachari, K., Ghosh, A., Goswami, R., & Mainuddin, M. (2025). Potato cultivation under zero tillage and straw mulching: Option for land and cropping system intensification for Indian Sundarbans. *Land*, 14(3), Article 563. <https://doi.org/10.3390/land14030563>
10. Ierna, A., & Distefano, M. (2024). Crop nutrition and soil fertility management in organic potato production systems. *Horticulturae*, 10, Article 886. <https://doi.org/10.3390/horticulturae10080886>
11. Jia, S., Yuan, D., Li, W., He, W., Raza, S., Kuzyakov, Y., Zamanian, K., & Zhao, X. (2022). Soil chemical properties depending on fertilization and management in China: A meta-analysis. *Agronomy*, 12(10),

Article 2501. <https://doi.org/10.3390/agronomy12102501>

12. Koco, Š., Vilček, J., Torma, S., Michaeli, E., & Solár, V. (2020). Optimising potato (*Solanum tuberosum* L.) cultivation by selection of proper soils. *Agriculture*, 10(5), Article 155. <https://doi.org/10.3390/agriculture10050155>
13. Love, S. L., & Pavék, J. J. (2008). Positioning the potato as a primary food source of vitamin C. *American Journal of Potato Research*, 85(4), 277–285. <https://doi.org/10.1007/s12230-008-9030-6>
14. Mansour, S. A., Belal, M. H., Abou-Arab, A. A., Ashour, H. M., & Gad, M. F. (2008). Evaluation of some pollutant levels in conventionally and organically farmed potato tubers and their risks to human health. *Food and Chemical Toxicology*, 47(3), 615–624. <https://doi.org/10.1016/j.fct.2008.12.019>
15. Molla, S. H., Rukhsana, N., & Alam, A. (2020). Land suitability appraisal for the growth of potato cultivation: A study of Sagar Island, India. In *Sustainable development practices using geoinformatics* (pp. 111–125). <https://doi.org/10.1002/9781119687160.ch7>
16. National Horticulture Board. (n.d.). *Potato*. Government of India. <https://nhb.gov.in/pdf/vegetable/potato/pot007.pdf>
17. Pal, S., Manna, S., Aich, A., Chattopadhyay, B., Mukhopadhyay, S. K., et al. (2014). Assessment of the spatio-temporal distribution of soil properties in East Kolkata wetland ecosystem (A Ramsar site: 1208). *Journal of Earth System Science*, 123, 729–740.
18. Panpatte, D. G., Jhala, Y. K., Shelat, H. N., & Vyas, R. V. (2016). *Pseudomonas fluorescens*: A promising biocontrol agent and PGPR for sustainable agriculture. In *Microbial inoculants in sustainable agricultural productivity* (pp. 257–270). https://doi.org/10.1007/978-81-322-2647-5_15
19. Purwantisari, S., Priyatmojo, A., Sancayaningsih, R. P., Kasiamdari, R. S., & Budihardjo, K. (2020). Lignification on potatoes by application of *Trichoderma viride*. *IOP Conference Series: Earth and Environmental Science*, 518(1), Article 012075. <https://doi.org/10.1088/1755-1315/518/1/012075>
20. Ray Chaudhuri, S., Mukherjee, I., Ghosh, D., Thakur, A. R., & RayChaudhuri, S. (2012). East Kolkata wetland: A multifunctional niche of international importance. *OnLine Journal of Biological Sciences*, 12(2), 80–88.
21. Roy, A., Siddique, G., & Mondal, M. H. (2019). A study on the productivity of potato in Hugli District, West Bengal, India. *Journal of Geography, Environment and Earth Science International*, 20(4), 1–14. <https://doi.org/10.9734/JGEESI/2019/v20i430114>
22. Selim, T., Elkefay, S. M., Berndtsson, R., Elkiki, M., & El-Kharbotly, A. A. (2022). Can potato crop on sandy soil be safely irrigated with heavy metal polluted water? *Water*, 14(8), Article 1226. <https://doi.org/10.3390/w14081226>
23. Yang, C., Wu, J., Li, P., Wang, Y., & Yang, N. (2023). Evaluation of soil-water characteristic curves for different textural soils using fractal analysis. *Water*, 15(4), Article 772. <https://doi.org/10.3390/w15040772>

Figures

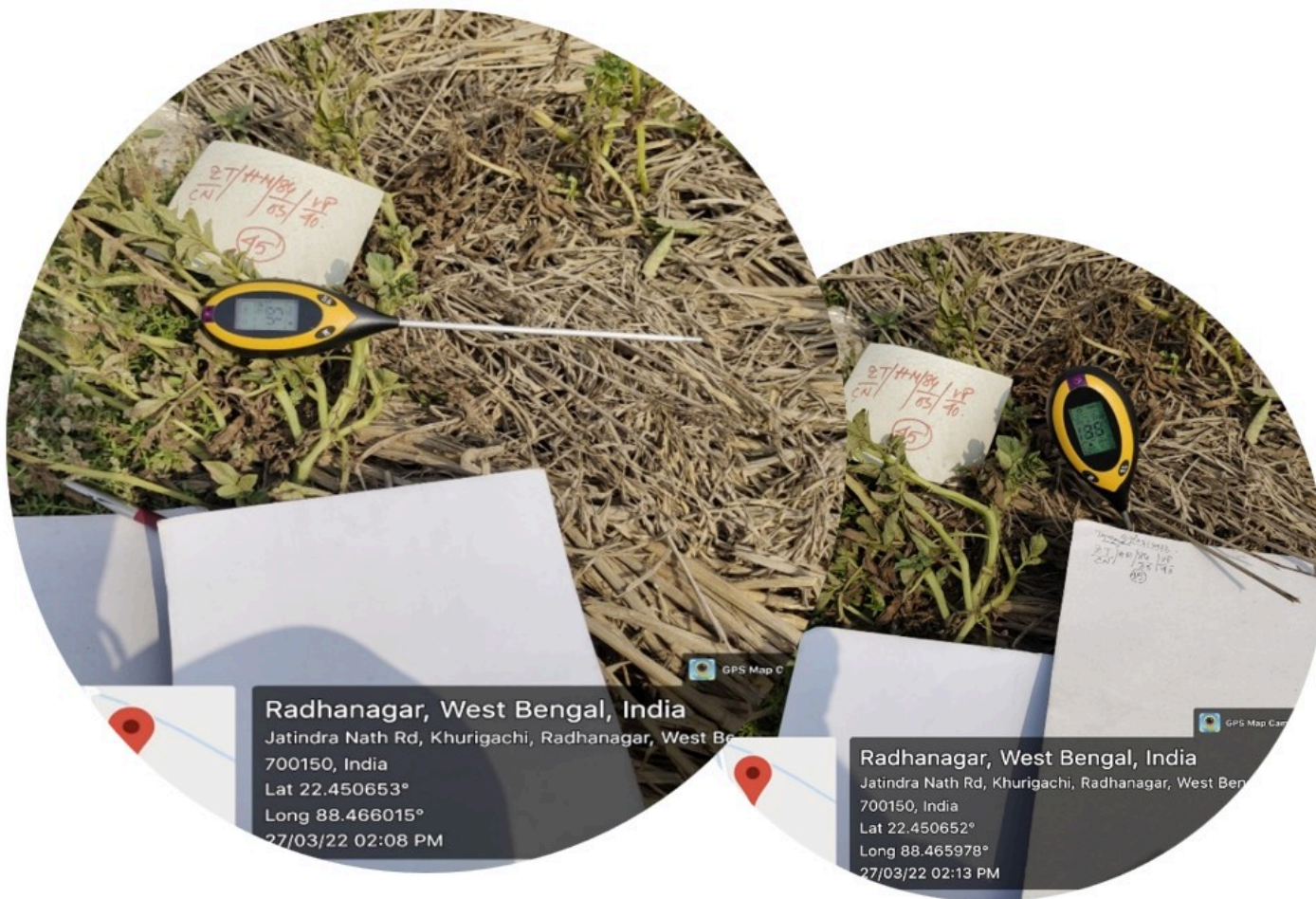


Figure 1

Unnumbered image in the Results and Discussion section.