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# Physico-chemical Properties of Soil as Influenced by Combined Application of Organic and Inorganic Sources to Fodder Oat and Succeeding Residual Fodder Maize

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***Authors' contributions***

*This work was carried out in collaboration among all the authors. Author HN conducted the study, wrote the protocol, and wrote the first draft of the manuscript. Author JSB planned, designed and supervised the study. Authors HN and SPY performed the statistical analysis and involved in laboratory work. Authors TS and PS managed the literature searches. All authors read and approved the final manuscript.*

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## ABSTRACT

An experimental trial was carried out during 2018-19 and 2019-20 at Banaras Hindu University, Varanasi, to assess the direct and residual effect of varying levels of fertility and organic sources on different soil chemical properties. Application of fertility levels had non-significant direct and residual effects on soil health in both the years, though maximum values were obtained with 100% RDF. After fodder oat harvest, the maximum values of available NPK in the soil were observed using FYM over poultry manure and vermicompost. Application of 50 kg nitrogen $ha^{-1}$ through organic sources recorded distinctly higher soil available N, P, and K after the harvest of fodder oat. However, the residual effect of nitrogen levels and organic sources failed to touch the significant level of soil health parameters after harvesting fodder maize.

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## 1. INTRODUCTION

India supports about 17% of the human population and 15% livestock population from 2.3% geographical area and 4.2% water resources of the world [1]. Livestock production is a major component of the Indian farming system which contributes 7% to the national GDP and provides employment and livelihood for 70% population in rural areas [2]. Recent reports indicated that India faces a net deficit of green fodder by 61.1%, dry crop residues by 21.9%, and feeds as high as 64% [1]. To meet livestock feed requirement, fodder production needs special emphasis for assured green fodder supply throughout the year. Therefore, oat can be taken as a fodder crop in winter due to its fast- growing nature and high nutritional value, followed by fodder maize during summer. However, nutrient management in intensive cereals- cereals cropping system is a major challenge. Soil nutrients supplied through sole usage of mineral NPK fertilizers in a continuous intensive cropping system may deplete soil fertility, especially micronutrients [3] and organic carbon, because fertilizers have no direct effect on soil physical properties [4]. The strategic use of organic and inorganic sources positively impacted soil organic carbon, available nutrient status, and soil quality indicators [5]. The higher soil available N, P, K, and micronutrient status can be maintained using vermicompost, compost, and biofertilizers with inorganic fertilizers [6]. Supplementation of the recommended dose of nutrients through vermicompost and compost enhances the total uptake of macro (N, P, and K) and micronutrients (Zn, Cu, Fe, and Mn) [7]. Organic nutrient sources enhance microbial proliferation leading to better nutrient mobilization for crop assimilation.

Additionally, manure may directly enhance soil physical properties such as aggregate stability [8] and water retention [9]. Diacono and Montemurro [10] opined that adding organic manure to cropland could enhance soil biological functions for more than 15 years after use; however repeated applications were needed to elicit the effect. Using organic sources in crop nutrition provides a balanced supply of mineral nutrients to the main crop and has some additional influence on the succeeding crop. Residual effects of organic sources on the chemical properties of soil were studied by Tabibian et al. [11] and reported significant improvement in organic matter and soil health. Residual amendment effects on total nitrogen and phosphorus were apparent even after 11.5 years of application [12]. Given the above facts, the present study was conducted to compare three organic sources, *viz.,* farmyard manure, poultry manure, and vermicompost, for their direct and residual effects on soil Physico-chemical properties on fodder oat and succeeding fodder maize.

## 2. MATERIALS AND METHODS

**Site and Soil Conditions:** The field trial was conducted during 2018-19 and 2019-20 to study the direct and residual effect of varying fertility levels and organic sources on soil health after the harvest of fodder oat and residual fodder maize. The experiment was laid out in the IFS block of Agricultural Research Farm, Banaras Hindu University, Varanasi, under an assured irrigation facility. The experimental site was located at $5^0$ 18'N latitude and $88^0$ 03'E longitudes at an altitude of 128.93 meters above the mean sea level at the centre of North- alluvial Gangetic plain. Climatologically, Varanasi lies under a subtropical zone having extreme climatic features such as scorching summer and chilling winter. The region falls under a semi-arid to sub-humid climate, having a mean annual rainfall and potential evapotranspiration (PET) of 1102.4 mm and 1550 mm, respectively, with a moisture deficit index ranging between -20 to -40. The soil of the experimental site was Gangetic alluvial having uniform fertility and leveled topography. The initial Physico-chemical properties of the experimental site are presented in Table 1.

**Experimental Design, Treatment Details and Crop Management:** During the *rabi* (winter) season of both the experimental years fodder oat cv. Kent was grown in a split-plot design with a plot size of 4.5 cm × 4.0 cm comprising eighteen treatment combinations. The main plot was allocated with three fertility levels (100%, 75%, and 50% RDF) whereas the subplot was comprised of combinations of three organic sources (FYM, Poultry manure, and Vermicompost) and two nitrogen levels (25 and 50 kg N $ha^{-1}$) applied through the above-mentioned organic sources. In fodder oat, nitrogen is applied in three splits, *i.e.*, 50% at basal, 25% at first irrigation, and 25% after the first cut in the form of urea. The entire doses of

**Table 1. Initial physico-chemical properties of experimental field**

| Particulars | Value | | Method employed |
|---|---|---|---|
| Soil properties (%) | 2015 | 2016 | |
| **Mechanical analysis** | | | |
| Sand | 48.74 | 48.47 | Hydrometric method [13] |
| Silt | 28.72 | 28.88 | |
| Clay | 22.54 | 22.65 | |
| Textural class | Sandy clay loam | | |
| Taxonomy | Ustochrept | | |
| **Physical analysis** | | | |
| Bulk density ($Mg/m^3$) | 1.39 | 1.35 | Core sampler [14] |
| Chemical analysis | | | |
| Soil pH (1:2.5 soil: water suspension) | 7.34 | 7.32 | Glass electrode pH meter [15] |
| Electrical Conductivity (dS/m at 25°C) | 0.221 | 0.223 | Systronics electrical conductivity meter [15] |
| Organic Carbon (%) | 0.34 | 0.36 | Walkley and Black method [16] |
| Available Nitrogen (N kg/ha) | 180.44 | 182.67 | Alkaline permanganate method [17] |
| Available Phosphorus (P kg/ha) | 17.12 | 18.85 | 0.5 M $NaHCO_3$ Olsen’s Colorimetric method [18] |
| Available Potassium (K kg/ha) | 198.8 | 197.5 | Flame Photometer method [15] |

phosphorus and potassium were applied through Di-ammonium phosphate (DAP) and Muriate of potash (MOP) at the time of final land preparation. The recommended dose of NPK (100% RDF) represents 120-60-60 kg NPK $ha^{-1}$. Organic manures are incorporated fresh in each plot two weeks before sowing of fodder oat. The required quantities of organic manures were calculated on the basis of their nitrogen content. The moisture and nitrogen content of each organic manure was estimated on a dry weight basis, and required amount of fresh manure was worked out. After harvesting of fodder oat, fodder maize cv. African Tall was taken as a residual crop on the same experimental setup after applying a light pre-sowing irrigation without disturbing the layout during the summer season of both the years. A spacing of 30cm×10cm was maintained with a seed rate of 40 kg $ha^{-1}$. In the plots, nutrients were applied at 50% RDF (120- 60-60 kg NPK $ha^{-1}$). Half of the nitrogen and total doses of P and K were applied as basal, and the rest, 50%, was top-dressed at the knee-high stage of the crop. All other agronomic packages were kept normal and invariable in each plot. Plant protection measures were adopted to protect the crop from insectpests, weeds, and diseases. The crop was harvested at 70 DAS before tassel emergence,*i.e.,* $7^{th}$ and $4^{th}$ of June in 2019 and 2020, respectively.

**Soil Analysis:** The soil samples from 0-15 cm depth were collected before sowing to determine the initial physico-chemical properties and after the harvest of fodder oat and fodder maize to analyze various soil chemical properties. The samples were air-dried, grounded, and sieved through a 2mm sieve and analyzed for pH, EC, available N, P, and K in soil. The soil pH and EC were estimated with the help of pH meter ad EC meter, respectively. The analysis of soil nutrient status was accomplished by following the standard alkaline permanganate [17], Olsen's method [18], flame photometer method [15] for nitrogen, phosphorus and potassium analysis, respectively.

**Statistical Data Analysis:** The data of each character of the test crop was sorted out, tabulated, and finally analyzed statistically using the analysis of variance technique for split-plot design described by Gomez and Gomez [19]. Critical difference values at P=0.05 were used for determining the significance of differences between mean values of treatments.

## 3. RESULTS AND DISCUSSION

### Soil pH and EC

**Direct effect of treatments:** Results (Table. 2) revealed that the direct impact of fertility levels on soil failed to show considerable effect on soil pH and EC after harvesting fodder oat during both years of investigation. However, it showed an increasing trend with an increase in fertility levels from 50% to 100% RDF in soil pH and EC. A perusal of the data indicated that none of the three organic sources was able to influence significantly on soil pH and EC after the harvest of fodder oat (Table. 2). Notwithstanding, Poultry manure recorded the lowest soil pH due to more production of organic acids during decomposition process. Whereas, maximum EC was observed with FYM application. Similarly, the direct effect of nitrogen application through organic sources did not touch the significance level concerning soil pH and EC during both years. However, slight decrease in pH and increase in EC was noticed with the application of 50 kg N $ha^{-1}$ compared to 25 kg N $ha^{-1}$(Table. 2). The results are in agreement with earlier work done by Kumar et al*.* [20] and Kashyap et al*.*[21].

**Residual effect of treatments:** The treatments applied to fodder oat have been concerned for their residual effect on succeeding fodder maize. Data presented in the Table 3 showed that the residual effect of fertility levels had a non-significant effect on soil pH and EC after harvesting fodder maize in both the years. Nevertheless, it was recorded maximum with the application of 100% RDF compared to 75% and 50% RDF, respectively. Application of organic sources failed to show the appreciable residual effect on soil pH and EC (Table. 3). However, among the three organic sources, the residual effect of poultry manure reported a marginal decrease in soil pH and EC, thus improving soil health. A study of the data revealed that the soil pH and EC did not differ significantly due to the residual effect of the application of nitrogen through organic sources in either of the two-year experiments (Table. 3). Application of 50 kg N $ha^{-1}$ through organic sources improved the soil health by bringing the soil reaction near neutral. Sharma et al*.,* [22] also reported that there was decrease in pH in all the integrated nutrient management practices involving FYM @10 t $ha^{-1}$.

**Table 2. Effect of fertility levels, organic sources and nitrogen levels on soil health after harvesting of fodder oat**

| Treatment | pH | | EC (dS/m) | | Av. N (kg ha$^{-1}$) | | Av. P (kg ha$^{-1}$) | | Av. K (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2018-19 | 2019-20 | 2018-19 | 2019-20 | 2018-19 | 2019-20 | 2018-19 | 2019-20 | 2018-19 | 2019-20 |
| **Fertility levels** | | | | | | | | | | |
| 100% RDF | 7.31 | 7.33 | 0.218 | 0.220 | 201.2 | 209.8 | 18.88 | 19.38 | 199.57 | 196.11 |
| 75% RDF | 7.29 | 7.30 | 0.215 | 0.216 | 199.4 | 204.5 | 18.73 | 19.02 | 195.31 | 191.78 |
| 50% RDF | 7.26 | 7.27 | 0.209 | 0.209 | 195.7 | 199.9 | 18.52 | 18.70 | 189.90 | 185.60 |
| SE m± | 0.21 | 0.19 | 0.010 | 0.007 | 2.9 | 3.4 | 0.34 | 0.47 | 3.62 | 3.91 |
| CD 5% | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| **Organic sources** | | | | | | | | | | |
| FYM | 7.33 | 7.34 | 0.217 | 0.218 | 203.1 | 209.3 | 19.27 | 19.77 | 200.66 | 196.21 |
| Poultry manure | 7.25 | 7.27 | 0.214 | 0.215 | 198.6 | 205.5 | 18.72 | 19.00 | 195.51 | 192.33 |
| Vermicompost | 7.29 | 7.30 | 0.211 | 0.211 | 194.6 | 199.4 | 18.14 | 18.32 | 188.61 | 184.93 |
| SE m± | 0.17 | 0.14 | 0.009 | 0.007 | 2.1 | 2.5 | 0.30 | 0.40 | 2.91 | 2.63 |
| CD 5% | N.S. | N.S. | N.S. | N.S. | 6.1 | 7.1 | 0.85 | 1.14 | 8.42 | 7.60 |
| **Nitrogen levels** | | | | | | | | | | |
| 25 kg N ha$^{-1}$ | 7.31 | 7.32 | 0.212 | 0.213 | 196.1 | 201.7 | 18.28 | 18.42 | 191.41 | 188.02 |
| 50 kg N ha$^{-1}$ | 7.27 | 7.28 | 0.216 | 0.217 | 201.4 | 207.7 | 19.14 | 19.65 | 198.44 | 194.29 |
| SE m± | 0.14 | 0.12 | 0.006 | 0.006 | 1.7 | 2.0 | 0.24 | 0.32 | 2.38 | 2.15 |
| CD 5% | N.S. | N.S. | N.S. | N.S. | 5.0 | 5.8 | 0.70 | 0.93 | 6.87 | 6.21 |

**Table 3. The residual effect of fertility levels, organic sources, and nitrogen levels on soil health after harvesting fodder maize**

| Treatment | pH | | EC (dS/m) | | Av. N (kg $ha^{-1}$) | | Av. P (kg $ha^{-1}$) | | Av. K (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2018-19 | 2019-20 | 2018-19 | 2019-20 | 2018-19 | 2019-20 | 2018-19 | 2019-20 | 2018-19 | 2019-20 |
| **Fertility levels** | | | | | | | | | | |
| 100% RDF | 7.30 | 7.32 | 0.214 | 0.215 | 194.5 | 196.9 | 18.16 | 18.95 | 195.9 | 192.8 |
| 75% RDF | 7.28 | 7.29 | 0.211 | 0.212 | 191.5 | 192.6 | 17.92 | 18.54 | 192.1 | 188.6 |
| 50% RDF | 7.24 | 7.27 | 0.205 | 0.211 | 187.0 | 188.3 | 17.74 | 18.25 | 186.9 | 182.5 |
| SE m± | 0.20 | 0.19 | 0.007 | 0.008 | 2.45 | 3.26 | 0.36 | 0.41 | 3.81 | 3.42 |
| CD 5% | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| **Organic sources** | | | | | | | | | | |
| FYM | 7.31 | 7.33 | 0.214 | 0.215 | 193.7 | 195.5 | 18.34 | 19.16 | 195.3 | 190.9 |
| Poultry manure | 7.24 | 7.26 | 0.210 | 0.213 | 191.0 | 192.9 | 17.96 | 18.45 | 192.8 | 188.1 |
| Vermicompost | 7.28 | 7.30 | 0.206 | 0.210 | 188.3 | 189.4 | 17.51 | 18.13 | 186.8 | 184.9 |
| SE m± | 0.16 | 0.14 | 0.007 | 0.007 | 1.96 | 2.34 | 0.30 | 0.36 | 2.97 | 2.30 |
| CD 5% | N.S. | N.S. | N.S. | N.S. | N.S. | N.S | N.S | N.S | N.S | N.S |
| **Nitrogen levels** | | | | | | | | | | |
| 25 kg N $ha^{-1}$ | 7.30 | 7.31 | 0.207 | 0.210 | 188.8 | 190.1 | 17.59 | 18.19 | 188.6 | 186.0 |
| 50 kg N $ha^{-1}$ | 7.26 | 7.27 | 0.212 | 0.215 | 193.2 | 195.2 | 18.29 | 18.97 | 194.8 | 190.0 |
| SE m± | 0.13 | 0.11 | 0.005 | 0.006 | 1.60 | 1.91 | 0.24 | 0.29 | 2.43 | 1.88 |
| CD 5% | N.S. | N.S. | N.S. | N.S. | N.S | N.S | N.S | N.S | N.S | N.S |

**Available Nitrogen, Phosphorus and Potassium in Soil (kg ha$^{-1}$)**

**Direct effect of treatments:** Data presented in (Table.2) revealed that application of 100% RDF resulted in improved availability of soil nutrients such as nitrogen, phosphorus, and potassium as compared to lower levels of fertility through the differences among the fertility levels did not able to exert significant effect on soil available nitrogen, phosphorus and potassium after the harvest of fodder oat during both the years of study. The results corroborate the findings of Raghuveer and Bohra [23].

Application of organic sources resulted in lucid improvement in soil nutrient status after harvesting of fodder oat. Among different organic sources, FYM recorded significantly higher soil available nitrogen, phosphorus, and potassium than vermicompost. However, the differences between the application of FYM and poultry manure remained comparable during both the years of experimentation (Table 2). This could be attributed to the addition of organic manures, which slowly released the nutrients (NPK) to the soil and produced organic acids during the faster decomposition of manures due to enhanced activity of beneficial soil microbes, which helped in better mineralization and solubilization of nutrients thus improving soil NPK status. More availability of soil nutrients may be ascribed to FYM’s efficiency, which increases soil porosity and water holding capacity, thus allowing more nutrients to retain [24]. The findings are similar to those of Malik and Singh [25] Bajpai et al*.,* [26]. They reported that available nitrogen, phosphorus, and potassium content in soil were more when nutrients were supplied through FYM or vermicompost along with inorganic fertilizers to the preceding crops.

Increasing the dose of nitrogen from 25 to 50 kg ha$^{-1}$ applied through organic sources resulted in a specific enhancement in soil available nutrients. Application of 50 kg N ha$^{-1}$ significantly increased the soil available nitrogen, phosphorus and potassium when applied through organic manures during the course of study (Table. 2). The increase in soil nitrogen, phosphorus and potassium was 2.7%, 4.9% and 4.1%, respectively in 2018-19 and 3.0%, 7.2% and 3.56%, respectively in 2019-20. This might be due to applying higher doses of nitrogen through organic sources, which resulted in an enhanced soil microbial population that converted the organically bound nitrogen to inorganic form through mineralization. Higher phosphorus availability may be ascribed to the addition of nitrogen through organic manures, which not only improved the solubilization of fixed soil phosphorus but also restricted its fixation. Similarly, greater potassium availability might be due to the addition of a higher amount of potassium from the exchangeable pool to the available pool [26]. Similar results have also been reported by Pandey [27-29].

**Residual effect of treatments:** A close examination of the data revealed that the application of various fertility levels did not influence soil available nitrogen, phosphorus and potassium content. However, the highest values were obtained at 100% RDF over the lower levels of fertility (Table.3). The application of FYM recorded maximum soil available nitrogen, phosphorus, and potassium, though the differences among the sources did not touch the level of significance (Table.3). Likewise, application of nitrogen through organic sources did not bring any significant difference on soil available nitrogen, phosphorus and potassium during the period of investigation. Nonetheless, maximum available nitrogen, phosphorus, and potassium were registered with 50 kg N ha$^{-1}$ over 25 kg N ha$^{-1}$ (Table.3).

## 4. CONCLUSION

The above experiment concluded that the direct effect of fertility levels did not significantly affect the soil health. Similarly, various organic sources and application of nitrogen level through organic sources failed to directly affect soil pH and electrical conductivity in 2018-19 and 2019-20. At the same time, the application of 50 kg N ha$^{-1}$ through FYM recorded significant effect on soil available N, P, and K after the harvest of fodder oat. However, all the treatments failed to exhibit any residual impact on soil health during the study. Therefore, the application of 100% RDF along with 50 kg N ha$^{-1}$ through FYM can be practiced to maintain soil health in eastern Uttar Pradesh.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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