CHAPTER 6:

OBJECTIVE 3
6.1. RESULTS

6.1.1. Cumulative CO\textsubscript{2} emission

Results of CO\textsubscript{2} evolution with time showed a rapid increase of CO\textsubscript{2} evolution during the first week of incubation irrespective of treatments followed by a steady decrease till the end of the incubation experiment (Figure 6.1-6.6). In all the experiments, T1 recorded significantly lower rate of CO\textsubscript{2} evolution which resulted in the lowest cumulative CO\textsubscript{2} emission. Treatments with only inorganic fertilizers (T2 and T3) recorded lower CO\textsubscript{2} emission compared to the organic amendment applied plots (T3 to T12). Among the organics, the highest cumulative CO\textsubscript{2} emission was documented from FYM applied soil (T4) followed by vermicompost (T5) while, biochar application (T6) noted the lowest. In general, the average soil C-mineralization rate during 90 days of incubation exhibited the following trend: FYM > vermicompost > biochar > only inorganic > control.

An increased rate of C mineralization was documented due to continuous application of organic amendments over two years. Irrespective of the applied organic amendments, the rate of C-mineralization increased from experiment 1 (Figure 6.1) to experiment 6 (Figure 6.6).

6.1.2. Half-life of C and mineralization kinetics

The calculated first order rate constants ($k$) from the laboratory experiments varied from 0.008 day$^{-1}$ to 0.025 day$^{-1}$ (Table 6.1). Continuous application of organic amendments increased the $k$ value. Treatment with FYM (T7) recorded the highest value for rate constant ($k$) and the lowest was recorded in treatment T1, T2 and T3.

Control soil (T1) and only inorganic fertilizer applied soil (T2 and T3) recorded higher C half-life than that of the organic amendment applied soil (Figure 6.7). Among the organics, the half-life of C was highest in biochar (T6, T9 and T12) followed by vermicompost (T5, T8 and T11) amended soil in all the six laboratory experiments. Continuous application fertilizers (inorganic and organic) noted a decrease in C half-life from experiment 1 (with soil collected at harvest of wheat in year 1) to experiment 6 (with soil collected at harvest of green gram in year 2). However, among the organic amendments, biochar applied soil documented the lowest decrease in C half-life when compared from experiment 1 to experiment 6.
Figure 6.1: Soil C-mineralization during 90 days of incubation under application of organic and inorganic fertilizers (Soil collected after harvest of wheat, year 1)

Figure 6.2: Soil C-mineralization during 90 days of incubation under application of organic and inorganic fertilizers (Soil collected after harvest of okra, year 1)
Figure 6.3: Soil C-mineralization during 90 days of incubation under application of organic and inorganic fertilizers (Soil collected after harvest of green gram, year 1)

Figure 6.4: Soil C-mineralization during 90 days of incubation under application of organic and inorganic fertilizers (Soil collected after harvest of wheat, year 2)
Figure 6.5: Soil C-mineralization during 90 days of incubation under application of organic and inorganic fertilizers (Soil collected after harvest of okra, year 2)

Figure 6.6: Soil C-mineralization during 90 days of incubation under application of organic and inorganic fertilizers (Soil collected after harvest of green gram, year 2)
Figure 6.7: Half-life of C under different treatments (Soil collected after harvest of wheat, okra and green gram in year 1 and 2)

Table 6.1: Rate constant of first order kinetics ($k$ in day$^{-1}$) under different treatments in soil collected after harvest of wheat, okra and green gram in year 1 and 2

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Year 1</th>
<th>Year 2</th>
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<tbody>
<tr>
<td></td>
<td>Wheat</td>
<td>Okra</td>
</tr>
<tr>
<td>T1</td>
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<td>0.008</td>
</tr>
<tr>
<td>T2</td>
<td>0.008</td>
<td>0.008</td>
</tr>
<tr>
<td>T3</td>
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</tr>
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<td>0.020</td>
</tr>
<tr>
<td>T5</td>
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<td>0.015</td>
</tr>
<tr>
<td>T6</td>
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<td>0.011</td>
</tr>
<tr>
<td>T7</td>
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<td>0.022</td>
</tr>
<tr>
<td>T8</td>
<td>0.016</td>
<td>0.015</td>
</tr>
<tr>
<td>T9</td>
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<td>0.012</td>
</tr>
<tr>
<td>T10</td>
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<td>0.022</td>
</tr>
<tr>
<td>T11</td>
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<td>0.020</td>
</tr>
<tr>
<td>T12</td>
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</tr>
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</table>
6.2. DISCUSSION

The results of CO$_2$ released during incubation study were used to assess the rate of C-mineralization in soil amended with different organic amendments and inorganic fertilizers. The curvilinear pattern of C-mineralization observed in this study under different treatments indicated the presence of different SOC pools that releases C at different rates following the first-order kinetic equation [1].

Continuous cultivation without the external input of fertilizers causes depletion of nutrients and negatively affects the soil physical, chemical and biological parameters leading to an unfavorable environment for the microbial growth and in turn reduced the CO$_2$ emission. This explains the lower values of C-mineralization in the control plots irrespective of the experiments which also resulted in higher half-life of C. The results of lower C-mineralization in control soil than that of amended soil is in confirmation with the findings of Li et al. [2].

In the present investigation, lower C-mineralization was recorded from only inorganic applied soil compared to only organic amendment applied soil. In inorganic fertilizer applied soil, C-mineralization occurs mainly in the first two weeks and ceases thereafter till the end of the incubation period. Urea addition stimulates C-mineralization and release of CO$_2$ from urea hydrolysis [(NH$_2$)$_2$CO + 3H$_2$O = 2NH$_4$+ + CO$_2$ + 2OH$^-$]. Thus, the priming effect of urea addition causes a net soil C loss due to formation of ammonia and CO$_2$ from urea [3] following which the rate of C-mineralization is reduced. Production of the hydrolysis product of inorganic N (from urea to NH$_4$-N) [4] and lack of C substrate till the end of the incubation period restricts the microbial activity thereby reducing the C-mineralization in only inorganic fertilizer applied soil.

The enhanced C-mineralization with the addition of organic amendment in soil is related to the availability of easily degradable C pool and higher activities of microbes and enzymes under application of organic amendments [5] Moreover, application of inorganic fertilizers along with organic amendments (Treatment T6 to T12) in our experiment increased the cumulative CO$_2$ emission and reduced the C half-life which can be explained by the cumulative effects of inorganic fertilizers and organic amendments on SOC mineralization. Our results on higher activities of soil enzymes (urease, phosphatase and dehydrogenase) and presence of higher labile SOC fractions (POC,
MBC) under these treatments further elucidate the fact. Being a major source of SOM, addition of organic amendments stimulates microbial decomposition of SOM as the first phase of organic matter mineralization is governed by the content of soluble material in it [6].

Among the organics, FYM applied soil noted the highest mineralization rate while biochar showed the lowest. Soil microorganisms require a favourable C/N ratio during the decomposition process [7]. Thus, the presence of favorable C/N ratio in vermicompost (12.21) and FYM (15.61) compared to biochar (65.34) promoted higher microbial activity and thereby increases the CO₂ emission and mineralization rate. Moreover, the increased activity of soil enzymes such as dehydrogenase, urease and phosphatase in FYM and vermicompost applied soil further contributed to increase the mineralization rate. Higher activities of indigenous microbes and less humified C in FYM accelerate microbial and enzymatic activities in soil and thereby increase the cumulative CO₂ emission. Lower C-mineralization in vermicompost compared to manure is reported by Morvan and Nicolardot [8]. Contrary to this, the presence lesser amount of labile C substrate for microbial activity in biochar resulted in reduced cumulative CO₂ emission in our experiment. Dossa et al. [9] working with crop residues also suggested that the application of low N concentration and incorporation of amendment with high C/N ratio immobilize N and decrease CO₂ emissions. Similar results higher C-mineralization in manure and compost applied soil compared to biochar applied soil has been documented by Ngo et al. [10].

The rate constant \( (k) \) of the first order kinetic equation is inversely related to the residence time of substrate and often used to derive the carbon turnover period in soil [11]. From our experiment, the obtained lower value of \( k \) under biochar application compared to vermicompost and FYM indicated that biochar has greater potentiality to resist mineralization and hence, can store the C for longer time as evident from the recorded higher half-life of C under biochar application. Presence of organic matter that are resistant to decomposition and mineralization in biochar had been earlier [12,13]. The relatively lower C-mineralization rate under biochar application indicates significant C-sequestration potential of this amendment in comparison to vermicompost and FYM.
In the present investigation, continuous application of fertilizers increased the mineralization rate and decreased the C half-life. The possible reason for such increase is the addition of labile SOC fractions (as evident from the results of objective 2), which might have created environment conducive for higher microbial activities and thereby increasing the CO₂ emission. Also the combined mineralization of previously applied organics along the recently added organics might have resulted in the increased mineralization rate. The inclusion of leguminous crop (green gram) in the crop sequence further promoted favorable environment and nutrients for microbes. The positive response of C-mineralization to the inclusion of cover crops has also been reported by Li et al. [2].

6.3. Salient findings

- The emission of CO₂ i.e. SOC mineralization increases with the addition of fertilizers. And this is further aggravated with the incorporation of organic amendment.
- Lack of nutrients in control soil results in reduced C-mineralization.
- Among the studied organic amendments, biochar amended soil showed the lowest C-mineralization while FYM showed the highest.
- C-mineralization rate increases with the continuous application of fertilizers which consequently increase the kinetic rate constant \((k)\) and reduce the half-life of C.
- Biochar application shows higher C half-life even under continuous application for two years in the acidic inceptisols of northeast India.
Chapter 6 – Objective 3

References


