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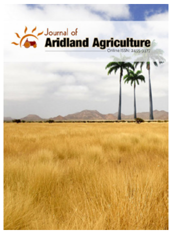


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# Carbon balance in Maize (*Zea mays* L.) with various combinations of organic and inorganic fertilizers

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## ABSTRACT

Fertilization in agricultural cultivation has an important role in the carbon cycle. This study aims to evaluate using organic fertilizers with inorganic fertilizers that can produce high carbon sequestration with low $CO_2$ emission levels in maize (*Zea mays* L.) cultivation. There were seven combinations of NPK and organic fertilizers, namely ¼ NPK + 1 OF (C), ½ NPK + 1 OF (D), ¾ NPK + 1 OF (E), 1 NPK + 1 OF (F), ¾ NPK + ¼ OF (G), ¾ NPK + ½ OF (H), ¾ NPK + ¾ OF (I), and two controls, namely no fertilizer (A) and standard NPK (350 kg/ha, SP36 150 kg/ha, KCl 75 kg/ha) (B). Organic fertilizer was applied one week before planting, SP-36 and KCl fertilizer at planting, and urea fertilizer at 0, 14, and 28 HST. Maize was planted with a spacing of 20 x 70 cm. Parameters observed included $CO_2$ emissions, soil pH, C-Organic, C-microbial, and plant growth parameters. The combined use of NPK and organic fertilizer significantly increased soil carbon stocks (33.25-64.04 Mg/ha) and carbon sequestration by plants (3.76-5.98 Mg/ha). Therefore, using organic and inorganic fertilizer can be considered more environmentally friendly and effective in managing carbon balance on farmland and has great potential to contribute to climate change mitigation through increased soil and plant carbon sequestration.

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**KEYWORDS:** Carbon Sequestration, $CO_2$ Emissions, Soil C-Stock

## INTRODUCTION

Rising temperatures due to global warming have led to a decline in production on agricultural land (Chauhan *et al.*, 2014). A nearly fifty percent increase in the concentration of carbon dioxide ($CO_2$) in the atmosphere, from 280 ppm in 1750 to 414.7 ppm in May 2019 (Nema *et al.*, 2012; Wu *et al.*, 2020), often considered to be a significant contributor to global warming and climate change (Li *et al.*, 2013; Al-Ghussain, 2019). One of the causes of increased carbon dioxide ($CO_2$) concentrations is agricultural activities such as tillage and fertilization.

Fertilization using inorganic fertilizers has contributed to increasing $CO_2$, this is one of the triggers for global warming in the agricultural sector, as is the use of organic fertilizers. Inorganic fertilizers can contribute to $CO_2$ emissions through increased root respiration (Chu *et al.*, 2007). At the same time, it can also increase the absorption of $CO_2$ by the leaves through photosynthesis (Kartikawati & Nursyamsi, 2013). Using organic fertilizers can also contribute to $CO_2$ emissions from mineralization and microbial activity (Maswar *et al.*, 2014). However, the use of organic fertilizer has other advantages, namely organic fertilizers can increase soil nutrient availability, microbial activity, and microbial diversity (Yuan *et al.*, 2017), and increase soil C-Stock (Zuo *et al.*, 2023). Although the use of organic fertilizer can increase $CO_2$ emissions, on the other hand, it can also reduce $CO_2$ emissions by increasing C-stock. Various studies on $CO_2$ emissions and C sequestration have been conducted, such as $CO_2$ emissions in pineapple cultivation in the tropics (Liang *et al.*, 2022), the cultivation of wheat, rice, and maize (Shakoor *et al.*, 2022), in rice-wheat rotation (Zhang *et al.*, 2016), and onion plants (Suwandi *et al.*, 2015).

The increase in the amount of $CO_2$ must be controlled by increasing the amount of $CO_2$ absorbed by plants and suppressing the emission of $CO_2$ back into the air (Ferrini *et al.*, 2020). Thus, it is crucial to quantify the variability of carbon stocks and fluxes through on-farm carbon balance (Béziat *et al.*, 2009; Wang *et al.*, 2015). However, most previous research on carbon balance has focused on forest and grassland ecosystems and only a tiny proportion of agricultural land (Machado *et al.*, 2016). The use of organic fertilizer is the main choice in efforts to reduce CO2 emissions. Several previous studies have reported that the use of organic amendments can produce the highest carbon balance in horticultural crops (Persiani *et al.*, 2019), upland rice (Dossou-Yovo *et al.*, 2016), and wheat crops (Roß *et al.*, 2022). In practice, the use of organic fertilizer affects the availability of nutrients in the soil because it is slow-release. In fact, plants need nutrients for growth, so the addition of inorganic fertilizer is still needed. The use of inorganic fertilizers is related to carbon absorption. According to (Rasse *et al.*, 2005; Russell *et al.*, 2009) increasing the nitrogen fertilization dose is also recommended to increase soil carbon sequestration due to increased aboveground biomass. However, the increased carbon uptake resulting from increased nitrogen fertilization may be offset by high $CO_2$ emissions to the atmosphere (Liu *et al.*, 2019). More effective efforts are needed to reduce $CO_2$ emissions, one of which is by integrating organic and inorganic fertilizers. Based on these data, it appears that different fertilization patterns have other impacts on carbon balance. However, there is little information on the integrated assessment of the effects of organic and inorganic fertilizer balances on soil C balance processes. This study aims to evaluating the use of organic fertilizers with inorganic fertilizers that can produce high carbon sequestration with low $CO_2$ emission levels in maize (*Z. mays* L.) cultivation.

## MATERIALS AND METHODS

The research was conducted in Klaten, Central Java (7°63'70.053" LS 110°70'04.27" East) from August 2021 to March 2022 on Inceptisol soil with the characteristics presented in Table 2. This field experiment used a randomized complete block design (RCBD) consisting of 7 treatments of NPK and organic fertilizer combinations, namely ¼ NPK + 1 organic fertilizer (C), ½ NPK + 1 organic fertilizer (D), ¾ NPK + 1 organic fertilizer (E), 1 NPK + 1 organic fertilizer (F), ¾ NPK + ¼ organic fertilizer (G), ¾ NPK + ½ organic fertilizer (H), ¾ NPK + ¾ organic fertilizer (I) and two control treatments consisting of no fertilizer (A) and standard NPK (350 kg/ha, SP36 150 kg/ha, KCl 75 kg/ha) (B) (Table 1). Crumb organic fertilizer with the properties in Table 3 was applied one week before planting, SP-36, and KCl fertilizers at planting while urea fertilizer at 0, 14, and 28 DAP. The experimental plot size was 20 $m^2$ (4 m x 5 m) with a planting distance of 20 cm x 70 cm. Maintenance was carried out as usual by farmers.

$CO_2$ emissions were measured three times at 35, 49, and 63 HST with a modified Alkali Trap method (Figure 1) (Franzluebbers & Veum, 2020). Measurements were taken in the morning to minimize daily variations and obtain representative daily average soil $CO_2$ emissions (Xu & Qi, 2001). Samples of disturbed soil were taken at a depth of 0-20 cm to measure various parameters, including soil pH (potentiometry), which was measured three times along with emission sampling (Oladele & Adetunji, 2021), C-Organic (Walkey and Black) (Romadhan *et al.*, 2022), and C-microbe (Fumigation and Extraction) (Rotbart *et al.*, 2017), while Bulk density is measured using undisturbed soil samples taken with a sampling ring (Gravimetric method) (Irawan *et al.*, 2022). Dry plant biomass was calculated using two plant samples in each plot (Gravimetric Method) (Ekowati & Nasir, 2011).

Soil $CO_2$ emissions are calculated using the equation:

Soil $CO_2$ emissions $\left(\frac{mg}{m^2}\right) = (C - S)\ x\ N\ x\ E$ (Ölinger *et al.*, 1996) (1)

The formula calculates soil C-stock:

SOC Stock (Mg C $ha^{-1}$) = [SOC %] x BD 0-20 cm (g/$cm^3$) x D (0,2 m) (Li *et al.*, 2017; Abera *et al.*, 2021) (2)

The amount of carbon in plant biomass is calculated using the following formula:

C = Biomassa x % C Biomassa (IPCC, 2006) (3)

Carbon balance is calculated using the formula:

Carbon balance: C soil input - C soil output (Singh *et al.*, 2009; Sainju *et al.*, 2021) (4)

The research data were analyzed using Analysis of Variance (Anova) with a confidence level of 95%. If the results of Anova achieved are significantly different, it is continued with Duncan's Multiple Range Test (DMRT) to determine differences between treatment means and Pearson -elation test to see the relationship between variables.

## RESULTS AND DISCUSSION

Soil $CO_2$ emission is the release of $CO_2$ from root respiration, soil microbes, and fauna in the subsoil through biological processes by converting organic carbon into $CO_2$ (Ebrahimi *et al.*, 2019). $CO_2$ emissions were significantly affected by organic and inorganic fertilizers (p=0.000). The average $CO_2$ emissions produced ranged from 1.92-6.16 mg $CO_2$/$m^2$/week and increased with increasing doses of organic fertilizer. This result is consistent with Liu *et al.* (2011) that the balanced application of organic and inorganic fertilizers resulted in higher $CO_2$ emissions than NPK-only and no-fertilizer treatments due to increased microbial activity from organic amendments. Organic fertilizers applied can increase soil C (Zulkarnain *et al.*, 2013; Syamsiyah *et al.*, 2023a, b) and will supply nutrients for microorganisms as well as stimulate heterotrophic soil respiration and $CO_2$ emission (Wang *et al.*, 2022). This can be seen in the positive correlation between $CO_2$ emissions and soil organic C (r=0.834**) and C-microbe (r=0.527**). The same thing was also stated by De Urzedo *et al.* (2013) and Syamsiyah *et al.* (2019) that $CO_2$ emissions on farmland increase after organic fertilizer application due to the rise in the supply of labile C to soil microorganisms, thereby increasing the activity of microorganisms and resulting in an increase in soil $CO_2$ emissions.

Table 1: Experimental treatment design

| S. No. | Treatment | Organic Fertilizer (kg/h) | NPK fertilizer (kg/h) | | |
|---|---|---|---|---|---|
| | | | Urea | SP36 | KCl |
| 1 | No fertilizer | 0 | 0 | 0 | 0 |
| 2 | Standard NPK | 0 | 350 | 150 | 75 |
| 3 | ¼ NPK+1 Organic Fertilizer | 10000 | 87.5 | 37.5 | 18.75 |
| 4 | ½ NPK+1 Organic Fertilizer | 10000 | 175 | 75 | 37.5 |
| 5 | ¾ NPK+1 Organic Fertilizer | 10000 | 262.5 | 112.5 | 56.25 |
| 6 | 1 NPK+1 Organic Fertilizer | 10000 | 350 | 150 | 75 |
| 7 | ¾ NPK + ¼ Organic Fertilizer | 2500 | 262.5 | 112.5 | 56.25 |
| 8 | ¾ NPK + ½ Organic Fertilizer | 5000 | 262.5 | 112.5 | 56.25 |
| 9 | ¾ NPK + ¾ Organic Fertilizer | 7500 | 262.5 | 112.5 | 56.25 |

Table 2: Characteristics of Inceptisol Soil at the Research Site

| S. No. | Parameter | Value | Unit | Rating* |
|---|---|---|---|---|
| 1 | N-total | 0.28 | % | Medium |
| 2 | P-available | 1.17 | ppm | Very Low |
| 3 | K-available | 0.46 | (me/100 g) | Medium |
| 4 | C-Organic | 1.55 | % | Low |
| 5 | pH | 6.5 | - | Somewhat Acidic (5.5-6.5) |
| 6 | BV | 0.92 | ($g/cm^3$) | Medium |

Source: Primary data. *Based on the scoring of the Indonesian Soil Research Institute (2023)

Table 3: Analytical results of solid organic fertilizer

| S. No. | Parameter | Value |
|---|---|---|
| 1 | Moisture Content (%) | 20.08% |
| 2 | N-total (%) | 1.32% |
| 3 | $P_2O_5$ (%) | 2.62% |
| 4 | $K_2O$ (%) | 1.38% |
| 5 | pH | 7.69 |
| 6 | C-Organic (%) | 22.51% |
| 7 | C/N | 17.05 |

Table 4: Average $CO_2$ emission values at various organic and inorganic fertilizer balances. The highest $CO_2$ emission values were dominated by the balance treatment with high organic fertilizer doses

| Treatment | Soil $CO_2$ emission (mg $CO_2/m_2$/week) |
|---|---|
| No fertilizer | 1.92[c] |
| Standard NPK | 4.73[b] |
| ¼ NPK+1 Organic Fertilizer | 5.62[a] |
| ½ NPK+1 Organic Fertilizer | 5.74[a] |
| ¾ NPK+1 Organic Fertilizer | 5.80[a] |
| 1 NPK+1 Organic Fertilizer | 6.16[a] |
| ¾ NPK + ¼ Organic Fertilizer | 4.19[b] |
| ¾ NPK + ½ Organic Fertilizer | 4.72[b] |
| ¾ NPK + ¾ Organic Fertilizer | 5,81[a] |

Different lowercase letters in rows and columns indicate significant differences at 5% DMRT

On the other hand, the application of inorganic fertilizers results in high plant growth (Rahayu *et al.*, 2019; Baharuddin & Sutriana, 2020), including plant roots (Serri *et al.*, 2021; Syamsiyah *et al.*, 2023c), so that root respiration increases and causes $CO_2$ emissions, this can be seen in the correlation between $CO_2$ emissions and root biomass (r=0.330*) (Figure 2). These results align with research by Oladele and Adetunji (2021) that applying

Table 5: Correlation between $CO_2$ emissions and soil properties

| | RB | pH | SOC | C-mic |
|---|---|---|---|---|
| Soil $CO_2$ emission | 0.330* | 0.568** | 0.834** | 0.527** |

RB=Root Biomass, SOC=Soil Organic Carbon, C-mic=C-microba, * and ** indicate significance at $p<0.05$ and $p<0.01$, respectively

Table 6: Average soil C-stock values at different organic and inorganic fertilizer rates. Soil C-stock was lower in the treatment without organic fertilizer addition

| Treatment | Soil C-Stock (Mg/ha) |
|---|---|
| No fertilizer | 28.55[d] |
| Standard NPK | 32.53[d] |
| ¼ NPK+1 Organic Fertilizer | 50.25[c] |
| ½ NPK+1 Organic Fertilizer | 58.61[ab] |
| ¾ NPK+1 Organic Fertilizer | 59.13[ab] |
| 1 NPK+1 Organic Fertilizer | 64.04[a] |
| ¾ NPK + ¼ Organic Fertilizer | 33.25[d] |
| ¾ NPK + ½ Organic Fertilizer | 50.78[c] |
| ¾ NPK + ¾ Organic Fertilizer | 53.51[bc] |

Different lowercase letters in rows and columns indicate significant differences at 5% DMRT

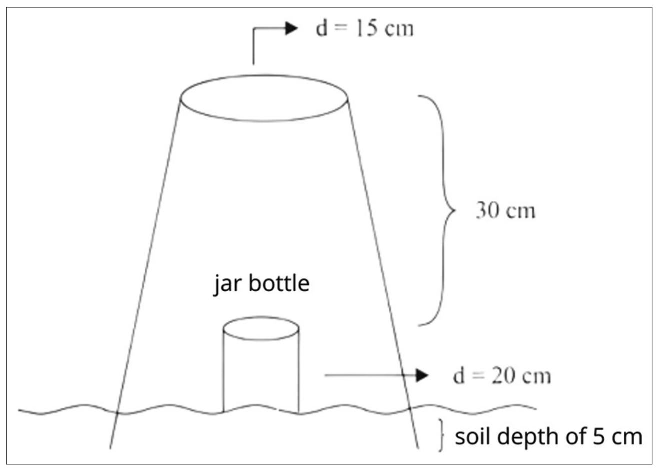


**Figure 1:** Schematic of alkali trap installation (Modified alkali trap (Singh *et al.*, 2009))

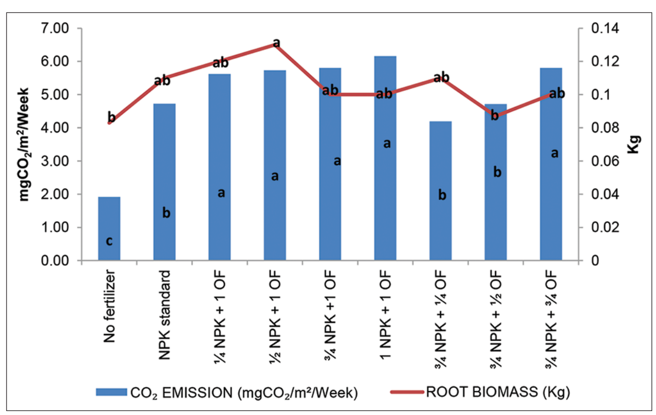


**Figure 2:** Relationship pattern of $CO_2$ emission and root biomass in various treatments. Bars and lines represent means (n=9) and the same letter appearing on bars and lines throughout the figure indicates no significant difference (according to DMRT test) (Description: Statistical analysis).

**Table 7: The average value of plant carbon sequestration in various combinations of organic and inorganic fertilizers. The highest carbon sequestration value was achieved in the balanced treatment with high addition of organic fertilizer**

| Treatment | Plant Biomass Weight (Kg) | | | Plant Biomass C Content (%) | | | Plant Biomass C Sequestration (Mg/ha)* | | | Plant Carbon Sequestration (Mg/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Stem | Leaf | Root | Stem | Leaf | Root | Stem | Leaf | Root | |
| No fertilizer | 0.063 | 0.023 | 0.083 | 43.31 | 4.89 | 2.83 | 1.92 | 0.08 | 0.16 | 2.17[d] |
| Standard NPK | 0.087 | 0.040 | 0.110 | 52.15 | 6.06 | 4.90 | 3.09 | 0.17 | 0.38 | 3.65[c] |
| ¼ NPK+1 OF | 0.120 | 0.039 | 0.120 | 55.01 | 6.53 | 5.89 | 4.78 | 0.18 | 0.48 | 5.44[ab] |
| ½ NPK+1 OF | 0.120 | 0.040 | 0.130 | 58.31 | 6.19 | 5.76 | 4.97 | 0.18 | 0.55 | 5.69[a] |
| ¾ NPK+1 OF | 0.123 | 0.039 | 0.100 | 56.16 | 6.27 | 5.60 | 4.94 | 0.18 | 0.40 | 5.51[a] |
| 1 NPK+1 OF | 0.120 | 0.043 | 0.100 | 61.74 | 6.74 | 6.13 | 5.33 | 0.21 | 0.45 | 5.98[a] |
| ¾ NPK + ¼ OF | 0.083 | 0.033 | 0.110 | 52.18 | 6.19 | 5.71 | 3.14 | 0.15 | 0.47 | 3.76[c] |
| ¾ NPK + ½ OF | 0.110 | 0.037 | 0.087 | 54.24 | 6.50 | 5.70 | 4.25 | 0.17 | 0.35 | 4.77[b] |
| ¾ NPK + ¾ OF | 0.123 | 0.041 | 0.100 | 53.53 | 6.46 | 6.15 | 4.66 | 0.19 | 0.44 | 5.29[ab] |
| Average C Sequestration of Plants (Mg/ha) | | | | | | | | | | 4.69 |

Different lowercase letters in rows and columns indicate significant differences at 5% DMRT. *Biomass C sequestration=Biomass weight x C biomass %

**Table 8: The average value of N, P, and K nutrient uptake in various combinations of organic and inorganic fertilizers**

| Treatment | Nutrient Uptake | | |
|---|---|---|---|
| | N (g/plant) | P (g/plant) | K (g/plant) |
| No fertilizer | 1.27[f] | 0.28[h] | 0.86[e] |
| Standard NPK | 3.17[de] | 0.76[fg] | 2.03[cd] |
| ¼ NPK+1 Organic Fertilizer | 2.91[e] | 0.98[cd] | 2.39[ab] |
| ½ NPK+1 Organic Fertilizer | 3.43[cd] | 1.11[ab] | 2.54[a] |
| ¾ NPK+1 Organic Fertilizer | 4.03[ab] | 1.07[bc] | 2.31[abc] |
| 1 NPK+1 Organic Fertilizer | 4.38[a] | 1.22[a] | 2.59[a] |
| ¾ NPK + ¼ Organic Fertilizer | 3.31[d] | 0.68[g] | 1.91[d] |
| ¾ NPK + ½ Organic Fertilizer | 3.73[bc] | 0.83[ef] | 2.15[bcd] |
| ¾ NPK + ¾ Organic Fertilizer | 4.13[a] | 0.94[de] | 2.37[abc] |

Different lowercase letters in rows and columns indicate significant differences at 5% DMRT

**Table 9: Average values of plant growth at various balances of organic and inorganic fertilizers**

| Treatment | Plant Growth | | |
|---|---|---|---|
| | Plant Height (cm) | Number of Leaves (blades) | Stem Diameter (mm) |
| No fertilizer | 151[c] | 12[c] | 2.99[c] |
| Standard NPK | 180[b] | 14[ab] | 3.72[ab] |
| ¼ NPK+1 Organic Fertilizer | 183[ab] | 13[bc] | 3.94[ab] |
| ½ NPK+1 Organic Fertilizer | 194[ab] | 14[ab] | 3.99[ab] |
| ¾ NPK+1 Organic Fertilizer | 200[a] | 15[ab] | 4.10[ab] |
| 1 NPK+1 Organic Fertilizer | 202[a] | 15[a] | 4.16[a] |
| ¾ NPK + ¼ Organic Fertilizer | 198[ab] | 13[bc] | 3.97[ab] |
| ¾ NPK + ½ Organic Fertilizer | 191[ab] | 13[bc] | 3.90[ab] |
| ¾ NPK + ¾ Organic Fertilizer | 191[ab] | 13[bc] | 3.64[b] |

Different lowercase letters in rows and columns indicate significant differences at 5% DMRT

high N fertilizer can increase plant growth and root biomass, which affects the level of plant root respiration. Root respiration at the ecosystem level is the result of multiplying specific root respiration and root biomass. In other words, the total $CO_2$ released through root respiration in the ecosystem is directly related to the total amount of root mass in the soil. An increase in root biomass leads to more metabolically active root tissues, thus producing more $CO_2$ (Jarvi & Burton, 2020). Conversely, a decrease in root biomass will reduce total root respiration due to less root tissue involved in the process. $CO_2$ emissions were also influenced by an increase in soil pH (r=0.568**) (Table 5), low soil pH can inhibit soil microbial activity. Soil acidity can be reduced by applying soil amendments, where these soil amendments can not only increase soil pH but also play a role in increasing microbial activity which has an impact on increasing heterotrophic respiration and ultimately contributes to increasing soil respiration (Zhang *et al.*, 2019). Soil pH can increase cellulose decomposition by almost twofold due to increased soil microbial activity, leading to more excellent emission release (Moilanen *et al.*, 2012). The combination of ½ NPK and 1 organic fertilizer (10 tons/ha) produced lower $CO_2$ emissions than 1 NPK and 1 organic fertilizer, although not significantly different, but higher than no fertilizer and standard NPK (Table 4). This is thought to be related to root weight, where this treatment has the highest root weight compared to other treatments.

Efforts to increase carbon storage in soil can reduce $CO_2$ levels in the atmosphere. The results showed that soil C-Stock content was significantly influenced by organic fertilizer and inorganic fertilizer (p=0.000). In the treatment given organic fertilizer input, the soil C-Stock value was higher due to the supply of organic matter (Table 6). This result is consistent with Zhang *et al.* (2022) that the simultaneous application of mineral and organic fertilizers can increase soil C-Organic.

The balance of ½ NPK and 1 organic fertilizer produced soil C-Stock that was not significantly different from 1 NPK and 1 organic fertilizer and higher than no fertilizer and standard NPK (Table 6). These results align with Brar *et al.* (2013) that the application of a combination of organic and inorganic fertilizers with a proportion of 100% NPK + FYM (farmyard manure) significantly increased soil carbon sequestration and was able to increase soil organic carbon content up to 88%. Zuo *et al.* (2023) state that carbon inputs in crop residues and manure are essential in soil organic carbon sequestration, which can directly increase soil C-Stock. Applying organic fertilizers to replace synthetic N fertilizers (with equivalent N levels) can significantly increase annual SOC sequestration by about 700 kg C $ha^{-1}$ $year^{-1}$ in upland soils (Xia *et al.*, 2017).

$CO_2$ emission levels can be reduced by increasing the amount of $CO_2$ sequestration by plants. In this study, plant carbon

**Table 10: The average value of plant carbon balance in various combinations of organic and inorganic fertilizers**

| Treatment | C- INPUT | | | | | C- OUTPUT | Carbon balance (Kg/ha) |
|---|---|---|---|---|---|---|---|
| | Plant Biomass C Sequestration (Kg/ha) | | | Soil C-Stock (Kg/ha) | C-input of fertilizer (Kg/ha) | $CO_2$-C flux (Kg/ha) | |
| | Stem | Leaf | Root | | | | |
| No fertilizer | 1918.06 | 81.67 | 163.61 | 28554.41 | 0.00 | 0.22 | 30717.52[d] |
| Standard NPK | 3089.67 | 172.08 | 386.21 | 32529.23 | 0.00 | 0.54 | 36176.64[d] |
| ¼ NPK+1 OF | 4781.78 | 182.05 | 477.65 | 50252.25 | 1125.50 | 0.64 | 56818.58[c] |
| ½ NPK+1 OF | 4970.47 | 175.40 | 547.65 | 55648.14 | 1125.50 | 0.66 | 65425.43[ab] |
| ¾ NPK+1 OF | 4935.23 | 175.85 | 397.37 | 59131.79 | 1125.50 | 0.66 | 65765.08[ab] |
| 1 NPK+1 OF | 5329.69 | 206.37 | 446.69 | 64035.94 | 1125.50 | 0.70 | 71143.49[a] |
| ¾ NPK + ¼ OF | 3138.83 | 145.25 | 472.36 | 33246.12 | 281.38 | 0.48 | 37283.46[d] |
| ¾ NPK + ½ OF | 4245.59 | 172.31 | 350.58 | 50783.75 | 562.75 | 0.54 | 56114.44[c] |
| ¾ NPK + ¾ OF | 4661.83 | 188.07 | 437.63 | 53505.93 | 844.13 | 0.66 | 59636.92[bc] |

Different lowercase letters in rows and columns indicate significant differences at 5% DMRT

sequestration was significantly affected by organic fertilizer and inorganic fertilizer (p=0.000). This can be caused by an increase in soil fertility conditions due to an increase in organic carbon levels in the soil, where organic carbon levels act as a source of nutrients (Hairiah & Rahayu, 2007; Masryfah *et al.*, 2019; Punuindoong *et al.*, 2021) which affects plant growth (Purakayastha *et al.*, 2008). Plant carbon sequestration in various treatments ranged from 2.10-5.98 Mg/ha (Table 7). The experimental results showed that the treatment of ½ NPK and 1 organic fertilizer resulted in carbon sequestration, which was not significantly different from 1 NPK and 1 organic fertilizer and higher than no fertilizer and standard NPK. These results align with Sulaeman *et al.* (2016) that the input of organic fertilizer plus NPK fertilizer at a dose of 50 and 75% of the recommended dose can produce an increase in plant growth manifested in total biomass production and significantly increase carbon sequestration in biomass compared to the use of organic fertilizer alone. This can be seen in the correlation between total plant biomass and plant height (r=0.612**), number of leaves (r=0.423*), and stem diameter (r=0.548**).

The balance also achieved higher plant uptake of N, P, and K nutrients compared to no fertilizer and standard NPK (Table 8). The reduction of inorganic fertilizers balanced with organic fertilizers can increase the value of N-total, P-available, K-available in the soil so as to increase the uptake of N, P, and K nutrients in plant tissues (Table 9) (Syamsiyah *et al.*, 2023d), followed by increased plant growth where the element that plays the most role in increasing plant growth, especially plant height, is nitrogen nutrients (r=0.816**) (Syamsiyah *et al.*, 2020). Maize plants need nitrogen nutrients both in the vegetative growth phase and the generative phase. Nitrogen is a constituent in the hormone auxin, a plant growth hormone (Oleńska *et al.*, 2020). Plant physiological processes will produce height and width in plants, affecting the number of leaves (r=0.582**) (Marian & Tuhuteru, 2019). In addition, the results showed a positive correlation between stem diameter and potassium levels in plant tissue (r=0.721**). Potassium is an essential element that plays a vital role in increasing stem diameter due to its role in increasing the level of sclerenchyma in the stem, which provides thickening and strength to the stem tissue (Attia *et al.*, 2022). This also explains why the balanced treatment of organic and inorganic fertilizers in this study had higher plant C sequestration results than the treatment without fertilizer and standard NPK.

Carbon balance is calculated using all carbon inputs and outputs (Rutledge *et al.*, 2015). The soil's supply or carbon input can be achieved from photosynthesis and other organic matter from outside. Carbon output can be affected by the decomposition process due to the conversion of soil carbon into $CO_2$ (Liddicoat *et al.*, 2010). In this study, organic and inorganic fertilizers significantly affected the carbon balance (p=0.000). The average carbon balance of all treatments ranged from 30717.52-71143.49 Kg/ha (Table 10). The combination of ½ NPK and 1 organic fertilizer (10 tons/ha) produced a lower carbon balance than 1 NPK and 1 organic fertilizer, although not significantly different, but higher than no fertilizer and standard NPK (Table 10). The carbon balance results show that applying organic fertilizer causes higher $CO_2$ storage than $CO_2$ released. Fertile soil conditions accompanied by high plant productivity allow carbon input through photosynthesis to exceed the amount of carbon lost (Siringoringo, 2014; Persiani *et al.*, 2019). These results align with Xu *et al.* (2020) that tillage practices that can increase carbon inputs, such as applying organic fertilizers, are highly recommended because of their high efficiency in supporting soil carbon sequestration processes.

## CONCLUSIONS AND SUGGESTION

The use of a fertilizer combination of NPK and organic fertilizers significantly increased soil carbon stocks (33.25-64.04 Mg/ha) and carbon sequestration (3.76-5.98 Mg/ha). The integration of organic fertilizers with inorganic fertilizers has proven to be effective in increasing C sequestration, reducing production costs, and increasing agricultural productivity. Thus, the use of organic fertilizers in agricultural systems is essential to improve fertilizer use efficiency, maintain carbon balance, and reduce negative impacts on the environment.

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