Dynamics of CO_2 emission under sweet corn (*Zea mays* Saccharata) cultivation at ultisol applied with compost

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Abstract. One source of atmospheric carbon dioxide (CO_2) comes from agricultural activities, especially crop cultivation. This research was aimed to measure the amount of CO_2 emitted from Ultisol treated with compost during the cultivation of sweet corn. This research was a field experiment with 5 doses of compost (0, 5, 10, 15, and 20 T/ha) and 3 replications. The experimental units were allocated in the field according to a randomized block design (RBD). CO_2 emission was measured 4 times (initial, after compost application, maximum vegetative growth, and after harvest). The results showed that there were no significant differences in CO_2 emissions between experimental plots before compost application (at initial). However, CO_2 emissions were significantly different among treatments after compost application, at maximum vegetative growth, and after harvest. At the three measurements, CO_2 emissions increased by increasing doses of compost applied. In addition, laboratory analysis showed that the Ultisol at the research site had a clay texture (53.7% clay particles), low organic carbon (0.77%), and pH (5.21), high bulk density (1.14 Mg m^{-3}), and low total soil pore (56.31%). Although CO_2 emissions from the soil surface increased with increasing compost dosage, soil characteristics improved, and crop production increased.

Keywords: Cow dung compost, CO_2 emission, soil properties, sweet corn, Ultisols

1 Introduction

Carbon dioxide (CO_2) is one of greenhouse gases contributing to global warming. One source of CO_2 emitted to the atmosphere comes from agriculture. Based on FAO [1] agriculture sector contributed about 31% to global warming in 2019 due to human activities, including all activities for food crop production, especially when converting land

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from forest to farming land. From that amount, CO_2 contributed approximately 21% of the total CO_2 emision. Management given to agricultural land will impact on CO_2 emission and sequestration, such as tillage [2] fertilization process etc [3]. On the other hand, soil is also known as a carbon sequestration medium. This is found to be true since the CO_2 is converted to O_2 and carbohydrate through photosynthesis process by vegetation, either natural or cultivated plants. Sequestered organic matter (OM) will end with CO_2 emission from soil if it does not follow conservation rule in managing the land. As stated by Prasetyo *et al*. [4] that human activities using soils as the crop growth medium positively correlated to CO_2 emission.

There are some factors affecting CO_2 emission from agricultural land, for examples were land use, soil types, land management, and soil tillage, besides climate factors. especially rainfall and temperature [5]. Different soil managenet, especially tillage practice can result in different CO_2 emission although other factors are the same [2] . This is due to differences in soil physical properties, with soil texture being one of the most influential factors. The finer the soil texture is the more OM sequestered in the soils [6]. It is due to the fact that fine textured soils having high clay particles produce small sized pores which cannot be accessed by decomposing organisms. It means that it is physically protected within the soils [7].

One of fine textured soil mostly used for agriculture in the tropics is Ultisols. Ultisols as an advance weathered soil in general contains high clay and, less OM content [8]. Therefore, the soil is dominated by micropores and less macropores. The characteristics having sticky and plastic consistency [8] will impact on low soil infiltration rate, low hydraulic conductivity, hard root penetration and proliferation in the soils. One method to improve the physical properties of the soils for agricultre purposes is by applying OM regularly to the soils. According to *Low Carbon Development Indonesia* [9] agricultural sector contributed approximately 13% of total CO_2 emission in Indonesia. Jamaludin *et al.* [10] fond that amount of CO_2 emission from agricultural land varied based on the land use and the management given. Content of OM in soil was found to positively correlate to the CO2 emission from the soil [12] [13] .

Crop growth will emit CO_2 due to respiration process, meanwhile it also absorbs CO_2 as a basic material for photosynthesis process [14]. Barmintoro [15] found that amount of CO_2 emission in one season of corn growth under no-till and minimum till was lower than that under conventional tillage. Similarly, Putra *et al* [16] stated that CO_2 emission was different at different land use. They furthermore found that CO_2 emission from soil surface under corn cultivation was 5.05 kg/ha/d, oil palm was 5.00 kg/ha/d, vegetable was 4.97 kg/ha/d, rubber tree was 4.81 kg/ha/d, coffee was 4.80 kg/ha/d, and forest was 4.76 kg/ha/d.

Plant respiration process will produce CO_2 (Equation 1). The CO_2 produced can be used back by plants during photosynthesis or emitted to the atmosphere. Respiration reaction as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy (38 ATP)}$$

As a C4 plant, corn has high photosynthesis activity, low respiration, and efficient water use under normal condition [17]. Corn has *bundle-sheath cell* which helps to reduce CO2 loss during photosynthesis [18].

Sitorus and Sembiring [19] stated that there was a positive correlation between soil OM content and CO_2 emission. Application either fresh OM to soil will increase soil OM. Since OM is an energy source for microorganisms, the more the OM added to soil, the more intensive the activity of microorganisms meaning the more CO_2 emitted due to its activity. Emission of CO_2 gas to the atmosphere could be due to soil respiration besides OM decomposition [20]. This research was aimed to measure the amount of CO_2 emission under one growth season of sweet corn *(Zea Mays Saccharata*) in Ultisols applied with cow dung compost (CDC).

2 Materials and Methods

2.1 Research Design

This research was in form of field experiment. It was conducted in Farmer land in Pauh, Padang City, West Sumatra Indonesia (0º55'46.1" S and 100º27'46.2" E). The soil in the research site was classified as Ultisols. Soil samples and plant analyses were conducted at Soil Laboratory, Universitas Andalas Padang. The treatment applied was compost derived from cow dung called as CDC (cow dung compost). The CDC characteristics were presented in Table 1.

This research had one factor, doses of CDC, consisting of 5 levels (0, 5, 10, 15, and 20 T CDC/ha) with 3 replicates. The experimental units were allocated in the field based on Randomized Block Design (RBD).

Carbon dioxide emission from the corn land was measured using Carbon Dioxide monitor. Undisturbed soil samples were taken using ring samples while composite soils were taken using soil bore for each plot. A plot was sized 3 m by 1 m, with crop spacing 0.5 m by 0.2 m, therefore there were 30 crops for each plot.

The treatments were as follows:
P0 = 0 T CDC/Ha (Control)
P1 = 5 T CDC/Ha equals to 0.5 kg/m^2
P2 = 10 T CDC/Ha equals 1 kg/m^2
P3 = 15 T CDC/Ha equals 1.5 kg/m^2
P4 = 20 T CDC/Ha equals 2.0 kg/m^2

Table 1. Chemical characteristics of compost used for this research.

No.	Composition	Value
1.	Organic-C (%)	12.85
2.	C/N ratio	18.26
3.	Water content (%)	25.00
4.	Total-N (%)	0.81
5.	Total-P (%)	0.11
6.	Total-K (%)	6.47
7.	Total-Ca (%)	3.84
8.	Total-Mg (%)	2.01
9.	pH Value	7.43

Note: Based on producers attached to the package

Soil samples were taken twice, before treatment and after harvested. The soil samples were taken for the 0-30 cm depth either for disturbed or undisturbed soil samples. Disturbed soil samples were taken for soil texture, soil OM content, and soil pH measurement, while undisturbed soil samples for bulk density (BD), total soil pore (TSP, and hydraulic conductivity measurement. After taking initial soil samples, the land was divided into 15 plots (3 m x 1 m) and then applied with CDC as the treatment by distributing it evenly on the soil surface. Then, the compost was mixed with and incorporated into soil on the rooting zones using hoe. After that, the soil was watered until filed capacity and incubated for two (2) weeks before corn seeds were planted. Corn seeds were planted with spacing 20 x 50 cm. Therefre, there were 30 crops for each plot. The variety of sweetcorn used was Paragon with potential yield is 19.61 – 28.77 T/ha. Besides CDC, synthetic fertilizers (157 kg N, 37 kg K, dan 20 kg P) were also applied for the crop growth.

After harvesting, soil samples were taken from each plot between the crops at 30 cm soil depth. Undisturbed soil samples were taken using ring samples and disturbed soil samples using mineral soil bore. Then, the soil samples were processed (air-dried, ground, and sieved) and analysed in soil laboratory Universitas Andalas.

2.2 CO_2 Emission Measurement

Measurement of CO_2 was conducted by using portable CO_2 monitor (Figure 1). During research, CO_2 was measured 5 times, those were: (1) before soil tillage (2) after soil tillage before CDC application (3) Two weeks after CDC application (4) during maximum vegetative growth of corn and (5) after corn was harvested. The measurement of CO_2 was conducted using *carbon dioxide* (CO_2) *monitor* (portable equipment). Every time of measurement was conducted for 10 minutes for each plot during day time between 10 am to 3 pm. It was conducted in the middle of each plot.

Besides on soil surface, CO_2 emission was also measured on the above canopy of the crops. It also took 10 minutes for each measurement. This is important to calculate the net amount of CO_2 emitted to the atmosphere and how much it was used by crops for photosynthesis.

Figure 1. Portable CO_2 monitor

2.3 Soil Analyses

Soil analyses was conducted at Soil Laboratory, Agriculture Faculty Universitas Andalas Padang. Among the parameter analysed were soil texture (Sieve and Pipette method), BD and TSP (Gravimetry method), pH (Electrometry method), organic carbon (wet oxidation method).

2.4 Crop Production Measurement

Crop production parameters were measured the height and yield of the crop. The crop height was measured from the 1st until the 8th weeks after planting. Then, fresh corn cob which was sampled 10% of the total population.

2.5 Data Analyses

Data collected after CDC application were statistically analysed the variance using F-test, and then continued using DNMRT at 5% level of significance by using Stat-8 Program. Soil analyses data were presented in tables and CO_2 emission as well as crop height were presented in graphs. While data for initial soil characteristics were only compared to the soil criteria.

3 Results and Discussion

3.1 Characteristics of Ultisol in the Research Site

The soils at the research site were cultivated by local farmers using tractors and synthetic fertilizers, without the addition of organic matter. As a result, the soil tended to become compacted. The soil characteristics were presented in Table 2.

Table 2. Initial soil analyses in the research site

Parameter	Value	Unit	Criteria
Texture			
- Sand	12.90	(%)	Clay*
- Silt	33.44		
- Clay	53.70		
Organic-C	0.77	%	Low**
Bulk Density (BD)	1.14	Mg/m^3	High***
Total Soil Pore (TSP)	56.31	%	Low***
pH H_2O (1:2)	5.21	Unit	Acidic**
Emisi CO_2	45.55	T CO_2 /Ha/y	-

Source: *) Texture triangle (USDA. 1951)
**) Institute for Soil and Fertilizer Instrument Standard Testing (BPSITP, 2023)
***) Soil Research Institute (LPT), Bogor (1979)

Based on Table 1 it was found that the soil used in this research had clay in texture, with more than 50% clay. High clay content with low organic-C, the soil will be dominated by micropores having high water retention, however have aeration and drainage problem. The compact the soil is the less the percentage of their total pores. The same soils having different BD and OC content will cause different density. The higher the soil BD, the denser the soil is. As found by Sandrawati *et al*. [21], that the higher the soil BD, the lower the pore percentage is.

That condition will have problem for root growth and development, especially for cultivation of dryland crop. Therefore, improving the soil physical properties was really needed to support good rooting zone. One of the efforts that could be done was by applying organic matter, such as compost [22].

The soil reaction in the research site was classified as acid [23]. Since the soil belongs to Ultisols under very high annual rainfall, most of the basic cations was leached and the colloid sites of the soil were occupied by acid cations such as Al_3^+ and H^+. Soil pH could be increased by applying compost enriched by fly ash [24]. Increasing soil pH will increase soil chemical properties, because the availability of the most plant nutrients is found around neutral pH, such as 6.5. At low pH, there were more micro essential nutrients available. The exessive availability of micronutrients in soils will be toxic for plant growth if the plants absorb more than they needs [25].

Low OC content affected microorganism activity in decomposing OM, because microorganisms need OM as the energy source. The lower the OM concentration in a soil, the lower the microorganism activity, and consequently the lower the amount of CO_2 emitted from the soil. Based on the data resulted in the field measurement, the Ultisols in the research site emitted 45.55 T /y. The result was in line with data reported [12] [13] that the amount of CO_2 emission positively correlated to the soil OC content.

3.2 Soil Characteristics After Compost Application

Soil characteristics at 2 weeks after of CDC application were presented in Table 3 and Figure 2.

Table 3. Soil OM, BD and TSP at two weeks after CDC application

CDC Dose (T/Ha)	OM Content (%)		BD (Mg/m^3)	TSP (%)	pH H_2O (1:2)	pH KCl (1:2)
	After CDC Incubation	After Harvest	..................After CDC Incubation...............			
0	1.19 a	2.28 a	0.98 a	62.42 a	5.21 a	5.12 a
5	1.35 ab	2.61 b	0.95 ab	63.68 ab	5.29 a	5.20 a
10	1.51 bc	2.76 bc	0.92 ab	64.73 ab	5.30 a	5.22 a
15	1.62 c	2.91 cd	0.89 b	65.93 b	5.48 a	5.42 a
20	1.94 d	3.06 d	0.76 c	70.78 c	5.51 a	5.43 a

**Note: Data followed by the same small letters were not significantly difference based on DNMRT at 5% level of significance*

Table 3 showed that increasing CDC applied from 0 to 20 T/Ha increased the soil OC content. This was due to that the compost contained 12.85% of OC (Table 1), so it contributed to the soil OC content. Organic carbon helps aggregation process, creates more pores causing soil becomes less mass per unit volume or bulk density value. The more the compost (OM) applied was the lower the soil BD, and the higher TSP. There was a negative correlation between the soil organic carbon and the bulk density of a soil ($p < 0.01$) [26].

Application of 25 T/ha compost enriched with fly ash could incease soil pH as well as soil chemical properties [24]. This was due to the effect of CDC application as a source of OM. Organic matter has an important role for aggregate formation and stabilization. Since OM has lower weight per its unit volume, the weight of the soil having OM will be lower mass per unit soil volume.

As reported by Lawenga *et al*, [27] that decomposed organic fertilizer will create crumb soil aggregates, increase and balance micro and macro pores. As a result, the value of soil bulk density decreased and the total soil pores increased.

Based on Table 3, it was found that soil pH either dissolved with H_2O or with KCl did not vary by increasing CDC dosage improved. This could be due to the effect of OM content added to the soil which was not high in pH. As it is known that organic matter can contribute organic acids during its decomposition, therefore it cannot increase soil pH. However, Figure 2 showed that there was a tendency of increasing soil pH by increasing CDC application (r=0.90). This could be due to the role of OM in binding metal, especially Al, which prohibits Al hydrolyses producing 3 H^+ ions for each Al ion, causing low pH in soils [28].

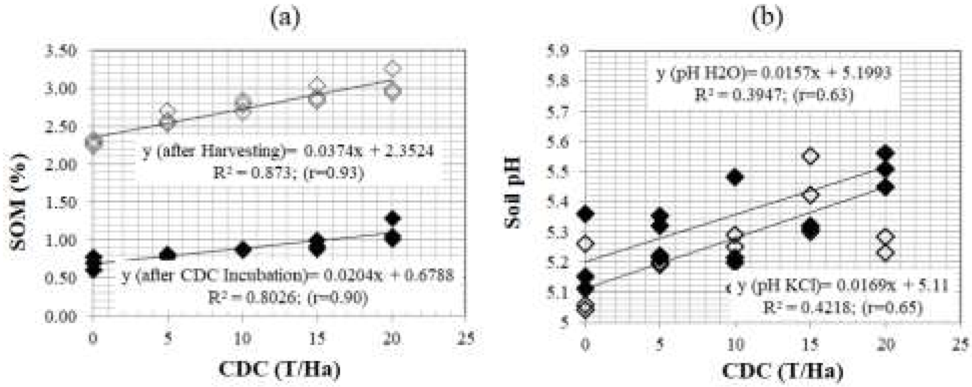

Figure 2. Correlation between CDC dossage and SOM content (a) and soil pH (b)

Increasing S OM after harvesting was due to the contribution of root exudates [29] as well as the plant litters compared to two weeks after CDC application. This is in line with the results found by Yandi *et.al*. [30] that the longer the organic fertilizer incubated the more the OC provided to the soils. Furthermore, the exudates from the growing crop roots will contribute some OM to the soils [31]. Among the organic compound from the root exudates are carbohydrates, organic acids, amino acid, flavonoid, fenolic, and volatile compound [32].

3.3. Carbon Dioxide Emission During a Growing Season of Sweet Corn

Emission of CO_2 was measured from soil surface and above plant canopy from 4 different times during sweet corn cultivation. Concentration of CO_2 emission from soil surface at each growth stage was presented at Figure 3. Initial concentration of CO_2 emission from soil surface before soil tillage was 553.67 (±27.60). Then, the amount of CO_2 emission increased by growth stage from after soil tillage until maximum vegetative growth, and then decreased after harvesting.

Increasing CO_2 emission after tillage was due to the fact that the effect of tillage which improves soil aeration and as a consequence the activity of decomposing microorganisms [2]. Furthermore, the amount of CO_2 within soil pores will go out fast as the soil cultivated. As reported [2] that the amount of CO_2 increased much higher after than before plowing the soils. Then, the concentration of CO_2 emission increased again after CDC application. This was due to the OM oxidation in the soil, the higher the amount of CDC applied the more the CO_2 emitted [5] . The highest CO_2 emission was found during the maximum vegetative growth of the sweet corn. The highest increase was observed at the highest dosage of CDC applied. Elevated CO_2 emissions during maximum vegetative growth may be attributed to increased root and rhizosphere microbial activity. During this phase, plant roots are highly active in nutrient uptake and excretion of root exudates, which are then oxidized by microorganisms, resulting in CO_2 emissions into the atmosphere.

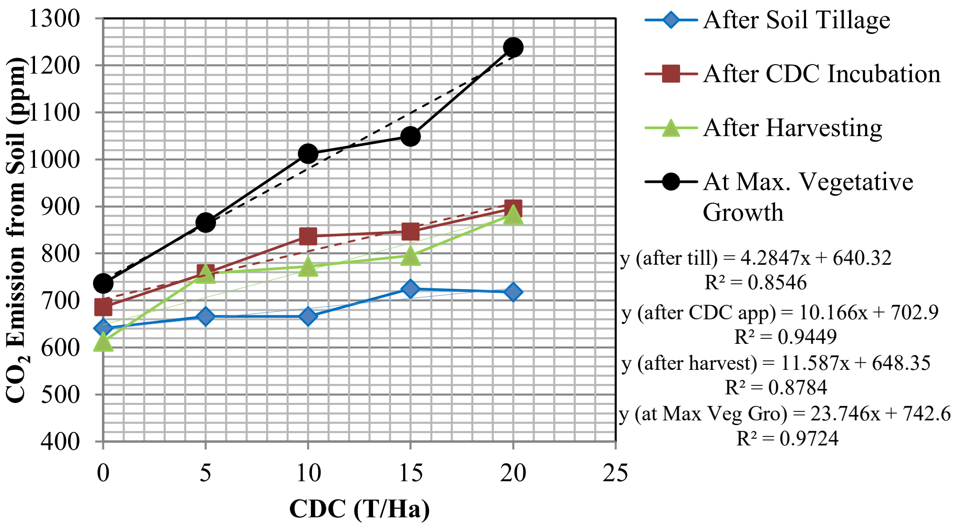

Figure 3. Emission of CO_2 from soil surface at different CDC application

Putri *et al.* [11] found that soil cultivation significantly increased CO_2 emission. By cultivating, the soil aggregates breaks down, therefore the CO_2 which has already been within the soil pores will directly goes out to the atmosphere, it increased the CO_2 emission. Furthermore, cultivation also makes the soil to be more porous, more oxygen available for organism activity in decomposing and oxidizing soil OM [32]. Therefore, the amount of CO_2 emission under tillage soil is much higher than that under no tillage soils.

The gradient of CO_2 emission increased from after tillage (4.28) to after CDC application (10.17) (Fig. 3). Then, the gradient found to be the highest (23.75) as the crop growth reached maximum vegetative growth. Higher CO_2 emission after CDC application was due to the fact that OM is an energy source of microorganisms. The more the SOM content, the more intensive the microorganism activity, therefore, the more CO_2 emission as the product of OM oxidation [2]. It was also reported by Sitorus and Sembiring [19] that CO_2 emission was significantly affected by dosage of compost applied.

Among the phases of crop growth, the highest CO_2 emission was from maximum vegetative growth (Figure 4). It was due to the fact that the microorganism activity was quite intensive at that periode because more root exudates were produced and available for the microorganisms during maximum plant growth [33], as known that microorganisms need OM as their energy source. Therefore, the more the root exudates excreted meaning more SOM in the soil is the more intensive microorganism activity, and the more CO_2 emission from the soil [7]. Furthermore, after maximum vegetative growth, the root exudate production decreases then the activitity of microorganisms also decrease causing low CO_2 emission. As found after harvest time, the amount of CO_2 emission sharply decreased. It indicated that there was no more exudates from plant roots that can attract microorganisms except the crop residue. As known, respiration of soil microorganisms increases CO_2 emission from soils. Rosalina dan Kahar [34] found that CO_2 emission increased after organic fertilizer applied, and then it decreased by time due to reducing microorganism activity.

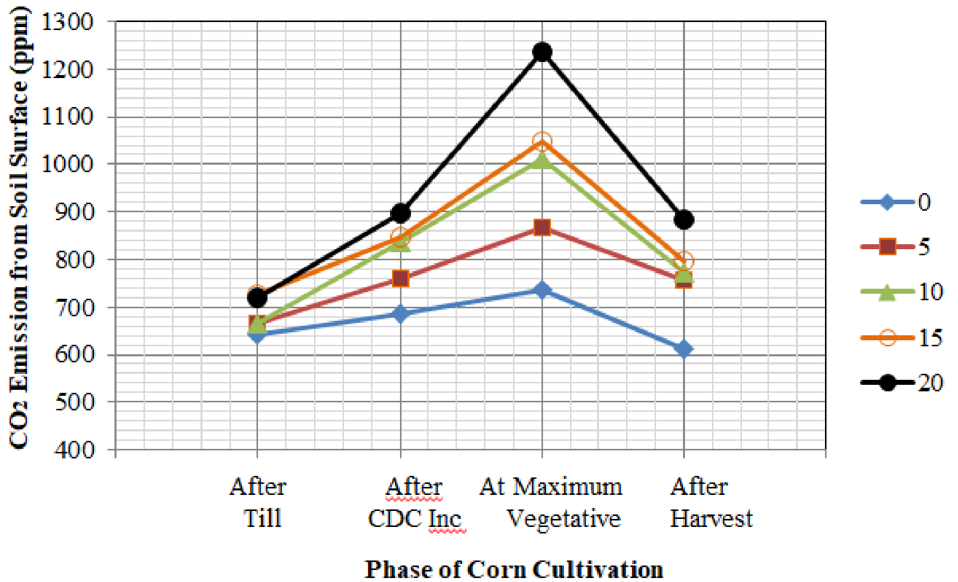

Figure 4. CO_2 emission from surface soil at different growth stage of sweet corn

However, CO_2 emission from sweet corn canopy was not significantly affected by the CDC application (Tabel 4). The amount of CO_2 emitted to the atmosphere above crop canopy were not significantly different. It meant that some of the CO_2 emitted by soil was absorbed by crops to be converted to carbohydrates during photosynthasis process. The percentage of CO_2 absorbed by sweet corn tended to decrease (from 63.1%, 53.6%, 46.5%, 44.5%, to 38.6% respectively) as the CDC applied increased (from 0 to 5, 10, 15, to 20 T CDC/Ha). Therefore, net CO_2 emission from sweet corn cultivated land was lower than the amount of CO_2 emitted from the soil surface. This means that vegetation growing on a piece of land will control the amount of CO_2 emission from the soil to the atmosphere.

Table 4. Total emission of CO_2 during corn cultivation

CDC Dossage (T/Ha)	Total of CO_2 emission from soil surface (T CO_2/Ha/y)	Total of CO_2 emission from crop canopy (T CO_2/Ha/y)	Net CO_2 emission from sweet corn cultivation land (T CO_2/Ha/y)
0	61.30 c	38.70 a	22.13 d
5	72.12 bc	38.67 a	33.45 cd
10	84.29 ab	39.22 a	45.08 bc
15	87.37 ab	38.92 a	48.44 b
20	103.13 a	39.77 a	63.36 a

Note: Data followed by the same small letters were not significantly difference based on DNMRT at 5% level of significance

3.4 Sweet Corn Production as Affected by CDC Application

Crop height and yield as a manifestation of soil fertility after CDC application was presented in Table 5.

Table 5. Crop production in Ultisols applied with CDC

CDC dose (T/Ha)	Crop height (cm)	Fresh weight of corn cob (g)
0	236.43 a	294.97 a
5	242.87 ab	324.80 ab
10	248.87 bc	338.67 ab
15	256.57 cd	375.43 b
20	264.43 d	378.67 b

Note: Data followed by the same small letters were not significantly difference based on DNMRT at 5% level of significance

Table 5 showed that there was a significance difference both for crop height and crop yield as affected by different doses of CDC application. The crop height and yield significantly increased by increasing CDC dose applied from 0 to 20 T/Ha. This could be due to the improving condition of soil physical especially soil OM, BD, TSP (Table 3) after CDC application. As an organic fertilizer, CDC improved soil physical properties in rooting zone, therefore the crop roots can grow well in collecting water and plant nutrients. Then, the decomposed OM will provide additional nutrients for crop growth [37]. This is in line with data resulted [11] that application of SOM to soils increased the nutrient availability as well as crop production. Crop height from the 1^{st} to 8^{th} week after planting was provided in Figure 5. Figure 5 showed that there was no significant difference on crop height among the treatments. This was due to the effect of synthetic fertilizer application which was more influential on crop growth. Since the crops were equally applied with the same amount of synthetic fertilizers, the crop height tended to be the same.

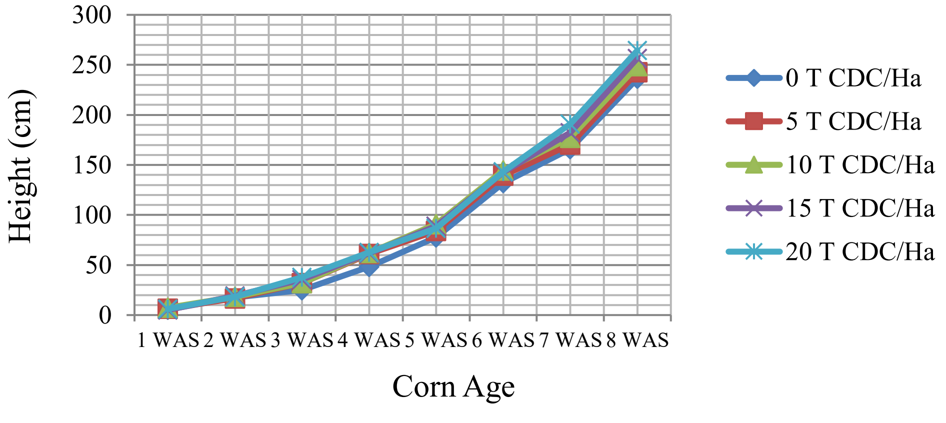

Figure 5. Height of corn crop at Ultisol applied with CDC

Pangaribuan *et al.* [36] presented that good corn yield was affected by organic fertilizer application. Organic matter as a fertilizer functions in improving soil physical and chemical properties of the root zone. Haitami dan Wahyudi [37] as well as Herman and Resigia [38] stated that crop height could increase by increasing compost dose applied. This was due to the fact that compost as an organic fertilizer can improve soil BD, so the crop roots could grow and proliferate well besides plant nutrition for the crop growth.

4 Conclusion

Based on the research conducted, it could be concluded that application of CDC (cow dung compost) improves soil physical properties, especially total soil pores, SOM content, and soil BD. Dosage of CDC applied and SOM content positively correlated to CO_2 emission. The highest net CO_2 emission (63.36 T CO_2/Ha/y) was found under 20 T/ha and the lowest (22.13 T CO_2/Ha/y) was found under 0 T/Ha CDC applied. However, the SOM content was also positively correlated to the corn yield. The highest corn yield (378.67 g/cob) was found at the highest CDC applied (20 T CDC/Ha). It will be interesting to determine the amount of CO_2 which can be absorbed by other seasonal crops during their growth.

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