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# Effect of Mineralization of Plant and Animal Residues on Aggregate Stability

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**Abstract**

The study aims to elucidate the impact of different organic inputs (plants straws and animal residues) on the rate of biodegradation and stability of aggregates in a silty loam soil. A laboratory experiment was performed by using four levels (0, 1, 2, and 100%) of three types of plants straws (wheat, corn and legume) and three types of animal manure (cow, sheep, and poultry) which is incubated at 28$^{O}$ C for different periods of times (7,14, 21, 28, 42, 56. 70,84,and 112) days. The experiment was setup in completely randomize design with three replicates for each addition level. The results indicated that the mineralized carbon increased gradually with increasing residual percentage and incubation period. The amount of mineralized carbon is increased with the incubation time, but it was obvious in the first 56 days of incubation. The highest degradation percent was observed at lower C: N ratio epically with poultry and legumes. The accumulative mineralized carbon increased with increasing the amount of residual added. Addition of organic substrates significantly improved soil organic C contents, but the type and source of inputs had different impacts. In addition, higher macro-aggregates in the crop residue- and farmyard manure-treated soils resulted in a higher aggregate mean weight diameter (MWD), which also had higher soil organic C contents. The order of MWD values were wheat < corn < legume < cow < sheep < poultry. The value increased in MWD by 154 and 291% in raised level of poultry manure from zero to 1 and 2% respectively.

## Introduction

Most soils of semi-arid regions are poor in organic matter ***[1];*** therefore, organic amendment has been widely used to increase the soil organic matter content ***[2, 3].*** The effectiveness of organic inputs on improving soil structural stability is not only dependent on the quantity but also on the quality of adding organic materials specially their rate of decomposability and their capacity to induce soil microbial activity ***[4, 5 , 6].***

Application of crop and plant biomass for improving soil organic matter and enhancing soil quality is well recognized in sustainable agriculture ***[7, 8].*** Recycling of these surplus agricultural byproducts has the advantage to meet nutrient requirements for the crop and expanded use as effective soil amendments. During the last several decades much attention has been paid to the utilization of crop and plant residues as soil amendments as well as to evaluate the effects of existing organic matters on soil physical and biological properties *[9]* such as soil structure and aggregate stability ***[10, 11]*** by increasing stability of soil aggregates because of the physical and chemical actions of the molecules contained in the organic products and/or the increase in the hydrophobicity of soil aggregates ***[6].*** Straw incorporation is an important management practice with the potential to improve dependence on mineral fertilizers, maintain soil nutrient balance and soil structure ***[12].*** As with other organic amendments, straw incorporation provides nutrients for plant growth and the organic carbon serves as an energy supply for soil microorganisms. Many researches show that straw incorporation can increase soil organic carbon ***[13],*** increase soil aggregate size distribution ***[14, 15]*** and increase crop production ***[16, 17].*** Therefore, straw incorporation may be consider as important method to improve soil fertility and soil aggregates which are proposed to be the basic units of soil structure ***[18].*** So, maintaining high stability of soil aggregates is necessary for maintaining soil productivity, decreasing soil degradation and thus minimizing environmental pollution as well. An increase in soil organic matter with the addition of organic residues caused formation of disperse-resistant aggregates and increased the percentage of large sized water stable aggregates (WSA) (> 5 mm) ***[19].*** Water stability of aggregates is an indicator of soil resistance against disintegration ***[20],*** while the size of aggregates indicates the influence of management on soil structural stability. Organic binding agents are mostly responsible for development and stability of macro-aggregates (>0.25 mm), implying the role of organic matter in aggregate stability. The Soil organic carbon (SOC) content decreases with intensive cultivation, which corresponds to a decrease in aggregate stability by ***[21].*** The main objective of the study was to examine (1) the effect of different types of organic fertilizers such as wheat, corn, legume, cow, sheep and poultry farmyard manure and time of incubation on biodegradation process; (2) the effect of added organic fertilizer on aggregate stability and carbon content. Our hypotheses were i) the use of organic fertilizers increase the proportion of water stable macroaggregates ii) soil macroaggregates stability increases when more recalcitrant products (e.g., poultry manure) are used.

**Material and Methods**

The experiment was conducted in the laboratory of Soil and Water Science Department, Faculty of Agricultural Sciences, University of Sulaimani, Iraqi Kurdistan region, during (January 2012 to April 2012). Different amount of fresh plants residues and animal manure were mixed with soil. Three plant residues (corn, wheat straw and broad been straw) and three animal residues (poultry, cow and sheep manure) were dried at 65º C for 48 hours and milled with stainless steel mill and passed through a 1- 2 mm sieve. Four levels (0, 1, 2 and 100%) of these residues were mixed with soils collected from Ap (0 – 15 cm plowed) horizon at the depth of 0-15 cm from wheat's farm Faculty of Agricultural Sciences at Bakrajow after had been air dried and sieved to pass through 8 mm opening sieve. Soil samples were adjusted to 40% of the water-holding capacity (WHC), calculated from repacked air-dried soils. Rewetted soils were equilibrated by incubating at constant moisture and temperature (28 ºC) for different period of times.

In order to study the rate of decomposition of the organic residue, Carbon mineralization was analyzed by alkali absorption of $CO_2$ released at regular intervals over 112 day, the measurement of the liberated $CO_2$ was determined quantitatively. This was achieved as following: for each sample unit container a test tube containing 10 ml of 1 *M* NaOH inserted and placed in slant posture to avoid pouring out of the NaOH, then the container sealed carefully to prevent the loss of liberated $CO_2$, then the units incubated at 28º±1ºC for different periods of time (7, 14, 21, 28, 42, 56, 70, 84 and 112) days. The amount of liberated $CO_2$ measured at the end of each period by measuring the amount of residual NaOH which represented the un-reacted part and subtracted from the blank to find out the reacted part with $CO_2$. This was conducted by titration of the NaOH previously inserted in each unit against standard HCl according to ***[22].*** The NaOH transferred into 250 conical flask and 2 ml of 1.0 *M* of barium chloride was added in order to precipitate the $Na_2CO_3$ formed due to absorption of the liberated $CO_2$ existing in the internal ambient of the container by the NaOH. Then a few drops of phenolphthalein indicator were added and pine color developed. Thin it was titrated against standardized 1*M* HCl until the pink color turned to colorless, the volume of the HCl recorded to be used in the calculation of the liberated $CO_2$ according to Miller and Keeney ***[23].*** The particle size distributions were determined according to the international pipette methods ***[24].*** Total nitrogen was determined by the kjeldahl digestion –distillation method ***[25].*** Organic carbon was determined according to Walky Black ***[26]***. Soil pH was determined in soil water suspension with a glass electro.

A modification of the Yoder ***[27]*** wet sieving procedure ***[28, 29]*** was used to determine wet aggregate stability. A set of five 100 mm diameter sieves of 4000, 2000, 500, 250, 125 µm size screens was used. A further 125 µm sieve was used for a lid. The 30 g sample of the soil (< 8 mm) was placed on the top sieve and immersed in distilled water at approximately 25° C (or as stated for the water temperature experiment) for 30 sec before being sieved for 10 min through an amplitude of 17 mm at 34 cycles/min. Following sieving, the sieves were drained and the soil dried at 50° C for 24 h prior to weighing. Soil weights for soil dried at less than 50° C were corrected for water content before calculations were made. Large (>2 mm) and small (0.25-2 mm) macroaggregates, microaggregates (0.053-0.25 mm), and 'silt+clay' sized aggregate fractions (<0.053 mm) were determined ***[30].*** Mean weight diameter (MWD) was computed for each soil the following formula:

$$\mathbf{MWD} = \sum_{i=1}^{n} x_i w_i$$

where $x_i$ is the mean diameter of any particular size range of aggregates separated by sieving, and $w_i$ is the weight of aggregates in that size range as a fraction of the total dry weight of soil used.

**Results and discussions**

The results in Table (1) showed that the soil was calcareous with a high amount of calcium carbonate equivalent and the value was 210.6 g kg $^{-1}$ which is reflects in the pH value more than 7. The organic carbon content was low and the value was 12.8 g kg $^{-1}$ with low total nitrogen content (1.19 g kg $^{-1}$).

Table 1: Some chemical and physical properties of the soil used.

| Horizon | pH | Organic carbon | $CaCO_3$ equivalent | Total nitrogen | Water holding Capacity | clay | silt |
|---|---|---|---|---|---|---|---|
| | | ---------------- | g kg$^{-1}$ | ---------------- | | | |
| Ap | 7.89 | 12.8 | 210.6 | 1.19 | 389 | 203 | 758 |

The amount of initial total carbon and nitrogen were shown in Table (2) and the result indicated that the amount of total nitrogen in the residues was vary and depending on the type of residue. The nitrogen values were range from 6.6 mg kg$^{-1,}$ in wheat straw to 46.3 mg kg$^{-1}$ in poultry manure. The lowest C: N ratio was found in poultry manure and the value is less than one, while the highest C: N ratio (8.3) was found in the wheat straw.

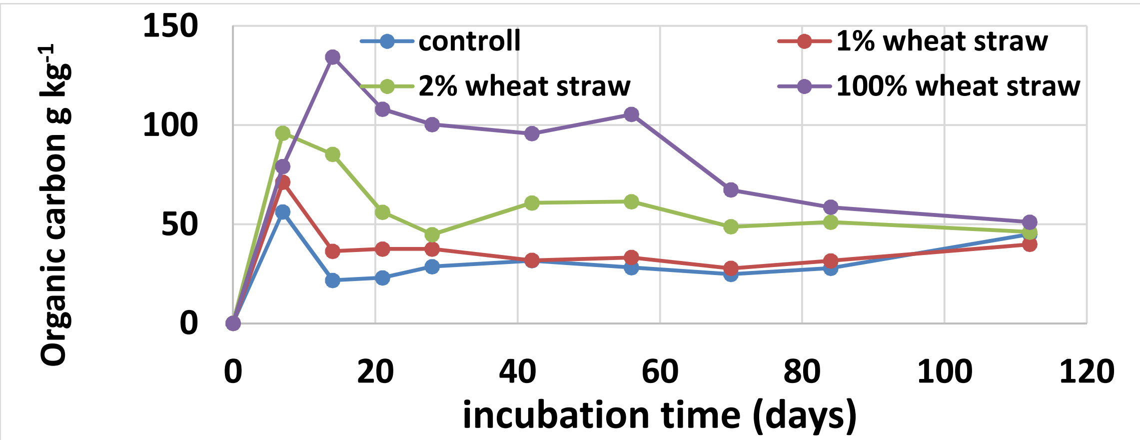
Table 2: Carbon, nitrogen and carbon: nitrogen ratio for different fresh plants and animals residues

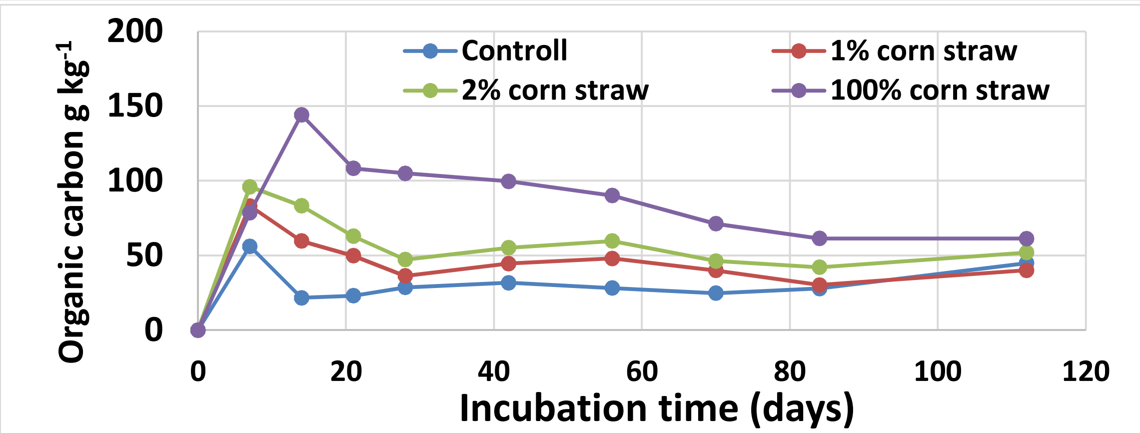
| | Wheat | Cow | sheep | corn | legume | poultry |
|---|---|---|---|---|---|---|
| | **mg kg $^{-1}$** | | | | | |
| **Nitrogen** | 6.6 | 11.3 | 14.1 | 26.7 | 43.0 | 46.3 |
| **Carbon** | 54.6 | 39.5 | 53.0 | 53.0 | 55.3 | 43.0 |
| **C : N** | 1: 8.3 | 1 : 3.5 | 1: 3.7 | 1 : 2.0 | 1 :1.3 | 1 : 0.9 |

The amount of non- accumulative mineralized carbons from soil samples treated with different plants and animals residues incubated at 28±1°C for 112 days were shown in Fig *(1 and 2).* The results indicated that the mineralized carbon increased gradually with increasing residual percentage and incubation period of times. Generally, the maximum amount of mineralized carbon was found with the 100 % residual irrespective to the type of residual. This may be due to presence of higher amount of easily available OC to be utilized by indigenous microorganisms. The results also showed that the importance of the nitrogen content in decreasing the C:N ratio, especially poultry and legumes residues, is considered as imperative criteria in the biodegradation process of OM, while apparent relationships between the C:N ratio and the biodegradation percentage were evident. The highest degradation percent was observed at lower C:N ratio. Low N content or high C:N ratios were associated with slow decay.

The accumulative mineralized carbon at different plants and animal residues percentage levels added showed in Fig *(3 and 4).* The result indicated the superiority of 100% of the residue compared to other treatments for all type of the residues. The curve was linear with higher elevation than the rest and simultaneously there was increasing in the curve slope in the first 56 days that was due to higher released amount of accumulative mineralized carbon compared to the others. This was expected simply because it contained much more available carbon than the 2% residue to be utilized by microorganisms. On the other hand, the rates of decomposition of different added plants and animal manure increased with increasing organic residue, and for example the percent values for both 1% and 2% poultry residue were 30% and 50.6% compared to 0% addition.

There are several models that can be used for describing the decomposition pattern of organic matter, which were Zero, First, Second-orders, Hyperbolic, Parabolic diffusion, Modified Elovich, Power function and Logarithmic function, which successfully applied and tested in order to find out the best fitting model describing the decomposition of soil organic matter by using the standard error (SE) and coefficient of determination ($R^2$) values. These parameters can be used as criteria in determining the best model for the determination of half-life decomposition duration of soil organic residue. So, the model that gave the lowest standard error (SE) and the highest coefficient of determination ($R^2$) was used in describing the decomposition pattern and consequently to calculate the half-life value. From the result shown in Table *(3),* it appeared that the second order model was the best model because gave the lowest standard error (SE) and the highest coefficient of determination ($R^2$) under the experiment condition. The coefficient of determination values was significantly high for all the models but the lowest value ($R^2$ = 0.682) was found for hyperbolic model.



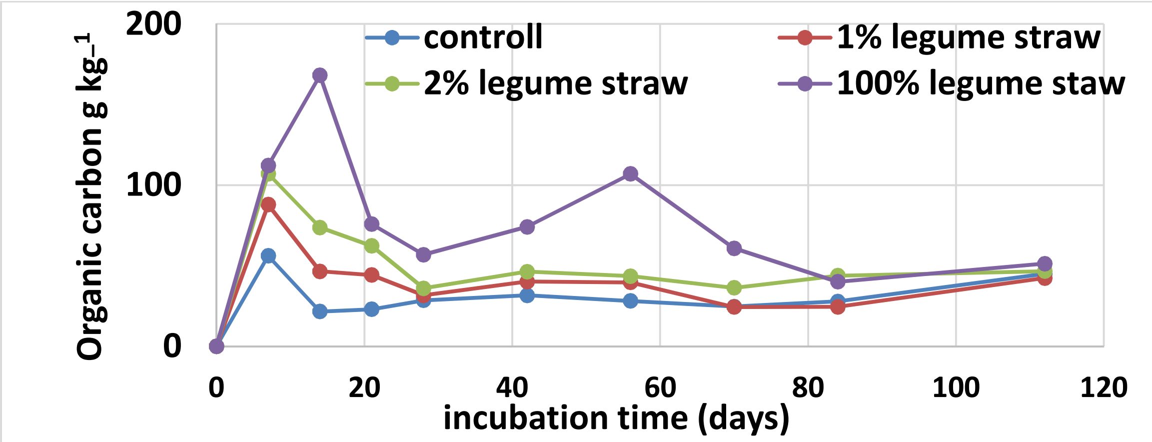



Figure-1: Non -accumulative mineralized carbon (mg kg$^{-1}$) for soil treated with different plant residues percentage.

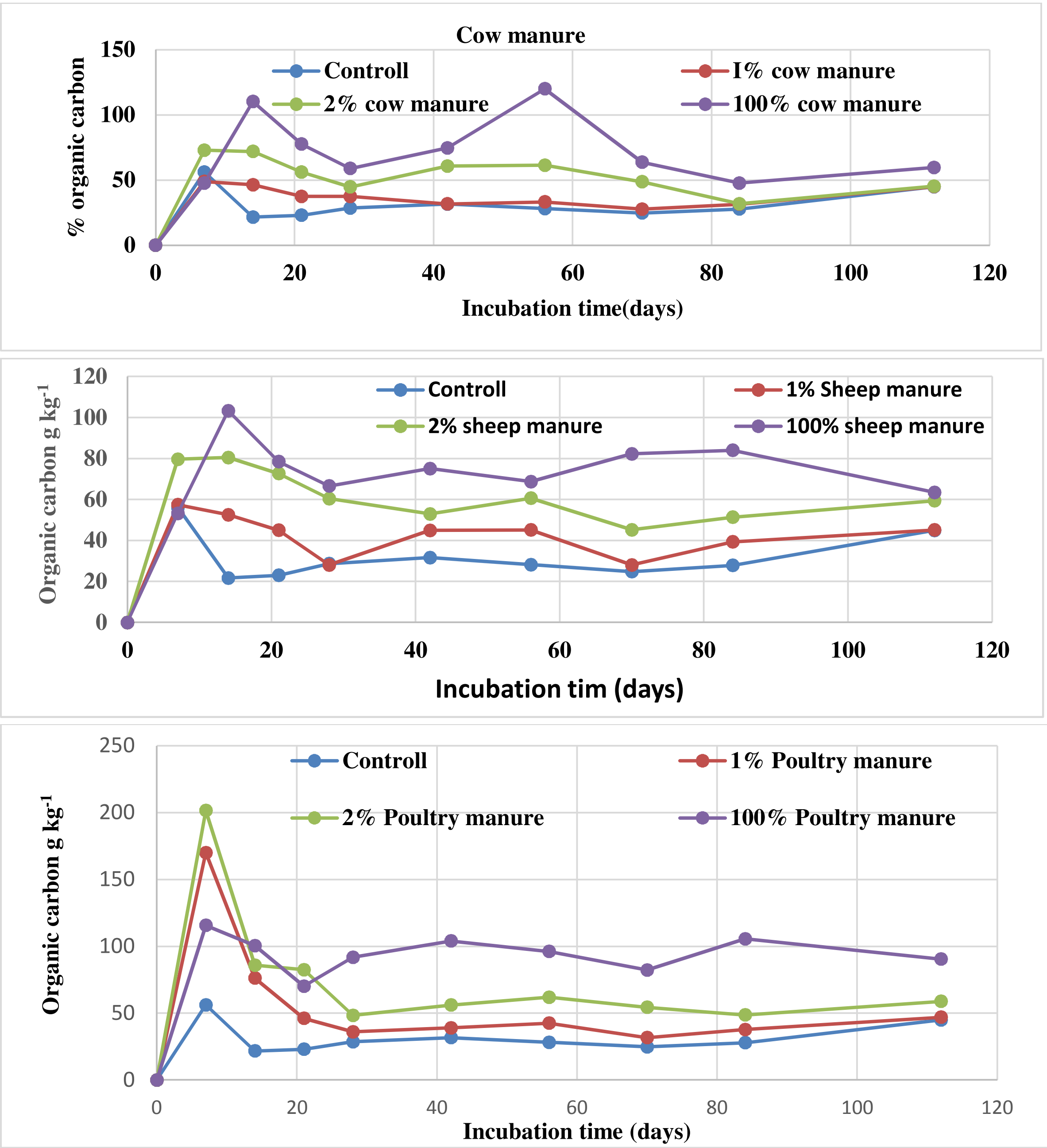



Figure- 2: Non -accumulative mineralized carbon (mg kg$^{-1}$) for soil treated with different animal manure percentage.

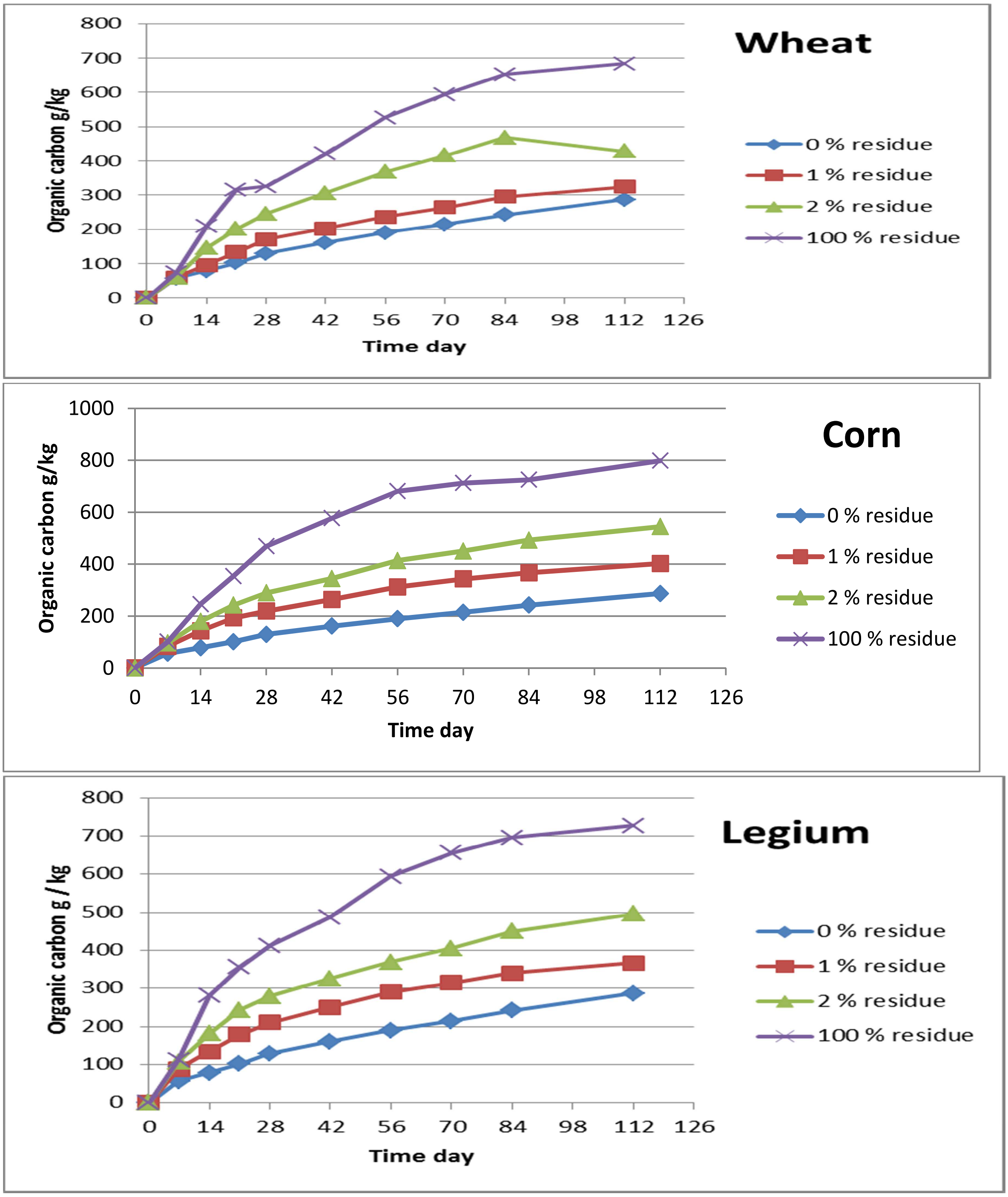



Figure- 3: Accumulative mineralized carbon (g $kg^{-1}$) for different levels of plant residues during different incubation periods.

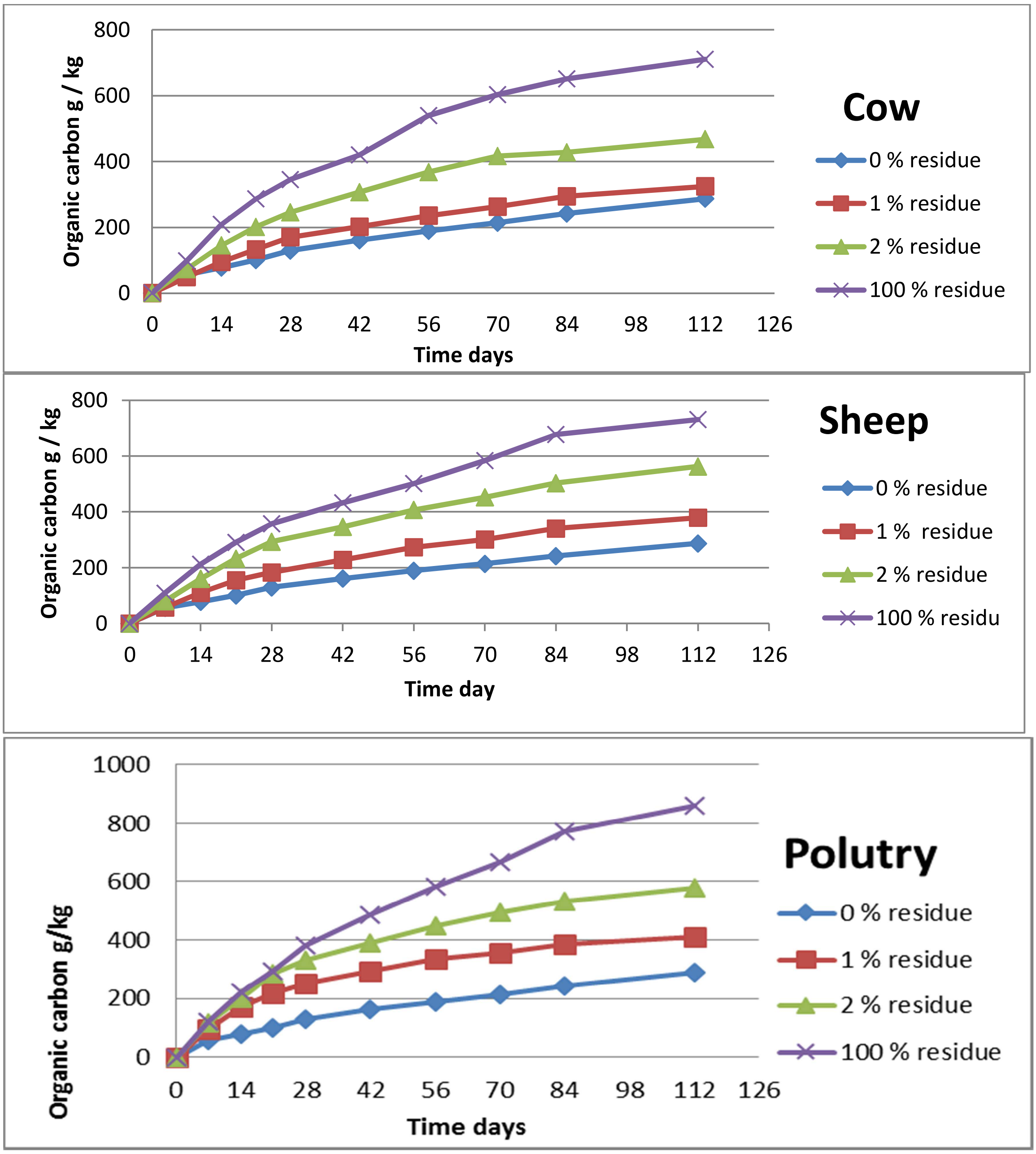



Figure-4: Accumulative mineralized carbon (g $kg^{-1}$ ) for different levels of animal residues during different incubation periods.

Soil organic matter improves aggregate stability by different mechanisms and different fractions. Indeed, Primary particles and clay microstructure are bound together with bacterial and fungal debris into stable micro-aggregates. These latter may be bound together with fungal and plant debris giving a larger microaggregates. These microaggregates are bound into macro-aggregates *(11, 32).* The results in Figure ( *5 )* show the distribution of the wet-stable aggregate size classes (average percentage of stable aggregates on the initial sample mass) as affected by organic residue changes. As expected, there were differences in the distributions of WSA between plants straw and animal manure. There were no many large-sized aggregates (>2 mm) in any of the investigated amended treatments. It may be observed in Fig.*( 5),* where only an average of 10% of aggregates is over 2 mm. The WSA were distributed mainly in the smaller diameter classes. The soils treated with animal manure had significantly larger proportion in the 4–2 mm, 2–1 and 1–0.5 mm ranges and smaller proportions in the <0.25 mm ranges than soils treated with plant straw. Results from this study are in disagreement with the observations of Broersma et al. *[32]* who found that macro-aggregates (>2.0 mm) are the most frequent aggregate fraction (50.0%). Results obtained in the present study showed significant relationships between organic matter fractions and aggregates stability. Aggregate stability was associated to the organic matter (significant correlations). It can be concludted that organic compounds were the principal binding agents of aggregate and the most factors influencing their stability.

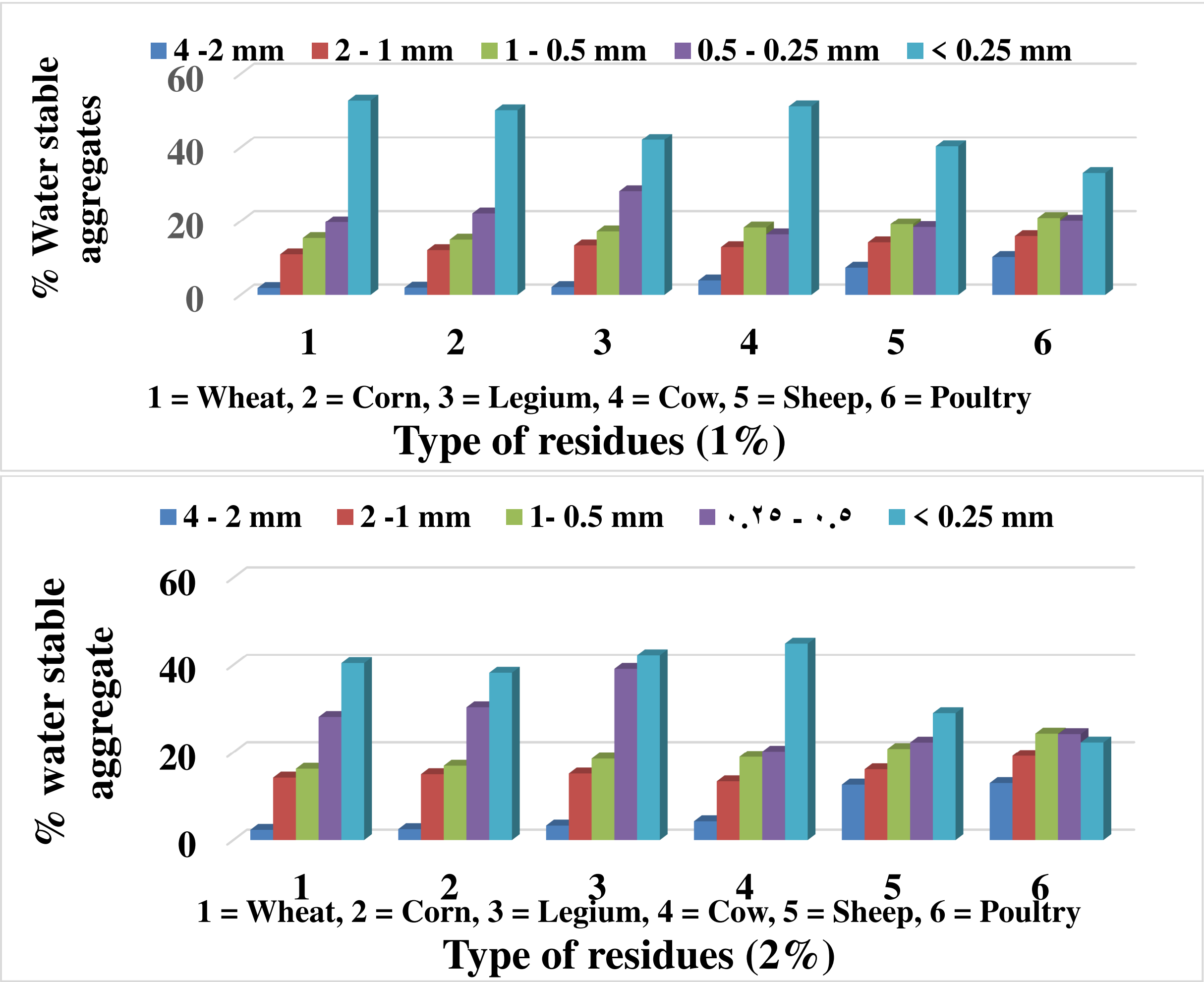



Figure- 5: Effect of different level of plant and animal residues on percent of water stable aggregates of different sizes.

The mean weight diameter (MWD) was a single value, which was a sensitive index of the aggregation status of a soil in order to gain a quantitative evaluation of soil structure. The results showed the significant effect of adding organic residues on the soil aggregates stability expressed as the MWD for the two levels. The average values of aggregation indices MWD wheat, corn, and legume straw, cow, sheep and poultry manure with different rates of addition were shown in Fig (6). The mean values of MWD ranged from 0.54 for control to 1.88 for 2% addition of poultry residue. Generally, the MWD values were increased with increasing the addition of residues, and the highest mean MWD values were found in soil with 2% poultry residue addition. The order of MWD values were wheat < corn < legume < cow < sheep < poultry. The highest increased in MWD by 154 and 291% in raised level of poultry manure from 0 to 1 and 2% respectively, while the highest increased in MWD by 33 and 96% in raised level of legume straw from 0 to 1 and 2% respectively. The improvement in MWD in soils indirectly suggested the potential for increasing soil

C under higher addition of the residues, therefore attributed to improve soil aggregation, especially higher proportion of macro- aggregate under 2% addition compared to other additions. Organic matter plays an important role in maintaining structural stability in most agricultural soils ***[33, 34, 35].*** According to Piccolo *et al* ***[36],*** higher values of MWD indicated the dominance of large aggregates of the soil. Since the improvement in the soil structure was higher in the poultry residues, this may be due the higher mineralization rates and microbial growth because of lower C : N ratio *(Table 2).*

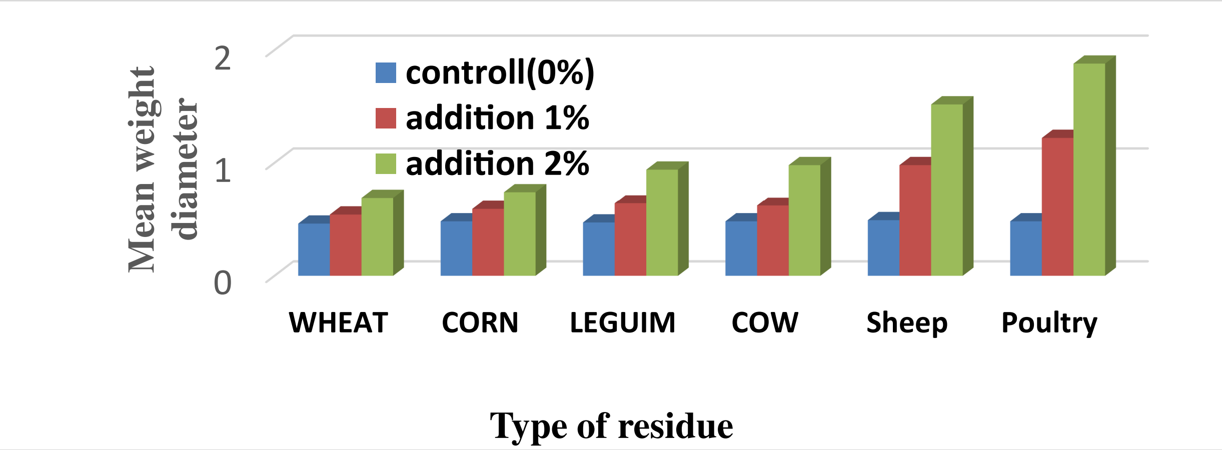



Figure- 6: Effect of different levels of Plant and animal residues on mean weight diameter.

Table 3: Stander error (SE) and coefficient of determination ($R^2$) values for different models.

| Treatment | | Zero order | | 1st order | | 2nd order | | Hyperbolic | | Parabolic | | Modified Elovich | | Power functi | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SE | $R^2$ | SE | $R^2$ | SE | $R^2$ | SE | $R^2$ | SE | $R^2$ | SE | $R^2$ | SE | R2 |
| wheat | 1 | 21.75 | -0.973 | 0.0367 | -0.991 | 0.0000493 | 0.998 | 15.55 | -0.731 | 8.16 | -0.990 | 16.47 | -0.984 | 0.13 | -0.952 |
| | 2 | 41.58 | -0.956 | 0.0432 | -0.970 | 0.0000435 | 0.981 | 29.21 | -0.729 | 19.79 | -0.996 | 20.36 | -0.989 | 0.008 | -0.961 |
| | 100 | 57.88 | -0.962 | 0.0110 | -0.965 | 0.0000020 | 0.968 | 165.4 | -0.743 | 28.86 | -0.990 | 36.75 | -0.985 | 0.067 | -0.962 |
| Corn | 1 | 29.33 | -0.966 | 0.0601 | -0.988 | 0.0001792 | 0.993 | 14.75 | -0.736 | 17.69 | -0.988 | 26.82 | -0.972 | 0.124 | -0.949 |
| | 2 | 39.13 | -0969 | 0.0387 | -0.983 | 0.0000039 | 0.933 | 161.9 | -0.739 | 58.29 | -0.973 | 29.04 | -0.993 | 0.006 | -0.993 |
| | 100 | 97.71 | -0.212 | 0.0195 | - 0.928 | 0.0000367 | 0.991 | 30.96 | -0.740 | 22.70 | -0.989 | 36.54 | -0.973 | 0.056 | -0.962 |
| legume | 1 | 32.01 | -0.951 | 0.0663 | -0.980 | 0.0001729 | 0.994 | 15.87 | -0.717 | 15.02 | -0.989 | 9.56 | -0.995 | 0.066 | - 0.980 |
| | 2 | 40.64 | -0.952 | 0.0404 | -0.970 | 0.0000289 | 0.997 | 32.27 | -0.723 | 21.93 | -0.986 | 14.89 | -0.994 | 0.029 | -0.984 |
| | 100 | 67.07 | -0.948 | 0.0062 | -0.950 | 0.0000019 | 0.980 | 336.0 | -0.744 | 33.93 | -0.987 | 23.66 | -0.993 | 0.002 | -0.993 |
| Sheep | 1 | 27.21 | -0.971 | 0.0344 | -0.996 | 0.000224 | 0.994 | 15.87 | -0.717 | 8.42 | -0.997 | 15.87 | -0.990 | 0.116 | -0.957 |
| | 2 | 45.97 | -0.963 | 0.0416 | -0.985 | 0.000028 | 0.997 | 32.27 | -0.723 | 18.35 | -0.994 | 18.66 | -0.994 | 0.048 | -0.979 |
| | 100 | 52.95 | -0.972 | 0.0101 | -0.976 | 0.0000005 | 0.956 | 161.6 | -0.741 | 20.51 | -0.996 | 35.88 | -0.987 | 0.008 | -0.984 |
| Poultry | 1 | 38.87 | -0.938 | 0.0801 | -0.996 | 00006971 | 0.899 | 12.08 | -0.682 | 20.75 | -0.983 | 3.89 | -0.999 | 0.368 | -0.924 |
| | 2 | 51.59 | -0.951 | 0.0615 | -0.984 | 0.000038 | 0.998 | 25.19 | -0.711 | 24.50 | -0.989 | 11.82 | -0.997 | 0.189 | -0.980 |
| | 100 | 57.30 | -0.964 | 0.0138 | -0.969 | 0.000003 | 0.973 | 130.30 | -0.741 | 25.24 | 0.993 | 33.93 | -0.987 | 0.009 | -0.985 |

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