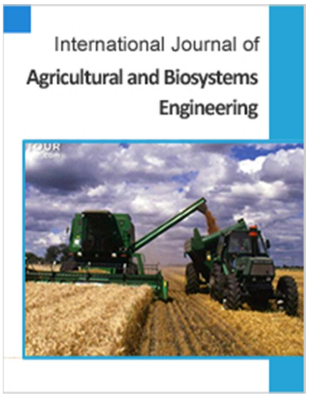
International Journal of Agricultural and Biosystems Engineering
2017; 2(4): 26-33
http://www.aascit.org/journal/ijabe

American Association for Science and Technology



The Effect of Mungbean (*Vigna radiata*) as Green Manure on some Chemical Characteristics of Tropical Soil Condition of Padang Besar, Perlis, Malaysia

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Citation

Ghassan Jayed Zaidan, Zakaria Wahab, Abdul Razak Shaari. The Effect of Mungbean (*Vigna radiata*) as Green Manure on some Chemical Characteristics of Tropical Soil Condition of Padang Besar, Perlis, Malaysia. International Journal of Agricultural and Biosystems Engineering. *International Journal of Agricultural and Biosystems Engineering.* Vol. 2, No. 4, 2017, pp. 26-33.

Keywords

Incubation,
Green Manure,
Soil pH,
Soil Chemical Properties,
Fertilizer

Received: July 20, 2017
Accepted: August 6, 2017
Published: September 14, 2017

Abstract

Decreased soil fertility represents a major constraint towards agricultural production and food security in farming. As farmers are unable to massively invest in fertilizers, they use green manure to compensate for this. This study was carried out in an experimental farm and laboratory of Inst. of Sustainable Agrotechnology, University Malaysia Perlis, Padang Besar, Perlis, Malaysia to determine the optimal time for decomposition and nutrient release from green manure legume (mungbean residue) in a tropical soil. The treatments involved four decomposition duration of 0, 1, 2, and 4 weeks after its incorporation. They are laid out in a Randomized Complete Block Design (RCBD) with five replications. The content of nitrogen (N) decreased, while other elements increased during decomposition. Organic matter content (OM) increased from 2.10% (non-treated) to 2.50, 2.65, and 2.60% after 1, 2, and 4 weeks of incubation, respectively. The content of P increased by 60 mg kg^{-1} when treated for two weeks. The contents of potassium (K), magnesium (Mg), cation exchange capacity (CEC), organic carbon (OC) and carbon to nitrogen (C:N) ratio were all significantly influenced by periods of incubation. The pH of the soil also increased after four weeks of incubation.

1. Introduction

Leguminous green manure is regarded as a common management tool in the context of cropping systems, due to it being rich in nitrogen (N). Its use is fast fading from modern cropping systems due to the widespread availability of synthetic fertilizers and the associated opportunity costs associated with green manure crop. Green manure remains widespread in low-input cropping systems in tropical and subtropical areas [1]. However, increased cost of synthetic fertilizers and the fast declining soil properties from the lack of legumes have led to many farmers reconsidering the usage of leguminous green manure [2].

Also, well established agricultural practices and technologies such as monocultures, excessively utilize inorganic fertilizers and pesticides, which decreases organic manure amendments to the soil, uses heavy agricultural machinery and inadequate practices of soil management, which are all factors that can negatively influence soil quality as it erodes the physical, chemical and biological properties of the soil [3]. Consequently, organic matter content will be lost while the sustainability of the soil will be quite poor in the long run.

Soil sustainability is becoming a concern, resulting in a set of management practices that might mitigate the negative influence of agricultural activities. Properly managing organic matter is most crucial, however the influence of organic matter on the properties of the soil is reliant upon the amount, type and size of the added organic materials and the incubation period of organic matter in the soil [4].

There are results that proved the positive influence of legume crops upon the chemical properties of soil. Jude [5] indicated that three legumes species (Mucuna, Lablab and Sunhemp) could contribute significant amounts of N to the soil at different incubation durations from 2 to 18 weeks. Abdollah [6] reported that the application of green manure (grasspea, vetch, berseem clover, sainfoin and maragheh vetch) significantly influence organic carbon (OC) and calcium carbonate content of the soil.

This study intends to assess the influence of three incubation duration of mungbean as green manure at upon soil chemical properties, such as exchangeable bases (K, Mg, Ca), soil pH, cation exchange capacity (CEC), as well as soil nutrients (such as N, P), organic matter (OM), organic carbon (OC) and C:N ratio.

2. Material and Methods

2.1. The Study Area

The study was conducted in an experimental farm of Institute of Sustainable Agrotechnology (INSAT), University Malaysia Perlis, Padang Besar, Perlis, Malaysia. The coordinate of the farm is 6.653°N 100.261°E.

The climate is hot and humid with an annual average rainfall of about 3,000 mm, reaching maximum levels between September-November. Relative humidity fluctuates between 80-90%, while the maximum and minimum temperature fluctuates between 27-35°C and 21-25°C, respectively.

2.2. Mungbean Residue

Mungbean was planted on 17^{th} November 2015 in an open field at the experimental farm of INSAT. It was harvested on 18^{th} December 2015 at the vegetative growth stage. The chemical characteristics of green manure are shown in Table 1.

2.3. Experimental Description

The experiment was carried out between Nov. 2015 and Jan. 2016 in a Randomized Complete Block Design (RCBD) with four treatments viz., control, 1 week incubation, 2 weeks incubation and 4 weeks incubation with five replications. Mungbean residue was applied at the rate of 100 $g.kg^{-1}$ soil and incorporated into the soil.

2.4. Soil Analysis

Surface soil samples (0-30 cm) were gathered prior to the experiments and air dried. The air dried soil was ground so that it was able to pass through a 2 mm sieve before being analysed. The pH of the soil was measured in a 2 mM $CaCl_2$ at a solution ratio of 1:2. The ammonium saturated soils were prepared by allowing the starting sample to stand overnight in 1N ammonium acetate solution which had been adjusted to pH 7, after which the samples were leached with 1N NH_4Cl [7]. Excess ammonium salts were removed by washing with isopropyl alcohol, after which the clays were dried and ready for determination of CEC. After extraction, the determination of exchangeable cations was done by atomic absorption spectrometer (Ca and Mg) and flame photometer (K). Total N content of soil was determined by Kjeldahl method. The relative liming efficiency was calculated for each organic material used alone or in combination as per the method given by Gichangi and Mnkeni [8].

2.5. Statistical Analysis

The collected data was analysed using the analysis of variance (ANOVA) for a randomized complete block design with five replications with the SAS software package, version 9.0 [9]. The comparison of means was performed by Duncan at 95% level of probability and correlation analysis was carried out to elucidate the link between the parameters.

3. Results and Discussion

3.1. Some of Soil and Plant Residues Properties

Table 1 shows the sand, silt, and clay contents being 79.1, 11.1 and 6.1%, respectively, in the soil, corresponding to a loamy sand texture. The soil organic carbon was 0.14%, organic matter 2.1%, P was 44 ppm, total N 0.13%. The cation exchange capacity was 23%, exchangeable K and Mg at 0.19% and 0.67%, respectively. The C:N ratio and pH were 1.07 and 5.1, respectively.

Table 1. *Initial chemical characteristics of applied soil.*

Chemical properties	Soil depth (0-30 cm)
pH	5.1
CEC (%)	23
Exchangeable K^+ (%)	0.19
Exchangeable Mg^{+2} (%)	0.67
Organic carbon (%)	0.14
C:N ratio	1.07
Total nitrogen (%)	0.13
Available phosphorus (ppm)	44
Organic matter (%)	2.1
Sand (%)	79.1
Silt (%)	11.1
Clay (%)	6.1
Texture class	Loam sand

Table 2 shows some properties of the applied mungbean residue. It has a pH of 5.2, OC of 27%, high OM of 79%, N 3.6%, P 2440 ppm, C:N 6.75, K and Mg of 29.6 and 11%, respectively.

Table 2. *Chemical properties of mungbean residue.*

Chemical properties	Mungbean residue
pH	5.2
Exchangeable K^+ (%)	29.6
Exchangeable Mg^{+2} (%)	11
Organic carbon (%)	27
C:N ratio	6.75
Total nitrogen (%)	3.6
Available phosphorus (ppm)	2440
Organic matter (%)	79

3.2. Effects of Different Incubation Duration of Mungbean Residue on Potassium

The addition of mungbean residue increased the content of K in the soil with incremental incubation times (Figure 1). High microbial biomass and activity will usually lead to increased nutrient availability to the crops [10] via the enhancement of both the microbial biomass turnover and degradation of non-microbial organic materials [11]. Gomes et al., [12] reported that 90% of the K stored in the leaves of *Crotalaria juncea* was released in the first two weeks of decomposition. Mulugeta et al., [13] also pointed out the increment of K as a function of decomposition time is extended from 7 to 35 days after its incorporation.

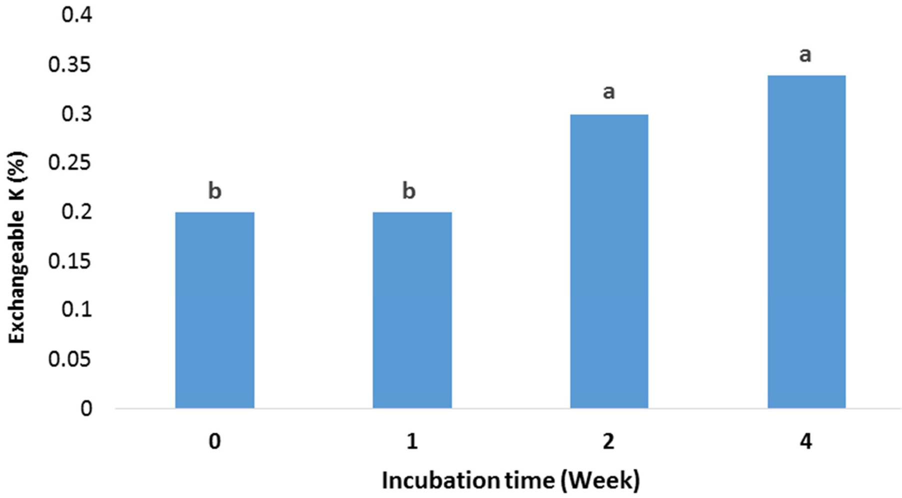

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Figure 1. *Effects of different incubation duration of mungbean residue on potassium content in the soil.*

3.3. Effects of Different Incubation Duration of Mungbean Residue on Magnesium

The concentration of Mg significantly increased due to the incorporation of crop resides compared with the control (Figure 2). The largest amount of Mg was found for the 2 weeks of incubation treated plots (Figure 2). Indeed, in the 1, 2 and 4 weeks of incubation treated plots, the content of Mg significantly increased to 76.47%, 186.09% and 183.42%, respectively. The addition of mungbean residue to the soil might have provided the soil with extra Mg. It was postulated that the introduction of organic manure increases the concentration of organic matter, which subsequently increases the levels of Mg. Nutrients are released over time via chemical, physical, and biological processes. Considerable quantities were released within a short period of time depending on the residue quality [14]. Increases in exchangeable cations Mg and based saturation have been reported by Kretzschmar et al., [15] and Geiger et al., [16].

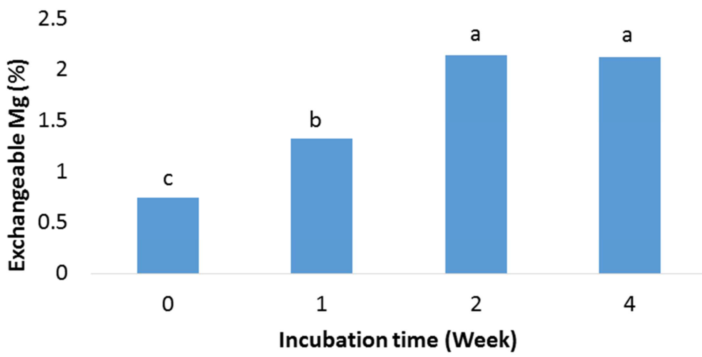

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Figure 2. *Effects of different incubation duration of mungbean residue on magnesium content in the soil.*

3.4. Effects of Different Incubation Duration of Mungbean Residue on Cation Exchange Capacity (CEC)

The amount of CEC was highest after 1 week of the addition of mungbean residue (Figure 3). As times increased (2 weeks), CEC was nearly constant, with a little fluctuation, then decreasing to levels similar with the control samples after 4 weeks of mungbean residue incorporation. According to Testa et al. [17], the usage of legumes will produce high amounts of waste that act to reduce leaching of cations and increased CEC. The cation exchange capacity levels increased due to the application of manure, which agree with Magdoff [18] and Frempong et al., [19].

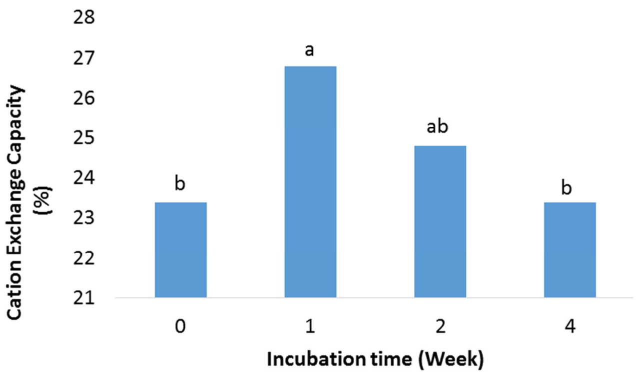

Figure 3 *Effects of different incubation duration of mungbean residue on CEC in the soil.*

(Different alphabets show significant difference using Duncan's Multiple Range test (P≤ 0.05))

3.5. Effects of Different Incubation Duration of Mungbean Residue on Soil pH

Figure 4 shows increased acidity of soil, which subsequently decreased with increased incubation time, probably due to their hypo-buffering capacities. These profound changes clearly indicated the importance of mungbean residue in modifying the exchange capacities of soils and the total acidity of soils (Figure 4). This initial pH change is attributed to the dissociation of organic acids released from the mungbean residues, as outlined by Rukshana et al. [20]. The synchronization between the boosted respiration and quick pH restoration suggested that this soil pH increase might be highly related to decarboxylation of organic acids. However, the pH increase is caused by the decarboxylation of organic compounds being transient, as reported by Butterly et al. [21]. pH neutralization during decarboxylation will be high in soils with higher, as opposed to lower pHs, due to high pH being more susceptible to microbial activity [20]. Noble et al., [22], Tang and Yu [23], Tang et al., [24], Marschner and Noble [25] and Xu et al., [26] suggested that there are four components that caused pH change to the soil, which are 1) the release of alkalinity (decomposition of organic anions) derived from the added plant residues, 2) ammonification of the plant residue N, causing the soil's pH to increase, 3) nitrification of mineral N derived from the plant residue N, causing the soil pH to decrease, and 4) the association/dissociation of organic compounds could also change the soil pH, depending upon the initial soil pH. The overall effect on the soil's pH post-addition of plant resides is therefore reliant upon the extent and interactions of these processes under multiple conditions. Many investigators seem to agree with the point that the decomposition of green manure alters the pH of the soil. Sangakkara et al. [27] pointed out that the decomposition of organic residues will influence the soil pH, resulting in aggravating acidity. Somado et al. [28] also outlined that the incubation of maize stover increases the pH of the soil. Mulugeta et al., [13] indicated a decreasing trend in the pH from 7 to 35 days of post-incorporation of green manure (*Tephrosia vogelii* and *Crotalaria juncea*) into the soil. Kongcao et al., [29] noted that the soil's pH was quickly restored from the initial decrease and rapidly increased in parallel with a rapid increase in the rates of CO_2 emission.

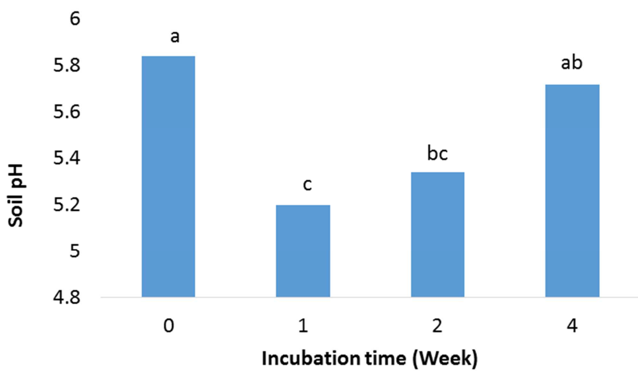

Figure 4*. Effects of different incubation duration of mungbean residue on pH of the soil.*

(Different alphabets show significant difference using Duncan's Multiple Range test (P≤ 0.05))

3.6. Effects of Different Incubation Duration of Mungbean Residue on Soil Nitrogen

Incubation treatments significantly decreased the amount of N in the soil (Figure 5). The largest amount of N was found in control treated plots (0.162%), while 4 weeks of incubation treated plots had the lowest amount of N (0.074%) (Figure 5). The concentration of N in the incubation treated plots significantly decreased by 29.62%, 37.03%, and 54.32% at 1, 2, and 4 weeks, respectively. Low levels of N imply that nitrification was rapid in this soil. Nitrogen is vital towards microbial growth, which greatly influence residual breakdown. Overall, the content of N residues was determined to be low and highly variable [30], which is indicative of the fact that the rapid growth of the soil microorganisms decrease the amount of N due to the incorporation of low quality residue. Microbial biomass and the gathering of microbial recalcitrant metabolites represent the main sinks for immobilized N [31]. This agrees with Aulakh et al., [32], who showed that the incorporation of wheat, corn, or soybean residues will result in the immobilization of significant number of N in the case of incubated soils, especially in the case of the initial 17 days of incubation. The apparent net immobilization (mineral N in amended soil minus mineral N in check soil) from the addition of residues after 35 days was 32 to 34 mg N kg^{-1}. Also, Fosu et al., [33] reported that some of residual N immobilization occurs during the decomposition of legume residues regardless of residual quality. However, the amount of immobilized N and the period of immobilization both increase with decreasing residue. Rahman et al. [34] reported that the mineralization of nitrogen is affected by how long it is incubated, the rate of organic material application, moisture regime, and the type of soil.

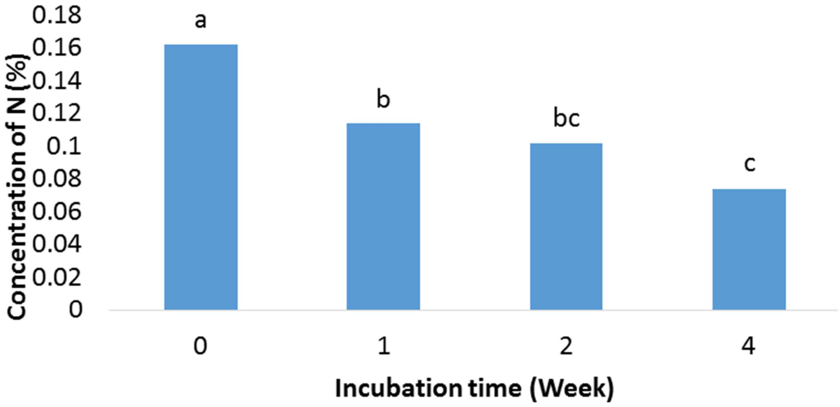

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Figure 5. *Effects of different incubation duration of mungbean residue on nitrogen content in the soil.*

3.7. Effects of Different Incubation Duration of Mungbean Residue on Phosphorus

The results show that the application of green manure would initially increase the content of P in the soil (Figure 6). The content of P peaked at 2 weeks of incubation time, and subsequently decreased as a function of time. After an incubation time of 4 weeks, the amount of P in the soil showed a significant decrease. However, there as no significant decrease detected in the period of 1 week of incubation when compared to the control samples. Mungbean residues is capable of quick absorption of applied P fertilizers, which is assumed to block the fixation of P compared to soils lacking mungbean residues 2 weeks after its incubation. It is also probable that the decrease in P sorption is unrelated to the competition coming from the decomposition products of the mungbean residue, instead it was from the released P from the mungbean residue two weeks after incubation, where its availability exceeded that of soils without mungbean residue. Mungbean residue act as a source of subsurface P and mobilizing agent [35]. Hussain et al. [36] reported that soils possessing high P sorption abilities and P binding energy releases P to the soil solution in smaller concentrations to delay the fixation of P in the soils and keep the P fertilizer accessible for longer periods of time.

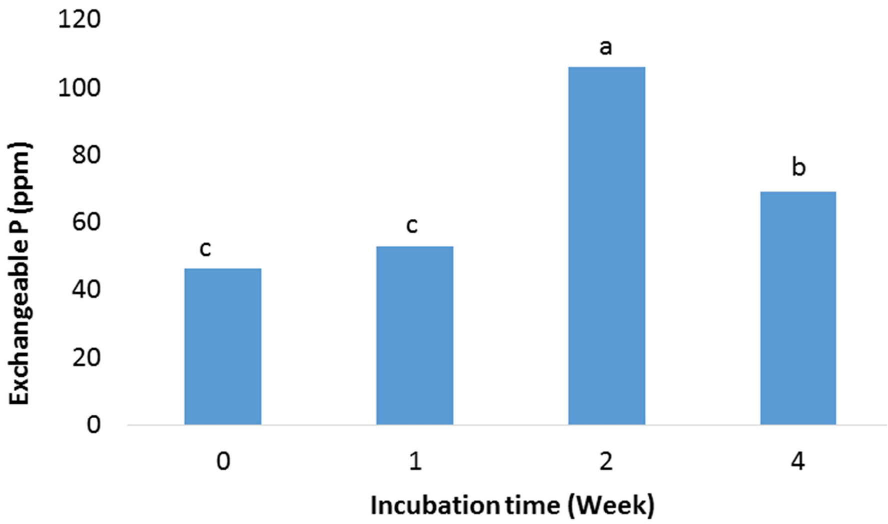

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Figure 6. *Effects of different incubation duration of mungbean residue on phosphorus content in the soil.*

3.8. Effects of Different Incubation Duration of Mungbean Residue on Organic Carbon (OC)

Organic carbon rates of the mungbean residue at four incubation durations are shown in Figure 7. It can be seen that under incubation, the organic carbon rates of the mungbean residue were statistically exceeding the control. It was apparent that the addition of residues encouraged microbial activities, as it supply mineralizable residue C against the native soil organic C, which is quite resistant against biodegradation [36]. This agrees with Hadas et al., [38] and Zita et al., [39], both of whom pointed out that under aerobic conditions, microbial activity and nitrogen immobilization are preferred over residues with high available carbon. However, the temporary unavailability of nitrogen causes microorganisms to quickly use the nitrogen present in the crop residues to decompose carbon.

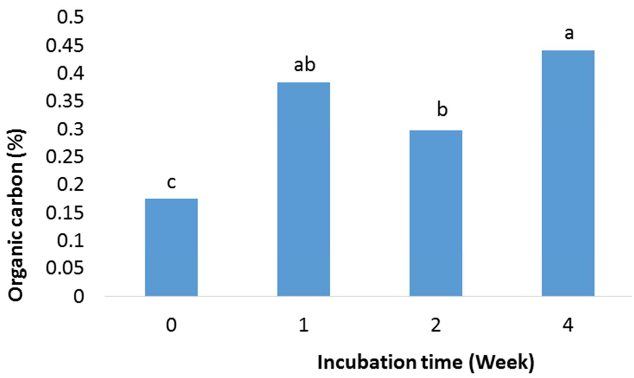

Figure 7. *Effects of different incubation duration of mungbean residue on organic carbon content in the soil.*

(Different alphabets show significant difference using Duncan's Multiple Range test (P≤ 0.05))

3.9. Effects of Different Incubation Duration of Mungbean Residue on Organic Matter (OM)

Figure 8 shows that OM was significantly influenced by the timing of the incubations. The results indicated that the OM in the control sample released a maximum of 2.10% compared to 2.50%, 2.65%, and 2.60% at 1, 2, and 4 weeks of incubation times, respectively. This could probably be due to the breakdown of mungbean residue by soil microorganisms, as they were incorporated into the soil prior to harvesting [13]. This corresponds to an increase of 19.04%, 26.19% and 23.80% for 1, 2 and 4 weeks incubation, respectively, compared to control treatment. This result agree with what other studies have found Lehtinen et al., [40] and Liu et al., [41] that the effect depends on many variables, both natural conditions, management practices and duration of incubation.

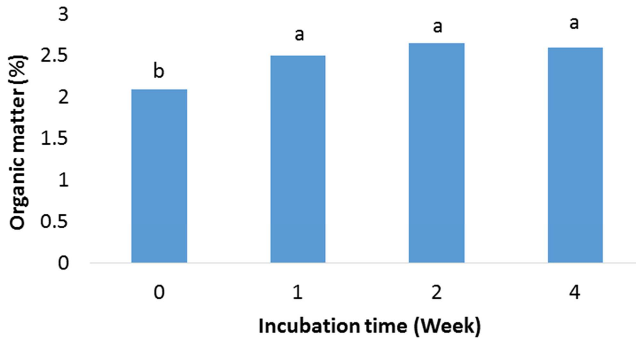

Figure 8. *Effects of different incubation duration of mungbean residue on organic matter content in the soil.*

(Different alphabets show significant difference using Duncan's Multiple Range test (P≤ 0.05))

3.10. Effects of Different Incubation Duration of Mungbean Residue on C:N Ratio

Figure 9 shows that the amount of C:N in the soil did not show regular pattern with the initial composition of mungbean residues. The C:N ratio was in the order of control<2 weeks < 1 week < 4 weeks of mungbean residue incubation. The increment of C:N ratios of the incubation durations are expected, as they lose nitrogen from the quick decomposition of the mungbean residue (Figure 5). This result confirms the previous results [42-43].

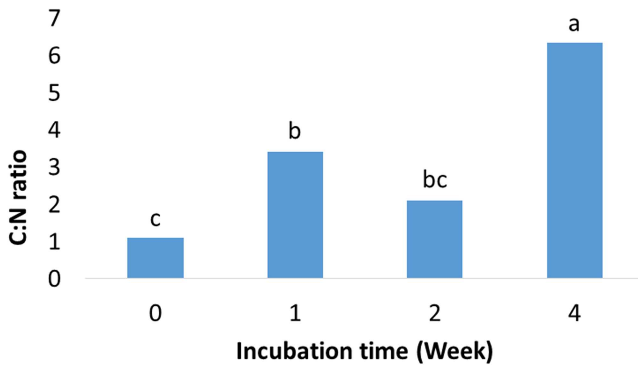

Figure 9. *Effects of different incubation duration of mungbean residue on C:N in the soil.*

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4. Conclusion

The results from this study indicated that all the three durations of incubation can contribute significant amounts of K, Mg, P, OC and OM for improved chemical soil parameters. This may be of significant benefit to smallholder farmers in Perlis region with limited resources to purchase sufficient fertilizers, although field trials are necessary to validate the results in terms of the synchrony between soil nutrients release by the mungbean residue and soil improvements. The nutrient elements, organic matter and another characteristics of the soil were found to be significantly affected by incubation durations of mungbean residue into soil, where rate of Mg, P and OM increased at the end of the 2 weeks incubation duration in the soil, while the rate of K, OC and C:N increased at the end of the 4 weeks incubation duration in the soil. On the other hand, CEC content in the soil was highest value at 1 week incubation. The rate of N release during the incubation durations was lower than in control. Given that by the end of the 4 weeks incubation duration, N release by the decomposing mungbean residues was still on a reducing trend. A study with a more prolonged incubation duration would provide some useful insights on the long-term dynamics of soil nutrients release in soil amended with mungbean residue.

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