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Effect of bio-char on growth and yield of onion (*allium cepa*) and soil properties of Calcic Red Yellow Latasols in Jaffna District

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Abstract: *An experiment was conducted to study the effect of three different types of biochar applied to soil in combination with organic and inorganic fertilizers on growth and yield of Onion (Allium cepa) and on soil properties. The field research was carried out during the Yala season of 2016 at the Regional Agriculture Research Station, Thirunelvely. Randomized Complete Block design was used with three blocks and eight treatments. There were two fertilizer application treatments such as department recommended fertilizer (DRF) and farmers practice fertilizer(FPF) because farmers of study area usually applies 185% of the Department of Agriculture recommended fertilizer dosage. In addition there were three bio-char treatments namely coconut char (CC), Palmyra char (PC), and paddy husk char (PHC). Each fertilizer application treatment has a control treatment without the application of bio-char. Each biochar is applied with either department recommended fertilizer or farmers practice fertilizer. All the other cultural practices were same for all the treatments. Growth, yield and soil parameters were monitored continuously during the growing season. Significantly highest mean fresh weight of onions as yield (6750 kg/ha) was measured in treatment T7 (FPF+PHC). This contributes to 57% of fresh weight of yield compared to the control treatment T8 (FPF). Similarly significantly highest 51% increase in fresh weight of onions as yield was measured in treatment T3 (DRF +PHC) compared to the control treatment T4 (DRF). Statistically significant 60% dry weight of onions as yield increase was observed in both treatments T3 (DRF+PHC) and T7 (FPF +PHC) respectively compared to control treatment T4 (DRF) and T8 (FPF). Soil available phosphorus content has increased in all biochar applied treatments compared to the control treatments in both farmer practice fertilizer (FPF) and department recommended fertilizer (DRF). Significantly highest soil available potassium was obtained in paddy husk char with farmer practice fertilizer treatment. Soil available potassium is increased in all biochar applied treatments compared to the control treatments in both farmer practice fertilizer (FPF) and department recommended fertilizer (DRF). Soil organic carbon content has increased in all biochar applied treatments compared to the control treatments in both farmer practice fertilizer (FPF) and department recommended fertilizer (DRF). Therefore paddy husk char has increased the yield of onion significantly irrespective of the fertilizer application treatments compared to other biochar namely coconut char and palmyrah char. Therefore paddy husk char performs best when applied with farmer practice fertilizer or department recommended fertilizer application. However, coconut char and palm char has the potential to increase yield and improve soil properties with both DRF and FPF.*

Key words: *Bio char, soil properties, growth, yield, Onion*

1 INTRODUCTION

Increasing in population results in greater proportions of land needing to be cropped under cultivation and there is an urgent need to use of fertilizer to increase the crop yield by enhancing the soil productivity. However the rates of fertilizer applied by farmers concern about profit are usually much higher than the quantity recommended by the Department of Agriculture (DOA). Farmers apply nitrogen fertilizers when crop shows reduction in greenness of leaf caused by reduced crop response. Therefore it stimulates farmers to apply higher amount of urea (nitrogen fertilizer) which is cheap (Wijewardena, 1996; Wijewardena, 2001). Therefore loss of nutrient elements from fertilizers into the environment increases the environmental pollution.

Soils in Sri Lanka are low in organic matter (Panabokke and Nagarajah, 1964; Wijewardena, 1995; Wickramasinghe and Wijewardena, 2003). Cation Exchange Capacity (CEC) levels in majority of the soils are lower than 10 cmo1/kg, lead to poor retention of plant nutrients (Panabokke, 1966; Wijewardena 1993; 2000). Agricultural lands diminish in crop production potential or suitability for crop production through various types of land degradation in Sri Lanka (Nayakekorale, 1998). National average yields of paddy and several other food crops have been stagnating over the last decade (Wickramasinghe and Wijewardena, 2003) due to the degradation of overall soil fertility in cultivated lands in Sri Lanka. Being an agricultural country, Sri Lanka has to place much attention on soil degradation problem in consideration of the low per capita land availability at present. Soil fertility decline in Sri Lanka is mainly due to depletion of soil organic matter as well as loss of plant nutrients etc. Soil analytical studies conducted in various parts of the country revealed that low plant nutrient content is a major threat to crop production in Sri Lanka (Wijewardena, 1995; Nayakekorale and Prasantha, 1996). The depletion of soil nutrient due to leaching and run off could be considered as major course of fertility decline. Thus, many agricultural farming systems are becoming non-profitable to farmers.

Due to rigorous cultivation, greater amounts of CO_2 could be released to the atmosphere from biomass and soil. A reduction of this substantial CO_2 release could be achieved through bio-char (it is the carbon-rich product through heating of biomass under limited oxygen conditions) as a soil management system. Carbon sequestrations in the environment can off-set unavoidable greenhouse gas emissions. The application of bio-char to soil is proposed as an approach to establish a significant, long term, sink for atmospheric carbon dioxide in terrestrial ecosystems. Apart from positive effects in both reducing emissions and increasing the sequestration of greenhouse gases, the application of bio-char to soil will deliver immediate benefits through improved soil fertility and increased crop production.

Bio-char can be formed from a wide range of organic feed stocks under different pyrolysis conditions and at a range of scales. Many different materials have been proposed as biomass feed stocks for bio-char. The suitability of each biomass type for such an application is dependent on a number of chemical, physical, environmental, as well as economic and logistical factors. Application of bio-char varies with cultivation techniques. The application strategy used to apply bio-char to soils is an important factor to consider when evaluating the effects of bio-char on soil properties and processes. The placement of the bio-char directly into the rhizosphere is thought to be more beneficial for crop growth and less susceptible to erosion. Bio-char appears to improve a soils ability to retain and use fertilizers, reducing the amount lost to leaching and increasing soil water retention. If fully documented, this capability could be tied to water quality improvement as less phosphorous and nitrates are lost from agricultural lands into waters.

In Jaffna neck of land, soil has low organic matter content and less CEC hence farmers use inorganic fertilizers at very higher rates than the DOA recommended rates (per.comm, 2016). This is leading to soil salinity, soil fertility decline and environmental pollution specially ground water (Mikunthan and De Silva, 2008). Bio-char has the ability to overcome these problems through improve the physical, chemical and biological properties of soil. In this background a field experiment was planned using the test crop as Onion (*Allium cepa*) with different charred biomass namely coconut char (CC), Palmyrah char (PC) and paddy husk char (PHC) in combination of inorganic and organic materials commonly used by Jaffna farmers. The field trial was conducted with the objectives of study the effect of different types of charred biomass in combination with department recommended fertilizer (DRF) and farmer practice fertilizer (FPF) on growth and yield of Onion (*Allium cepa*)and to study the effect of such treatments on important soil properties.

2 MATERIALS AND METHODS

The research was conducted at Regional Agricultural Research Station, Thirunelvely during the *yala* season of 2016. Two fertilizer treatments were used in this study because farmers in the study area usually use 185% of the Department of Agriculture recommended fertilizer dosage as shown in Table 1.Agriculture department recommended fertilizer (DRF) and Farmers practice fertilizer (FPF) were applied each with three types of charred biomass namely coconut char, palm char and paddy husk char and without any char. Coconut char, palm char and paddy husk char were produced through pit method. Eight treatments (Table 2) were tested in the field using as Onion (*Allium cepa)* test crop.

Table: 1 Rates of fertilizers

Fertilizers			Rate
DRF	Basal	Urea	50Kg/ha
		TSP	100Kg/ha
		MOP	50Kg/ha
		Cow dung	10 Ton/ha
	TD	Urea	100Kg/ha
		MOP	25Kg/ha
FPF	Basal	Urea	92.5Kg/ha
		TSP	185Kg/ha
		MOP	92.5Kg/ha
		Cow dung	10 Ton/ha
	TD	Urea	185Kg/ha
		MOP	46.25Kg/ha

Table 2: Treatments

Treatment	Char and fertilizer (for onion) combinations
T1	DRF+CC
T2	DRF+PC
T3	DRF+PHC
T4	DRF
T5	FPF+CC
T6	FPF+PC
T7	FPF+PHC
T8	FPF

The field was layout with blocking which was done perpendicular to the slope of the land. Three blocks were made and each block was further divided into eight plots with the plot size of 2m X 1.5m to each treatment (Figure 1). The soil layer up to the depth of 10 cm was removed and heaped in the each corner of the plot and basal fertilizer and cow dung were mixed with the heaped soil. Six years ago char was put in the plot as layer of five mm to ten mm below 10 cm from the soil surface. Then fertilizer and cow dung mixed soil was placed above the char layer and leveled. This the way the farmers were applying bio char in the study area. Therefore the same practice in done for this research too. These eight treatments were arranged using randomized complete block design with three replications. Before planting, the field was thoroughly irrigated. Onion bulbs were cleaned and 300 onion bulbs were allocated to each plot and weight of those onions were measured by balance. After 6 gram Captan was mixed into 10 l liter water and onion bulbs were soaked into that water before planted to field by hand with the spacing of 10 cm X 10 cm. As mentioned in the Table 1 fertilizers were applied to related treatments. All three types of char were applied at the rate of 20 tones/ha.

Figure 1: Onion trial field

Top dressing was done 2nd week after planting for treatments T1, T2, T3 and T4. For treatments T5 (FPF +CC), T6 (FPF + PC), T7 (FPF + PHC) and T8 (FPF) top dressing was done 2nd week after transplanting to farmer practice. Water was applied to the plots using hosepipe directly up to the field capacity level of the soil moisture and prevent the mixing of soil between the plots. At early stage of planting field was irrigated at two days interval then four days interval. Hand weeding was done whenever weeds emerged. Weedicide (Goal) was applied at recommended rate to control the weeds.

Plant height was taken randomly selected five plants per plot. Plant height was determined in cm from the ground to the highest point of plant by using measuring tape at 2^{nd} , 4^{th} and 6^{th} week after planting.

Each plot fresh weight of the yield onions were weighted by using balance immediately after the harvest. And dry weights of onion yield of each plot were weighted by using balance after one week from the harvest. Numbers of cluster, Numbers of cluster with leaves. Numbers of cluster without leaves were taken from five randomly selected plants in all treatments.

After the harvest soil from each plot in the field was collected by core sampler at the depth of 15 cm from the soil surface. Then collected samples were prepared by air drying, crushing and sieving to pass through 2mm sieve and important basic properties were determined. Soil pH and EC were measured preparing soil solutions using pH and electrical conductivity meter. Soil available potassium extraction was done using 1M neutral Ammonium acetate and exchangeable K was measured by flame photo meter (Knudsen et al., 1982). Soil's P content was measured by Olsen and Sommers (1982) method using 0.5M $NaHCO_3$ to extract. Moreover Available P in the extract was measured colourimetrically by Ammonium molybdate-$SnCl_2$ method at the wave length of 660nm. Soil organic matter content of the soil was done by the Walkley and Black (1934) method. Results were analyzed by SAS package and the mean separation was done by Duncan method (Probability 5%).

3 RESULTS AND DISCUSSION

3.1 Plant Height

Plant height data are summarized in Figure 2. Only 4^{th} week mean plant height was significant (P=0.0166). Significantly highest mean plant height (23.3 cm) was observed in treatment T7 (FPF+PHC). Second highest mean plant height (18.5 cm) was observed in control treatment T8 (FPF). Plant height of 22.3cm, 21.7cm, 21.5cm, 21.5cm and 21.2cm were observed in treatments T6 (FPF+PC), T5 (FPF+CC) T2 (DRF+PC), T8 (FPF), T1 (DRF+CC) respectively. However these results were statistically not significant. Among the DRF treatments T1 to T4, control treatment T4 (DRF) showed the lowest mean plant height and among FPF treatments control treatment T8 (FPF) showed the lowest mean plant height. Plant height was increased by the application of all three types of bio-char compared to the respective control treatments (T4, T8). Overall, T7 showed the highest significant plant height. Bio-char applications has increased the plant height compared to fertilizer alone applied treatments. The findings of this research agree with Graber (2010) who has reported increased plant height in tomato crop was due to bio-char application.

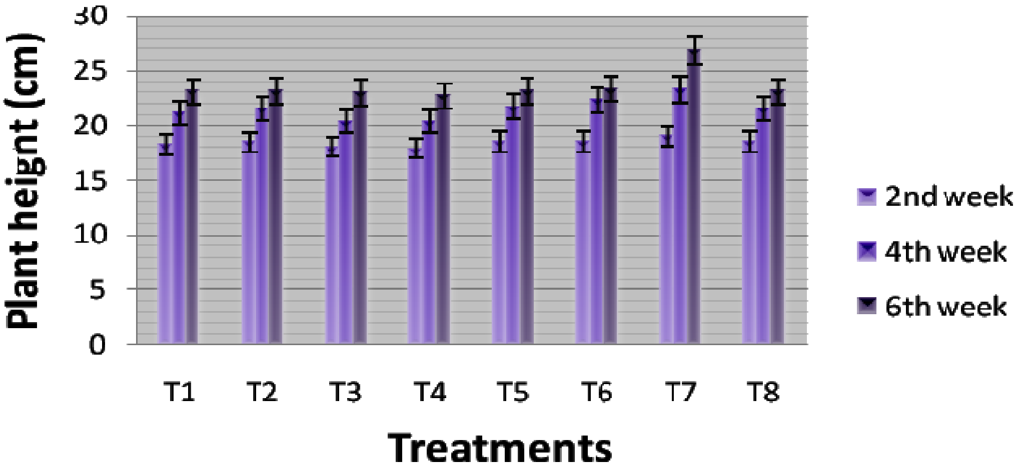

Figure 2: Effect of different treatments on height of Onion

3.2 Yield parameters

Number of cluster per plant

Number of cluster per plant data are summarized in Figure 3. Statistically significant highest mean of number of cluster per plant (7) was measured in the treatment T7 (FPF+PHC). Second highest mean of number of cluster per plant (6) was measured in T8 (FPF) followed by T2 (DRF+PC), T6 (FPF+PC), T4 (DRF Control) and T5 (FPF + CC) and T6 (FPF +PC) and these are statistically not significant from each other. The lowest mean number of cluster per plant (4) was observed in treatment T3 which is statistically not significant from T1 (DRF + CC), T4 (DRF) and T5 (FPF+CC).

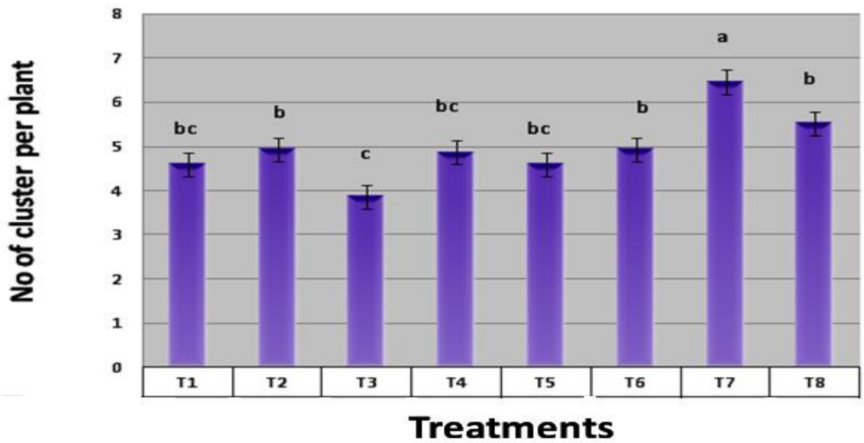

Figure 3: Effect of different treatments on number of cluster per plant

Cluster weight without leaves

Cluster weight without leaves data are summarized in Figure 4. Statistically significant highest mean of cluster weight without leaves (14.8 g) was observed in treatment T7 (FPF + PHC). Second highest mean of cluster weight without leaves (13.8 g) was observed in treatment T6 (FPF +PC) which is statistically not significant from T7 (FPF + PHC), T3 and T5 treatments. Treatments T1, T5, T6, and T8 were statistically significant. Treatment T1 (DRF+CC) was the lowest mean of cluster weight without leaves (9.5g). Compared to control T4, increased cluster weight without leaves was observed only in treatment T3. Compared to control T8, increase in cluster weight without leaves were observed in treatment T5, T6, and T7.

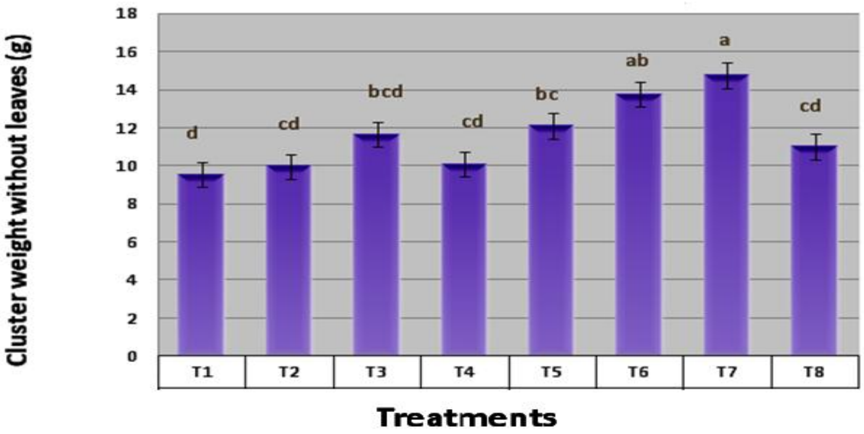

Figure 4: Effect of different treatments on cluster weight without leaves per plant

Fresh weight of the yield of onions

Fresh weight of the yield of onions data are summarized in Figure 5. According to the Figure 5, significantly highest mean fresh weight of yield (6750 kg/ha) was measured in T7 (FPF+PHC). Second highest mean fresh weight of yield (5100 kg/ha) was obtained in T6 (FPF+PC), followed by T3 (DRF+PHC) and these were statistically not significant to each other. Lowest mean fresh weight of yield (2650kg/ha) was observed in T1 (DRF+CC) followed by T2 (DRF+PC) and T4 (DRF) and these were statistically not significant to each other. Compared to control T4, increase in yield increase was observed only in treatment T3. Compared to control T8, increase in yield was observed in treatments T6 and T7.

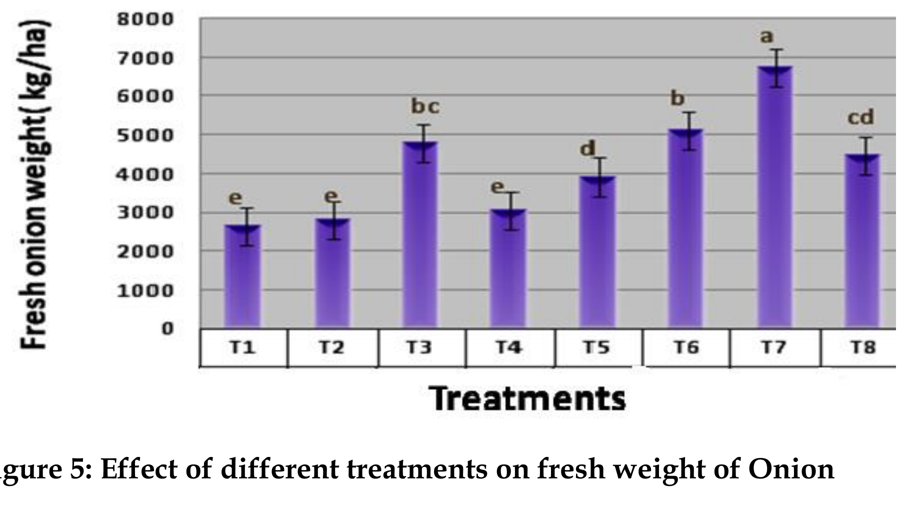

Figure 5: Effect of different treatments on fresh weight of Onion

Dry weight of the yield onions

Figure 6 shows the effect of different treatments on dry weight of the onions as yield. The highest average yield (6393.3 kg/ha) was obtained in treatment T7 (FPF + PHC) which was statistically significant to all other treatments. Second highest yield of 4566.7kg/ha was obtained in Treatment T6 (FRF+ PC) which is statistically not significant to the yield

(4433.3 kg/ha) of treatment T3 (DRF +PHC). The dry yield obtained was statistically significant in control treatments T4 (DRF) and T8 (FPF). Lowest dry weight of the yield (1966.3 kg/ha) was obtained on T1 (DRF+CC). Compared to control T4, yield increase was observed only in treatment T3. Compared to control T8, yield increase was observed in treatments T6 and T7. Among the FPF treatments T7 showed highest yield which was significantly different to treatments T5, T6 and T8. Among the DRF treatments T3 treatment showed highest yield which was significantly different to T1, T2 and T4. The results of field trial indicate that the application of bio-char improves the crop yield. Beneficial effects on crop yields by bio-char have been also documented in a number of pot and field trials (Asai *et* al., 2009; Chan *et* al., 2007; Major et al., 2010; Van Zwieten *et* al., 2010). Result revealed that the paddy husk char can give better yield when more fertilizer application than that of department recommendation. However better yield was obtained under paddy husk char even in department recommended fertilizer application.

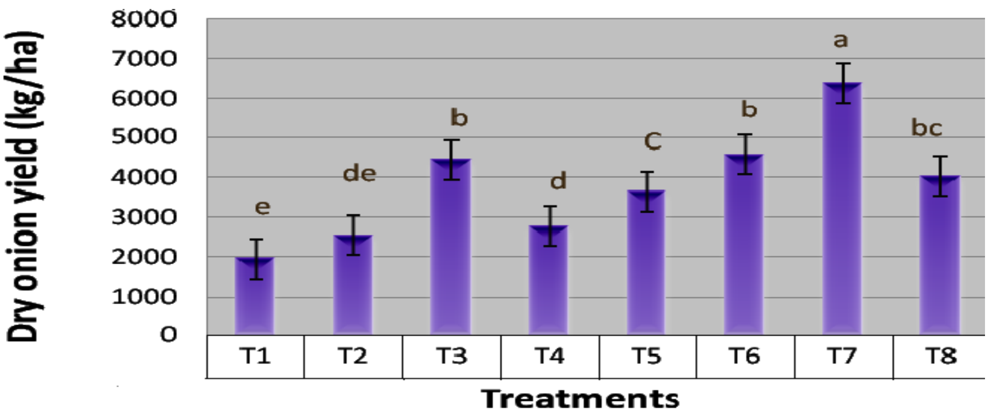

Figure 6: Effect of different treatments on dry weight of Onion

3.3 Soil parameters

Soil pH

The highest mean of soil pH (7.9) was observed in treatment T1 (DRF+CC) compared to all other treatments (Figure 7). However pH of treatments T1, T2, T3 and T4 are statistically not significant to DRF treatments. Among FRF treatments, the mean soil pH of treatment T6 (FPF+PC), T7 (FPF+PHC) and T8 (FPF) were statically not significant, but T5 (FRF + CC) treatment showed the highest pH which is statistically significant to other treatments. The lowest mean soil pH (7.2) was observed in treatment T8 (FPF). Among DRF treatments T1 to T4 soil pH was increased by the application of bio-char in all treatments compared to control treatment T4 (DRF). Among FPF treatments T5 to T8, soil pH was also increased by the application of bio-char in all treatments compared to control treatment T8 (FPF). Several studies have been reported that bio-char addition increases the soil pH (Deluca et al., 2006). The addition of bio-char to soil will amend the chemical and physical properties soils and turned into a valuable resource for improving crop yields on acid and infertile tropical soils where nutrient resources are scarce (Lehmann and Rondon, 2005). According to the results of soil pH in different treatments, higher rate of fertilizer application in FRF treatments had reduced the soil pH. In farmers practice fertilizer have high amount of urea than that in department recommendation fertilizer. Soil pH decreases after application of urea due to acidification resulting from dissociation of urea to produce H+ ions (Yeboah *et* al., 2009). This may also be reason for the reduced soil pH in treatments related to farmers practice fertilizer compared to treatments related to DRF even in same type of bio-char applied treatments.

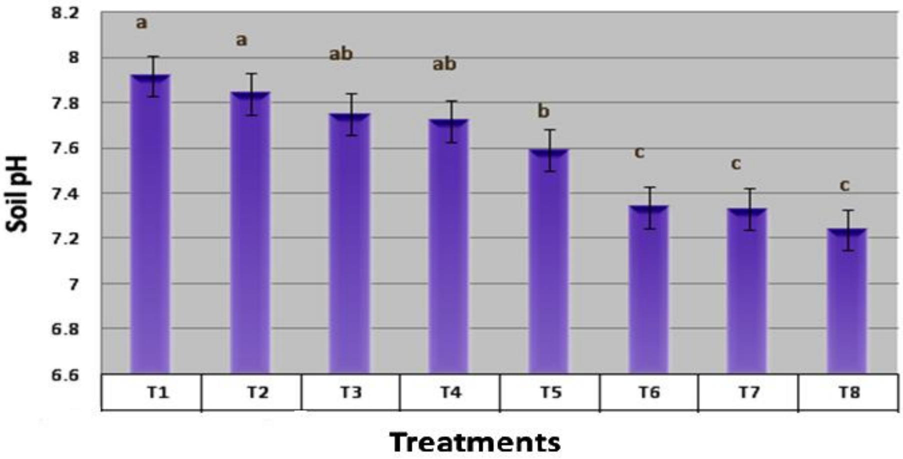

Figure 7: Effect of different treatments on soil pH

Electrical Conductivity (µs/cm)

Among the FRF treatments, highest electrical conductivity (108.3 µs/cm) was obtained in treatment T7 (FPF + PHC) and lowest electrical conductivity (89.9 µs/cm) in control treatment T8 which are statistically significant to each other (Figure 8). However treatment T5, T6 and T7 are statistically not significant to each other. Among the DRF treatments, the highest electrical conductivity (92.4 µs/cm) was observed in treatment T2 (DRF +PC) which statistically significant to T1, T3 and T4 treatments. Soil electrical Conductivity was increased by the application of all three types of bio-char compared to control. From treatments T1 to T4, Control T4 (DRF) is the lowest measured mean soil electrical conductivity. From treatments T5 to T8, Control T8 (FPF) is the lowest measured char improves the soil electrical conductivity. Nigussie *et al* (2012) reported of increased EC due to bio-char application at the rate of 10 tones/ha in Cr polluted soil which agrees with the results of this study.

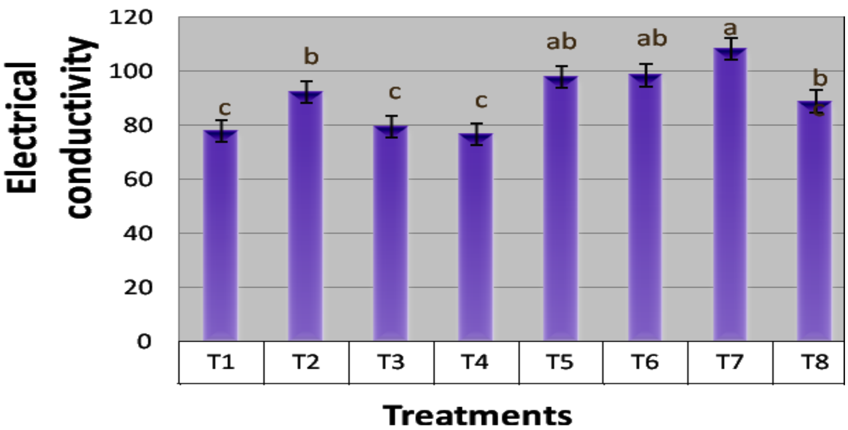

Figure 8: Effect of different treatments on soil EC (µs/cm)

Available phosphorous (kg/ha)

Available phosphorus data are summarized in Figure 9. Significantly highest available phosphorus (134.9kg/ha) was obtained in T7 (FPF+PHC) and the lowest available phosphorus (96.1 kg/ha) was in treatment T4 (DRF). Among the DRF treatments the highest available phosphorous (120.7 kg/ha) was obtained in T2 (DRF + PC), but it is statistically not significant to the available phosphorus content (107.3 kg/ha) of treatment T3 (DFR +PC). Lowest available phosphorus was obtained in control treatment T4 which is without biochar application. Similarly among the FPF treatments the treatment T7 is statically not significant to treatments T5 (FPF +CC) and T6 (FPF +PC), but statistically significant to the lowest available phosphorus treatment T8 (FPR) which is without bio char application. Soil available phosphorous was increased by the application of all three types of bio-char compared to control. The release of P from bio-char has long been recognized (Tyron, 1948), and the mechanism for direct P release from bio-char is not complex. Further Biochar may have an indirect effect on P availability and uptake by providing a beneficial environment for microorganisms that, in turn provide greater access to P from organic and insoluble inorganic pools, produce and recycle a highly labile pool of organic P and improve direct access to P through improved mycorrhizal activity (Deluca et al, 2006)

Available potassium (kg/ha)

Significantly highest mean of available potassium (103.4kg/ha) was observed in treatment T7 (FPF+PHC) to all other treatments (Figure 10). The lowest mean of available potassium (56kg/ha) was observed in treatment T4 (DRF). Among the DRF the highest available potassium was obtained in treatment T2 (DRF +PC) which is statistically significant to T1, T3 and T4. Soil available potassium was increased by the application of bio-char compared to control treatment T4. Among the FPF treatments T5 to T8, Control T8 (FPF) is the lowest measured mean soil available potassium (79.4kg/ha) but it is statically not significant to T5 and T6 treatments. Increased potassium availability was observed in bio-char amended treatments compared to the treatments for which fertilizer alone was applied. This is due to the higher K content of bio-char. The supply of available K in bio-char is typically high and increased K uptake as a result of bio-char application has been frequently reported (Lehmann et al., 2003b; Chan et al., 2007).

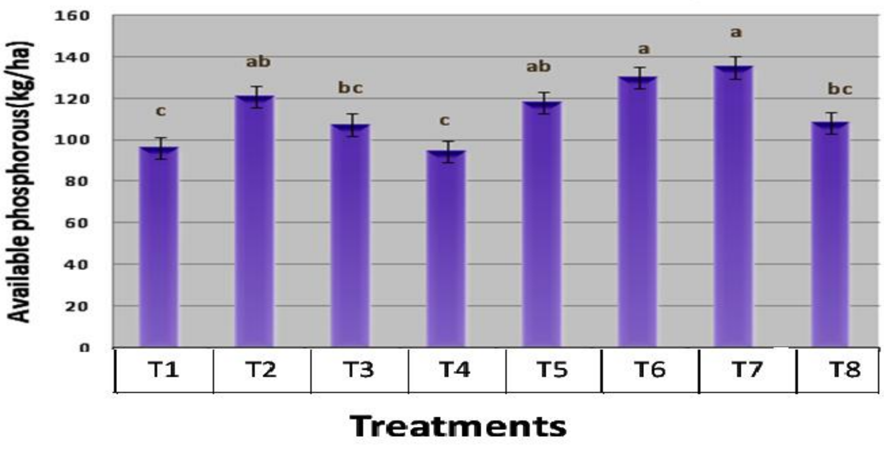

Figure 9: Effect of different treatments on soil available phosphorous

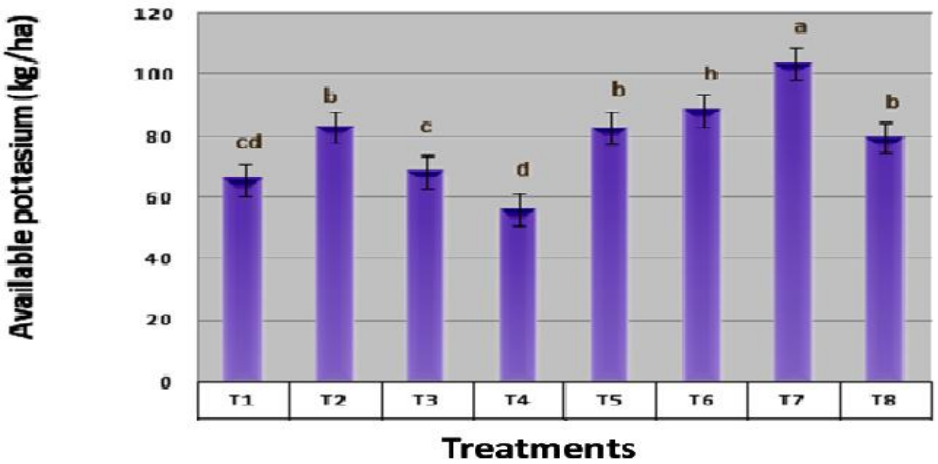

Figure 10: Effect of different treatments on soil available potassium

Soil Organic carbon

Soil organic carbon data are summarized in Figure 11. Significantly highest (0.98) and lowest (0.08) soil organic carbon percentages were obtained in treatments T1 (DRF+CC) and T8 (FPF) respectively. Among DRF treatments highest and second highest (0.84) percentage of soil organic carbon was obtained in T1 and T3 (DPF +PHC) treatments, but these treatments are statistically not significant to each other. The lowest soil organic carbon percentage was obtained in T4 treatment which is without biochar application. Among the FPF treatments significantly highest soil organic carbon percentage was obtained in T5 (FPF+CC) and the lowest soil organic carbon percentage was obtained in treatment T8 (DRF) which is without bio char application. Soil organic carbon percentage was increased by the application of all three types of bio-char compared to control. Nigussie *et* al (2012) reported significantly increased mean value of soil organic carbon (SOC) in soil amended with maize stalk bio-char. The highest values of organic carbon in bio-char treated soils indicate the recalcitrance of organic carbon in bio-char. Bio-char offers a way of safely storing C for long periods of time while enhancing the productivity of terrestrial ecosystems. Moreover, bio-char technology, like other biomass conversion approaches that include C sequestration options, offers a way to decrease the levels of CO_2 in the atmosphere (Lehmann and Joseph, 2007).

More over biochar can improve plant productivity directly as a result of its nutrient content and release characteristics, as well as indirectly, through improved retention of nutrients (Lehmann et al., 2003; Wardle *et al.,* 1998), improvements in soil pH (Rondon *et al*., 2007), increased soil cation exchange capacity (Liang *et al*., 2006), improved soil physical properties (Chan et al., 2008), including an increase in soil water retention (Laird *et al*., 2010). These effects may also act in concert to result in improved crop performance. Biochar is also thought that the porous and light nature of biochar can help to improve the structure of compacted soils and improve soil aggregation that also increases the water retention (Sohi *et al.,* 2010). Fresh biochar contains different proportions of ash, which is rich in minerals and benefits plant growth (Verheijen *et al*., 2010). One important measurement of soil fertility is called the Cation Exchange Capacity. CEC of soil increases with biochar that increases nutrient retention and reduces the leaching losses. Increased nutrient availability (P and K), organic matter content due to applied charred biomass were observed at the end of the experiment.

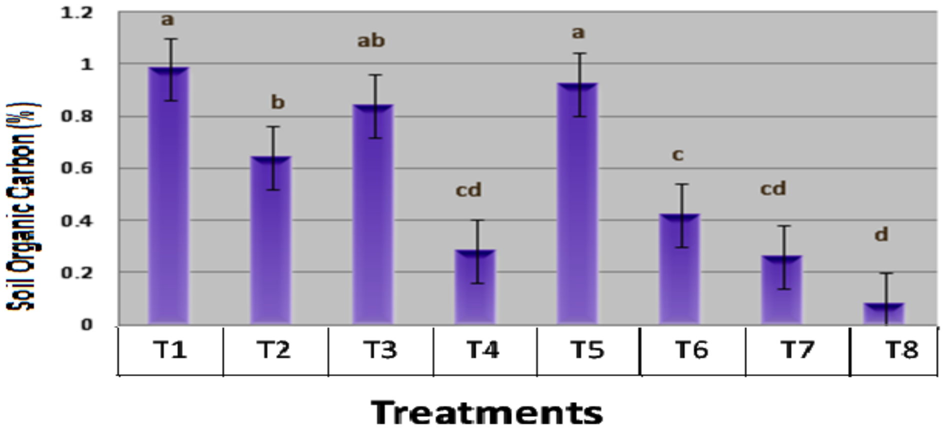

Figure 11: Effect of different treatments on soil organic carbon

4 CONCLUSIONS

Significantly highest mean fresh weight of onions as yield (6750 kg/ha) was measured in treatment T7 (FPF+PHC). This contributes to 57% of fresh weight of yield compared to the control treatment T8 (FPF). Similarly significantly highest 51% increase in fresh weight of onions as yield was measured in treatment T3 (DRF +PHC) compared to the control treatment T4 (DRF). Statistically significant 60% dry weight of onions as yield increase was observed in both treatments T3 (DRF+PHC) and T7 (FPF +PHC) respectively compared to control treatment T4 (DRF) and T8 (FPF).

Results of soil analysis at the end of the experiment reveals, which all treatments with bio char application have increased available P and available K compared to control treatments. Highest P and K availability was found in T7 (FPF + PHC). Reduced soil pH in treatments related to FPF and increased soil pH in treatments related to DRF was recorded even in same bio-char applied treatments. Soil Organic matter content was increased by the application of all three types of bio-char compared to control. All treatments have shown increased EC compared to Controls.

Therefore it could be concluded that paddy husk char has increased yield and performed the best when applied with FPF and DRF. Moreover, However, coconut char and palmyra char has the potential to increase yield with both DRF and FPF. Paddy husk is freely available in the paddy field of Jaffna District. Paddy Husk Char could be easily produced with low cost to increase the yield of onions.

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