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Assessing soil amendment potentials of *Mucuna pruriens* and *Crotalaria juncea* when used as fallow crops

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This research was carried out to assess the soil amendment potentials of *Mucuna pruriens* and *Crotalaria juncea* when used as fallow crops. The research made use of randomized complete block design (RCBD) with three treatments replicated three times. The study revealed higher mean levels of percentage nitrogen, phosphorus, potassium, percentage organic carbon and soil pH after incorporation as compared to the results obtained before planting (Control). The results revealed significant difference in the levels of the above mentioned parameters before planting and after incorporation in soils under both *M. pruriens* and *C. juncea* but there were no significant differences in soils under the natural regeneration. Although there were no significant differences in the results obtained after incorporation between *M. pruriens* and *C. juncea*, *M. pruriens* recorded higher mean levels of percentage nitrogen, phosphorus, percentage organic carbon and soil pH except in potassium where the mean added level was higher in *C. juncea*. Though there was no significant difference in the soil amendment potentials of *M. pruriens* and *C. juncea*, *M. pruriens* is recommended to be used as a fallow crop since it has an added advantage of serving as a cover crop to control soil erosion.

Key words: Fallow, soil amendment, potential, *Mucuna pruriens*, *Crotalaria Juncea*.

INTRODUCTION

Fallow management and improvement is as old as agriculture itself. Fallows are still intrinsic parts of many tropical farming systems. While fallow is commonly referred to as resting period for agricultural land between two cropping cycles during which soil fertility is restored, it has more roles than just fertility restoration. Fallow functions include weed control and the interruption of pest and disease cycles. They provide cash income in times of immediate need and help to balance food supply (Styger, 1999). Physical properties such as hydraulic conductivity, bulk density, total porosity and aggregate stability all decrease as soil organic matter falls, as a result of the duration and intensity of cropping (Agboola, 1994). The degradation and irreversible destruction of soils have reached alarming proportions and every year, 5 to 7million ha of agricultural land is lost worldwide (Steiner, 1996). To maintain and improve soil fertility overtime, the incorporation of leguminous cover crops in farming systems has been advocated (Osei-Bonsu and Buckles, 1993).

Inclusion of these legumes into the farming systems has been shown to contribute nutrients to the soil through

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nitrogen fixation and through recycling of residues which also contribute organic matter into the soil (Anthofer, 1999).

They also play an important role in weed suppression and soil conservation. Increasing pressure on land is leading to shorter fallow periods, and soil fertility can no longer be regenerated naturally. This has led to a gradual destruction of the natural resource base, declining soil fertility and yields, and hence, reduced farm income. The integration of the leguminous cover crops into the existing farming systems to address these problems has been very successful because of the high agronomic benefits achieved from the use of these legumes (Loos et al., 2001). Soil is considered as number one growth medium in crop cultivation in the tropics. Therefore, there is the need to conserve this medium to enhance ideal plant growth and development. Different types of soils contain different plant nutrients depending on the parent material from which the soil was developed (Brady and Weil*,* 2008). Some soils contain high levels of plant nutrients, while others contain very low levels.

Farmers in Ghana normally leave their farmland to fallow after harvesting their crops. Most of these lands when left fallow become exposed to erosion and bushfires as a result; the expected fallowing which allows the decomposition of dead plants into the soil is not achieved. In areas where the soil is not burnt nor exposed to erosion, plants growing on the land may not be important species which can help replenish the nutrient levels of the soil. *Mucuna* and *Crotalaria* are leguminous plants which fix nitrogen into the soil. *Mucuna* and *Crotalaria* also serve as effective cover crops in controlling erosion and excessive loss of soil moisture. *Mucuna pruriens* and *Crotalaria juncea* are known to improve soil fertility but as to which one is most effective in improving the nutrient level is not known. It is for this reason that this research was conducted to ascertain soil improvement potentials of *M. pruriens* and *C. juncea*. This will help determine which of these plants will serve as an effective fallow crop in addressing problems like nutrient inadequacies and soil erosion in fallow lands to increase crop production.

MATERIALS AND METHODS

Study area

The study was carried out on the research plot of the Faculty of Renewable Natural Resources, University for Development Studies, Nyankpala Campus. Geographically, the campus lies within latitudes 9° 25'N and longitude 0° 58' W. Nyankpala is 16 km (10 miles) away from Tamale, the capital of the region with an altitude of 183 m above sea level .

The area experiences moderate annual rainfall pattern. Rains start in May and end in October. Monthly rainfall is 131.7 mm, the dry season which follows the wet season is normally between the months of November and April. During the dry season, the daily average temperature is as low as 18°C and maximum temperature reaches 44°C at the peak. The vegetation of the area is guinea savannah (grassland) type with extensive shrubby grassland and few sparse populations of trees. The common trees found include *Azadirachta indica, Parkia biglobosa, Adansonia digitata, Tectona grandis* and *Senna siamea.* The soil type is mainly Alfisols with clayey loam and coarse-grave (SARI, 2004). The people of the area are mostly farmers growing crops like maize, rice, sorghum millet, yam, groundnut and soybeans.

Experimental design

The research made use of randomized complete block design (RCBD) with three (3) treatments namely: *Mucuna* (T_1), natural regeneration (T_2) and *Crotalaria* (T_3) replicated 3 times giving a total of 9 experimental units. Nine (9) 2 × 2 m bed was prepared with 0.5 m spacing between each plot.

Soil sampling procedure

Soil samples were collected before planting using soil auger at the depth of 0 to 20 cm from the 9 sample plots. The soil samples were collected at three different spots on each plot and were bulked to have a composite sample for each plot. The soil samples were air-dried at the laboratory and the initial determination serving as the control for the various levels of nitrogen, phosphorus, potassium, pH and organic carbon were determined. *M. pruriens* and *C. juncea* were planted using the vines and seeds, respectively. Natural regeneration of weeds was allowed to occur to serve as the second treatment (T_2). The *M. pruriens*, *C. juncea* and the natural regeneration were incorporated into the soil 10 weeks after planting and allowed to decompose for 4 weeks. The final soil samples were then collected from the 9 plots and the levels of nitrogen, phosphorus, potassium, pH and organic carbon determined again.

Laboratory analysis

The samples were air-dried, ground, sieved to pass 2 mm size screen and stored in sealed plastic for laboratory analysis. pH was determined using an electronic pH meter (Bates, 1954). Nitrogen was determined using the Kjeldahl method (Jackson, 1962; Black, 1965). The OC content of the soil was then determined using the Walkley-Black method (Walkley and Black, 1934).

Two grams of air-dried soil sample was put into a 50 ml test tube and 14 ml extraction solution was added. The mixture was shaken for a few minutes and filtered. 1 ml of standard serves 2 ml boric acid and 3 ml of mixed reagent were homogenized. The solution was allowed to stand for 1 h for the blue color to develop and the absorbance measured on spectrometer at 720 nm. Standards were also prepared and the absorbance recorded was used to calculate for the phosphorus concentration (Jackson, 1962).

Five grams of air-dried soil sample was weighed into a shaking bottle. 50 ml ammonium acetate solution (1 N, pH = 7) was added and shaken for 2 h. The solution was filtered through No. 42 Whatman filter paper. The concentration of potassium in the soil extract was determined using the flame photometer.

Statistical analysis

Data collected from the laboratory analysis were analyzed with the general statistics software (GENSTATS). Analysis of variance (ANOVA) was conducted to determine significance of treatment effects. Microsoft Office Excel was used to present results in charts with error bars showing differences in the treatments.

RESULTS

Effects of *M. pruriens, C. juncea* and natural regeneration on soil nitrogen percentage

Figure 1 shows the comparative effect of *Mucuna*, *Crotalaria* and natural regeneration on the soil nitrogen. There were significant ($p < 0.05$) increases in the levels of nitrogen added to the soil by both *Mucuna* and *Crotalaria* but there was no significant ($p > 0.05$) change in the natural regeneration.

Effects of *M. pruriens, C. juncea* and natural regeneration on available soil phosphorous (Mg/kg)

From the ANOVA test, the levels of phosphorous added to the soil by *Mucuna* and *Crotalaria* before planting and after incorporation were significant ($p < 0.05$) but no significant ($p > 0.05$) change in the natural regeneration (Figure 2).

Effects of *Mucuna pruriens, Crotalaria juncea* and natural regeneration soil potassium (Mg/kg)

Figure 3 shows substantial increase in the levels of potassium when *Mucuna* and *Crotalaria* were incorporated into the soil but only a slight increase was observed in the control.

Effects of *Mucuna pruriens, Crotalaria juncea* and natural regeneration on soil pH (H_2O)

The incorporation of *Mucuna* and *Crotalaria* biomasses into the soil resulted in a significant ($p < 0.05$) increase in the pH levels of the soil (Figure 4). Though nominally, *Mucuna* recorded slightly higher pH value after incorporation than *Crotalaria*, there was no significant ($p > 0.05$) difference between the two crops.

Effects of *Mucuna pruriens, Crotalaria juncea* and natural regeneration on soil organic carbon percentage

Figure 5 shows the comparative effect of *Mucuna*, *Crotalaria* and natural vegetation on soil organic carbon. There was significant ($p < 0.05$) difference in the levels of organic carbon added to the soil by both *Mucuna* and *Crotalaria* but there was no significant ($p > 0.05$) change in the natural regeneration.

DISCUSSION

Effects of *M. pruriens, C. juncea* and natural regeneration on soil nitrogen

The results obtained after incorporation of *M. pruriens* and *C. juncea* into the soil showed a significant ($p < 0.05$) difference between the levels of nitrogen obtained before planting and after incorporation. The increase in the mean levels of nitrogen in both *Mucuna* and *Crotalaria* could be attributed to the fact that leguminous plants are capable of fixing nitrogen through the formation of root nodules and can often provide the required quantity of nitrogen for crop production as reported by Thiessen-Martens et al. (2005). The increase in nitrogen levels could also be as a result of increasing decomposition and subsequent mineralization of biomass. However, the mean percentage nitrogen fixed by *M. pruriens* (0.13%) was higher as compared to *C. juncea* (0.09%). This could be as a result of different responses of the crops to climatic and biological processes in the study area. Cherr et al. (2006) reported that *C. juncea* retained large amounts of nitrogen and slowed decomposition due to the structural portioning of dry matter and minerals to the stem.

The results further showed that there was no significant difference in the level of nitrogen before and after incorporation of the natural regeneration. The low percentage of nitrogen in the natural regeneration soil could be as a result of the natural vegetation utilizing the already available nitrogen and not being able to replace them as they are not legumes.

Effects of *M. pruriens, C. juncea* and natural regeneration on soil phosphorous

The results obtained from the research showed that *M. pruriens* and *C. juncea* improves phosphorous availability. There was significant ($p < 0.05$) differences between the before planting and after incorporation of the plant materials of *Mucuna* and *Crotalaria*. This could be attributed to the fact that *M. pruriens and C. juncea* could access poorly available forms of phosphorous by altering the rhizosphere chemically through the exudation of compounds such as organic-acid anions (Ae et al., 1991). It was also reported by Vanlauwe et al. (2000) that in Nigeria, the legumes *M. pruriens* (velvet bean) and *C. juncea* has been found to increase the availability of phosphorus in soil when it was incorporated into the soil. Although both *Mucuna* and *Crotalaria* had a significant effects on the soil available phosphorous, the mean phosphorous added by *M. pruriens* (3.36 Mg/kg) was higher as compared to that added by *C. juncea* (2.94 Mg/kg). Also, the result obtained from the soil samples from the natural regeneration showed that there was no significant differences in the mean values of available phosphorous before and after incorporation. This could be as a result of leaching and heavy uptake of phosphorus from the soil by the natural regeneration.

Effects of *M. pruriens, C. juncea* and natural regeneration on soil potassium

The results indicate a significant ($p < 0.05$) difference in

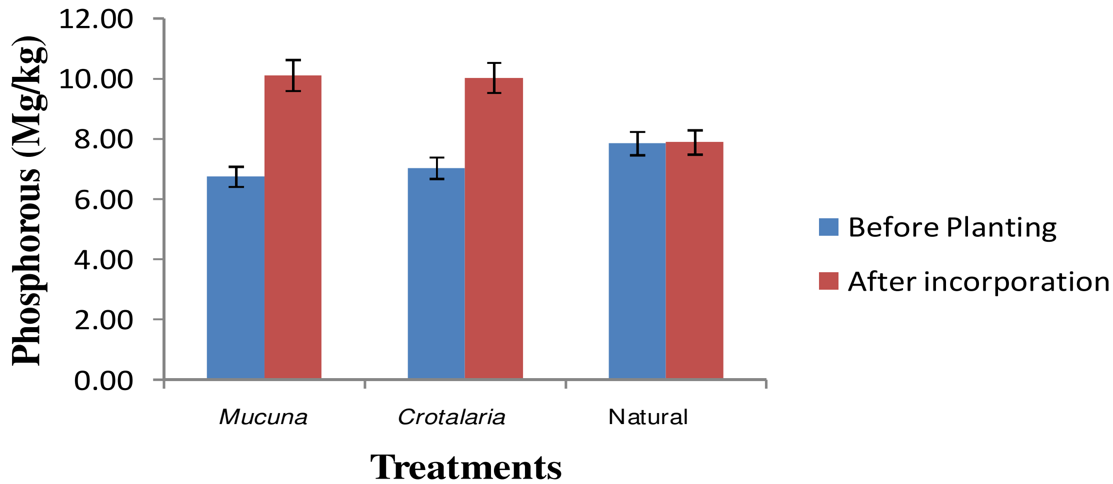

Figure 2. Effect of *M. pruriens*, *C. juncea* and natural regeneration on soil phosphorous.

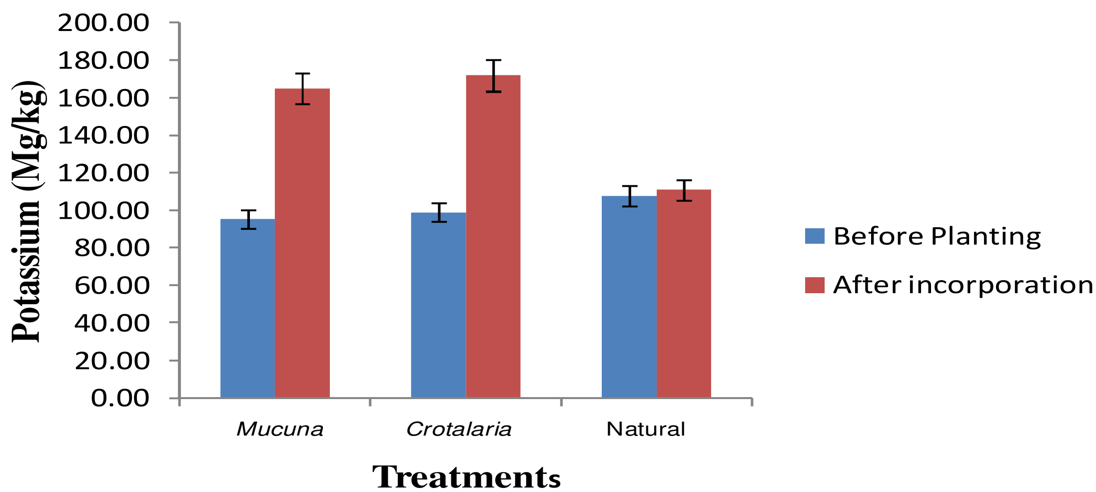

Figure 3. Effect of *M. pruriens*, *C. juncea* and natural regeneration on soil potassium.

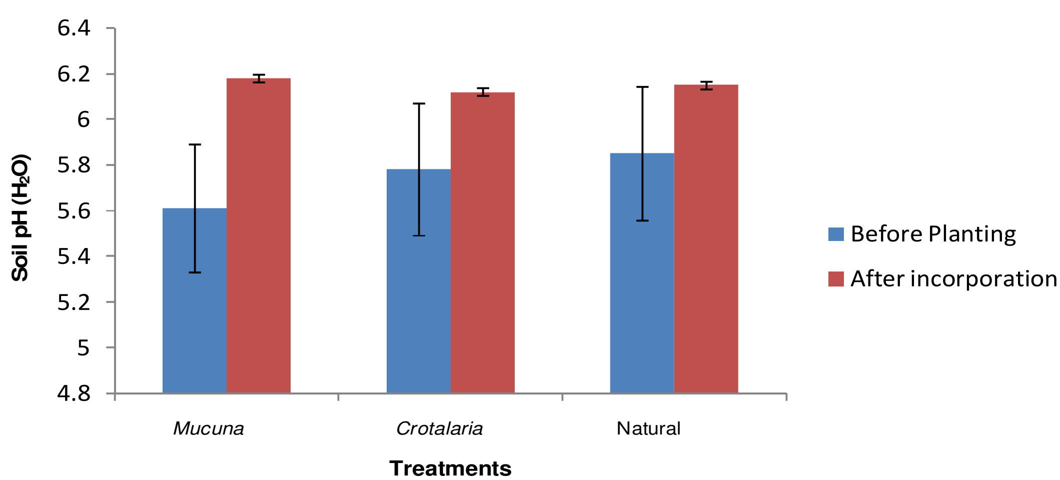

Figure 4. Effects of *M. pruriens*, *C. juncea* and natural regeneration on soil pH (H_2O).

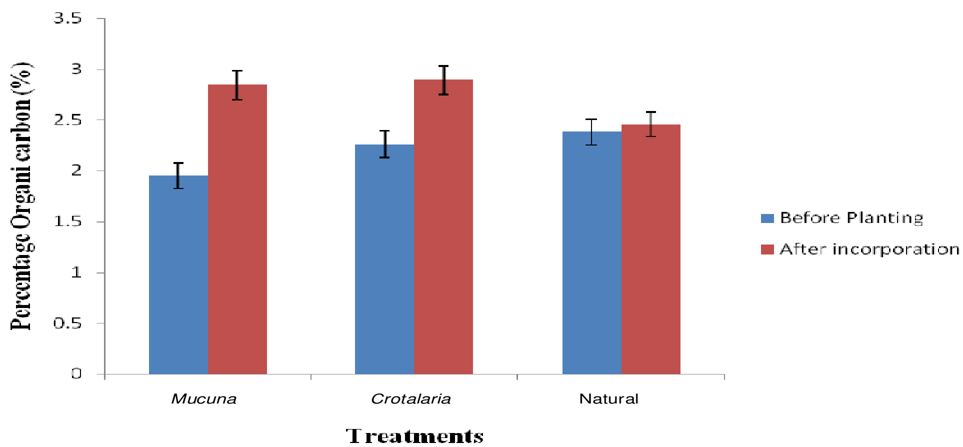

Figure 5. Effects of *M. pruriens*, *C. juncea* and natural regeneration on soil organic carbon.

the levels of potassium between *M. pruriens* and *C. juncea* but showed no significant difference in the natural regeneration before planting and after incorporation of the plant materials in the soil. This confirms the findings of Feichtinger et al. (2004) that, the use of *M. pruriens* and *C. juncea* can conserve the moisture, builds up organic matter and improves the properties of terrestrial soil and activity of microbes supporting the mineralization rate and release of potassium in greater proportion in the soil. Although the incorporation of *Mucuna* and *Crotalaria* led to increase in potassium levels, *C. juncea* (89.71 Mg/kg) added a higher amount of available potassium as compared to *M. pruriens* (69.51 Mg/kg). This could be attributed to the rooting system of the two plants where *Crotalaria* has deeper roots which could take up more residual potassium than that of *Mucuna*. The insignificant change in potassium levels in the natural regeneration may be due to lack of cover which promotes leaching of the available potassium. It could also be attributed to the fact that the natural vegetation takes up these available K without replenishing them.

Effects of *M. pruriens, C. juncea* and natural regeneration on soil pH

The result showed a significant ($p < 0.05$) difference between the soils samples under *M. pruriens, C. juncea* and the natural regeneration. The soils from the legume incorporation showed a higher mean pH levels with *M. pruriens* also indicating a higher mean pH level (6.18) as compared to *C. juncea* (6.12). The higher pH value of soil under both *M. pruriens* and *C. juncea* could be due to the plant biomass incorporated into the soil resulting in the conversion of organic element to inorganic form which increases soil pH (Weischt and Claviecles, 1993). Shoko and Tagwira (2005) also noted that legumes such as *Crotalaria* and *Mucuna* have the potential to improve soil pH and the availability of organic matter exchangeable bases. The pH largely controls plant nutrient availability and microbial reaction. This is evident in the study carried out when the amount of nitrogen, phosphorus, and potassium was high. This is in line with the findings of Hussein (1997), who reported that most of the essential plant nutrients are readily available in between pH 5.2 and 8.8. However, the low pH of the soils under the control may be due to the fact that the organic matter was not able to decompose as a result of changes in temperature with time.

Effects of *M. pruriens, C. juncea* and natural regeneration on soil organic carbon

The result revealed significant ($p < 0.05$) difference in levels of organic carbon in *M. pruriens* and *C. juncea* between before planting and after incorporation of their plant materials but no significant change was observed in the natural vegetation. The increase in the levels of organic carbon in the *Mucuna* and *Crotalaria* treated soils could be as a result of the plant residues added to the soil and hence are the primary source of organic matter which can release organic carbon into the soil. The increase in soil organic carbon by these legumes could also be as a result of *C. juncea* and *M. pruriens* in that they develop an organic layer above the mineral soil and this layer generally improves physical (soil aeration, water retention, resistance to erodability etc.) and biological properties (build-up of soil micro-organisms, nutrients etc.) which enhances the productivity of the soil and thereby increasing organic carbon levels of the soil. This is in line with Juo et al. (1995) who reported that the contribution of root biomass from legumes such as *C. juncea* and *M. pruriens* to the nutrient and organic matter of the soil is believed to be important for soil fertility maintenance and carbon sequestration, as the below-ground biomass forms a substantial proportion of the total biomass in an ecosystem. The low level or insignificant change in the organic carbon in the natural regeneration could be as a result of low amount of organic materials on the natural regeneration plot before incorporation.

Conclusion

The results obtained from the research showed an appreciable or significant effect of *M. pruriens* and *C. juncea* on the soil as it led to an increase in the chemical parameters studied in terms of the levels of nitrogen, phosphorous, potassium, organic carbon and soil pH after incorporating the organic materials into the soil. The natural regeneration plot did not show any significant change in the levels of the various parameters assessed. Apart from the natural regeneration plot where there was no significant change in the results obtained, *M. pruriens* and *C. juncea* showed significant change in the levels of nitrogen, phosphorous, potassium, pH and organic carbon after incorporation of the plant materials. *M. pruriens* added higher levels of nitrogen, phosphorous, organic carbon and pH to the soils as compared to *C. juncea* which showed a higher level only in soil potassium *M. pruriens*. This could mean that nominally *M. pruriens* contributes more to soil nutrient improvement when used as fallow crops than *C. juncea* but both crops could be used as fallow crops.

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