Organic matter enrichment through cowpea fodder clipping management for sustainable productivity in degraded savannah soils of Nigeria

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ABSTRACT

Cowpea is a vital food crop in the semi-arid tropics where it is reported to be the second most important food legume in tropical Africa. It is grown mainly for the mature seeds and therefore features prominently in the farming systems of the region. However the severe nutrient depletion of the soils of the savannah tropics of the African region over the years has made it difficult to improve the productivity of these varieties using cultural practices only. But, it has been observed that when the cowpea crop plant is cut (clipped) before senescence, it can regenerate after defoliation (provided there is enough soil moisture). And when the clipped organic fodder is added and/or ploughed back into the soil, it enriches the content of the soil organic matter (SOM), which in turn enhances crop productivity. In the light of the above, this study was carried out with the objective of determining the influence of intra-row spacing, clipping height and time on soil organic matter (SOM) and yield of the dual purpose cowpea. Results showed that total harvested organic fodder yield of about 15t ha^{-1} were obtained; and when this quantum of green organic plant biomass was added back into the soil, it increased the soil organic matter (SOM) content by about 70%. Consequently, cowpea pod and grain yield were highest at the closest (15cm) intra-row spacing. Though higher grain yield was produced with the unclipped (control) plants compared to the clipped plants, the control plots produced statistically similar pod yields with plots clipped at 25.0cm heights. Significantly, the gain recorded in the amount of SOM added to the soil, compensates for the little grain loss. Generally higher pod and grain yields were recorded when crop plants were clipped at 64 days after planting - DAP than at 74 and 84 DAP respectively. Based on the result of these investigations, it can be concluded that the adoption of this innovative clipping management technology, holds great potential of increasing the soil organic matter (SOM) and crop productivity for the resource poor farmers in a sustainable manner in the region. Indeed, this ecologically friendly farming practice promotes the building of improved soils and fertility, safer use and healthier livelihoods; which are at the core of organic agriculture (OA) management principles.

Keywords: Innovative, clipping, management, technology, potential, soil organic matter, productivity, sustainable, organic agriculture

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INTRODUCTION

Cowpea, *Vigna unguiculata,* features prominently in the farming systems of the region - the semi-arid tropics - where they are grown mainly for both fodder (haulm) and their mature seeds (Onwueme and Sinha, 1991; Odion and Singh, 2005b). The crop is sometimes grown on poor acid soils for soil improvement (Onwueme and Sinha, 1991).

In the savanna area, the dual purpose cowpea types are sown later in the season and at wider spacing's. As a result of the short growing season often experienced, the late planting of the dual purpose cowpea often result in poor vegetative growth with little or no grain production. But when these dual purpose cowpea varieties are planted early in the season, and at closer intra-row spacing, like the grain types, they grow vegetative and the reproductive phase is either suppressed or completely absent. As a result, it has been difficult to improve the productivity of these varieties using only cultural practices. However, it has been discovered and observed that if the cowpea plant is cut (clipped) at 7-10 Weeks after Planting (WAP), before senescence, it can regenerate after defoliation (and provided there is enough soil moisture), and produce grains (Singh, 1993; Odion and Singh, 2005b). This ability of the cowpea plant to maintain some growth or at least survive under dry soils conditions is explained in part by the fact that it is drought hardy and the deep rooted growth habit of some varieties accounts for the crop's ability to grow and yield under the semi desert conditions of the African Sahel (Singh *et al*., 1997). Thus, Odion and Singh (2005b) concluded that the reproductive growth of the dual-purpose cowpea varieties was enhanced in these trials by the clipping management despite the close intra-row spacing under which the crop was grown. Hence, they postulated that it is possible that after clipping, the re-growth from clipped plots behaved like the semi-erect grain type of cowpea that are grown at this closer intra-row spacing's.

Since the cowpea crop when cut at the vegetative growth phase can regenerate provided there is enough soil moisture; then it is possible to grow cowpea crop for "green manure" by clipping its foliage and allowing the clipped crop plants to grow to maturity for grains (Odion and Singh, 2005b). The advantage of the above stated practice is in the ability of low resources, low input and technology based farmers to improve on the soil organic matter (SOM) and/or nutrient status of their soils - bearing in mind that most African soils are reported to be typically impoverished and seriously deficient in nutrients - a situation compounded by the agricultural system (permanent) practiced in the tropics which results in severe nutrient depletion in sub-Saharan Africa (Zake, 1993).

But given that a proportionately large amount of available nutrients are retained in the vegetative cover and the soil–OM accumulates on the surface and subsequently mixes with the upper part of the soil; the continuous practice of removing/exporting the top vegetative cover from the farmlands – which is a common feature of the farming systems of the semi-arid regions - means that the fertility of the soil declines rapidly as the soil – OM is unable to be maintained at an appropriate level. However, green manuring - as in the placement and/or working into the soil of fresh green nonwoody plant, rich in water, sugars, starches, protein and nitrogen (Kahnt, 1983); as organic fertilizer, could provide some solution and thus enhance growth and productivity of crops (Karunairanjan, 1980). The green-manure crop supplies organic matter (OM) as well as additional nitrogen particularly if it is a legume crop, which has the ability to fix atmospheric nitrogen (Patnaik, 2004); the green manure crops also exercise a protective action against erosion and leaching. Green manures are either cut or brought from outside or grown in the field intended to be ploughed in as manure (Yegna Narayan Aiyer, 1975; Reijntjes *et al.,* 1992).

The maintenance of organic matter (OM) is of fundamental importance to the productivity of tropical soils. If soil fertility in the tropics is to be maintained, fertilization must first and foremost be organic. What this means in practical terms is that, a proper management of tropical soils which have only recently come under cultivation must aim to maintain both the structure as well as the content of organic matter. In soils that have been cultivated for a long time, the aim should be to increase the organic mass and to improve structure (Muller-Samann and Kotschi, 1994).

Thus far, in many tropical cropping systems, little or no agricultural residues are returned to the soil. This is reported to lead to a decline in soil organic matter - SOM (Lal, 1986; Bouwman, 1990; Post and Mann, 1990; Woomer and Ingran, 1990); which frequently results in lower crop yields (Lal, 1986), or plant biomass productivity (Woomer and Ingran, 1990),

Recent studies have focused on the effect of green clipped crop materials and placing or incorporating such plant residues into the soil for fertility maintenance and or improvement. Since cowpea can regenerate after defoliation, it might be possible to grow the crop of dual purpose cowpea for both grain and fodder and through clipping management, placement and or incorporation, for fertility maintenance and/or improvement of the soils organic matter (SOM) content (Odion and Singh, 2005a; Odion *et al.,* 2007).

Cowpea fodder can potentially serve as a source for both soil nutrients and organic matter as well as for other beneficial agricultural purposes which hitherto have been constraints to the improvement and sustainability of crops production in the savanna; and the remedies had been both expensive to the resource poor farmers and have to be gotten from outside the farm. However, the process of ameliorating the negative effects of soil organic matter (SOM) loss for sustain fertility and crop productivity are now within the farmers' reach and may not be as expensive as the imported technologies (Smalling and Nandwa, 1996; Henao and Baanante, 1999). In the light of the foregone, this study was carried out with the objective of determining the influence of intra-row spacing, clipping height and time on soil organic matter (SOM) and productivity of the dual purpose cowpea (*Vigna unguiculata* (L.) Walp).

MATERIALS AND METHODS

Field experiments were carried out on the research farm of the Institute for Agriculture Research, Samaru, Nigeria, during the 2002, 2003, 2004 and 2005 cropping seasons. Samaru

(11^0.11'N, 07^0.38'E and 686m above sea level) is located in the northern Guinea savanna agro-ecology of Nigeria (Keay, 1959). Usually, rainfall in the region establishes between mid-May and early June and peaks in July/August. Total annual rainfall ranges between 883 - 1062mm, with an average of 945.20mm. The dry season starts at about mid-October and extends to the end of April. The mean minimum and maximum temperatures during the rainy seasons range between 14 - 22^0C and 29 - 34^0, respectively. The soil of the experimental site at the beginning of the trials in 2002 was loamy characterized by a pH of 6.60; low organic carbon content low organic carbon content (0.299%); and low nitrogen (0.087%).

The treatments comprised of three intra-row spacing, 15.0, 30.0 and 45.0cm on ridges 75cm apart; three clipping heights (no clipping control - 0 , 12.5cm and 25.0cm); and three clipping periods (64,74 and 84 days after planting – DAP) respectively. Factorial combinations of these treatments were laid out in a randomized complete block design replicated three times. The gross plot size was ($9.0m^2$).

In all the four years, the land was ploughed and harrowed twice mechanically to give a good soil tilt; then ridged at 75cm spacing and demarcated into various plots according to the specified dimensions. Two seeds of cowpea were planted per hole at about 5cm depth manually. The fields were planted on 13th July, 17th July, 7th June and 17th June, in 2002, 2003, 2004 and 2005 respectively. The cowpea crop was clipped (harvested) at 64, 74 and 84 days after planting (DAP). The first clipping was done on 15th September, 2002; 19th September, 2003; 10th August, 2004, and 17th August, 2005, respectively. The clipped fodder was placed on the plots to decay and act as a source of organic manure; while the clipped plants were left to grow to maturity alongside the control (unclipped) plots for further yield analysis.

Four plants per plot were sampled at 64, 74 and 84 DAP for the determination of the following parameters:

Total clipped fodder yield: The clipped fodder yield was obtained by weighing and recording the total clipped crop residue (fodder) from each plot at 64, 74 and 84 DAP, and this was recorded per plot and later converted to total fodder yield in tons per hectare (t ha^{-1}) basis.

Soil Organic Matter (SOM): Soil nutrient (status) analysis was undertaken using a 5g air dry soil, which was taken and analyzed for the soil organic matter (SOM) content was calculated according to the procedures as described by (Bray and Kurtz, 1945; Black, 1965; Day, 1965; Bremmer, 1965; IITA, 1975; Kundsen *et al*., 1982).

Pod and Grain yield: This was taken and calculated on kg ha^{-1} basis.

The data collected was compiled and analyzed statistically using the analysis of variance test (F-test) as described by (Snedecor and Cochran 1967); and the means were compared using the Duncan Multiple Range Test-DMRT (Duncan, 1955).

RESULTS AND DISCUSSION

Fresh fodder yield of cowpea

Fresh fodder yield of the dual purpose cowpea were highest at 15cm intra-row spacing. Indeed, if rapid production of the crop biomass is desired, (i.e. when yield is the product of growth of vegetative material), then denser sowing (much higher than for grain or fruit crop) is preferable, as a higher yield per area is achieved (as rapidly as possible) through greater population pressures; for maximum radiation interception. But if the stand is too dense, the only loss is from greater seeding expense. And this partially explains why recommended seeding rates for forages are often so high. The consideration is to ensure that enough water is available for the development of the grain or other reproductive parts is far less important when sowing for green manure. Here, the aim is simply to produce a large amount of plant material (Gardner, *et al.,* 1985; Muller-Samann and Kotschi, 1994).

Clipping management practices have been reported to be more common with grasses and forage legumes (Chapparo and Sollenberger, 1991). In the present study, the application of this clipping management practice showed that it facilitates the production of large amounts of green plant organic material (fresh fodder) on-farm which can be put to various uses. The total amount of clipped fresh fodder averaged about 15t ha^1. Fresh fodder yield of plots clipped at 74DAP was 62.2.0% more than the plants clipped at 64 DAP; but was statistically the same with plants clipped at 84 DAP. This is probably and consistent with the fact that at 64 DAP, maximum crop growth - full vegetative coverage - is yet to be attained. Indeed, the observed increase in fresh fodder yield at 74 DAP, has been reported to coincide with the period of the crops maximum vegetative growth (Musa, 1990).

Pod and grain yield of cowpea

Mean dry grain and pod yield of cowpea was higher at 15cm intra-row spacing (highest crop density) in the combined analysis (2002 - 2005). This finding agrees with those of Odion and Singh (2005b) who had reported similar higher seed and pod yield at 15cm intra-row spacing's. It appears that the higher crop yield value recorded at the 15cm intra-row spacing could be ascribed to the increase in number of plants per unit area. This resulted in a commensurate increase in the assimilatory area, which is basically the total area of leaves, and the efficiency with which this assimilatory area functions during the crops growth. Consequently, increased light absorption and its full utilization is achieved by the close crop canopy which ensures an adequate coverage of the soil surface; not allowing for the incoming solar radiation to fall on bare ground and thus be wasted. With time, this enhanced the crop photosynthetic efficiency. If at all there was shading of leaves at such close intra-row spacing, dry matter production and yield was not adversely affected (Arnon, 1977; Williams and Joseph, 1976; Williams, 1975; Loomis and Williams, 1963).

The discovery and application of clipping management on the cowpea crop is a recent crop management innovation which has shown remarkable success and promise; though it needs further investigation in regions where the crop features prominently in the farming systems (Odion and Singh, 2005a; 2005b). In the present study, though cowpea grain yield of the control produced higher

Table 1: Harvested fresh fodder (t ha^{-1}) of cowpea as influenced by intra-row spacing, clipping management and time treatment at Samaru, Zaria - Nigeria

Treatment	Harvested fresh fodder yield	
	2002	Combined 2002 – 2005
Intra-row spacing (cm)		
15	42.86a	18.96a
30	29.88b	13.95b
45	19.05c	11.43b
SE±	2.90	0.93
Clipping height (cm)		
0 (Control)	-	-
12.5	30.26	15.22
25.0	30.93	14.22
SE±	2.90	0.93
Clipping Time (DAP)		
64	7.64b	7.30b
74	43.66a	19.31a
84	40.49a	17.73a
SE±	2.90	0.93

Means followed by different letter(s) are significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Table 2: Percent (%) Soil Organic Carbon (SOC) and Soil Organic Matter (SOM) content as influenced by intra-row spacing, clipping management and time treatment at Samaru, Zaria - Nigeria

Treatment	Soil Organic Matter (SOM) content (%)	
	2002	Combined 2002 - 2005
Intra-row spacing (cm)		
15	0.527	1.323a
30	0.514	1.292b
45	0.511	1.066c
SE±	0.009	0.004
Clipping height (cm)		
0 (Control)	0.503	0.838b
12.5	0.520	1.420a
25.0	0.528	1.422a
SE±	0.009	0.004
Clipping Time (DAP)		
64	0.503	1.217
74	0.516	1.229
84	0.532	1.259
SE±	0.009	0.004

Means followed by different letter(s) are significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Table 3: Pod yield (kg ha^{-1}) of cowpea as influenced by intra-row spacing, clipping management and time treatment at Samaru, Zaria - Nigeria

Treatment	Pod yield 2002	Combined 2002 – 2005
Intra-row spacing (cm)		
15	1,428.80	1,328.59
30	1,385.80	1,246.76
45	1,248.00	1,297.66
SE±	88.88	55.11
Clipping height (cm)		
0 (Control)	1,310.50a	1,314.74a
12.5	788.00b	1,073.83b
25.0	1,116.50a	1,272.53a
SE±	88.88	55.11
Clipping Time (DAP)		
64	1,490.50	1,338.80
74	1,343.40	1,324.79
84	1,228.70	1,209.44
SE±	88.88	55.11

Means followed by different letter(s) are significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

Table 4: Grain yield (kg ha^{-1}) of cowpea as influenced by intra-row spacing, clipping management and time treatment at Samaru, Zaria - Nigeria

Treatment	Grain yield 2002	Combined 2002 - 2005
Intra-row spacing (cm)		
15	891.11	888.27
30	815.19	850.92
45	751.85	753.27
SE±	60.95	37.05
Clipping height (cm)		
0 (Control)	1,340.00a	988.26a
12.5	436.30c	685.32c
25.0	681.85b	818.86b
SE±	60.95	37.05
Clipping Time (DAP)		
64	924.44	866.80
74	800.37	838.01
84	733.33	787.65
SE±	60.95	37.05

Means followed by different letter(s) are significantly different at 5% level of probability using Duncan's Multiple Range Test (DMRT).

grain yield than those clipped; the pod yield of the control plots were statistically not different with the pod yield of crop plants clipped at 25.0cm height. Significantly, the gain recorded in the amount of soil organic matter (SOM) added to the soil, could be said to more than compensate for the little grain loss (Sambo and Odion, 2011). In effect, this low differences in yield could be explained and ascribed to several factors among which is the fact that crop plants clipped at 22.5cm height performed better because they were advantaged by the possession of longer stem stouts with many vegetative lateral buds which facilitated their re-growth capacity. They were therefore able to grow faster caught up with the control plots and with time attained near similar yield levels. This findings are in conformity with those of (Chaparro and Sollenberger, 1991; Tewolde and Mulkey, 1990), and have been explained by Gardner *et al*., (1985) who reported that the effect of clipping varies with species and is related to the amount of photosynthetic area remaining after defoliation, which may still maintain a critical leaf area index - LAI (95% of light absorption).

Pod and grain yield were generally high when crops were clipped at 64 DAP, against those clipped at 74 DAP and 84 DAP; for the fact that Musa (1990) in his work had reported that cowpea (1696), took 74 days to first flowering and 76 days to 50% flowering. This period is noted to be within the early and late-pod filling stage of cowpea growth (Gardner *et at.*, 1985). Consequently, yield differences could arise due to the fact that early clipping at 64 DAP, gave the crop a time advantage for the re-growth to re-establish good root development, grow vegetative and attain high leaf area (LA) to support the reproductive growth phase. Indeed, observed difference in yield with increasing time of clipping has been explicitly explained in terms of the leaf area duration (LAD), i.e. LAI integrated over time (Gardner *et al*., 1985). Therefore, the longer days advantage for vegetative re-growth of crop plants clipped at 64 DAP, allows it time to express the magnitude and persistence of its leaf area or leafiness during the period of growth; and because usually, LAD is closely correlated with yield; because the interception of solar radiation over longer periods of time generally means greater total dry matter production. Large differences in total biomass yields are often a much or more the result of duration of photosynthesis as of photosynthetic rate. As such flowers produced late in the flowering period, however, were less likely to produce mature pods by harvest; resulting in decreased seed yield with late clipping.

Soil organic matter (SOM) of cowpea

Soil-OC and OM content decreased with increasing intra-row spacing and clipping treatment over the control. This could be attributed to the high volume of added plant organic material obtained at high plant densities. This is in conformity with the findings of Murthy and Hirekerur (2004), which highlighted that the vegetation determines the quantities and quality of organic material added each year. Further, Adams *et al*., (1998) reported that most soil- OM is concentrated on the top soil because most of the roots occur in the zone and the plant residues tend to be added to the surface, forming the leaf litter layer. In this study, soil-OM content increased by 70%. Indeed, this result is supported by the findings of Jones (1971), who in a study in the dry savanna climate of Samaru, Nigeria, reported that the C-content of a sandy loam (Alfisol) was improved from 0.45% to 0.67% in 9 years; signifying a 66% increase.

Soil organic matter, fertility, organic agriculture and sustainability

Organic manure often includes wastes from both plants and animals whether composted or fresh but intended for use in farming. It is often brought into the field to improve the soils physical, chemical and biological properties, so as to enhance crop performance. Organic matter plays a key role in soils and the significance of organic mass in tropical soils is greater than any other soil characteristics apart from moisture (Asadu *et al.,* 2004). Thus, the maintenance of organic matter is of fundamental importance to the productivity of tropical soils. If soil fertility in the tropics is to be maintained, fertilization must first and foremost be organic. What this means in practical terms is that, a proper management of tropical soils must aim to maintain both the structure as well as the content of organic matter; and for soils that have been cultivated for a long time, the aim should be to increase the organic mass and to improve structure (Muller-Samann and Kotschi, 1994).

Without a doubt, organic farming avoids or largely excludes the use of synthetic fertilizers and pesticides and as far as possible promotes the purposeful maintenance and replenishment of soil fertility; as in crop rotation, crop residues and animal manures to supply plant nutrients, and to control weeds, insects and other pests (Wikipedia, 2005).

Yet in many tropical cropping systems, little or no agricultural residues are returned to the soil leading to a decline in soil organic matter (Lal, 1986; Bouwman, 1990; Post and Mann, 1990; Woomer and Ingran, 1990); and lower crop yields (Lal, 1986), or plant biomass productivity (Woomer and Ingran, 1990).

It is therefore clear that if soil fertility in the tropics is to be sustained, then, the amount of soil organic matter will need to be maintained at the level of economic yields and not degraded through cultural practices.

CONCLUSION

Finally, based on the results obtained from these investigations, it can be concluded that, cowpea possesses a great potential for enhancing the soil- OM in degraded tropical soils; provided appropriate cultural and management practices are adopted. In this regard, the adoption of this innovative clipping management technology enhanced the production of large amounts of organic plant biomass (clipped fodder) on-farm/in-situ which could be put to various uses: it could be incorporated into the soil as organic (green) manure for enhancing the soil- OM status. Indeed, it can be adduced that, overcoming soil- OM decline is an important component in the development of more sustainable agro-systems; which encompasses the successful management of resources for agriculture to satisfy human needs, while maintaining or enhancing the quality of the environment and conserving natural resources (FAO, 1989).

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