

CONSERVATION-ORGANIC AGRICULTURE: PANACEA FOR ENHANCED PRODUCTIVITY, SOIL FERTILITY IMPROVEMENT, INCOME GROWTH AND SUSTAINABILITY IN THE SAVANNAH REGIONS OF NIGERIA

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Abstract

The study was conducted on the research farm of the Institute for Agriculture Research, Samaru, Zaria; in the northern Guinea savanna agro-ecology of Nigeria; with the objective of determining the influence of intra-row spacing, innovative clipping height and time management and the effects of added clipped organic fodder on soil fertility improvements, economic growth and productivity of dual purpose cowpea (*Vigna unguiculata* (L.) Walp). Result proved that the adoption of this innovative clipping management technology produced high fresh organic biomass (fodder) and grain yields of cowpea when crops were planted at the lowest intra-row spacing (15cm). Though highest grain yield was recorded with the unclipped (control) plants compared to plots clipped at 12.5cm and 25.0cm heights; and highest pod and grain yields were recorded when crops were clipped at 64 DAP than at 74 and 84 DAP respectively. However, this difference was more than compensated by the high quantity and quality of clipped fresh organic fodder that was added to the soil (14 – 15t ha¹) on-farm/in-situ; which availed the resource poor farmer a window for enhanced economic growth (N41, 000 - N46, 000); and further reflected in the total amount of N- gained (70%) by the soil (186-187kgha⁻¹) in the four years period (2002-2005) from clipped plots over the control (unclipped) plots. And when converted to monetary (financial) terms, a total of N18, 000 – N24, 000 was gained from added soil-N; and this potentially saved the resource poor farmer about 70%, in terms of the financial cost requirement, that would have otherwise being used to procure N-fertilizer inputs. Similarly, there was a 41% increase in the soil-OM content. It is concluded that such pro-poor income growths (from such innovative, technologically managed production systems) should be encouraged and supported. To be able to achieve increased and sustained (less chemicals and thus healthy) food production in these regions, there is a need to adopt this alternative integrated and practical soil fertility management method which incorporates and conserves organic nutrient sources that can also serve as a buffer for minimizing the negative effects of fertilizers. Evidences from conservative, organic agriculture (CA, OA), studies as this, is sustainable and productive.

Keywords: Sustainable, Conservation, organic, agriculture, productivity, clipped, biomass, fodder and innovative.

Introduction

Most African soils come from rocks low in nutrient contents and being of ancient origin and having been subjected to leaching for a

long time, and are typically impoverished and seriously deficient in phosphate. But a proportionately large amount of available

nutrients are retained in the vegetative cover and the soil organic matter (soil-OM) accumulates on the surface and subsequently mixes with the upper part of the soil. As such, if the vegetative cover is removed for cultivation (as in traditional farming systems and densely populated areas, where the pressures of urbanization on the land can lead to shortening of the fallow period; so that soil fertility can no longer be restored) and the soil put under intensive use without ensuring that the soil – OM is maintained at an appropriate level, with the attendant result that the fertility of the soil declines rapidly. Other factors consequential to the low fertility status of these soils includes amongst others the fact that nutrients are constantly exported in the form of harvested crops (soil mining); high rainfall intensity – resulting in compaction and the hardening of soils, erosion, leaching – leading to low soil – OM content, low cation exchange capacity (CEC), and low water retention capacity. This problem is further compounded by the permanent agriculture

Improving Fertility Productivity and Income Growth Potentials Using Organic Materials – Green Manures

The introduction of green plant residues into farming systems (arable and agro-forestry) has its attendant multi-beneficial effects (Tian *et al.*, 1992); through exploring the potentials of N-fixing micro-organisms on the root of leguminous crop plants for the replenishment of nitrogen in low fertility arable soils (Asadu *et al.*, 2004). The amount of residue of nitrogen added to the soil has been estimated at 30 - 60kg N ha⁻¹ annually (Reijntjes *et al.*, 1992). This amount of organic plant biomass when added to the soil (through placement and/or incorporation) could increase soil organic matter (SOM) and provide a potential solution to the inherent low fertility problem of these Savannah soils. In this regard, if soil fertility in the tropics is to be sustained, then the amount of soil organic matter will need

system practiced in the tropics which generally leads to severe nutrient depletion in sub-Saharan Africa (Zake, 1993); resulting in lower crop yields (Lal, 1986), or plant biomass productivity (Woomer and Ingran, 1990). It is estimated that about 1.5 billion people are directly affected by degraded land and soil erosion and over half of the worlds grasslands are degraded (Action Aid, 2009). Consequently, a major problem of most African soils is the rehabilitation of the degraded soils; where the continuous use of chemical fertilizers to improve on the soils nutrient content for crop production has impacted negatively on the soil physical characteristics as well as human health (Cooke, 1982; Tian *et al.*, 1994). However, these problems are reported to be ameliorated through practices known to provide the soil with organic matter from decaying plant residue, such as clipped cowpea fodder (Lu and Hue, 1990; Woomer and Mulchena, 1993; Odion and Singh, 2005a).

to be maintained at the level of economic yields and not degraded through cultural practices.

Cowpea fodder can 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 through of green manuring, 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). Soil fertility has been noted to be central to the sustainability of both natural and managed ecosystems

because it is the medium from which terrestrial production emanates. To be able to achieve increased and sustained food production in this region, there is a need to find alternative integrated and practical soil fertility management methods which incorporates organic nutrient sources (as in green clipped cowpea fodder) that can also

Materials and Methods

Field experiments were carried out on the research farm of the Institute for Agriculture Research, Samaru (11^o.11'N, 07^o.38'E and 686m above sea level); located in the northern Guinea savanna agro-ecology of Nigeria (Keay, 1959); during the 2002, 2003, 2004 and 2005 cropping seasons. The soil of the experimental site was loamy characterized by a pH of 6.60; 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 (giving plant densities of 88,000, 444,000 and 29,000 stands ha⁻¹ respectively); 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; these treatments were laid out in a randomized complete block design replicated three times. The gross and net plot sizes were 9.0m².

In all years, the land was ploughed and harrowed twice using mechanical power; then ridged at 75cm spacing and demarcated into various plots according to specified dimensions. Two seeds of cowpea were manually planted per hole at about 5cm depth; at 15, 30 and 45cm intra-row spacing's and on 75cm ridges. The crop was planted on 13th July, 17th July, 7th June and 17th June, in 2002, 2003, 2004 and 2005 respectively; and clipped (harvested) at 64,

serve as a buffer for minimizing the negative effects of fertilizers. It is against this background that this study was conducted on the influence of intra-row spacing, clipping management and time on the productivity of cowpea (*Vigna unguiculata* (L) Walp) and soil fertility.

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 the clipped plants left to grow to maturity alongside the control (unclipped) plots for further growth analysis. The soil nutrient analysis was conducted; while a cost economic analysis was done (considering the total amount of N added to the soil during the experimental period which was converted to amount of N in kg ha⁻¹) to determine the amount (in Nigerian Naira) saved in cost that would have otherwise been invested on the procurement of N -fertilizer inputs by the resource poor farmer. The total harvested fresh fodder, pod and grain yield was obtained per plot and then converted to kg and/or tons per hectare. Similarly, a cost benefit analysis was conducted (in Nigerian Naira equivalent) to determine what accrued from the sale of this harvested fresh fodder to the resource poor farmer. This net margin of income from harvested fresh fodder yield sales took into consideration the yearly variable input cost levels. The data collected was compiled and analyzed statistically using the analysis of variance test (F-test) as described by (Snedecor and Cochran 1967). The means were compared using the Duncan Multiple Range Test-DMRT (Duncan, 1955).

Results

Crop Growth

The combined analysis for 2002 – 2005, showed that vine length of plants

spaced 15cm apart was similar to that spaced 30cm apart; but was significantly longer than at 45cm. While the combined analysis for 2002-2005, showed that delaying clipping time from 64 to 84 DAP resulted in production of significantly longer vines (Table 1). The combined analysis for 2002 - 2005, showed that fresh fodder yield was significantly higher at 15cm intra-row spacing than at 30 and 45cm intra-row

Grain and Pod Yield

Clipping height significantly influenced pod yield in the combined analysis for 2002 – 2005; where the unclipped plots and those clipped at 22.5cm produced similar pod yields; which were in-turn significantly higher than those clipped at 12.5cm height (Table 2). Also, clipping height significantly influenced pod yield in the combined analysis for 2002 – 2005; where the unclipped plots and plots clipped at 22.5cm gave similar pod yield; which were in turn significantly higher than those clipped at 12.5cm height (Table 2).

Soil Fertility

Intra-row spacing and clipping height in the combined analysis for 2002 – 2005, significantly affected the N-content of

Economic Benefits

Fresh Fodder Yield Sales

Intra-row spacing and clipping time had a significant effect on the net margin of income (in Nigerian Naira equivalent) from fresh fodder yield sales in the combined analysis for 2002 – 2005; where the net margin of income decreased with increasing intra-row spacing from 15 to 45cm. While the net income generated when the plants were clipped at 74 and 84 DAP, was statistically similar, and significantly higher than was realized at 64 DAP (Table 4).

spacing; which were in turn statistically at par with each other (Table 1). Clipping time had a significant effect on fresh fodder yield in the combined analysis for 2002 – 2005; which showed that plots clipped at 74 and 84 DAP were statistically the same; but significantly higher than the fresh fodder obtained from plots clipped at 64 DAP (Table 1).

the soil; where soil-N at 15 and 30cm intra-row spacing was statistically similar, but significantly higher than at 45cm (Table 3). While clipping at 12.5 and 25.0cm produced soil N-content which were statistically similar, but significantly higher than the unclipped plots. The soil-OM content consistently, significantly increased with increase in intra-row spacing from 15 to 45cm. While, the soil-OM content of plots clipped at 12.5 and 25cm heights were statistically not different, but were however, significantly higher than the soil-OM content of the unclipped plots. Clipping time had no significant effect on soil OM-content (Table 3).

Amount of N- added to the Soil and Converted into Nigerian Naira (₦) Equivalent

The influence of clipping height on the economic return from the total amount of N gained during the four year period, 2002-2005, was significant where the result showed that the economic gain in Nigerian Naira (₦) equivalent from plots clipped at 12.5 and 25.0cm heights were statistically at par; but significantly higher than the unclipped plots (Table 4).

Table 1: Vine length (cm) and Fresh fodder yield (t ha⁻¹), as influenced by intra-row spacing, clipping management and time treatment; combined analysis for 2002-2005; at Samaru, Zaria - Nigeria

Treatment	Vine length (cm)	Fresh (clipped) fodder yield (t ha ⁻¹)
Combined	Combined 2002 – 2005	2002 - 2005
Intra-row spacing (cm)		
15	102.91a	18.96a
30	97.24ab	13.95b
45	89.48b	11.43b
SE±	2.42	0.93
Clipping height (cm)		
0 (Control)	96.54	-
12.5	95.31	15.22
25.0	97.78	14.35
SE±	2.42	0.93
Clipping Time (DAP)		
64	79.40c	7.30b
74	100.56b	19.31a
84	109.66a	17.73a
SE±	2.42	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: Pod and grain yield (kg ha⁻¹), as influenced by intra-row spacing, clipping management and time treatment; combined analysis for 2002-2005; at Samaru, Zaria - Nigeria

Treatment	Pod yield (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)
Combined	Combined 2002 – 2005	2002 - 2005
Intra-row spacing (cm)		
15	1,328.59	888.27
30	1,246.76	850.92
45	1,297.66	753.27
SE±	55.11	37.05
Clipping height (cm)		
0 (Control)	1,314.74a	988.26a
12.5	1,073.83b	685.32c
25.0	1,272.53a	818.86b
SE±	55.11	37.05
Clipping Time (DAP)		
64	1,338.80	866.80
74	1,324.79	838.01
84	1,209.44	787.65
SE±	55.11	37.05

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

Table 3: Soil-N and OM (%) as influenced by intra-row spacing, clipping management and time treatment; combined analysis for 2002-2005; at Samaru, Zaria - Nigeria

Treatment	Soil-N (%)	Total Soil-N (kg/ha)	Soil-OM (%)
Combined	Combined 2002 – 2005	2002 – 2005	2002 - 2005
Intra-row spacing (cm)			
15	0.148a	144.97	1.323a
30	0.141a	142.60	1.292b
45	0.131b	142.18	1.066c
SE±	0.018	1.72	0.004
Clipping height (cm)			
0 (Control)	0.092b	55.59b	0.838b
12.5	0.165a	186.93a	1.420a
25.0	0.164a	187.23a	1.422a
SE±	0.018	1.72	0.004
Clipping Time (DAP)			
64	0.139	142.82	1.217
74	0.161	143.43	1.229
84	0.141	143.50	1.259
SE±	0.018	1.72	0.004

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

Table 4: Economic analysis: net income from cowpea fresh fodder yield sales combined analysis for (2002-2005) and nitrogen gained in the four year period (2002-2005) in Nigerian Naira (₦) equivalent as influenced by intra-row spacing, clipping management and time treatment; at Samaru, Zaria - Nigeria

Treatment	Fresh fodder yield sales (₦)	Total N converted to Naira equivalent (₦)
Combined	2002 – 200	2002 - 2005
Intra-row spacing (cm)		
15	56,947.00a	18,912.70
30	42,161.00b	18,600.60
45	32,857.00c	18,527.90
SE±	4,345.59	112.85
Clipping height (cm)		
0 (Control)	-	7,245.90b
12.5	46,119.00	24,370.40a
25.0	41,859.00	24,424.90a
SE±	4,345.59	112.85
Clipping Time (DAP)		
64	18,912.00b	18,709.50
74	58,356.00a	18,699.50
84	54,698.00a	18,632.30
SE±	4,345.59	122.85

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

Discussion

Influence of Intra-row Spacing, Clipping Height and Time on Added Clipped Cowpea Residue on:

Crop Productivity

In this study, the tallest plant and highest crop yields of cowpea were recorded at 15cm intra-row spacing. This contrasted with the recommended spacing of 20 to 30cm for grain types and 45cm for fodder type production (Singh and Rachie, 1985; Onwueme and Sinha, 1991); and conforms to the findings of Odion and Singh (2005b), who reported similar higher pod and seed yields of dual purpose cowpea planted at 15cm intra-row spacing under clipping management; which could be ascribed to the increase in number of plants per unit area which resulted in a commensurate increase in the assimilatory area, close canopy and adequate coverage of the soil surface for light absorption and its full utilization thus enhancing the crops photosynthetic efficiency (Williams and Joseph, 1976; Arnon, 1977). Similarly, who reported that increased density causes crop plants and stems to become smaller, weaker, and often taller (Gardner *et al.*, 1985).

In the present study, insignificant yield differences were recorded between crop plants clipped at 25.0cm compared to the unclipped plants. This is ascribed to the fact that they were advantaged by the possession of longer stem stouts which possessed a greater number of potentially formed reproductive buds. Thus, their re-growth capacities were better enhanced as they were able to grow faster and with time, caught up with the control plots; attaining near similar yield levels. These findings are in conformity with those of (Tewolde and Mulkey 1990; Chaparro and Sollenberger, 1991), and this phenomenon has 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. While Odion and Singh (2005a) obtained yields of 500kg ha⁻¹; in the present study, higher grain yields of 700 – 900kg ha⁻¹ were recorded.

The high yields obtained when crop plants were clipped at 64 DAP, could be explained in terms of the leaf area duration (LAD), i.e. LAI integrated over time. 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 (Gardner *et al.*, 1985). Conversely, fresh fodder yield of plots clipped at 74 DAP 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 due to the fact that at 64 DAP, maximum crop growth - full vegetative expression - is yet to be attained.

Income Growth Potentials

Clipping management facilitates the production of large amounts of green plant organic material (fresh fodder) on-farm (14-15t ha⁻¹); and if this large quantity of harvested organic plant biomass is sold off, it could generate a net income of ₦41, 000 - ₦46, 000. This shows that substantial financial profits can be made by the resource poor farmer. The option of usage lies with the farmer who could choose to sell and use this extra income for his farms operational and other family economic activities; or keep and use the fodder to feed his animals and/ or use the proceeds to subsidize on his fertilizer requirement. This is in conformity with Singh *et al.*, (1997) who reported that farmers who cut and store cowpea fodder, for subsequent sale at the peak of the dry season, have been found to obtain as much as 25% of their annual income by this means. Eckert and Hall (1991) similarly postulated that forage legumes can be clipped for sustained yield, and economic return.

On the other hand, if the farmer chooses to add the clipped cowpea crop residue, it generally has the effect of

improving the soil quality (soil fertility) through increase in soil -N content on farm; and the advantage here is that, the maintenance (or increase) in soil fertility is based on the farmer's own resources (and less capital input is required). If the total amount of N added to the soil is converted to monetary (financial) equivalent, result showed that a total of ₦18, 000 – ₦24, 000 was saved by the farmer; thus potentially saving the resource poor farmer about 70% in terms of the financial cost requirement which would have otherwise being needed and/or used to procure N-fertilizer inputs.

Indeed, it has been highlighted that if green manure crops are not associated with a direct increase in income, then the subsistence farmers are not likely to be interested in them. Therefore, for these farmers, a green manure crop should be a cover crop of economic value, such that the fodder is allowed to grow after the harvest of grains. Such a crop provides green manure from re-growth at the beginning of the next season. Thus crops for green manure should raise the farmers income not only indirectly by improving soil fertility but also directly by yielding by-products of economic importance such as fuel, stakes for climbing plants, food, fodder and medicines (Reijntjes *et al.*, 1992).

Soil Fertility Improvements: Soil Nitrogen (N) and Organic Matter (SOM) Content

About 44% N was added to the soil when plots were clipped compared to the control (unclipped) plots. This increase in soil-N is could be attributed to the high amount of organic matter (OM) added to the soil at closer intra-row spacing's and with clipping management. This agrees with the report of Graham (1981), and Muller - Samann and Kotschi (1994), who reported that high plant densities in legume crops generally, are advantageous because of the increase nitrogen fixation that accompanies it. Similarly, the amount of N added to the soil increased with increasing clipping time

i.e. age of the crop – from 74 to 84 DAP – which is about the peak period of maximum vegetative growth and covering (fresh fodder production); flowering and early pod-filling stages of the cowpea crop plant (Musa, 1990). And Virtarinen and Meitinen (1963), and Grahammer *et al.*, (1991) had reported that N-release from fodder increased in rate with age until mid-pod fill. They highlighted the fact that at this stage, the uptake of plant food both from the soil and from the air, as well as assimilation of carbon and the development of organic matter reach practically the maximum and the plants are rich in sugars, energy and easily soluble N-compounds, and poor in lignin and cellulose. Thus, the materials are favorably disposed for rapid decomposition, mineralization, and the release of nutrients (Yegna Narayan Aiya, 1975; Muller-Samann and Kotschi, 1994); especially N. This probably explains why there was a 70% increase in the soil N-content when plots were clipped and the organic plant material was added to the soil compared to the unclipped plots. The significant contribution of cowpea to soil- N levels has been put at 40 - 80kg ha⁻¹ annually; while, the total amount of N-fixation by the cowpea crop is estimated at 70 - 350kg ha⁻¹(Singh *et al.*, 1997). Muller-Samann and Kotschi (1994) reported a mean value of 198kg ha⁻¹ per year. The total soil- N enrichment in the four year period (2002-2005) of this investigation was 142 - 187 kg N ha⁻¹ (signifying an annual mean value of 35 - 47kg ha⁻¹). This observed low N-level has in part been explained by Muller-Samann and Kotschi (1994) who highlighted the fact that legumes grown under good nutrient conditions are capable of fixing considerably more N than on deficient nutrient soils.

Soil-OM content increased with decreasing intra-row spacing and clipping management treatment over the unclipped plots. This could be attributed to the high volume of added plant organic material obtained at high plant densities; which is in

conformity with the findings of Murthy and Hirekerur (2004) which highlighted the fact that the vegetation determines the quantities and quality of organic material added to the soil each year. As such, most soil- OM is concentrated on the top soil

Conservation – Organic Agriculture As Sustainable Agricultural Production Systems

The Food and Agricultural Organization (FAO) has characterized conservation agriculture as that which maintains a permanent or semi-permanent organic soil cover (FAO, 2007). This can be a growing crop or dead mulch. Its function is to protect the soil physically from sun, rain and wind and to feed soil biota. The soil micro-organisms and soil fauna take over the tillage function and soil nutrient balancing (FAO, 2007; Hobbs, 2010). Indeed, conservation agriculture is a concept for resource-saving agricultural crop production that strives to achieve production increases sustainably, by minimizing negative environmental effects and, equally important, providing increased income to help improve the livelihoods of those employed in agricultural production while concurrently conserving the environment (FAO, 2007); through reduced use of fossil fuels, pesticides, and other pollutants (Dumanski *et al.*, 2006).

Organic farming avoids or largely excludes the use of synthetic fertilizers and pesticides, plant growth regulators, and livestock feed additives. As far as possible

Conclusion

Sustainable agriculture can greatly increase productivity among resource poor small holder farming communities in developing countries as Nigeria. This is particularly true if the existing farming system uses few (CA) or no (OA) fertilizers and other chemicals. In this regard, farming systems which conserves and/or improves on resources have numerous advantages: It

where most of the roots occur (Adams *et al.*, 1998). Consequently, overcoming soil OM decline is an important component in the development of more sustainable agro-systems.

organic farmers rely on developing biological diversity in the field to disrupt habitat for pest organisms, and the purposeful maintenance and replenishment of soil fertility; as in crop rotation, crop residues, animal manures and mechanical cultivation to maintain soil productivity and tilth, to supply plant nutrients, and to control weeds, insects and other pests (Wikipedia, 2005). Indeed, organic agriculture is “a holistic production management [whose] primary goal is to optimize the health and productivity of interdependent communities of soil, life, plants animal and people” (UNCTAD, 2008).

In this regard, the relationship between conservation agriculture (CA) and organic agriculture (OA) is based on the fact that both systems aim to use resources responsibly in a manner that will not cause damage to the environment and human health. Thus, if sustainable agricultural systems are those that aim to make the best use of environmental goods and services while not damaging the five assets – particularly natural, social and human capital; then an integrated organic farming system (and by extension conservation agricultural systems) can be considered inherently sustainable (UNCTAD, 2008).

has tremendous potential for achieving sustainable yield increases by improving the growth conditions for crops; leading to higher yields and greater access to food - increased food security for all members of the household and higher incomes - giving farm families opportunities to improve their livelihoods: It builds up soil fertility amongst others: consequently, smallholder farmers are able to save money through none or less

fertilizer and pesticide use. Such pro-poor income growths originating from sustainable agricultural development need to be encouraged and supported; as evident by the facts that it is productive and

sustainable and has the potential of reducing global hunger, poverty and food insecurity (Odion *et al.*, 2007; Sambo, 2009; ActionAid, 2009; Ching, 2009).

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