Effect Of Green Manure And Intercropping On Potato Production In The Western Highlands Of Cameroon.

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Abstract— Organic fertilizers are indispensable for vegetable cultivation in the western highlands of Cameroon. The main objective of this work was to evaluate the potential of Crotalaria grahamiana green manure as a source of organic fertilizer in addition to methods of producing the green manure. The treatments tested consisted of crotalaria green manure obtained from different cropping systems; chicken droppings; mineral fertilizer; combinations of crotalaria green manure and mineral fertilizer; combination of chicken droppings and mineral fertilizer and a control with no fertilizer input. The potato variety used was 'Spunta'. The results showed that green manure and woody biomass produced through simultaneous intercropping was significantly higher ($P<0.05$). Treatments with chicken droppings and mineral fertilizers had significantly ($P<0.05$) higher average crop cover fraction. There was no significant difference ($P<0.05$) amongst treatments with chicken droppings, combination of crotalaria green manure and mineral fertilizer, crotalaria green manure obtained from the intercropping system and crotalaria obtained from the sole cropping system. The lowest score on crop cover fraction was obtained from plots with no fertilizer input. The highest average fresh tuber weight was obtained from treatments with chicken droppings and mineral fertilizers and those treated solely with chicken droppings (234g and 231g respectively), followed by treatments with crotalaria and mineral fertilizer and crotalaria green manure sole (133.8g and 133.6 g respectively). Results obtained so far show that crotalaria green manure can contribute significantly as an organic fertilizer in potato production.

Index Terms— Crotalaria grahamiana, crop cover fraction, intercropping, potato, Western Highlands of Cameroon,

INTRODUCTION

Organic fertilizers are indispensable for vegetable cultivation in the densely populated western highlands of Cameroon due to the often low organic matter content of the arable land. This production system is an important priority area globally in view of the growing demand for safe and healthy food and long term sustainability in addition to concerns on environmental pollution. In this system, production is based on synergism with nature which accounts for its sustainability (Sheraz et al., 2010). Though the use of chemical inputs in agriculture is inevitable to meet the growing demand for food and feed in the world, there exist opportunities for some crops and niche areas for successful organic production. Sustainable nutrient management is very indispensable in the densely populated western highland agro-ecological zone of Cameroon characterized by intensive cultivation. This requires a set of management practices to conserve soil resources, maintain or enhance productivity, and help reduce framers' reliance on costly chemical fertilizers. One of the important components of the sustainable system is the use of legume rotation crops and/or organic soil amendments such as green manure**.** Green manure crops are are grown to be directly incorporated for the purpose of enriching the soil. It has been demonstrated that legume green manures can: provide a significant source of nitrogen to the subsequent crop plant by converting the un-reactive form of nitrogen from the air (N_2) to reactive forms of nitrogen (NH_4 and NO_3) that plants can utilize (MacDicken 1994); recycling nutrients from the subsoil (Hartemink et al. 1996) and root decay, thus replacing some portion of economically and environmentally costly chemical fertilizers (Maroko et al. 1998).

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Green manures also increase soil organic carbon for sustenance of soil quality and future agricultural productivity (Ramesh, 2008). Cropping systems in which large amounts of organic residues from green manures, animal wastes, or composts are applied to the soil have the potential for improved soil nutrient availability, tilth, water-holding capacity, and aeration (Bullock 1992, Honeycutt et al. 1995, Macrae and Mehuys 1985, Smith et al. 1987). Crotalaria grahamiana is a recently introduced species in the western highland agroecological zone of Cameroon. Green biomass (tender stems plus leaves) of crotalaria has been recognized as an effective source of nutrients in crop production (Jama and Van straiten, 2006). High biomass production can be assured on-farm owing to the fact that it is not palatable to local animals as is the case with other green manure species. Potato (Solanum tuberosum L.) cultivation is one of the major sources of income to the local farmers in the western highland region of Cameroon (Tankou, 2004). Nutrient management in potato production in this area is highly intensive, relying heavily on chemical fertilizers. Crop rotations that include intensive potato production are generally more prone to erosion than those that utilize more crop cover with perennial green manures (Perfect et al. 1990). The organic fertilizer currently used in the western highland zone of Cameroon is chicken droppings. The price of this organic source increases every year due to the high demand because it is primordial for the cultivation of all other vegetable crops (Tankou and Aziwo 2004).One of the key limitations to the more extensive use of different types of organic residues as nutrient sources in potato cropping systems has been the relative lack of quantitative information on the contributions of different organic residue management practices on nutrient cycling, nutrient-use efficiency and net economic return (Alford et al. 1996). Crotalaria grahamiana has been studied in other intercropping systems with maize as the component crop Jama and Van straiten, 2006) while maize and potato intercropping has also been investigated (Jamshidi et al. 2008; Saddam, 2009).. Intercropping of green manure species in general and Crotalaria grahamiana in particular with potato as a component crop has not yet been studied It is in

this light that Crotalaria grahamiana was evaluated as a source of organic fertilizer obtained from potato / Crotalaria grahamiana intercropping systems. The objectives of this study were to assess the potential of crotalaria green manure in different cropping systems and the performance of potato under different treatments of organic fertilizers combined with mineral fertilizer.

MATERIALS AND METHODS

The experiment was conducted on-farm under rain-fed conditions during two cropping seasons (2005 and 2006). The growing period covered mid-March to mid-November. The experimental site was at an altitude of 2185m (asl) located at longitude 10° 02′ east and latitude5° 35′ north. The annual rainfall was estimated at 1800 mm and the average annual temperature estimated at 18°C. The soil was an alfisol and results of soil analysis before the start of experiment was as follows:

Soil pH	
pH water	5.5
pH 1M KCl	4.8
Exchangeable cations (cmol+/kg)	
Ca++	1.38
Mg++	0.37
K+	0.43
Exch Al Cmol(+)/kg	0.02
ECEC Cmol(+)/kg	2.32
CEC NH4Cl Cmol(+)/kg	3.12
OM (%)	15.65
P (mg/Kg)	0.98
Base saturation (% CEC NH4OAc)	59.22

EXPERIMENTAL TREATMENTS

During the first cropping season, the treatments were made up of:

- Sole cropping of potato (P1)
- Simultaneous intercropping of potato and crotalaria (P2)
- Relay intercropping of crotalaria in potato (crotalaria intercropped in a one month old potato plot) (P3)
- Sole cropping of crotalaria (P4)
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In order to provide enough plots for the second cropping experiment, 3 plots of P1, 2 plots of P2, 2 plots of P3 and 1 plot of P4 were randomized per block in the first cropping season experiment. The experiment was set up using a randomized complete block design with 4 blocks. Each plot had an area of 25 m^2. Potato was planted at a spacing of 80 cm between the rows and 30 cm within the row. Crotalaria was planted between the rows of potato at 30 cm within the row. During the second cropping season, the following fertilizer treatments were tested on potatoes:

- Crotalaria green manure obtained from P2 plus mineral fertilizer (600 kg/ha of 20.10.10) (T1)
- Crotalaria green manure obtained from P4 (T2)
- Crotalaria green manure obtained from P3 plus mineral fertilizer (600 kg/ha of 20.10.10) (T3)
- Crotalaria green manure obtained from P3 (T4)
- Chicken droppings (1520 kg/ha) (T5)
- Crotalaria green manure obtained from P2 (T6)
- Chicken droppings (1520 kg/ha) plus mineral fertilizer (600 kg 20.10.10) (T7)
- No fertilizer input (T8)

Measurements:

Crop cover was measured on a sample of 5 plants per treatment with a rectangular wooden grid measuring 80 by 30 cm (internal length and width) with 1 m^2 squares following the method outlined by Tankou and Aighewi, 1991. It has been shown that crop cover fraction of potato is highly correlated with the total dry matter content of the tubers (Tankou and Aighewi, 1991). Crop cover also mitigates the negative environmental effects of intensive agricultural production such as nitrate leaching and soil erosion.Weight and number of tubers were obtained per plot after harvesting at full maturity. Tubers weighing at least 70 g were considered as ware tubers.

Statistical analysis

Analyses of variance were conducted using MSTAC. Means were separated using the Student-Neuman-Keul's test, contrast analyses were conducted and regression analyses were calculated based on plot data using the Sigma plot software. Results were considered to be statistically significant at $P<0.05$.

RESULTS

A significant ($P<0.05$) positive quadratic relationship was found between tuber weight per plant and crop cover fraction (Figure 1).

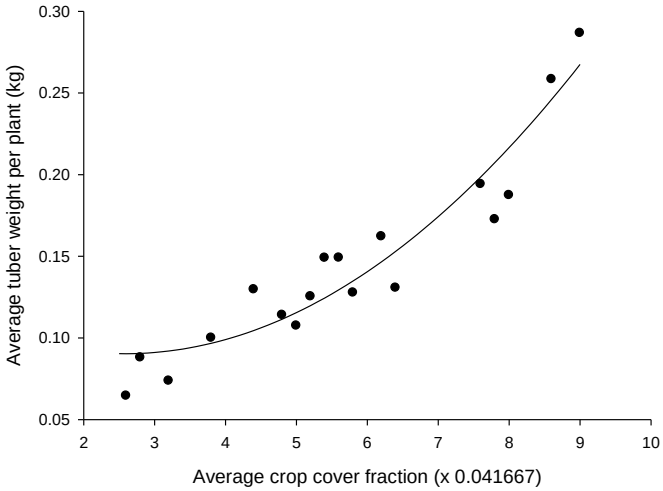

Figure 1. Relationship between Average tuber weight and crop cover fraction. $y=0.12-0.02x+0.004x^2$ $R^2 = 0.7$

The highest crop cover fraction obtained at full vegetative growth was less than half the maximum of 1.

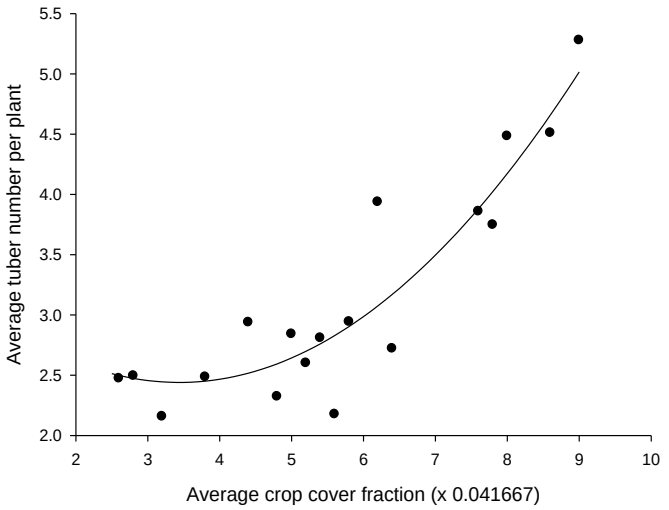

Figure 2. Relationship between Average tuber number and crop cover fraction. $y=3.42-0.57x+0.08x^2$ $R^2 = 0.66$

The same relationship was shown by tuber number and crop cover fraction (Figure 2).

Table 1. Effect of cropping system on crotalaria green manure and woody biomass.

Treatment	Green biomass (leaves and tender stems) per plant (kg)[1]	Woody biomass (stems, branches and roots) per plant (kg)
P2	0.29 a	0.29 a
P3	0.09 b	0.09 b
P4	0.24 ab	0.22 ab

Means followed by the same letter (s) in each column are not significantly different at the 5% probability level. The amount of green manure and woody biomass were significantly higher from simultaneous intercropping of crotalaria with potatoes than for relay intercropping of crotalaria in potatoes (Table 1).

Table 2. Effect of types of fertilizer on yield related variables.

Treatment	Average crop cover fraction	Average weight of ware (kg)	Average weight of tuber (kg)
T1	0.61 ab	0.13 b	0.09 b
T2	0.59 ab	0.13 b	0.08 b
T3	0.5 bc	0.12 bc	0.08 b
T4	0.52 bc	0.12bc	0.07 b
T5	0.64 ab	0.23 a	0.15 a
T6	0.57 ab	0.12 bc	0.07 b
T7	0.70 a	0.23 a	0.15 a
T8	0.38 c	0.08 c	0.04 b

Means followed by the same letter (s) in each column are not significantly different at the 5% probability level. The highest crop cover fraction was observed in the treatment with chicken droppings as organic fertilizer plus 20.10.10 (NPK) as mineral fertilizer and the lowest was the control treatment. The same performance was observed with the average ware tuber weight variable. The highest average weight of tubers was shown by chicken droppings combined with mineral fertilizer treatment and the treatment with sole chicken droppings (Table 2).

Table 3. Average tuber weight per plant difference from contrast of planned comparisons

Treatments	Average tuber weight per plant (kg) increase(+) or decrease (-)[a]
T1 vs T6	+0.012 ns
T2 vs T4	+0.017 ns
T2 vs T6	+0.012 ns
T3 vs T4	+0.003 ns
T2, T4, T6 vs T5	-0.107**
T5 vs T7	-0.003 ns
T2, T4, T6 vs T8	+0.044*

[a]ns non significance; *P<0.05 ; ** P<0.01

Results from the contrast analysis showed that chicken droppings performed better than crotalaria green manure obtained from the different cropping systems (P<0.001). Significant differences were also shown between the crotalaria green manure and the control treatment (P<0.05). With respect to tuber weight per plant, the combination of mineral and organic fertilizers compared with only organic fertilizers showed no significant differences (Table 3).

DISCUSSION

Intercropping crotalaria green manure was advantageous in terms of the biomass production. Similar results with other green manure species were found by Kae et al. 2014. Positive relationships between the diversity of plant species and biomass production have been reported in other ecosystems (Tilman et al., 2006). The complementary use of nutrients, water, and light by different species are considered as the mechanisms underlying productivity gains when species are intercropped (Loreau, 2000). The improved fallow with sole crotalaria did not show any significant difference with other two cropping systems. Owing to the fact that land is a very scarce resource in this zone, these results are very encouraging since farmers practicing such a system could produce both crotalaria and potato at the same time. The poor biomass yield in the relay cropping system could be greatly attributed to the shade effect produce by the potato crop on the crotalaria at the early growth stage. The woody biomass produced in the different systems followed the same pattern. The contribution of the woody biomass as a source of fuel wood adds value to the potato-crotalaria cropping system. The quadratic relationship found between crop cover fraction and tuber weight per plant (Figure 1) and with tuber number per plant (Figure 2), indicated that increase in crop cover fraction provoked increase of tuber weight and tuber number. Crop cover fraction which is a measure of the leaf surface area covered by the plant with respect to the total surface that the plant can cover based on the planting density, depends greatly on the nutrient available to the plant. Crotalaria green manure contains high amount of nitrogen. Its average nutrient content on dry matter basis is 21 Kg t^{-1} nitrogen, 1.6 Kg t^{-1} phosphorus and 12 Kg t^{-1} potassium (Tankou and Aziwo, 2004). Generally, increasing soil nitrogen content tends to favour above ground vegetative growth at the expense of the below ground tuber growth. Westermann and Kleinkopf (1985) noted that matching N

mineralization patterns with potato N uptake patterns was primordial in optimizing the effectiveness of N released from legume residues. Nitrogen released too early from green manures can delay tuber bulking and promote excessive vine growth, resulting in reduced yields and increased proportions of immature tubers (Ojala et al. 1990). Alternatively, N released too late can reduce N use efficiency and increase the potential for nitrate leaching. The difference in N amount and N availability in our study could have been caused by the different amount of biomass applied in different treatments. This is reflected in the results found in Table 2 where the highest crop cover fraction was exhibited by the treatment with both mineral fertilizer and chicken droppings (T7) while the least was shown by the control treatment with no fertilization (T8). With respect to the general weight of tubers, the treatment that received only chicken droppings (T5) showed no significant difference with the treatment that received both chicken droppings and mineral fertilizer (T7). It was equally noted that treatments which received only crotalaria green manure were not statistically different ($P<0.05$) from those that received both the crotalaria green manure and mineral fertilizer. From the contrast analysis, it was shown that the treatment with sole chicken droppings performed better than those with sole crotalaria green manure (T2, T4, T6 vs T5) with an average of 0.107 kg of tuber weight per plant higher. Treatments with sole crotalaria green manure outperformed the control (T2, T4, T6 vs T8) with an average of 0.44 kg of tuber weight per plant higher. No significant differences ($P<0.05$) were observed between sole crotalaria green manure treatments and the mixture of crotalaria green manure and mineral fertilizer with respect to average weight of tuber per plant. Ware tuber yield from this study varied from 3333 to 9583 kg ha^{-1} while seed tuber yield varied from 1667 to 6250 kg ha^{-1}. Organic nutrient application in potato cultivation is important because potato vines return relatively little organic matter and carbon to the soil (Alford et al. 1996; Plotkin 2000) and many indicators of a healthy soil are highly dependent on soil organic carbon (Bragato and Primavera, 1998). In addition, potato production generally requires more tillage operations which tend to break soil aggregates, oxidize soil organic matter, and increase erosion (Lal et al. 1994; Unger 1992). As a result, soil organic matter levels can be expected to decline as the frequency of potato production increases. The soil ability to hold nutrients can also be expected to decline since soil organic matter contributes markedly to both cation and anion exchange sites.

CONCLUSION

The common practice in potato production in the western highland agroecological zone of Cameroon was treatment T7 with Chicken droppings (1520 kg/ha) plus mineral fertilizer (600 kg 20.10.10). This treatment produced the best result in our experiment. The performance of crotalaria was significant and could be considered as a potential source of organic nutrient for the cultivation of potato. Future research focused on the N mineralization patterns of crotalaria in addition to economic analyses could produce more satisfactory results.

REFERENCES

[1] Alford, A.R, Drummond, F.A, Gallandt, E.R, Groden, E., Lambert, D.A, Liebman, M., Marra, M.C, McBurnie, J.C, Porter, G.A, and Salas, B. (1996). The ecology, economics, and management of potato cropping systems: A report of the first four years of the Maine potato ecosystem project. Maine Agric Exp Stn Bulletin 843.

[2] Bragato, G. and Primavera, F. (1998). Manuring and soil type influence on spatial variation of soil organic matter properties. Soil Sci Soc Am J 62:1313-1319.

[3] Bullock, D.G. (1992). Crop rotation. Critical Rev. Plant Sci 11:309- 326.

[4] Hartemink, A.E., Buresh, R.J., Jama, B., Janseen, B.H. (1996). Soil nitrates and water dynamics in Sesbania fallows, weed fallows and maize. Soil Sci Soc Am J 60 :568-574.

[5] Honeycutt, C.W, Clapham, W.M, and Leach, S.S. (1995). Influence of crop rotation on selected chemical and physical properties in potato cropping systems. Am Potato J 72:721-735.

[6] Jama, B. and Van straiten, P. (2006). Potential of East African phosphate rock deposits in integrated nutrient management strategies. Annals of the Brazilian Academy of Sciencesv 78(4): 781-790

[7] Jamshidi, K., Mazaheri, D. and Saba, J. (2008). An evaluation of yield in "intercropping of maize and potato". DESERT 12: 105-111

[8] Kae, M., Masae, T., Toshifumi, M. and Tohru, M. (2014). Dual and Triple Intercropping: Potential Benefits for Annual Green Manure Production. Plant Prod. Sci. 17(2): 194-201

[9] Lal R, Mahboubi A.A, and Fausey N.R. (1994). Long-term tillage and rotation effects on properties of a central Ohio soil. Soil Sci Soc Am J 58:517-522.

[10] Loreau, M. (2000). Biodiversity and ecosystem functioning: recent theoretical advances. Oikos 91: 3-17

[11] MacDicken, K.G. (1994). Selection and management of nitrogen fixing trees. Winrock International, Morrilton, Arkansas and FAO, Bangkok.

[12] Macrae R.J, and Mehuys G.R. (1985). The effect of green manuri\ng on the physical properties of temperate area soils. Adv Soil Sci 3:71- 93.

[13] Maroko, J.B., Buresh, R.J., and Smithson, P.C. (1998). Soil nitrogen availability as affected by fallow-maize systems on two soils in Kenya. Biol Fertil Soils 26 :229-234.

[14] Opena, G.B, and Porter G.A. (1999). Soil management and supplemental irrigation effects on potato: II. Root growth. Agron J 91:426-431.

[15] Perfect, E., Kay, B.D., van Loon, W.K.P., Sheard, R.W, and Pojasok, T. (1990). Rates of change in soil structural stability under forages and corn. Soil Sci Soc Am J 54:179-186.

[16] Plotkin, J. (2000). The effect of green manure rotation crops on soils and potato yield and quality. MS thesis, University of Maine, Orono.

[17] Remesh, P. (2008). Organic farming research in M.P. Organic farming in rain fed agriculture: Central institute for dry land agriculture, Hyderabad, pp-13-17.

[18] Saddam, A.A.D. (2009). Effect of Intercropping of Zea Maize with Potato Solanum tuberosum, L. on Potato Growth and on the Productivity and Land Equivalent Ratio of Potato and Zea Maize. Agricultural journal 4 (3): 164-170.

[19] Smith, M.S, Frye W.W, and Varco J.J. (1987). Legume winter cover crops. Adv Soil Sci 7:95-139.

[20] Sheraz M.S., Hassan, G.I., Samoon, S.A., Rather, H.A., Showkat A. Dar and Zehra, B. (210). Bio-fertilizers in organic agriculture. Journal of Phytology 2(10): 42-54

[21] Tankou C.M. (2014). The interactions of Human Mobility and Farming Sysyems on Biodiversity and Soil Quality in the Western Highlands of Cameroon. Langaa Research & Publishing Common Initiative Group, Bamenda, North-West Region, Cameroon. 180 pp

[22] Tankou, C.M. and Aighewi, B. (1991). Effect of crop cover on growth and yield of potato (Solanum
[23] tuberosum). Proceedings of the ninth Symposium of the Internaonal Society for Tropical Root Crops. 20-26 October 1991. Accra, Ghana. Acta Hort. (ISHS) 380:502-505

[24] Tankou, C.M. and Aziwo, T.N. (2004). Farm Practice I. Course N0. AGRI 0501-10. Centre for Distance Education, University of Dschang, Cameroon. 146 pp

[25] Tilman, D., Reich, P.B., and Knops, J.M.H. (2006). Biodiversity and ecosystem stability in a decade-long grassland experiment. Nature 441: 629-632

[26] Unger, PW. (1992). Infiltration of simulated rainfall: tillage system and crop residue effects. Soil Sci Soc Am J 56:283-289.

[27] Westermann, D.T., and Kleinkopf, G.E. (1985). Nitrogen requirements of potatoes. Agron J 77:616-621.