International Journal of Sustainable Agricultural Research
2019 Vol. 6, No. 4, pp. 213-223
ISSN(e): 2312-6477
ISSN(p): 2313-0393
DOI: 10.18488/journal.70.2019.64.213.223

SHORT-TERM BENEFITS OF GRAIN LEGUME FALLOW SYSTEMS ON SOIL FERTILITY AND FARMERS' LIVELIHOOD IN THE HUMID FOREST ZONE OF CAMEROON

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Article History
Received: 12 August 2019
Revised: 16 September 2019
Accepted: 18 October 2019
Published: 22 November 2019

Keywords
Fallow systems
Grain legumes
Nitrogen
Organic carbon
Profitability
Smallholder farmers.

ABSTRACT

Soil fertility management of smallholder farms in the humid tropics is a major issue as a result of inherently low fertility with nitrogen being the most limiting plant nutrient. Use of grain legume fallows could improve soil quality through nitrogen fixation and ensure food and nutritional security in developing countries. This field trial was laid out in a Randomized Complete Block Design (RCBD) to evaluate the short-term benefits of grain legume fallows (common bean, groundnut, cowpea, and soybean) on soil fertility improvement and income generation in relation to a natural weed fallow system. The results showed that total soil nitrogen content ranged from 0.19–0.24%, and differed ($P < 0.001$) significantly with the highest in common bean plots as compared to the others. The soil organic carbon (SOC) content was highest in cowpea plots (3.36 %) and lowest in the natural weed fallow (2.77 %). However, the SOC were not significantly different among the fallow systems but were higher than the SOC of the soil before sowing (2.41 %). Grain yield ranged from 1.0–1.9 t/ha and differed ($P < 0.001$) significantly. The highest profitability of integrating grain legumes in farming systems was recorded in the groundnut fallow, followed by soybean, and bean. Cowpea generated a negative return, while the natural fallow system had no effect. Integrating grain legumes fallow into agricultural systems in the humid tropics enhance the value of the fallow lands and may serve as viable short-term economic incentives for smallholder farmers.

Contribution/Originality: This study contributes to the existing literature that reports the benefits of grain legumes on soil fertility improvement and also showed that the integration of grain legume fallows into agricultural systems in the humid tropics generate income for smallholder farmers and could serve as motivation for their adoption.

1. INTRODUCTION

Soil fertility decline in the tropics constitutes one of the major crop production constraints that threaten food and nutrition security (Dikand Kadiata and Lumpungu, 2003; Ngosong *et al*., 2018) with nitrogen (N) as the most limiting plant nutrient (Massawe *et al*., 2016). Managing soil fertility on smallholder farms has become a major issue as a result of degradation (Fritzpatrick, 1986). This is attributed to inherently low fertility, which could decrease rapidly when natural forest or fallow lands are converted to agricultural systems (Serrao *et al*., 1979; Koutika *et al*., 2005). In the case of the humid tropics, this rapid decline of soil fertility is due among other factors to the low buffering capacity, low activity clay content and small nutrient reserves of most of the soils and their vulnerability to erosion and compaction (Koutika *et al*., 2005). To improve soil fertility and optimize crop productivity, farmers often apply different fertilizers (Nottidge *et al*., 2005; Saha *et al*., 2008; Hepperly *et al*., 2009) including higher amount of nitrogenous fertilizers (Ngosong *et al*., 2019). However, fertilizers are expensive and are not easily affordable by most farmers in developing countries (Ngwu, 2008). As a result, soil degradation processes have intensified with soil nutrient mining as the most common form of soil degradation (Vanlauwe *et al*., 2015). Farmers have however turned to other sustainable alternative soil fertility management strategies such as crop rotation, intercropping with legumes, and fallow systems to improve soil quality.

Traditionally, fields are left fallow for a number of years, so that the natural vegetation can regrow for soil fertility to be restored (Vanlauwe *et al*., 2015). But nowadays, natural fallow is no longer an option due to the increasing demand for arable land while the available land area has remained constant (Vanlauwe *et al*., 2015) (Koutika *et al*., 2005). Cultivation of grain legumes has always been a part of crop rotations or intercropping systems as they play an important role in sustainable farming (Reem, 2017). Legumes are considered as "soil building" crops as they improve soil quality through their beneficial effects on soil biological, chemical and physical properties (Anikwe *et al*., 2016). Legumes have high litter quality that decompose quickly and accelerate nutrient cycling. They fix atmospheric-Nitrogen through symbiosis, increase soil carbon content, and stimulate the productivity of the ensuing crops with positive impact on the environment through reduction in the use of N fertilizers and Nitrogen losses in agricultural fields (Anikwe *et al*., 2016; Meena and Lal, 2018). Therefore, legumes, either as monocrops or in a cropping sequence, have great potential to enhance soil functions capable of sustaining productivity in agricultural systems (Meena and Lal, 2018).

Grain legumes are also used as an option for improving the nutritional composition of foods in developing countries due to growing demands for healthy and nutritious food (Meena *et al*., 2015). In most of the developing countries, grain legumes are the major sources of protein and other essential minerals and amino acids for the poor sector of the population (Leterme and Carmenza, 2002). Hence grain legumes have huge ecological benefits as nitrogen suppliers to arable soils and their adoption in farming systems is widely recommended, especially for smallholder farming systems in Africa. These grain legume fallow systems have other benefits such as provision of food and income to smallholder farmers (Muoni *et al*., 2019). From 2013 - 2016 in the Southwest Region of Cameroon, grain yield ranged from 6.926 - 29.907 tons for groundnuts, 9.242 - 10.973 tons for common beans, 142.1 - 258 tons for soybean and 534.7 - 797 tons for cowpea. Though these figures show a rise in growing of grain legumes (especially groundnuts) in the study area, their production remain however low thus justifying the low adoption of grain legumes in the farming system as compared to other agro-ecological zones in Cameroon (Cameroon annual statistics, 2017 edition).

This study evaluated short-term benefits of grain legumes on soil fertility improvement and their associated economic returns. Therefore, we tested the hypothesis of differential improvement of total soil nitrogen and organic carbon contents under short-term grain legume fallows and the related grain yield and income as compared to natural weed fallow system.

2. MATERIALS AND METHODS

2.1. Site Location

This field experiment was conducted from April to September 2018 at the farm of the Institute of Agricultural Research for Development (IRAD) located at Ekona (its geographical coordinates are 4°14' 0" north, 9°20' 4" east), in Muyuka subdivision of Fako Division, Southwest Region, Cameroon. Ekona is situated on the Northeastern slopes of Mount Cameroon at 450 meters above sea level (Price, 1994) with humid tropical climatic conditions. It has two distinct seasons; a long rainy season from mid-March to mid-November and a short four-months dry season expanding from mid-November to mid-March. The mean temperature ranges between 23.70°C in the rainy season and 24.40°C in the dry season, with high annual humidity of 76 - 90% (Etchu *et al.*, 2012) and average annual rainfall of 2284 mm. These rich volcanic soils belong to the Ekona series which was formed on older mudflows and have a well-developed argillic horizon (FAO-UNDP/ONAREST, 1980; Nanganoa *et al.*, 2019).

2.2. Experimental Setup

The experimental site (759 m^2) was cleared with a cutlass and plots measuring 5 x 4 m each were demarcated in a randomized complete block design (RCBD) with 5 treatments (1 natural-weed fallow and 4 different grain legume fallow systems) and 4 replications, giving a total of 20 experimental plots. The experimental plots (raised beds, 30 cm high) were prepared manually using conventional tillage with hoes. 1 m alleys separated the experimental plots and blocks, while 2 m buffer strips surrounded the entire experimental field. The fallow systems included natural-weed fallow (control), groundnut (cultivar 'JL24'), common bean (cultivar 'DOR-701'), soybean (cultivar 'TGX14F') and cowpea (cultivar 'FEKEM'). Three seeds of each legume (obtained from the Institute of Agricultural Research for Development) were sown per hole on the 30th of April 2018. Groundnut, common bean, and soybean were planted at 40 x 20 cm spacing and cowpea at 75 x 25 cm spacing based on local recommendations. The seedlings were later thinned to two plants per stand at two weeks after planting (WAP), giving a plant population density of 250,000 plants per ha for groundnut, common bean, and soybean, and a plant population density of 106,667 plants per ha for cowpea. Weeds were controlled manually by weeding at 2, 4 and 6 WAP and each plot was fertilized with 0.1 kg N-P-K (20:10:10) fertilizer (Yara, Cameroon) at 2 WAP. Systemic and contact insecticide Paraster 40EC (Active ingredient: 20gr/l imidachlopride + 20gr/l lambdacyhalothrine) was applied at the rate of 40 ml in 16L knapsack sprayer at 2, 4, and 6 WAP to control insect pests. The soil moisture during the entire experimental period depended on the local rainfall regime.

2.3. Data Collection

2.3.1. Soil Physicochemical Properties

After clearing the experimental site in April 2018, pre-planting soil samples were randomly collected in a zigzag pattern at 0–20 cm depth with an auger and thoroughly mixed to form a composite sample. The soil was air-dried and sieved through 2 mm screen to remove stones and plant debris and then analysed as described below. The physicochemical properties of the pre-planting soil of the experimental site are presented in Table 1. On the 8th of September 2018, post-harvest soil samples were randomly collected (0 – 20 cm depth) from each fallow replicate and bulked to form a composite sample, giving a total of 20 composite post experimental soil samples. The soils were also air-dried and sieved through 2 mm screen. Soil pH was determined in the ratio of 1:2.5 soil/water suspensions using a digital pH meter. Available phosphorus was determined by Bray II method (Van Reeuwijk, 1992) organic carbon by the Walkley and Black wet digestion method (Kalra and Maynard, 1991) and total nitrogen by the Kjeldahl digestion method (Bremner and Mulvaney, 1982). Soil exchangeable bases were determined after extraction with 1 N ammonium acetate (NH_4OAc) solution at pH 7. Calcium and magnesium were analysed with atomic absorption spectrometer (AAS), while sodium and potassium by flame photometer (Rowell, 1994). Exchangeable acidity was determined by 1N KCl extraction method, and titrated with 0.01 N NaOH using phenolphthalein indicators (Van Reeuwijk, 1992). The Effective Cation Exchange Capacity (ECEC) was determined by sum of exchangeable bases and acidity, while particle size distribution was determined by the pipette method and the textural class assigned according to the USDA textural triangle (Van Reeuwijk, 1992).

2.3.2. Senescent Leaf Nutrients Analysis

Senescent leaves were also harvested from each legume fallow replicate on the 8th of September 2018. At this stage of the legume crop maturity, most leaves had fallen and decomposing. The legume leaf samples were oven-dried at 80 °C and their nutrient (N, P, K, Ca, and Mg) contents analysed after extraction by dry ashing – dilute HNO_3 method (Jones, 2001) following the elemental procedures described above for soil nutrient analyses. Several specimens of major plants in the natural weed fallow including foliage, stem, flowers and roots were taken to the laboratory, examined and identified by visible characteristics vis-à-vis photographs and written description of similar-looking weeds in the laboratory manual.

2.3.3. Grain Yield

The plants were harvested in August at physiological maturity when about 85% of the pods had turned brown. The entire plants from a net plot area of 1m x 1m in the center row were harvested by uprooting the whole plant. The pods were manually separated from the plants, sun-dried for one week, threshed and weighed to obtain the yield.

2.3.4. Economic Benefits of Legume Fallow

Cost-benefit analysis was performed to determine the economic benefit of the grain legume fallow systems in relation to natural fallow, and the profitability index was employed to estimate the land value during fallow. Gross income was determined in relation to the average local market prices (local currency – FCFA) recorded from two towns (Buea and Douala) in Cameroon, and reported in US dollars. The average market price per kg was $1.2 (588 FCFA) for groundnut, $1.2 (575 FCFA) for bean, $1.1 (550 FCFA) for soybean, and $0.8 (400 FCFA) for cowpea. Expenses for all farm related activities (e.g. clearing, weeding, raised beds, planting, thinning, fertilization, pest control, harvesting, drying, and shelling) were calculated for each fallow system to determine the total production cost. The net income and profitability index (benefit-cost ratio) were calculated as: $NI = GI - PC$ and $BCR = \frac{GI}{PC}$,

Where NI = net income, GI = gross income from total sales, PC = total production cost, and BCR = benefit-cost ratio with values greater than one (>1) indicating profitability of the fallow system.

2.4. Statistical Analyses

All data sets were analyzed using the statistical software package STATISTICA 13.2 for Windows (StatSoft, 2016). One-way analysis of variance (ANOVA) was used to compare the effects of different fallow systems on soil physicochemical properties, senescent leaf nutrients, grain yields and economic benefits. Significant data means were compared by post hoc Tukey's HSD test ($P < 0.05$).

3. RESULTS AND DISCUSSION

3.1. Major Plants in the Natural Weed Fallow

Weeds in this study were defined as all "invading species" that were present in the fallow plot, that were not specifically planted (Ngobo *et al.*, 2004). These weeds were identified and grouped into invasive (*Alternanthera brasiliana*, *Chromolaena odorata*, *Sorghum halepense*, *Macroptilium atropurpureum* and *Pueraria phaseoloides*) and non-invasive plants (*Nutsedges*, *Phyllanthus spp*, *Galinsoga parviflora*, *Desmodium spp*.). Among the weeds, *Chromolaena* *odorata*, *Macroptilium atropurpureum*, *Pueraria phaseoloides* and *Desmodium spp* have been reported to possibly improve soil nitrogen (Ojeniyi *et al*., 2012; Franke *et al*., 2018).

3.2. Effect of Fallow Systems on Soil Physicochemical Properties

The textural class of the pre-planting soil of the experimental site is clay and was moderately acidic Table 1. According to Landon (1991) the soil organic carbon (2.41 %) and total nitrogen (0.18 %) were low, exchangeable potassium (0.85 cmol/kg) was high while available phosphorus (62 mg/kg) was very high.

Table-1. Pre-planting soil analysis.

Soil parameters	Value
Particle size distribution	
Clay %	60.06
Silt %	29.58
Sand %	10.37
Soil texture	Clay
Moist. (105°c) %	13.6
Org. Carb. %	2.41
Total N%	0.18
C/N	12.68
Av. P (mg/kg)	62
pH(H_20) 1:2.5	5.63
pH(KCl) 1:2.5	4.93
Na^+ (cmol/kg)	0.19
K^+ (cmol/kg)	0.85
Mg^{2+} (cmol/kg)	4.69
Ca^{2+} (cmol/kg)	9.01
Al +H (cmol/Kg)	0.08
ECEC (cmol/kg)	14.82

Moist. – Moisture content, Org. Carb. – Organic carbon, Av. P – available phosphorus, ECEC – effective cation exchange capacity.

The different fallow systems had varying effects on the soil physicochemical properties. The most notable effect was the total nitrogen content that ranged from 0.19–0.24%, and differed ($P < 0.001$) significantly with the highest in common bean fallow system followed by cowpea, groundnuts, soybean and natural weed fallow Figure 1. Grain legumes improved soil physicochemical properties by fixing the atmospheric nitrogen converting it from an inert form to forms that are available for plants uptake. This biological fixed nitrogen can replace nitrogen fertilization wholly or in part (Dwivedi *et al*., 2015). Although the natural weed fallow system recorded the lowest total soil nitrogen, it was not significantly different from the groundnut, soybean and cowpea fallow systems. This might be as a result of *Chromolaena odorata*, *Macroptilium atropurpureum*, *Pueraria phaseoloides* and *Desmodium spp*. in the weed fallow plots. Their influence on total soil nitrogen contents had been widely reported (Fageria *et al*., 2005; Ojeniyi *et al*., 2012; Franke *et al*., 2018). Muhr *et al*. (1999) reported that green manure legumes such as *Pueraria phaseoloides* can contribute large quantities of residual biomass and nitrogen (N) to soil and Fening *et al*. (2009) showed that *Chromolaena odorata* contains appreciable quantities of plant nutrients. Hence, the natural weed fallow system that comprises some soil N-improving weeds would be a recommended sustainable soil regeneration option when only soil fertility improvement benefits are considered.

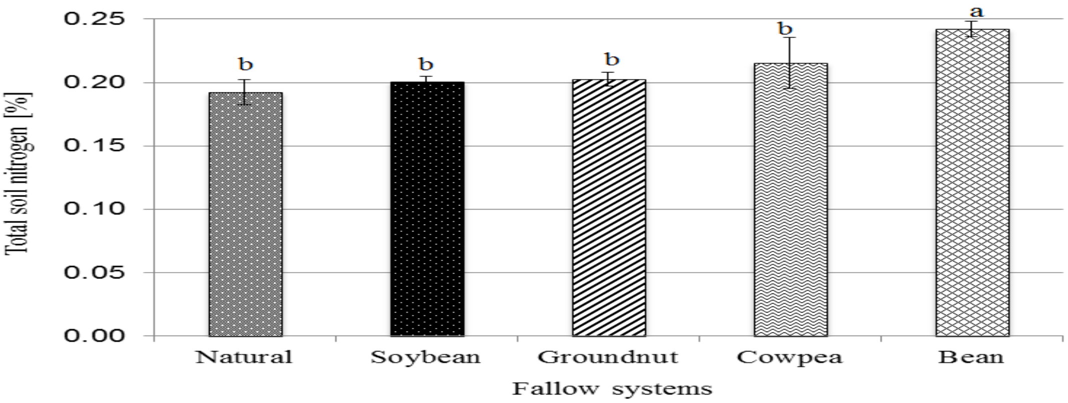

Figure-1. Effect of five fallow systems (Natural, soybean, groundnut, cowpea, and bean) on total soil nitrogen content (% ± SD) after nineteen weeks of crop cultivation. Data with different letters are significantly different ($P < 0.05$).

The soil organic carbon (SOC) content was highest in cowpea (3.36 %) and lowest in the natural weed fallow (2.77 %). However, the SOC were not significantly different among the fallow systems Table 2 but were higher than the SOC of the pre-planting soil 2.41 %, Table 1. This can be attributed to the conversion of biomass to organic matter, which increased the levels of SOC (Ojeniyi *et al*., 2012). Legume cultivation has also been associated with organic carbon dynamics in the rhizosphere (Hajduk *et al*., 2015; Bichel *et al*., 2016). The quantity of organic carbon buildup depends on the soil, climatic condition, and species of grain legume (Gogoi *et al*., 2018) and is essential to all soil processes that impact crop production and the environment. The C/N ratio ranged from 12.7–16.1, and differed ($P < 0.05$) significantly across fallow systems with the lowest in common bean as compared to the other treatments Table 2. The C/N ratios indicate the rate of decomposition of organic matter and these results in the mineralization or immobilization of soil nitrogen (Swangjang, 2015). Usually it is accepted that the optimal C/N ratio is around 10 while ratio over 30 is considered extremely high and can result in some soil nitrogen deficiencies. C/N ratio in cultivated lands commonly ranges from 8 – 15 (Brady and Wail, 2010).

Though not statistically significant, soil available phosphorus in the groundnut plot was higher (16.12 mg/kg) compared to the other fallow systems Table 2. However, available phosphorus in all the post-harvest soils was lower compared to soil phosphorus before sowing 62 mg/kg, Table 1. Among many environmental factors (temperature, water content, pH and N concentration), biological nitrogen fixation process in legume crops is also affected by plant nutritional status such as phosphorus level which controls nodule growth and nitrogenase activity (Liu *et al*., 2011; Sallaku *et al*., 2016) thus a high use of phosphorus was expected. The other soil parameters did not differ significantly across fallow systems. However potassium and calcium was highest in the natural weed fallow and magnesium in cowpea Table 2.

Table-2. Effect of five different fallow systems (Natural, soybean, groundnut, cowpea, and common bean) on soil physicochemical properties (Mean ± SD) after nineteen weeks of crop cultivation.

Soil physicochemical parameters	Fallow systems				
	Natural	Soybean	Groundnut	Cowpea	Common bean
pH	5.53 ± 0.54a	4.99 ± 0.22a	4.98 ± 0.25a	5.24 ± 0.29a	4.97 ± 0.16a
Organic carbon (%)	2.77 ± 0.12a	3.04 ± 0.28a	3.27 ± 0.37a	3.36 ± 0.23a	3.08 ± 0.24a
Carbon/Nitrogen	14.45 ± 0.99a	15.17 ± 1.59a	16.10 ± 1.62a	15.66 ± 1.57a	12.68 ± 0.69b
Phosphorus (mg/kg)	14.12 ± 5.77a	12.50 ± 1.90a	16.12 ± 2.62a	13.82 ± 2.36a	14.26 ± 2.31a
Sodium (cmol/kg)	0.21 ± 0.00a	0.21 ± 0.01ab	0.20 ± 0.01ab	0.20 ± 0.01ab	0.18 ± 0.02b
Potassium (cmol/kg)	0.94 ± 0.04a	0.69 ± 0.24a	0.77 ± 0.14a	0.75 ± 0.22a	0.70 ± 0.05a
Calcium (cmol/kg)	9.99 ± 0.06a	9.52 ± 0.99a	9.50 ± 0.79a	9.61 ± 0.64a	8.99 ± 1.18a
Magnessium (cmol/kg)	3.40 ± 0.08a	3.38 ± 0.23a	3.28 ± 0.11a	3.51 ± 0.33a	3.28 ± 0.26a
Acidity (cmol/kg)	0.06 ± 0.02a	0.05 ± 0.01a	0.05 ± 0.01a	0.06 ± 0.01a	0.07 ± 0.02a
ECEC (cmol/kg)	14.60 ± 0.17a	13.85 ± 1.28a	13.79 ± 0.90a	14.12 ± 0.36a	13.20 ± 1.42a

Values within columns with different letters are significantly different ($P < 0.05$).

3.3. Nutrient Accumulation in Senescent Leaf Biomass

The release of nutrients, from litters and crop residues, is an important potential source of nutrients for subsequent crops (Blair and Boland, 1978; McLaughlin *et al.*, 1988; Nanganoa and Njukeng, 2018). So the nutrient contents of the senescent leaves of different grain legume fallow systems were studied. The results showed that leaf nitrogen ranged from 1.5–2.6 % and differed ($P < 0.01$) significantly with the highest in groundnut, followed by cowpea, soybean, and common bean Figure 2. Flint and Roberts (1988) and Clark *et al.* (1998) also showed that the amount of nitrogen in legume crops varies among species. Leaf phosphorus varied from 0.25–0.41 % and differed ($P < 0.001$) significantly, with the highest in common bean, followed by cowpea, groundnut and soybean Table 3. Leaf potassium ranged from 5.0–8.4 % and also differed ($P < 0.001$) significantly, with the highest in common bean, followed by cowpea, groundnut, and soybean Table 3. The calcium content varied between 0.28–0.48 % and differed ($P < 0.001$) significantly, with the highest in soybean, followed by cowpea, common bean and groundnut Table 3. Magnesium content ranged from 0.16–0.20 % that differed ($P < 0.01$) significantly, with the highest in soybean, followed by cowpea, groundnut and common bean Table 3. Much of the soil nutrients including the Nitrogen (N) fixed by the legume crops is removed at harvest in seed and thus the net residual contributions of fixed N and other nutrients in the senescent leaves to agricultural soils after the harvest of legumes plays an important role in enriching the soil nutrients pool for the ensuing crops grown after the legumes.

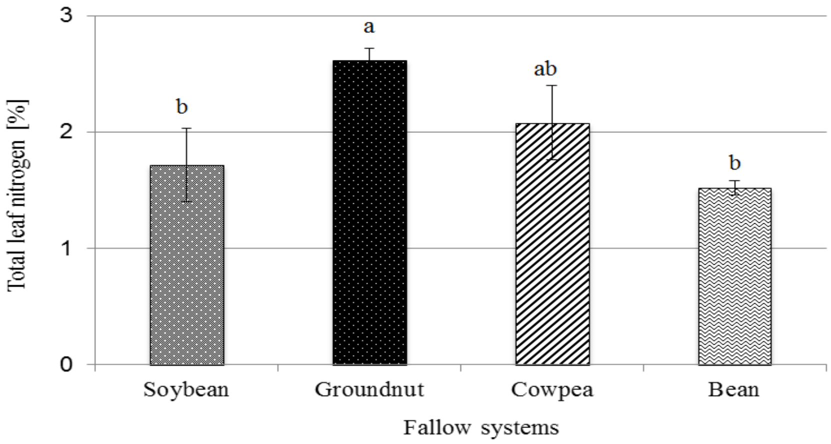

Figure-2. Total leaf nitrogen content (% ± SD) of four different fallow legumes (Soybean, groundnut, cowpea, and bean) after nineteen weeks of cultivation. Data with different letters are significantly different ($P < 0.05$).

Table-3. Elemental composition (Mean ± SD) of four different fallow legumes leaves (Soybean, groundnut, cowpea, and bean) after nineteen weeks.

Fallow systems	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)
Soybean	0.25 ± 0.01c	5.02 ± 0.30b	0.48 ± 0.02a	0.20 ± 0.01a
Groundnut	0.34 ± 0.02b	6.77 ± 0.69a	0.28 ± 0.01b	0.16 ± 0.01b
Cowpea	0.39 ± 0.01a	7.9 ± 0.35a	0.33 ± 0.05b	0.18 ± 0.02ab
Bean	0.41 ± 0.02a	8.35 ± 0.93a	0.28 ± 0.03b	0.16 ± 0.01b

Values within columns with different letters are significantly different ($P < 0.05$).

3.4. Yield and Profitability of Grain Legume Fallow Systems

The different legume fallow systems had varying grain yield and economic benefits that increased the economic value of the fallow land. Grain yield ranged from 1.0–1.9 t/ha that differed ($P < 0.001$) significantly, with the highest in groundnut (1.9 t/ha), followed by soybean (1.6 t/ha), common bean (1.3 t/ha), and cowpea (1.0 t/ha) Figure 3. The grain yields of the legumes used in this study are within the yield range of legumes grown as sole crops elsewhere in Sub Saharan Africa (Franke *et al.*, 2018). Considering the fact that farm management practices were the same for the four different grain legume fallow systems, yield variations between them is likely due to crop specific nutrient acquisition potentials and adaptation to environmental variables. This yield variation is reflected in the differential net income generated by the four grain legume fallow systems that differed ($P < 0.001$) significantly.

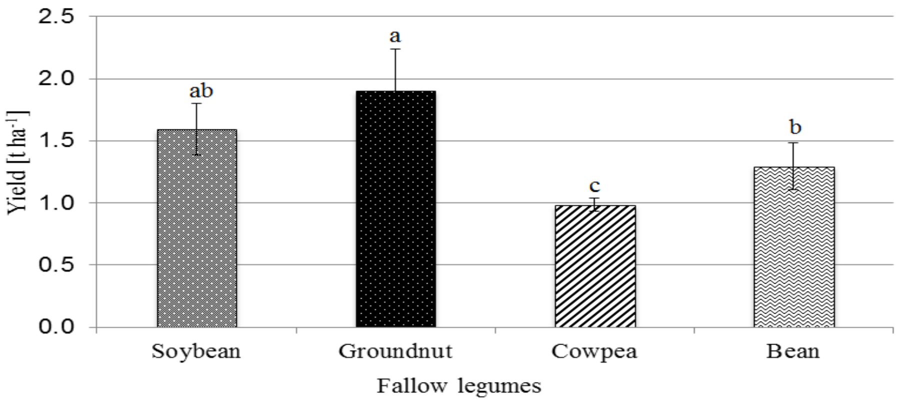

Figure-3. Yield (t ha^{-1} ± SD) of four different fallow grain legumes (Soybean, groundnut, cowpea, and bean). Data with different letters are significantly different ($P < 0.05$).

Accordingly, the highest profitability of integrating grain legumes in farming systems was recorded in the groundnut fallow, followed by soybean, and common bean, whereas cowpea generated a negative return, while the natural fallow system had no effect Table 4. The high profitability index recorded for groundnut fallow as compared to the other fallow systems justifies the dominance of groundnut cultivation in this study area (Cameroon's Annual Statistics, 2017). The negative return for cowpea could be attributed to brown rust (*Uromyces* spp) disease observed in the cowpea plots. Sulphur and potassium carbonate usually used to manage the disease were not readily available in the local markets. However, despite the negative returns, smallholder farmers rely almost exclusively on *family labour thus the grain produced* is consumed by the households that produce it.

Although the green manure legumes in the weed fallow improved soil nitrogen and organic carbon as compared to soil before sowing, their adoption by farmers has remained limited. All efforts to promote them among farmers and evidence of their beneficial effects on soil fertility and cereal yields have been futile (Muhr *et al*., 1999; Carsky *et al*., 2001). This is likely related to a general reluctance of farmers to invest land, labour and seed in a technology that does not provide a quick economic return on investments (Schulz *et al*., 2001).

Table-4. Net income (Mean ± SD) and profitability of five different fallow systems (Natural, soybean, groundnut, cowpea, and common bean).

Fallow systems	Net income ($/ha)	Profitability index
Groundnut	1401 ± 394a	2.7
Soybean	923 ± 229ab	2.1
Bean	657 ± 221b	1.8
Cowpea	−44 ± 40c	0.9
Natural	0.0 ± 0.0d	0.0

Values within columns with different letters are significantly different ($P < 0.05$).

4. CONCLUSION

The grain legume fallow systems enhanced the soil nitrogen and organic carbon contents while providing food and income for smallholder farmers as compared to the short natural weed fallow. The highest profitability index recorded for groundnut fallow justifies the dominance of groundnut cultivation in the study area, while the high value recorded for soybean and common bean fallows is indicative of the potential for adoption of these grain legumes in the local cropping systems. Therefore, besides the potential agronomic and environmental benefits of integrating grain legumes into fallow systems, income generation from the sale of grain legumes enhances the value of fallow lands and may serve as viable short-term economic incentive for the smallholder farmers.

Funding: The study was supported by the Agriculture Investment and Market Development Project (PIDMA), Cameroon.
Competing Interests: The authors declare that they have no competing interests.
Acknowledgement: All authors contributed significantly to this study and are grateful to the Soil, Plant and Water Analysis Laboratory, Ekona Regional Centre, Institute of Agricultural Research for Development (IRAD) for providing the analytical facility.

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