Annual Research & Review in Biology
12(1): 1-14, 2017; Article no.ARRB.32099
ISSN: 2347-565X, NLM ID: 101632869

SCIENCEDOMAIN *international*
www.sciencedomain.org

Field Evaluation of NERICA 8 (*Oryza sativa* L.) and JL24 (*Arachis hypogaea* L.) Spatial Arrangement on Agronomic Traits Performance in Humid Forest Zone of Cameroon

Thomas Arsene Nsea Mballa[1], Eddy Léonard Mangaptché Ngonkeu[1,2*], Dorothy Kenyi Malaa[2], Joseph Mouen[2], Paco Meppe[2], Carine Petmi[1], Vanessa Nanda[1], Honoré Tekeu[1] and Noe Woin[2]

[1]*Departement of Plant Biology and Physiology, Faculty of Science, University of Yaoundé I, P.O.Box: 812 Yaoundé, Cameroon.*
[2]*Institute of Agricultural Research for Development, IRAD, Box: 2123 Yaoundé, Cameroon.*

Authors' contributions

This work was carried out in collaboration between all authors. Authors TANM, ELMN and DKM defined the theme of this work. Authors NW, JM, ELMN, DKM and PM ensured the supervision and provided all logistical support. Authors TANM, CP and VN collected all agronomic data. Authors TANM and HT implemented and monitored the field test, statistical analysis and interpretation of collected data. Author TANM participated in the literature review and in writing of the first draft of the article. Author ELMN participated in the correction of the final draft of the article. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/32099
Editor(s):
(1) Jin-Zhi Zhang, College of Horticulture and Forestry Science, Huazhong Agricultural University, China.
(2) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) İlkay Yavaş, Adnan Menderes University, Turkey.
(2) Nazimah Maqbool, University of Sargodha, Lyallpur Campus, Faisalabad, Pakistan
(3) Narayan Khatri, Nepal Agricultural Research Council (NARC), Nepal.
Complete Peer review History: http://www.sciencedomain.org/review-history/18257

Original Research Article

Received 8th February 2017
Accepted 5th March 2017
Published 18th March 2017

ABSTRACT

Intercropping system is the most practiced soil fertility management strategies by small scale farmers in Cameroon. The aim of this study was to identify the least competitive rice-groundnut spatial arrangement and to assess the correlation between agronomic traits in an intercropping

**Corresponding author: E-mail: ngonkeu@yahoo.fr;*

system condition for both crops. The experiment was carried out in March 2015, in RCB designed with four treatments and four replications involving NERICA 8 and JL24 genotypes. Fourteen agronomic traits were collected, analyzed and Pearson's correlation test was performed at 1% and 5% level of probability. 3R+1G spatial arrangement gave nodules < 75 plant^{-1}, 4R+2G gave 98.13 plant^{-1}and SG gave 161 plant^{-1}. For 100 seed weight and number of grains plant^{-1}, 3R+1G gave the lowest value followed by 4R+2G and SG. No significant different was recorded for rice grain yield, while significant different was obtained in groundnut, 3R+1G recorded the lowest value (0.47tha^{-1}). Shelling % (r = 0.692*), number of grain plant^{-1}(r = 0.75**) and 100 seed weight (r = 0.756**) gave positive correlation with grain yield. Number of grain panicle^{-1} gave positive correlation with rice grain yield (r = 0.906**). These results can be included in crop breeding programs, to sustain rice-groundnut intercropping system.

Keywords: Rice; groundnut; intercropping system; phenotypic traits; tropical forest zone.

1. INTRODUCTION

Cameroon is endowed with its flora and fauna diversity and is ranked 5th African country from the biodiversity point of view [1]. Its agro-demographic potential carrying capacity of land is characterized by the increasing population and its five agro-ecological zones. The variability of environmental constrains in humid forest ecology had significantly impaired the production of several staple food crops. A decrease in maize grain yield (up to 60%) in acid tolerance population due to the acidity of the soil in humid forest zone had been reported [2,3]. A further decrease in the productivity of some other important staple food crops (rice and groundnut); will threatens food security in the nation, thus jeopardizing the millennium development goal to fight against malnutrition and chronic diseases in the sub region.

In fact, Cameroon rice consumption had gradually moved from luxserious food to subsistence food crop. Three out of four homes consume rice three to four times a week and almost 3% of the population eats rice on a daily basis. The national production oscillate around 170 000 tons far less than the demand estimated at 650 000 tons [4]. In 2015, the government spent more than 118 582 278 133 F CFA on importation to compensate for the deficit by importing more than 510 000 tons of rice. After the degradation of major rice production areas in the country, like SEMRY in Kouseri, Maga and Yagoua due to climatic hazards and insecurity in the Northern part of the country, the government get into several initiatives to curd down this situation with the aim of attaining a national rice self-sufficient production. Some of this includes; the dissemination of high yielding NERICA (new rice for Africa) progenies nationwide and orienting it production in upland rain fed ecology in the Southern part of the country left unexploited [5].

Indeed, more than 70% of these rice farmers are resource poor with limited financial facilities to afford inputs like pesticides and fertilizers. Taken into account that, rice farming is highly demanding financially particularly the application of mineral fertilizers, inaccessibility to credit to purchase these fertilizers, non-mastery on the quantity, quality or method of fertilizers application by resource poor farmers comes to worsen the plague of constrains face by rice grower in Cameroon as a whole [6].

Protein deficient diet had reached alarming proportion in SSA and groundnut is an important source of protein for most African population. It serves as forage for animal feed, reason why farmers are reluctant to forgo this farm growing crops in the Southern part of the country. However groundnut grain yield is in constant decrease in Cameroon (0.85 t/ha) [7] far from its grain yield potential of 1.5 t/ha. The major causes in the decrease in productivity are; the acidity of the soil, poor agricultural practices, land pressure [8]. The *A. hypogaea* JL-24 seeds were identified as one of the high yielding genotype following the IRAD/SSR4D Project for zone V [9]. The genotype JL-24 produce seeds rich with less saturated fat, proline (6.412%), crude protein (25.20%), crude fiber (1.149%), Carbohydrate (21.26%) and energy (601.856%) [10,11]. *A. hypogaea* is able to fixed 12-15 kg N/0.16h/year [12]. It is preferentially crop in tropical and subtropical ecologies [13]. However, investigations on JL24 genotype performances are limited in pure cropping system and green house condition [14]. Most resource limited farmers carry out mixed and intercropping farming system with rudimentary farm practice to improve the fertility of their soil as well as diversify their production. Grain legume-cereal intercropping is a method to obtain greater and more stable crop yields, improve plant resource utilization (water, light, nutrients), increase input of legume symbiotic Nitrogen fixation (SNF) to the cropping system and reduce impact on the environment. Intercropping system, according to many authors is more advantageous when well managed than sole cropping system. In this line, groundnut seems an appropriate candidate to achieve this objective [15,16,17,18].

In sole rice base farms, mineral losses due to high mineral fertilizers losses have been reported [17]. This N losses (25-109KgN/ha) are due to; leaching, runoff or by volatilization and end up contaminating water bodies. Alternative soil fertility management has been conducted by many researchers, like, rice-soybeans, rice-cawpea base systems [12,15,19,20]. Intercropping groundnut with rice, can helps to sustain the yield, increases the nutrient use efficiency of both crops, ensures the farmer earnings in case of crop failure, increase in a balanced diet and thus helps in fighting against malnutrition and food security [12,20,21,22]. Ecologically, it can help to promote auto-regulation mechanisms of the crops via competition and planned biodiversity to manage weeds [22]. However, integrating groundnut and rice intercropping system in rain fed upland ecology remains less known farming technique by farmers in the humid forest zone (HFZ). Consequently, inconsistency on agronomic traits and grain yield data in an intercropping system condition of rice and groundnut in HFZ of Cameroon is perceived.

In that respect, the aim of this study was to identify the least competitive rice-groundnut spatial arrangement and to assess the correlation between agronomic traits in an intercropping system condition for both crops, which can serve as bases to be exploited in breeding programs.

2. EXPERIMENTAL DETAILS

2.1 Site and Climatic Characteristics

The experiment was carried out in 2015 at IRAD- station (Institute of Agricultural Research for Development) located at Nkolbisson (Mfoundi Division): 11°27.542'E; 3°52.035'N at an altitude of 748 mm above sea level in the agro-ecological zone V (Fig. 1). The annual temperature of 23.5°c and an average annual bimodal rainfall of 1560mm (Source: climatic data service IRAD, 2015). Soil sampled show up a dominant red color, classified as Ferric soil [23] and with soil pH < 6. The soil is described as clay-loam texture made up of dominant middle-size pores and susceptible to drainage (Table 1).

Table 1. Soil physico-chemical characteristics of the experimental site before sowing and after harvest in sole rice and groundnut unit plots

Soil parameters	Norm*	Before sowing	After harvest	
			Sole rice	**Sole groundnut**
OM (g/kg)	-	22.90	2.12	1.57
Total C (g/kg)	-	13.28	1.23	0.91
Total N (g/kg)	> 0.14	1.49	1.41	1.60
C/N	-	8.90	0.87	0.82
Ca^{2+} (cmol/kg)	> 4.46	0.76	0.94	0.82
Mg^{2+}	-	0.22	0.07	0.09
K^{+1}	0.34-0.46	0.33	0.03	0.05
Na^{+1}	-	0.29	0.13	0.09
CEC (cmol/kg)	> 10	9.48	8.36	8.23
pH (H_2O) – 1:5	6-7	5.96	6.12	6.50
Clay (%)	-	48.95	49.04	50.49
Silt (%)	-	5.87	5.11	4.66
Sand (%)	-	19.45	20.27	20.03
Texture	Clay loam	Clay loam	Clay loam	Clay loam

** [13,24,25]*

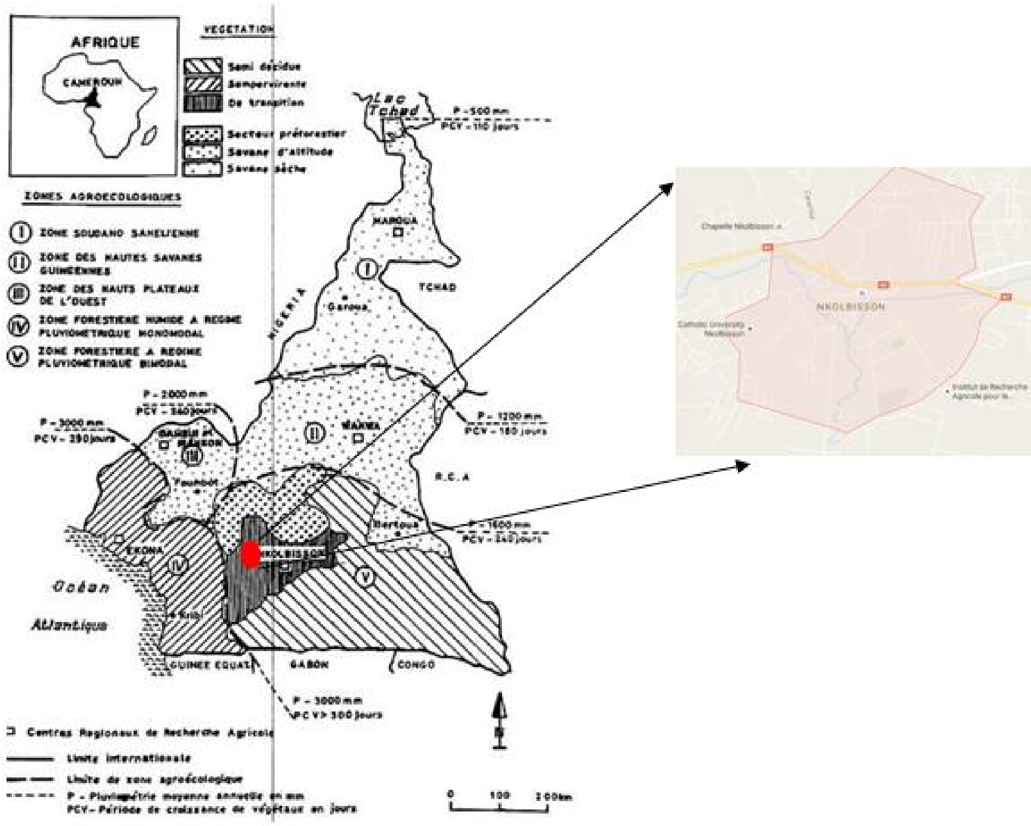

Fig. 1. Five agro ecological zones of Cameroon and location of the experimental site

2.2 Experimental Design and Treatments

The experimental design was a in a randomized complete block (RCB) (Gomez and Gomez, 1984) with four repetitions. Each experimental unit plot measured 12m^2 (3×4m) and different intercropping pattern and sole cropping system were allotted as main treatments and included:

SR: Sole rice, sown was done by dibbling in grooves of about 2-3 cm depth, with 5 seeds per hole and with a spacing of 20×30 cm. The seed rate and sowing density were: 26.25 kg/ha and 175 000 plants/ha respectively.

SG: Sole groundnut, sown was done by dibbling in grooves of about 2-3 cm depth, with one seed per hole with a spacing of 20×60 cm. Giving a population density of 87 500 plants/ha corresponding to 30.625 kg/ha seed rate.

3R+1G: Three rows for rice and one row for groundnut. Both rice and groundnut sowing depth, number of seeds per hole and sowing spacing were respected as in SR and SG above. But, the seed rate and density were respectively; 20.625 kg/ha and 137 500 plants/ha for rice, 13.125 kg/ha and 37 500 plants/ha for groundnut. A population ratio of 3.6: 1 was obtained for rice to groundnut ratio.

4R+2G: Four rows of rice to two rows of groundnut, with the seed rate and population density of 15.00 kg/ha and 100 000 plants/ha for rice, 17.50 kg/ha and 50 000plants/ha for groundnut. A population ratio of 2:1 was obtained for rice to groundnut ratio. Similar sowing depth and spacing were respected as in 3R+1G above.

2.3 Soil Sampling and Analyses

Two Soil sampling were done before sowing and after harvest in sole rice and sole groundnut plot treatments. Both soil samples were dug following a W-shape pattern with an anti-oxidant soil steel auger at a depth of 20-30 cm on top of the soil profile [17]. Soil sampling (45 samples) carried out in the whole plot constituted of a composite of 5.5 Kg, while a total of 20 samples were obtained in sole rice and in sole groundnut units constituting each a composite of 2.4 Kg. All soil samples were homogenized and kept in a non-degradable black plastic paper at room temperature. Later these soils were air dried under shallow for two to three days followed by sieving with pores of different sizes before physical and chemical analysis carried out at the soil laboratory of the Institute of Agricultural Research for Development (IRAD).

The pH_{water} was measured from a solution soil/water in the ratio 1:5 using a pH meter mounted with glass electrode [26]. Total soil Nitrogen was determined using Kjedhal method. It was obtained by sulfuric acid digestion in the addition of selenium in hydrogen peroxide at 30% and warm at 320°C for 3 hours. Total soil Carbon was obtained following the method describe by [27] and [28]. Organic matter was obtained by multiplying organic Carbon content by Sprengel factor [23]. Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} were extracted using Ammonium acetate solution ($CHOONH_4$) at a pH 7. CEC was done Ammonium acetate solution ($CHOONH_4$) at a pH 7 in a three phase process and determine by spectrometry.

2.4 Management Practice and Agronomic Data Collected

Sowing was done two weeks after effective rain had begun. Rice variety of short life cycle (95-100 days) used was NERICA 8 while groundnut variety used was JL24 with life cycle (90-95 days). Fertilizers application was done only in the treatments with sole rice. The fertilizers constituted of basal NPK at the rate of 200Kg/ha and of top dressing of urea at a rate of 100Kg/ha. NPK was applied two weeks after sowing (2 WAS) while Urea was applied in two splits, sixty days after sowing (60 DAS) and secondly seventy days after sowing (70 DAS) at the rate of 50 Kg/ha for each split. Necessary agronomic practice including weeding, were carried out regularly and was done manually. Eight agronomic data for groundnut were evaluated: number of nodules plant^{-1}, number of pods plant^{-1}, shelling percentage (%), number of grains plant^{-1}, number of grains pod^{-1}, number of empty pods plant^{-1}, 100 seed weight and grain yield. Seven agronomic data were collected for rice genotype: plant height, length of panicle, number of empty grains panicle^{-1}, number of grain panicle^{-1}, and number of panicle hill^{-1}, 1000 seed weight and grain yield.

2.5 Yield and Yield Component of Both Crops

A total of 30 plants and 18 plants in a quadrant of 1.2m^2 corresponding respectively for NERICA 8 and JL24 were harvested. A total of six panicles were harvested in each plot at random when 2/3 of the panicle had become mature to count the number of rice grain panicle^{-1}. 1000-seed weight of grains was evaluated at 14% seed moisture content. The grain yield component of JL24 comprises: number of pods per plant, number of grains per plant, number of grains per pod, number of plants per meter square and 100-seed weight of grains at 12% moisture content [15].

2.6 Assessment of Nodulation in JL24

The soil was wetted with tap water and five plants per treatment uprooted gentle six weeks after sowing (WAS) to evaluate the number of nodules [29]. Individual root system of each plant was washed twice with tap water and with care to avoid damage of the nodules.

2.7 Biological Efficiency of Intercropping Rice and Groundnut

2.7.1 Land equivalent ratio (LER)

$LER = L_R + L_G$
$L_R = Y_{R,\,IC} / Y_{R,\,SC}$
$L_G = Y_{G,\,IC} / Y_{G,\,SC}$

Where:

$Y_{R,\,IC}$ = rice yield in intercropped
$Y_{G,\,IC}$ = groundnut yield in intercropped
$Y_{R,\,SC}$ = rice yield in sole cropping
$Y_{G,\,SC}$ = groundnut yield in sole cropping
L_R is the partial land equivalent ratio of rice
L_G is the partial land equivalent ratio of groundnut.

2.7.2 Equivalent density coefficient (EDC) [30]

$EDC = EDC_R + EDC_G$
$EDC_G = EDC_{G,\,IG} / EDC_{G,\,SG}$
$EDC_R = EDC_{R,\,IR} / EDC_{R,\,SR}$

Where:

EDC_G: partial EDC of groundnut
EDC_R: partial EDC of rice
$EDC_{G,\,IG}$ density of groundnut when intercropped

$EDC_{G, SG}$ density of groundnut sole cropping
$EDC_{R, IR}$ density of rice in intercropping
$EDC_{R, SR}$ density of rice in sole cropping

2.8 Statistical Analyses

Data were managed with Excel Microsoft 2010, then subjected to analyses of variance (ANOVA) using the General Linear Model procedure with the Statistical Analyses System (SAS) software package 9.3 version. Separation of means was determined using the Student-Newman-Keuls test at 5 % probability level and Pearson's correlation test was performed at 1 % and 5 % level of probability.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Differences in the physical and chemical characteristics of soil at Nkolbisson under rice-groundnut cropping system

The soil at Nkolbisson is rich in clay and both crops do not significantly affect the physical nature of the soil. Whereas its chemical characteristics revealed that, the soil was rich in organic matter. The C/N ratio was suitable for crop production but with the rate of organic matter depletion of 90.75 % and 93.1 % for sole rice and sole groundnut cropping system respectively. The level of Nitrogen in the soil > than normal (Table 1), but in sole groundnut after harvest enrich the soil with N at a rate of 11% while rice deplete the soil with N at a rate of 8%, making the level of Nitrogen depletion significantly> in sole rice as compare to sole groundnut after harvest. The quantity of soil cations (Ca^{2+} and K^{+}) was < than normal, similarly trend was observed for CEC (cation exchange capacity) before sowing and after harvest. The rate at which groundnut crop depletes the soil in Ca^{2+} and Na^{+} in sole groundnut base system is > than sole rice after harvest. The studied site had a soil pH > 5.5, but after harvest no major difference existed for sole rice and sole groundnut unit plots. In the same line, the results show that, pH in sole rice and sole groundnut unit plots where within the normal range (6-7) [13,24,25].

3.1.2 Effect of different rice-groundnut different crop pattern on JL24 genotype nodulation

Sole groundnut (SG) recorded 161.00 numbers of nodules per plant root system while in the treatments 4R+2G and 3R+1G the nodulation were 98.13 and 73.50 per plant root system. When the number of nodulation per root system is <75 per plant root system is consider as poor [31]. In that respect only treatments SG and 4R+2G are characterized as good while 3R+1G is consider as poor. Computed at 5% probability level, there is no significant different in the number of nodules in the treatments SG and 4R+2G as well as between 3R+1G and 4R+2G but there is a significant different between 3R+1G and SG (Fig. 2).

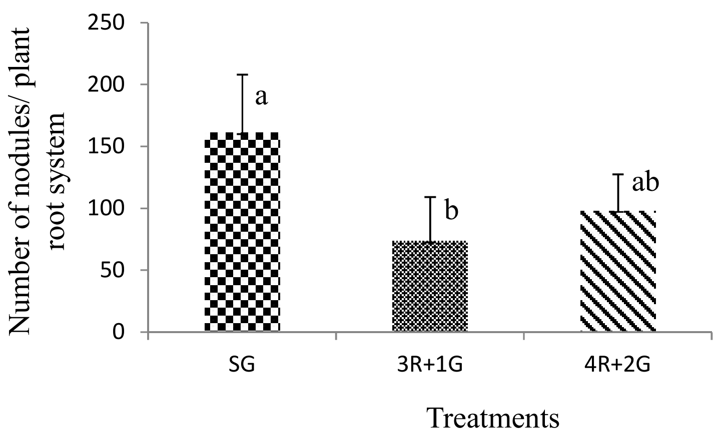

Fig. 2. Root nodulation in JL24 under different rice-groundnut crop spatial arrangement

3.1.3 Effect of rice-groundnut spatial arrangement on the number of groundnut grains per pod and number of empty pods per plant

The number of empty pods per plant and the number of filled pods per plant showed no significant difference at 5% level probability for all treatments. However, the treatment 3R+1G had the lowest number of empty pods/plant 106.5 of all the treatments. In treatments 4R+2G and SG, the number of empty pods/plant was 138.5 and 147.8 respectively. This implies that the number of empty pods increases with increase in the density of groundnut crop, that is for SG (87 500 plants ha^{-1}), 4R+2G (50 000 plants ha^{-1}), 3R+1G (37 500 plants ha^{-1}).Similarly, the number of grains per pod do not show any significant different at 5% level probability. However, SG showed 1.40 while the treatment 3R+1G and 4R+2G show 1.17 and 1.29 respectively. This shows that, the number of grains pod^{-1}decreases as the density of groundnut decreases from 3R+1G to SG.

3.1.4 Effect of rice-groundnut spatial arrangement on 100 seed weight of goundnut grain and on the number of grain per plant

With respect to the different treatments, 100-seed weight in SG is higher and significantly different of 3R+1G but significantly equal to 4R+2G. On the other hand, 3R+1G and 4R+2G are not significantly different at 5 % level (Fig. 3). Concerning the number of grain per groundnut plant, SG and 4R+2G score respectively 30.47 and 28.96 with no significant different between them computed at 5% level. Treatment 3R+1G gave the lowest value of 18.68 (Fig. 4) and significantly different from the other treatments.

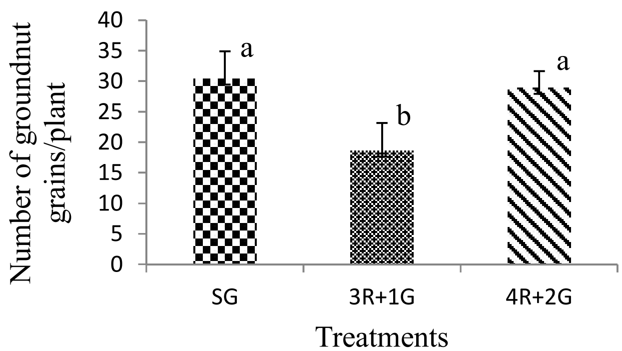

Fig. 3. Number of peanut grains per plant under sole groundnut and intercropping base system

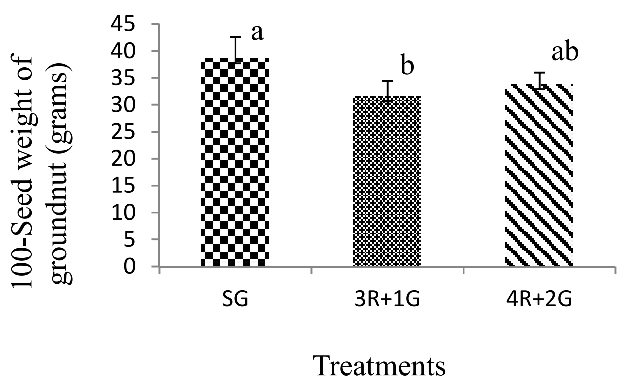

Fig. 4. Seed weight of groundnut grains under sole groundnut and intercropping system

3.1.5 Effect of rice-groundnut spatial arrangement on NERICA 8 plant height

The rice plant height measured at 58 DAS indicate that, the treatment with sole rice (SR) gave the lowest height (82.2cm) as compared to the other treatments (3R+1G = 88 cm and 4R+2G = 86.9) (Fig. 5). The result obtained was computed at 5% probability level and revealed that, there was no significant different between 3R+1G and 4R+2G, whereas both intercropping systems were significantly different from sole rice (SR). Also, it was observed that increased in rice plant height was not a function of the increase in groundnut crop density in an intercropping system.

3.1.6 Effect of rice-groundnut spatial arrangement on rice and groundnut grain yield

Rice grain yield in SR, 3R+1G and 4R+2G computed at 5% probability level indicates that the there is no significant different in the grain yield irrespective of the crop pattern. However, the yield obtained in SR, 3R+1G and 4R+2G (3.37, 3.02 and 3.29) tha^{1-} respectively fall with the potential grain yield of NERICA 8 (3-4.5 tha^{1-}) (WARDA, 2000).

Groundnut grain yield were 0.99, 0.47, 0.84 (tha^{1-}) for SG, 3R+1G and 4R+2G respectively. The grain yields in SG and 4R+2G were significantly different to treatment 3R+1G at 5% probability level (Table 2). In the same line, the grain yield between treatment SG and 4R+2G were not significantly different.

3.1.7 Biological efficiency of intercropping system over sole cropping system

Concerning the spatial arrangements of 3R+1G and 4R+2G, the total LER was greater than one (>1) that is 1.37 and 1.81 respectively. The partial LER on both crops remains less than 1. JL24 gave a partial LER of 0.48 and 0.84 in 3R+1G and 4R+2G respective while for NERICA 8 gave, the partial LER of 0.90 and 0.98 in 3R+1G and 4R+2G respective. Irrespective of the different crop pattern, NERICA 8 crop gave a higher partial LER of 1.88; whereas JL24 crop gave a value of 1.32. The EDC indicates that, the total EDC of both spatial arrangements are more than unity (Table 3). Again, the partial EDC of both NERICA 8 and JL24 are < 1, whereas it was observed that the partial EDC of NERICA 8 irrespective to the crop pattern to be 1.36, while the that of JL24 was equal to one (1).

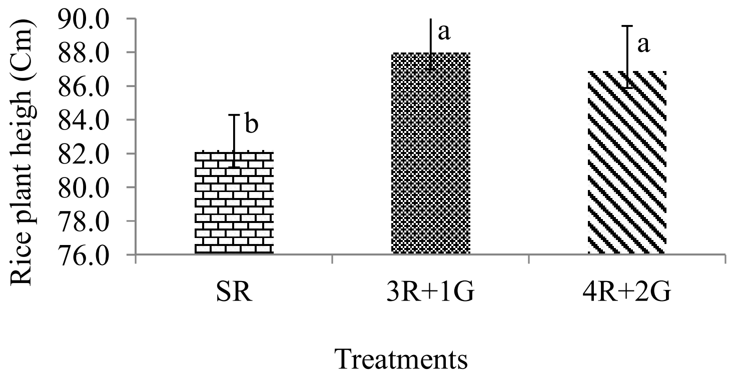

Fig. 5. Rice plant height in sole and intercropping base systems

Table 2. Effect of intercropping NERICA 8-JL24 on the grain yield of component crops

Test crops	NERICA 8			JL24		
Treatments	SR	3R+1G	4R+2G	SG	3R+1G	4R+2G
GY (t/ha)	3.37ns	3.02ns	3.29ns	0.99a	0.47b	0.84a
Std error	0.490	0.634	0.258	0.184	0.072	0.120
CV (%)	14.5	21	7.85	18.45	15.16	14.34
LSD	0.870	0.907	0.617	0.056	0.44	0.024

GY: Grain Yield, CV: Variation coefficient; Std error: standard error; t/ha: tons per hectares; same letters are not significantly different; ns: no significant different in the grain yield in all the treatments both for rice and groundnut crops computed at 5 % level probability

Table 3. Effect of intercropping NERICA 8 and JL24on the biological efficiency ofintercropping system

Treatments	Partial LER		Partial EDC		Total LER	Total EDC
	NERICA 8	JL24	NERICA 8	JL24	-	-
3R+1G	0.90	0.48	0.79	0.43	1.37	1.21
4R+2G	0.98	0.84	0.57	0.57	1.81	1.14
Total	1.88	1.32	1.36	1	-	-

EDC: Equivalent Density Coefficient [30] and LER: Land Equivalent Ratio

3.1.8 Correlation coefficient among agronomic traits in NERICA 8 and JL24 genotypes

Agronomic traits in JL24 genotype (Table 4) show a correlation that ranged from 0.6-0.87. The number of nodules did not show a significant correlation with any agronomic traits under study. The number of empty pods per plant shown a strong and negative correlation with shelling percentage (r = -0.87**) and with the number of grains per plant (r = -0.624*). Singularly, the number of empty pods per plant shows a strong positive and significant correlation with the number pods per plant (r = 0.78**). The grain yield shown a significant and positive correlation with the number of grain per plant (r = 0.75**) and with 100 seed weight (r = 0.756**). Whereas, grain yield shown a significant positive correlation with shelling percentage (r = 0.692*) and with the number of grain per plant (r = 0.698*). Also, the shelling percentage shown a significant and positive correlation with the number of grains per plant (r = 0.675*).

Agronomic traits in relation with NERICA 8 (Table 5), show a correlation that ranged from (0.744 - 0.906). The length of panicle showed no significant correlation at 5% and 1% level of probability with any other trait under study. However, the number of panicles per hill are strongly and negatively correlated with 1000seed weight (r = -0.744**). Whereas, the number of grains per panicle shown a positive correlation coefficient with rice grain yield (r = 0.906**).

Table 4. Correlation coefficient among agronomic traits in JL24 genotype

	NN	NEPP	NGP	100SW	SP	NPP	NGPL	YIELD
NN	-							
NEPP	0.445 ns	-						
NGP	0.528 ns	0.230 ns	-					
100SW	0.513 ns	0.152 ns	0.684*	-				
SP	-0.166 ns	-0.877**	0.110 ns	0.203 ns	-			
NPP	0.623 ns	0.786**	0.559 ns	0.538 ns	-0.414 ns	-		
NGPL	-0.032 ns	-0.624*	0.499 ns	0.227 ns	0.675*	-0.415 ns	-	
YIELD	0.311 ns	-0.350 ns	0.754**	0.756**	0.692*	0.193 ns	0.698*	-

***. Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).*
ns: non-significant; NN: Number of nodules, NEPP: number of empty pods per plant; NGP: number of grains per pod; 100SW: 100seed weight; SP: Shelling %; NPP: Number of pods per plant; NGPL: number of grains per plant; Yield (t/ha)

Table 5. Correlation coefficient among agronomic traits in NERICA 8 progeny

	LP	NEGP	1000SW	NGP	NPH	YIELD
LP	-					
NEGP	0.146 ns	-				
1000SW	0.200 ns	0.327 ns	-			
NGP	0.315 ns	-0.035 ns	-0.283 ns	-		
NPH	-0.055 ns	-0.350 ns	-0.744**	0.141 ns	-	
YIELD	0.391 ns	-0.127 ns	-0.329 ns	0.906**	0.413 ns	-

***. Correlation is significant at 0.01 level (2-tailed);*
**. Correlation is significant at 0.05 level (2-tailed); ns: non-significant*
LP: length of the panicle; NEGP: number of empty grain per panicle; 1000SW: 1000 seed weight,
NGP: number of grain per panicle; NPH: number of panicles per hill

3.2 Discussion

The soil at Nkolbisson is characterized as clay loam with a pH beyond the critical value (pH = 5.5) for a soil to be described as acidic [32] but the author evaluated a pH of 5.12 at Nkolbission in 2014 on evaluating different accession of Maize genotypes on acidic soil. The fluctuation in the author's pH with our result could be seen on two angles; firstly the author used a dilution pH soil/water of 1:2.5 ratio while 1:5 ratio was used for this experiment. In addition, the author's site was subjected to constant flooding; whereas the history of the experimental site indicates that, there was a high level of organic matter reason why the organic matter content was high (Table 1). But after harvest, the rate of organic matter depletion was greater than 90% indicating that both crops will grow efficiently in organic rich environment. However, the genotype JL24 shows the depletion greater than NERICA 8, this certainly because of the difference in the architecture of root system of both crops. Groundnut root systems were accessible to soil organic matter which was not certainly the case for rice root system. Groundnut after harvest enriches the soil with Nitrogen at a rate of 11% while rice depletes the soil with Nitrogen at a rate of 8%. This suggests that the soil dynamism of native Bradyrhizobia is high at Nkolbisson [31,33, 34] to enhance a symbiotic association with groundnut and can sustain rice-groundnut intercropping system. Similar observations in HFZ were brought forth by [34,35], but the authors revealed that, other environmental stresses could impair the action of these native rhrizobacteria during groundnut root nodulation.

In the same vein, the rice plant height when associated with groundnut increases as compare with sole rice treatment (Fig. 5). This is partially the genetic related character of NERICA 8, known to grow short as compare to other NERICA progenies in HFZ of Cameroon. Also this confirms the high mobility of mineral fertilizers revealed [17] in rice based system and at the same time comforts [12] on the availability of soil Nitrogen fixed by nitrogen fixing bacteria.

The rate at which groundnut crop deplete the soil in cations particularly, Ca^{2+} in sole groundnut base system is greater than sole rice after harvest showing crop nutrients preference and suggest that groundnut is more Ca^{2+} demanding as compare to rice. It was revealed by [36], that Ca^{2+} deficient soil will impair some grain yield components (100 seed weight) since Ca^{2+} is important in groundnut seed coat synthesis. In the same vein, Fig. 3 show that intercropping rice-groundnut affects 100-seed weight of groundnut grain and this was observed in 3R+1G as compare to SG and 4R+2G. Treatment 3R+1G gave the lowest 100 seed weight (31.6g), followed by 4R+2G (33.9g) and SG (38.7g) who shown the best result. A similar trend was equally observed with the number of seeds per plant. This result indicates that interspecies competition to Ca^{2+} is greater than intra species competition, consequently the high rice density in 3R+1G as compare to 4R+2G could explain the above differences. This result is in consistence with the findings of [37], who thinks that shading and moisture level are the two important parameters that may affect legume crop (groundnut) when intercropped with cereal (sorghum). On the other hand, [38] demonstrated that, maize-cowpea intercrop will not significantly reduce the 100 seed weight as well as the number of seeds per pod of cowpea. This finding contrast with our result and this may probably be because of a deficit in soil Ca^{2+} ion observed at Nkolbisson making a high level of competition among the companion crops in an intercropping system condition. However, the same author [38] agree that the none significant different observed in 100 seed weight and on the number of seed per pod may be attributed to lack of competition for resources such as light, nutrients and water.

The nodulation recorded in SG as compare to 3R+1G and 4R+2G treatments, may probably be due to the high competition to light. Light-dependent photosynthates are important during rhizobia-plant legume molecular interaction for an effective symbiotic process. Even though there is no significant different in the number of nodulation between 4R+2G and 3R+1G treatments, the number of nodules in the treatment 3R+1G remains very low according to [31]. The author suggests that the nodulation of less than 75 per groundnut root system is characterized as poor. This result could be due to light competition of rice crop over groundnut [39,40]. Author [40], show that the number of root nodule is a function on the type of companion crop as well as the cropping density, suggesting that, when a legume crop is intercropped with a taller crop like rice and maize, mobility of light-dependent photosynthates are impaired as a result of light competition. Consequently, This result agree with that obtained by [40] when maize/groundnut and cowpea/groundnut is intercropped with nodulation 35.11 and 36.56 respectively as compare to pure stand (15.93). Nodules need light-dependent photosynthates for their growth and function thus in 3R+1G and

4R+2G this shading effect decreased efficacy of this life process (photosysthesis). In addition many authors coined out two factors that influence legume-rhizobium symbioses, which are; soil moisture and temperature. These factors also could have contributed to bring about the drop in nodulation in 3R+1G treatment.

Treatment 3R+1G had the lowest number of empty pods/plant 106.5 of all the treatments. In treatments 4R+2G and SG, the number of empty pods/plant was 138.5 and 147.8 respectively. This means that the number of empty pods increases with increase in the density of groundnut crop, that is for SG (87 500 plants ha^{-1}), 4R+2G (50 000 plants ha^{-1}), 3R+1G (37 500 plants ha^{-1}). It is equally observed that, the number of grain in 3R+1G was low as compared to treatment 4R+2G and SG. This two results could suggest that, the genotype JL24 may be a high grain producing genotype but the number of filled pods should be due to low soil nutrients (particularly Ca^{+2}), and when the factor of competition arose as a result of high density the number of filled pods become serious.

Associating rice-groundnut effects groundnut grain yield and treatment 3R+1G had the lowest value (0.47t/ha). Groundnut crop is however the most affected crop in the association with a grain yield drops of 17.5% in 4R+2G and up to 52.8% in 3R+1G as compare to SG. These results go hand in hand with [15] who obtained similar grain yield drop when 1 row of Maize for 4 rows of groundnut (1M/4G) crop pattern. Also [19], in the Northern part of Cameroon found a grain yield drop of 66.8% for one row of Sorghum for two rows of groundnut (1S/2G) and 64.5% for one row of sorghum for four rows of groundnuts (1S/4G). These results suggest that, legume crops could be the most sacrifice crops whenever it is intercropped with non-legume crops.

Groundnut has a partial EDC and LER< 1 that is needs 0.52ha and 0.16ha of land extra in the treatment 3R+1G and 4R+2G, respectively to meet up with the same yield in pure cropping. Also even though the partial LER of rice is higher than that of groundnut it is still <1 with partial LER of 0.9 in 3R+1G and 0.98 in 4R+2G, meaning an extra 0.1ha and 0.12ha is needed to meet up with the yield in pure stand respectively. Implying that the association rice-groundnut will be a risk farming practice probably due to; above and underground competition for environmental nutrients, for which groundnut crop will be the most susceptible to be affected in the association.

The number of empty pods per plant shows a strong positive and significant correlation with the number pods per plant (r = 0.78**). This suggests that the genotype JL24, produce great number of pods but are susceptible to soil Ca^{+2} deficient soils. Since according to many authors, Ca^{+2} is an important constituent that reduces empty pods formation [36]. Also the fact that, groundnut yield correlates strongly and positively with the number of grain $plant^{-1}$ and on 100 seed weight suggest that, these yield characters are important and play a direct bearing on the final yield of JL24. Similarly, [41] with Bambara groundnut (*Vigna subterranean* L. Verdc), observed that the number of pods $plant^{-1}$ 100 seed weight and harvest index had a respective correlation of (r = 0.74**), (r = 0.35**) and (r = 0.83**) respectively with grain yield. Also [18], observed a positive and significant correlation between the number of pods $plant^{-1}$ and the terminal leaflet with (r = 0.92**); between number of pods $plant^{-1}$ and terminal leaflet length (r = 0.68*). From the above authors, it was revealed that the number of pods $plant^{-1}$, the harvest index and 100 seed weight are indirect criteria to increase Bambara groundnut grain yield. This could implies that, the number of grain $plant^{-1}$, the shelling percentage and 100 seed weight can be used as indirect criteria to increase the grain yield in *Arachis hypogaea* L. genotypes geared to be used in an intercropping system.

Rice grain yield of NERICA 8 is not much affected in an intercropping system condition with groundnut. This suggests that, NERICA progenies have yield genes that are much stable to agricultural practices as well as low nutrients environment. However, the number of panicles per hill show a negatively correlation with 1000seed weight (r = -0.744**). Whereas, the number of grains per panicle shown a positive correlation coefficient with rice grain yield (r = 0.906**). Implying that, increasing the seed rate of NERICA progenies in an intercropping condition will not necessarily increase rice grain yield probably due to intra specific competition.

4. CONCLUSION

Intercropping of rice-groundnut is detrimental for groundnut crops in terms of grain yield, this because of the high level of competition of soil nutrients, however the treatment 4R+2G remain favorable than 3R+1G crop pattern because it shows LER and EDC > than those of 3R+1G. In addition, light interception by rice in 3R+1G affect negatively the growth and development of groundnut and impairs physiological mechanisms like nodulation process. The spatial arrangement 4R+2G reduces shading effect, in this respect, intercropping rice-groundnut in a 4R+2G crop pattern could be recommended for a farmer who wishes to crop both crops simultaneously and have a grain yield advantage as compare to sole cropping. Groundnut grain yield correlated well and strongly with the number of grain per plant, 100 seed weight and shelling percentage. Indirectly, we can conclude that, the agronomic traits number of grain per plant, shelling percentage and 100 seed weight should be exploited in breeding programs for an increase in grain yield of groundnut crop (*Arachis hypogaea* L.) involved in intercropping system with rice. But for Ca^{+2} deficient soils, amendment with dolomite can be used or otherwise, the used of Ca^{+2} deficient soil tolerant populations should also be considered.

ACKNOWLEDGEMENT

This work is an output of funds from the C2D-PAR- RICE project in IRAD. We gratefully acknowledge the Institute of Agricultural Research for Development (IRAD-Nkolbisson) for providing logistical and technical support for this work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. MINEF. National Capacity Self Assessment in Global Environment Management. 2007;14-16.
2. Ngonkeu MEL. Tolérance de certaines variétés de maïs aux sols à toxicité aluminique et manganique du Cameroun et diversités moléculaire et fonctionnelle des mycorhizes à arbuscules. Thèse de Doctorat Ph D. Université de Yaoundé I, Cameroun. 2009;255.
3. Ngonkeu MEL, Thé C, Chaintreuil C, Amougou A, Dreyfus B, Owona A, Kuate J. Diversité mycorhizienne du sisongo sauvage (*Panicum maximum*) et amélioration des rendements de deux variétés contrastées de maïs sur sols à toxicité en Al et Mn du Sud Cameroun. Cameroon Biosciences Society. 2009;64.
4. Food and Agriculture Organization of the United Nations (FAO). Statistical pocket book world food and agriculture. Rome. 2015;26.
5. MINEFI. Document de la strategie national de développement de la riziculture au Cameroun (SNDR). Republique du Cameroun; 2009.
6. Piebiep Goufo. Evaluating the constraints and opportunities for sustainable rice production in Cameroon. Research Journal of Agriculture and Biological Sciences. 2008;4(6):734-744.
7. Laurette Ngo Nkot, Dieudonné Nwaga, Albert Ngakou, Henri Fankem, François-Xavier Etoa. Variation in nodulation and growth of groundnut (*Arachis hypogaea* L.) on oxisols from land use systems of the humid forest zone in southern Cameroon. African Journal of Biotechnology. 2011; 10(20):3996-4004.
8. Nwaga D, Jansa J, Abossolo Angue M, Frossard E. The potential of soil beneficial micro-organisms for slash-and-burn agriculture in the Humid Forest Zone of Sub-Saharan Africa. In Dion (ed.), Soil Biology and Agriculture in the Tropics, soil biology 21, Springer-Verlag Berlin Heidelberg. 2010;81-107.
9. Meppe P, Menge S. Selected peanuts varieties for Southern Cameroon. SSR4D Annual Report. 2014;20-25.
10. SatishIngale, Shrivastava SK. Nutritional study of new variety of groundnut (*Arachis hypogaea* L.) JL-24 seeds. African Journal of Food Science. 2011;5(8):490–498.
11. Tshilenge-Lukanda L, Kalonji-Mbuyi A, Nkongolo KKC, Kizungu RV. Effect of gamma irradiation on morpho-agronomic characteristics of groundnut (*Arachis hypogaea* L.). American Journal of Plant Sciences. 2013;4:2186-2192.
12. Chu GX, Shen QR, Cao JL. Nitrogen fixation and N transfer from peanut to rice cultivated in aerobic soil in an intercropping system and its effect on soil N fertility. Plant and Soil Journal. 2004;2(63):17-27.
13. Tilak KVBR. Response of *Sesbania* green manuring and Mungbean residue incorporation on microbial activities for sustainable of a rice-wheat cropping sytem. Journal of Agriculture and Rural Development in the Tropics and Subtropics. 2004;105(2):189-196.
14. Westphal E, Embrechts, Ferwerda JD, Van Gilsmeens HAE, Mutsaers HJW, Westphalstewels JMC. Cultures vivrières tropicales avec références spéciales au Cameroun. Pudoc, Wageningen. 1985; 514.
15. Nguimgo KAB, Balasuhbramanian V, Charles T, Patrik Z. Maize and groundnut

yield under different cassava planting patterns in Southern Cameroon. Agronomy and Physiology Journal. 2000;3(1):275-285.
16. Toomsam B, Cadisch G, Srichantawong M, Thongsodsaeng C, Giller KE, Limpinuntann V. Biological nitrogen fixation and residual nitrogen benefit of pre-rice leguminous crops and manures. Netherland Journal of Agricultural Sciences. 2000;48:19-29.
17. Bognonkpe JP, Becker M. Native soil N mineralization in major rice based cropping systems. Journal of Animal & Plant Sciences. 2009;4(3):384-398.
18. Ndiang Z, Joseph MB, Fokam PE, Qauttara B, Simo C, Dibong DS. Agro-morphological variability in twelve Bambara groundnut (*Vigna subterranean* (L.) Verdc.) accessions in Cameroon. Scieinces, Technologies and Development. 2014;16:38-45.
19. Hamasselbé A, Béyo J, et Bébom TN. Arrangement spatial du sorgho (*Sorghum bicolor* L. Moench) en association avec l'arachide (*Arachis hypogaea* L.) adapté aux conditions soudano-sahéliennes du North Cameroun. Cameroon Journal of Agricultural Science. 2006;2(2):1-44.
20. Ogutu MO, Ouma G, Ogolla H, Okech JN, Kidula N. Rainfed rice-legume based cropping systems for sustainable food security and soil fertility improvement in western Kenya. ARPN Journal of Agricultural and Biological Science. 2012;7(9):709-720.
21. Andika DO, Abukutsa MOO, Onyango JC, Stutzel H. Soil fertility dynamics in bambara groundnuts (*Vigna subterranea*) and nerica rice (*Oryza sativa*) intercrop system in small holder farms in Western Kenya. International Journal of Biological Sciences. 2014;01(02):13-22.
22. Matusso JMM, Mugwe JN, Mucheru-Muna M. Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of Sub-Saharan Africa. Research Journal of Agriculture and Environmental Management. 2014;3(3):162-174.
23. Tekeu H. Evaluation des hybrides de maïs (*Zea mays* L.) pour la tolérance aux sols acides à toxicité aluminique et manganique en zones forestières humides. University of Yaoundé I. 2013;1-87.
24. Estevez B. L'importance des éléments mineurs: Des carences à la toxicité: Une préoccupation en agriculture biologique « Tout est toxique, rien n'est toxique, c'est la dose qui fait la différence.», Québec. 2006;25.
25. Tamelokpo AF. Evaluation participative de la fertilité des sols. IFDC-Afrique, Rapport, Lomé. 2004;39.
26. Dinon E, Gerstmans A. Influence du pH sur l'assimilation des éléments nutritifs du sol par les plantes et sur la variété des plantes. Printemps des Sciences. Université de Liège. 2008;4.
27. Black CA. Methods of soil analysis agronomy no. 9. Part 2 Amer. Soc. Agronomy, Madison, Wisconsin; 1982.
28. Heanes DL. Determination of organic C in soils by an improved chromic acid digestion and spectrophotometric procedure. Comm. Soil Sci. Plant Anal. 1984;15:1191-1213.
29. Ngo Nkot L, Nwaga D, Ngakou A, Fankem H, Etoa FX. Variation in nodulation and growth of groundnut (*Arachis hypogaea* L.) on oxisols from land use systems of the humid forest zone in southern Cameroon. African Journal of Biotechnology. 2011; 10(20):3996-4004.
30. Fornage N, Lemus S, Comesa A, Boucher A. Etudes des systèmes de cultures associées dans la région de Colima (Mexique) dans leurs relations avec la société rurale. Les Cahiers de la Recherche-Developpment. 1986;11(2):7-16.
31. Giller KE. Nitrogen fixation in tropical cropping systems. 2nd Ed. CAB International; 2001.
32. Tekeu H, Ngonkeu MEL, Tandzi LN, Djocgoue PF, Bell JM, Mafouasson HA, Boyomo O, Petmi CL, Fokom R. Evaluation of maize (*Zea mays* L.) accessions using line x tester analysis for aluminum and Manganese tolerance. International Journal of Biological and Chemical Sciences. 2015;9(4):2161-2173.
33. Holt JG, Krieg NR, Sneath PHA, Staley JT, Williams ST. Bergey's. Manual of Determi-native Bacteriology. 9th Ed. Baltimore: Williams & Wilkins; 1994.
34. Ngo Nkot L, Krasova –Wade T, Etoa FX, Sylla SN, Nwaga D. Genetic diversity of rhizobia nodulation *Arachis hypogaea* L. in divers land used systems of humid forest zone of Cameroon. Applied Soil Ecology, 2008;40:411-416.
35. Ngo Nkot L, Ngo BM, Fonkem H, Adanou S, Kamguia K, Ngakou A, Nwaga D, Etoa FX. Isolation and screening of indigenous bambara groundnut (*Vigna subterranea*) nodulating bacteria for their tolerance to

some environmental stresses. American Journal of Microbiological Research. 2015; 3(2):65-75.

36. Hauggaard-Nielsen H, Jørnsgaard B, Kinane J, Jensen ES. Grain legume-cereal intercropping: the practical application of diversity, facilitation and competition in arable and organic cropping systems. Renewable and Agriculture and Food Systems. 2007;23(1):3-12.
37. Langat MC, Okiror MA, Ouma JP, Gesimba RM. The effect of intercropping groundnut (*Arachis hypogeal* L.) with sorghum (*Sorghum bicolor* L. Moench) on yield and cash income. Agriculturatropica and Subtropica Journal. 2006;39(2):87-91.
38. Gabatshele, Legwaila M, Teko, Marokane, Witrecs Mojeremane. Effect of intercropping on the performance of Maize and Caw pea in Botswana. International Journal of Agriculture and Forest. 2012; 2(6):307-310.
39. Ngakou A, Megueni C, Ousseni H, Massai A. Study on the isolation and characterization of rhizobia strains as biofertilizer tools for growth improvement of four grain legumes in Ngaoundéré-Cameroon. International Journal of Biological and Chemical Sciences. 2009;3(5):1078-1089.
40. Moses OE, Alhassan GA, Michael Ijoyah M. Nodulation, nitrogen yield and fixation by bambara groundnut (*Vigna subterranea* (L.) Verdc.) landraces intercropped with cowpea and maize in Southern Guinea Savanna of Nigeria. Agricultural Sciences, 2013;1(4):15-28.
41. Maunde SM, Tanimu B, Matimud M. Correlation and path coefficient analysis of yield characters of bambara (*Vigna subterranean* L. Verdc). African Journal of Environmental Science and Technology. 2015;9(1):12-15.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/18257