agronomy

MDPI

Article

Does Nitrogen Matter for Legumes? Starter Nitrogen Effects on Biological and Economic Benefits of Cowpea (*Vigna unguiculata* L.) in Guinea and Sudan Savanna of West Africa

Nurudeen Abdul Rahman [1,*], Asamoah Larbi [1], Bekele Kotu [1], Francis Marthy Tetteh [2] and Irmgard Hoeschle-Zeledon [3]

1 International Institute of Tropical Agriculture, TL 06 Tamale, Ghana; a.larbi@cgiar.org (A.L.); b.kotu@cgiar.org (B.K.)
2 Council for Scientific and Industrial Research-Soil Research Institute, P.M.B Academy Post Office, Kumasi, Ashanti, Ghana; fmarthy2002@yahoo.co.uk
3 International Institute of Tropical Agriculture, P.M.B 5320, Ibadan, Oyo State, Nigeria; i.hoeschle-zeledon@cgiar.org
* Correspondence: a.nurudeen@cgiar.org; Tel.: +233-244-955-123

Received: 18 May 2018; Accepted: 9 July 2018; Published: 16 July 2018

check for updates

Abstract: The hypothesis that application of starter nitrogen (N) fertilizer to cowpea may increase grain and fodder yields and profitability was tested in the Guinea and Sudan savanna zones of northern Ghana. Two cowpea varieties (Apagbaala: grain-type and Padi-Tuya: dual purpose) and three N fertilizer rates (0-30-30, 15-30-30 and 30-30-30 N-P_2O_5-K_2O kg/ha) were evaluated using a 2 × 3 factorial treatments arrangement in a randomized complete block design with three replicates. Grain and fodder yields, 100 seed weight (SW) and net return of Padi-Tuya increased significantly compared with Apagbaala in both zones. Application of starter N fertilizer increased grain yield, fodder yield, N use efficiency (NUE) and net return by more than 30% compared with the control in both zones. Padi-Tuya cowpea with 15 kg/ha N fertilizer was risk efficient at all risk aversion levels when only grain was considered, but Padi-Tuya with 30 kg/ha N fertilizer becomes the most risk efficient option when the value of fodder was included. The results suggest that small-scale farmers could apply starter N fertilizer at either 15 kg/ha N for grain only or 30 kg/ha N for both grain and fodder yields improvement of cowpea in West Africa and similar ecologies.

Keywords: inorganic fertilizer; profitability; risk; agronomic efficiency; savanna

1. Introduction

Cowpea (*Vigna unguiculata* L.) is an important food legume in the drier regions of tropical and subtropical parts of the world [1]. The grains are a good source of human protein, while the haulms are a valuable source of animal feed [2]. It also contributes to soil fertility improvement through symbiotic nitrogen fixation and ground cover [3]. About 96% of world production of cowpea is from Africa with West Africa accounting for 83% of the total production [4]. In West Africa, cowpea is produced mainly in the Guinea and Sudan savanna zones by small-scale farmers [5].

Despite the level of cowpea production in West Africa, yields of cowpea are low compared with other parts of the world [4] due to low soil fertility as soils in the tropical savanna are deficient in plant nutrients especially nitrogen (N) and phosphorus (P) [6]. Most small-scale cowpea producers in West Africa do not traditionally apply N fertilizer to cowpea due to its ability to fix N symbiotically [7,8]. However, plants dependent on symbiotic N (e.g., cowpea) suffer from temporal N deficiency during seedling growth when cotyledon reserves are exhausted [7]. The application of starter N fertilizer gives seedlings a good start, enhances early vegetative growth which results in increased branches, higher number of pods, seeds, and grain yield [7,9]. Other authors have also reported significant effect of N fertilization on yield of cowpea across many ecological zones of West Africa [8,10].

However, none of the above studies reported on the agronomic efficiency, profitability and the level of risk associated with applying starter N fertilizer on cowpea. Such information is critical for the adoption of improved technologies by farmers. This paper reports results from a study on the effects of starter N fertilizer application on yield, agronomic efficiency, profitability, and the risk associated with cowpea varieties in the Guinea and Sudan savanna zones of West Africa.

2. Materials and Methods

2.1. Study Area

The study was conducted at Nyankpala (09°23′22.5″ N; 001°00′26.5″ W; 186 m a.s.l) in the Guinea savanna zone and Bonia (10°30′11″ N; 000°01′30″ W; 300 m a.s.l) in the Sudan savanna zone of northern Ghana. Both locations have a mono-modal rainfall pattern with an average annual rainfall range of 800 to 1100 mm (Figure 1). The mean monthly minimum and maximum temperatures are 23 °C and 38 °C respectively. The soils in both locations are low in organic carbon (<15 g/kg), total nitrogen (<2 g/kg), exchangeable potassium (<100 mg/kg) and available phosphorus (<10 mg/kg) [11]. The soil at the Nyankpala experimental site was *Haplic Lixisol* while that of the Bonia experimental site was *Ferric Lixisol* [12].

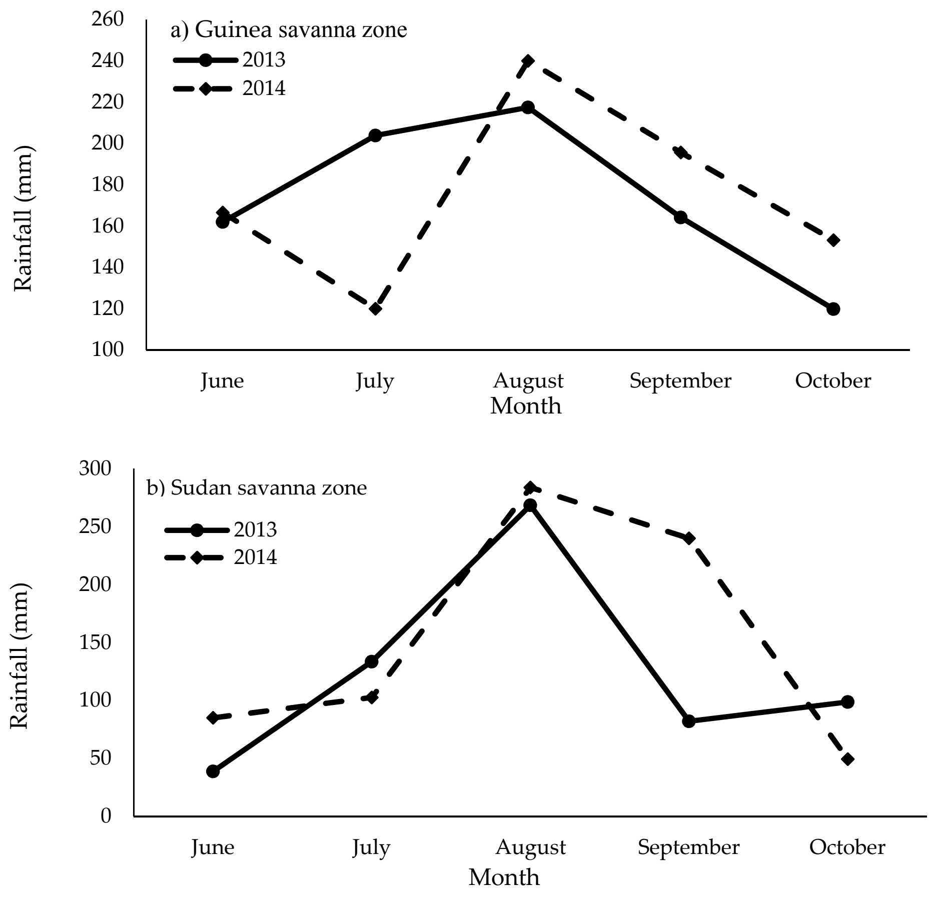

Figure 1. Rainfall pattern in Guinea and Sudan savanna ecology during 2013 and 2014 cropping seasons.

2.2. Experimental Design, Planting and Agronomic Practices

Two cowpea varieties (Apaagbala: grain-type and Padi-Tuya: dual purpose) and three N fertilizer rates (0-30-30, 15-30-30 and 30-30-30 N-P_2O_5-K_2O kg/ha) were evaluated using a 2 × 3 factorial treatment arranged in a randomized complete block design with three replicates. Single fertilizers of urea ($CO(NH_2)_2$), triple superphosphate ($Ca(H_2PO_4)_2$) and muriate of potash (KCl) were used.

The Apagbaala variety (ITXP-148-1) was released in Ghana in 2003 by the International Institute of Tropical Agriculture (IITA) and Council for Scientific and Industrial Research-Savanna Agriculture Research Institute (CSIR-SARI). The variety is erect, determinate, early-maturing (65 days). It has small seed size with white seed coat and black helium, prolific pods, and high yields [13]. The Padi-Tuya variety (SARC 3-122-2) was released in Ghana in 2008 by CSIR-SARI. The variety is semi-erect, medium-maturing (75 days). It has large seed size with white seed coat and black helium. It is preferred by most farmers due to high yield and taste [13].

The cowpea seeds were planted at two seeds per hill at a spacing of 60 cm × 20 cm. Planting was done on sixth July 2013 and fifth July 2014 cropping seasons in the Guinea savanna zone. In the Sudan savanna, planting was done on fifth August 2013 and twelfth July 2014 cropping seasons. The NPK fertilizer was applied 10 days after planting in both cropping seasons. Cymetox super (30 g Cyper metrin and 25 g dimethoate as active ingredients) was sprayed at 1 L/ha at pre-flowering and fifty percent flowering to control aphis (*Aphis craccivora*) and thrips (*Megalurothrips sjostedti, Taeniothrips sjostedti*, *Mylabris* spp., *Maruca testulalis*). Lamda cyhalotrine (25 g cyhalotrin as active ingredient) was also sprayed at 250 mL/ha at podding to control pod sucking buds (*Anoplocnemis curvipes*).

2.3. Yield and Yield Components

Plants from the three middle rows of each plot (net area of 7.2 m^2) were harvested to measure grain and fodder yield and 100 seed weight (SW). Cowpea pods from plants within the harvest area were harvested at physiological maturity, oven dried at 70 °C to a moisture content of 12%, threshed and winnowed before measuring grain yield. Random samples of hundred oven dried grains from each plot were taken and weighed to estimate SW. Fodder yield was measured by cutting the plants within the harvested area at ground level after harvesting the pods. Fodder samples were oven dried at 70 °C to a constant weight before estimating fodder yield. The nitrogen use efficiency (NUE) for the N fertilizer rates was estimated using the approach of Frageria et al. [14] as:

$$\text{NUE (kg grain/kg N)} = \left(\frac{Y - Y_O}{F}\right) \quad (1)$$

where Y = crop yield from fertilized plot; Y_O = crop yield from unfertilized plot and F = amount of N fertilizer applied in kg/ha.

2.4. Statistical Analysis

General Linear Model procedure of Statistical Analysis System was used to analyze the yield and yield components, net return, and benefit-cost ratio data [15]. The year was considered as random variable in the statistical analysis with the objective of identifying treatment whose average effect over the 2 years would be stable and high [16]. The data were analyzed using the model:

$$Y_{ijk} = \mu + B_i + C_j + F_k + (CF)_{jk} + e_{ijk} \quad (2)$$

where Y_{ijk} is an observation, μ is experimental mean, B_i is block effect, C_j is variety effect, F_k is N fertilizer effect, $(CF)_{jk}$ is variety by N fertilizer interaction effect and e_{ijk} is residual. Tukey Honest Significant Difference (HSD) test was used to separate treatment means at a probability level of 0.05. Univariate correlation and regression analysis were performed to establish relationship and predictive equation between grain yield and other yield components. Variables with correlation coefficient of 0.6 and above were used in the regression equation.

2.5. Economic Analysis

The economic viability of starter N fertilizer application on improved cowpea varieties was assessed in two scenarios: (i) by considering grains as the only outcome variable, and (ii) by considering both grain and fodder as outcome variables. Prices of grain and fodder were collected from Nyankpala market (about 6 km from the experimental site) in the Guinea savanna and Navrongo market (about 13 km from the experimental site) in the Sundan savanna during November–January of 2013 and 2014 cropping seasons. The prices of the grains and fodder were used to compute the total monetary value of the outputs. Costs of labor, seed, fertilizer, insecticide, and plowing constituted the total cost of production. Costs of labor for planting, weeding, fertilizer application, spraying, harvesting, and processing were collected from key informant interviews. Price of fertilizers and insecticides were collected from major agrochemical input shops in the Nyankpala and Navrongo markets of the study area. Seed prices were also collected from Seed Production Association of Ghana within the study area. Net return and benefit-cost ratio were computed based on the output-input data and related prices. All costs and benefits were measured in Ghana cedi (GHC).

In addition to the net revenue and cost benefit analysis, the degree of risk associated with economic outputs under the different variety-fertilizer combinations was assessed. Stochastic Efficiency with Respect to a Function (SERF) algorithm was used to rank the production options [17]. The SERF is the most preferred method for its discriminatory power of risky alternatives. It is based on the utility theory which assumes that risky alternative can be ordered based on subjective expected utilities of the decision makers. Since the exact shape of the utility function is unknown, SERF makes the ordering for absolute/ relative risk aversion function $r(I)$ that lies everywhere between the lower and upper bounds r_L(I) and $r_U(I)$. For a given risky alternative a utility function can be defined as follows for a continuous random variable:

$$U(I,\ r(I)\ =\int U\ (I,\ r(I))dF\ (I) \quad (3)$$

where I is a stochastic outcome such as income and U is evaluated for selected values of $r(W)$ in the range of $r_L(I)$ and $r_U(I)$.

The SERF uses Certainty Equivalents (CE) instead of utility values to rank risky alternatives which results in similar ordering. The CE values are computed by taking the inverse of the utility function.

$$CE\ (I,\ r(I))\ =\ U^{-1}(I,\ r(I)) \quad (4)$$

The calculation of CE values depends on the utility function of choice. The commonly used utility function is the negative exponential function which is expressed as follows:

$$CE(I,\ r_a(I))\ =\ \ln\left\{\left(\frac{1}{n}\sum_{i}^{n}\exp(-r_a(I)Ii)\right)^{\frac{-1}{r_a}(I)}\right\} \quad (5)$$

where $r_a(I)$ is the absolute risk aversion coefficient.

Determining the range of $r_a(I)$ is the next crucial task in the SERF analysis. Anderson and Dillon [18] established a schedule of the degree of risk aversion based on relative risk aversion coefficient $r_r(I)$ which ranges from 0.5 (slightly risk averse) to 4 (extremely risk averse). This information was used to establish the range of $r_a(I)$, using the following relationship:

$$r_a(I)\ =\ \frac{r_r(I)}{I} \quad (6)$$

where I represent wealth. The wealth of the typical farm household in Northern Ghana was GHC 10,700 ($4280) by considering the average annual national saving rate of 10.6% [19], average household income in rural savanna of GHC 10,095 [20] and the age of 10 years for a typical farm household. The lower and the upper bounds of $r_a(I)$ corresponding to this wealth level are 0.00005 and 0.0004 based on Equation (6). We adjusted the lower bound to zero in our SERF analysis to show outputs associated with risk neutral farmers. In addition to the rankings of production options based on CEs, we also computed the cumulative density functions (CDF) of the net returns associated with each option. The CDFs show the first order stochastic dominance of an alternative over the others.

3. Results

3.1. Yield and Yield Components

The cowpea variety × N fertilizer interaction did not affect ($p > 0.05$) grain and fodder yields, SW and NUE in both zones. The main effect of cowpea variety and N fertilizer had significant effect on grain and fodder yields, SW and NUE in both zones (Table 1). Padi-Tuya variety had higher ($p < 0.05$) grain and fodder yields and SW than those of Apagbaala variety in both zones. Similarly, application of starter N fertilizer to cowpea increased ($p < 0.01$) grain and fodder yields and NUE compared with planting cowpea without starter N fertilizer (control) in both zones. Increasing starter N fertilizer rate from15 to 30 kg/ha had no significant effect on grain yield and NUE in both zones. However, in Sudan savanna zone, applying 30 kg/ha starter N fertilizer to cowpea increased ($p < 0.05$) fodder yield. The grain yield was positively correlated with fodder yield ($r = 0.6$; $p < 0.001$) and SW ($r = 0.7$; $p < 0.001$). From the above relationship, grain yield could be predicted from fodder yield and SW as:

$$Y_{\text{Grain yield}} = 87.17 + 0.04_{\text{Fodder yield}} + 26.93_{\text{SW}},\ r^2 = 0.45 \quad (7)$$

3.2. Profitability and Risk Assessment

The two varieties were significantly different in terms of net returns and benefit-cost ratios (Tables 2 and 3). Padi-Tuya variety showed superior performance compared with the Apagbaala variety in both zones. The net return and benefit-cost ratio increased substantially when fodder was included in the analysis. The net return increment ranged from 168 to 203% for Padi-Tuya variety and 441 to 464% for Apagbaala variety in both zones. The increment for the benefit-cost ratio was in the range of 91 to 113% for Padi-Tuya variety and 108 to 140% for Apagbaala variety in both zones. In terms of starter N fertilizer rate application to cowpea, the 15 and 30 kg/ha N rates had higher ($p < 0.05$) but similar net returns and benefit-cost ratio compared with that of the control in both zones (Tables 2 and 3).

Figure 2a,b displays the CDF of the net returns associated with the six production options. The results showed that all the three N fertilizer combinations with Apagbaala variety were associated with some probability of producing negative returns when grain only was considered for analysis (Figure 2a). The highest probability of negative returns was associated with Apagbaala variety grown without starter N fertilizer (Apagbaala with 0 kg/ha N option). On the contrary, none of the N fertilizer rates associated with Padi-Tuya variety resulted in negative net returns. The inclusion of fodder into the analysis shifted the CDFs substantially to the right avoiding negative values. The shape and patterns of the CDFs remained, by and large, the same except that the CDF corresponding to Apagbaala with 15 kg/ha N fertilizer crossed the other two CDFs in the middle (Figure 2b). Overall, outcomes varied from 217 GHC/ha to 3993 GHC/ha when grain and fodder were considered in the analysis, while they ranged from −206 GH/ha to 1634 GHC/ha when only grain was considered. In both cases, the lowest and the highest values of net returns were associated with Apagbaala with 0 kg/ha N and Padi-Tuya with 30 kg/ha N, respectively.

Table 1. Cowpea grain and fodder yields, 100 seed weight (SWW) and nitrogen use efficiency (NUE) as affected by variety and N fertilizer rate during 2013 and 2014 cropping seasons.

	Guinea Savanna				**Sudan Savanna**				**Across Savanna**			
	Yield (kg/ha)				**Yield(kg/)**				**Yield (kg/ha)**			
	Grain	**Fodder**	**SW (g)**	**NUE (kg/kg N)**	**Grain**	**Fodder**	**SW (g)**	**NUE (kg/kg N)**	**Grain**	**Fodder**	**SW (g)**	**NUE (kg/kg N)**
Variety (V)												
Apagbaala	585 ± 45.0 [b]	2570 ± 225.9 [b]	12.2 ± 0.3 [b]	13.4 ± 2.7 [a]	659 ± 49.6 [b]	3754 ± 174.1 [b]	14.9 ± 0.6 [b]	11.6 ± 2.7 [a]	622 ± 33.6 [b]	3162 ± 172.6 [b]	13.5 ± 0.4 [b]	12.5 ± 1.9 [a]
Padi-Tuya	786 ± 50.1 [a]	3591 ± 223.0 [a]	20.3 ± 0.6 [a]	8.4 ± 1.5 [a]	812 ± 62.9 [a]	4632 ± 241.4[a]	21.8 ± 0.5 [a]	13.4 ± 2.0 [a]	799 ± 39.7 [a]	4111 ± 184.3 [a]	21.0 ± 0.4 [a]	10.9 ± 1.3 [a]
p-Value	0.0025	0.0017	<0.0001	0.0697	0.0462	0.0005	<0.0001	0.5299	0.0003	<0.0001	<0.0001	0.3947
Nitrogen rate (N; kg/ha)												
0	543 ± 60.5 [b]	2412 ± 275.1 [b]	15.3 ± 1.3 [a]		573 ± 53.9 [b]	3487 ± 195.6 [c]	16.9 ± 1.1 [a]		558 ± 39.8 [b]	2950 ± 199.5 [b]	16.1 ± 0.9 [b]	
15	771 ± 56.1 [a]	3331 ± 265.2 [a]	17.2 ± 1.3 [a]	15.2 ± 2.4 [a]	836 ±61.6 [a]	4201 ± 223.7 [b]	19.1 ± 1.3 [a]	17.5 ± 2.2 [a]	804 ± 41.3 [a]	3766 ± 192.4 [a]	18.1 ± 0.9 [a]	16.4 ± 1.6 [a]
30	742 ± 60.3 [a]	3498 ± 310.9 [a]	16.3 ± 1.3 [a]	6.7 ± 1.3 [b]	798 ± 78.1 [ab]	4890 ± 282.9 [a]	19.1 ± 1.3 [a]	7.5 ± 1.4 [b]	770 ± 48.6 [a]	4194 ± 251.6 [a]	17.7 ± 0.9 [ab]	7.1 ± 1.0 [b]
p-Value	0.0088	0.0113	0.0879	0.0039	0.0139	<0.0001	0.0308	0.002	<0.0001	0.0001	0.0095	<0.0001
V*N												
p-Value	0.685	0.8173	0.917	0.7723	0.8999	0.5535	0.5691	0.7718	0.9489	0.8958	0.6308	0.6738

Data are means with ± standard error of mean. Values with same letter(s) in column under a factor are not significantly different from each other according to Tukey HSD test.

Table 2. Net return and benefit-cost ratio (BCR) from cowpea grain yield only as affected by variety and N fertilizer rate averaged across 2013 and 2014 cropping seasons.

	Guinea Savanna		**Sudan Savanna**		**Across Savanna**	
	Net Return (GHC/ha)	**BCR**	**Net Return (GHC/ha)**	**BCR**	**Net Return (GHC/ha)**	**BCR**
Variety (V)						
Apagbaala	222 ± 69.4 [b]	1.3 ± 0.1 [b]	341 ± 77.7 [b]	1.5 ± 0.1 [b]	281 ± 52.3 [b]	1.4 ± 0.1 [b]
Padi-Tuya	857 ± 99.0 [a]	2.2 ± 0.1 [a]	911 ± 123.8 [a]	2.3 ± 0.2 [a]	884 ± 78.2 [a]	2.2 ± 0.1 [a]
p-Value	<0.0001	<0.0001	0.0004	0.0004	<0.0001	<0.0001
Nitrogen rate (N; kg/ha)						
0	314 ± 136.6 [b]	1.5 ± 0.2 [b]	354 ± 115.5 [b]	1.5 ± 0.2 [b]	334 ± 87.6 [b]	1.5 ± 0.1 [b]
15	692 ± 131.0 [a]	2.0 ± 0.2 [a]	805 ± 137.7 [a]	2.1 ± 0.2 [a]	749 ± 93.7 [a]	2.0 ± 0.1 [a]
30	612 ± 135.5 [ab]	1.8 ± 0.2 [ab]	718 ± 170.3 [ab]	2.0 ± 0.2 [ab]	665 ± 107.0 [a]	1.9 ± 0.2 [a]
p-Value	0.0267	0.0348	0.0332	0.0415	0.0005	0.0008
V*N						
p-Value	0.8658	0.7896	0.8000	0.8543	0.9789	0.9977

Data are means with ± standard error of mean. Values with same letter(s) in column under a factor are not significantly different from each other according to Tukey HSD test.

Table 3. Net return and BCR from cowpea grain and fodder yields as affected by variety and N fertilizer rates, 2013 and 2014 cropping seasons.

	Guinea Savanna		Sudan Savanna		Across Savanna	
	Net Return (GHC/ha)	**BCR**	**Net Return (GHC/ha)**	**BCR**	**Net Return (GHC/ha)**	**BCR**
Variety (V)						
Apagbaala	1250 ± 154.2 [b]	2.7 ± 0.2 [b]	1842 ± 107.4 [b]	3.6 ± 0.1 [b]	1546 ± 105.3 [b]	3.2 ± 0.1 [b]
Padi-Tuya	2294 ± 175.6 [a]	4.2 ± 0.2 [a]	2763 ± 174.0 [a]	4.9 ± 0.2 [a]	2529 ± 128.2 [a]	4.5 ± 0.2 [a]
p-Value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nitrogen rate (N; kg/ha)						
0	1279 ± 234.5 [b]	2.9 ± 0.3 [b]	1749 ± 147.9 [b]	3.5 ± 0.2 [b]	1514 ± 144.2 [b]	3.2 ± 0.2 [b]
15	2024 ± 224.6 [a]	3.8 ± 0.3 [a]	2486 ± 198.4 [a]	4.5 ± 0.3 [a]	2255 ± 154.3 [a]	4.2 ± 0.2 [a]
30	2012 ± 249.7 [a]	3.7 ± 0.3 [ab]	2674 ± 223.9 [a]	4.6 ± 0.3 [a]	2343 ± 177.9 [a]	4.2 ± 0.2 [a]
p-Value	0.0116	0.0241	<0.0001	0.0004	<0.0001	<0.0001
V*N						
p-Value	0.9546	0.9288	0.5534	0.613	0.9148	0.9692

Data are means with ± standard error of mean. Values with same letter(s) in column under a factor are not significantly different from each other according to Tukey HSD test.

The SERF results are summarized in Figure 3a,b. The figures compare the treatments in terms of risk efficiency (as measured by CE of net returns) along different risk aversion levels (as measured by absolute risk aversion coefficient (ARAC)). In terms of grain only, planting Padi-Tuya variety with the application of 15 kg/ha N fertilizer was the best option in terms of risk efficiency at all risk aversion levels followed by Padi-Tuya with 30 kg/ha N fertilizer (Figure 3a). However, applying 30 kg/ha N fertilizer to Padi-Tuya was the most risk efficient option when the value of fodder was included in the analysis (Figure 3b). The confidence premium for the efficient set was small for both outcomes indicating that farmers at all levels of risk attitude would not have a strict choice between Padi-Tuya with 15 kg/ha N fertilizer and Padi-Tuya with 30 kg/ha N fertilizer options.

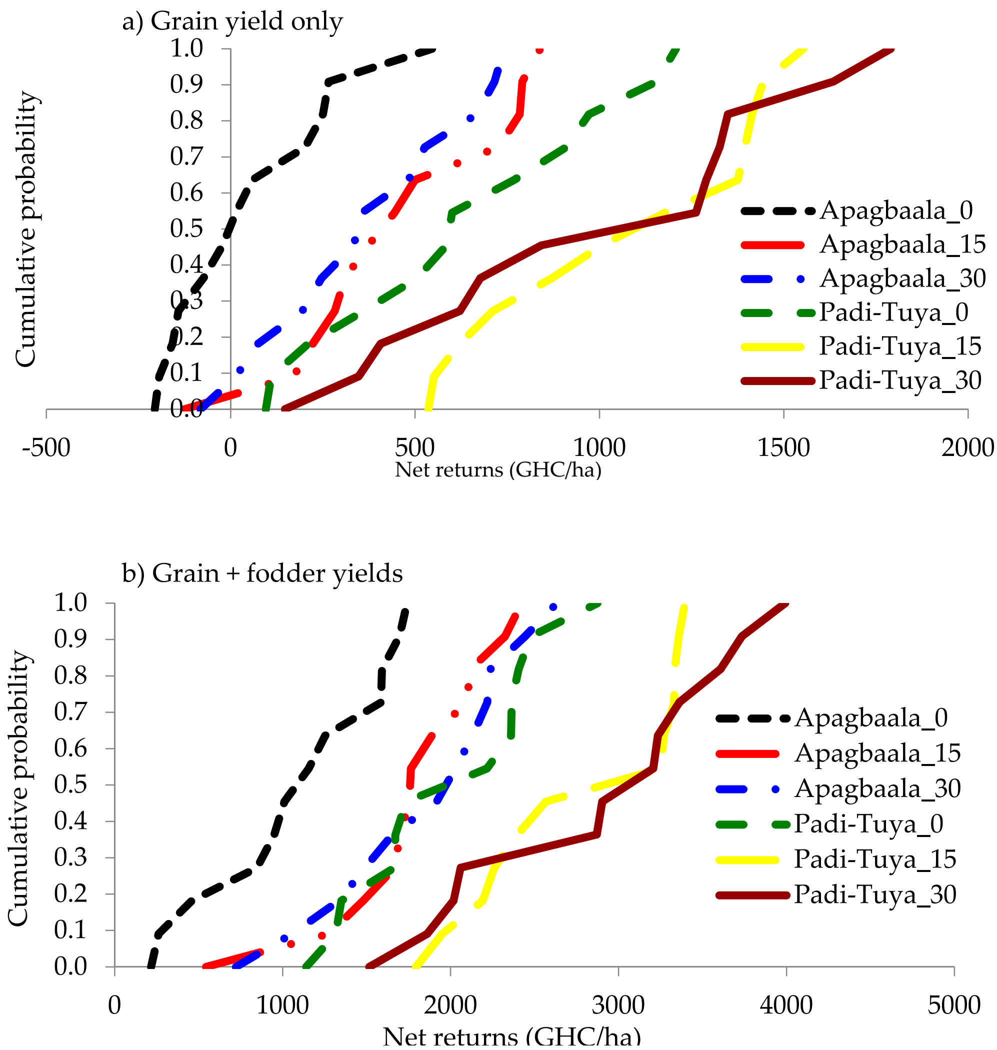

Figure 2. CDF of net returns.

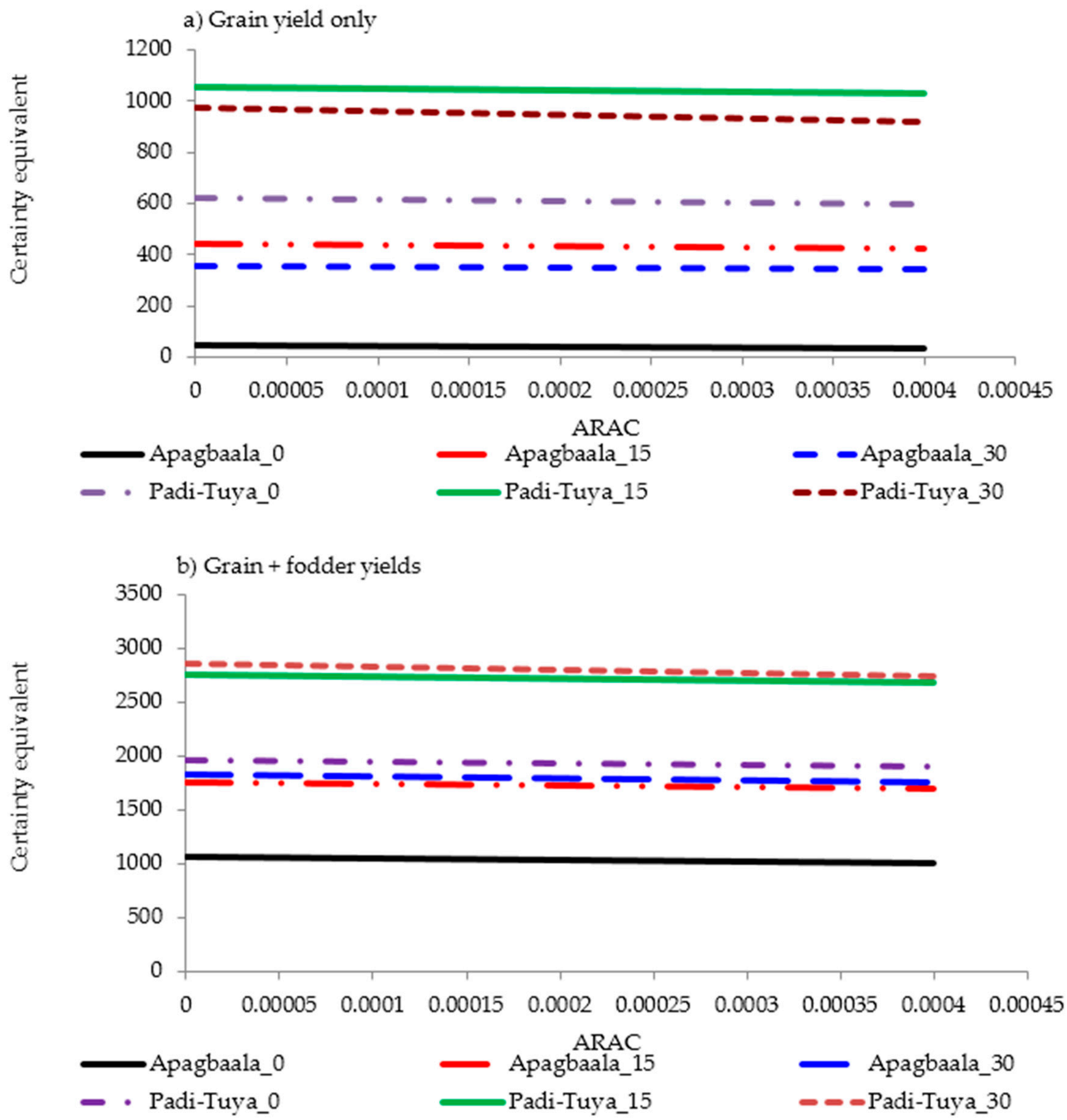

Figure 3. SERF of net returns.

4. Discussion

The difference in the performance of cowpea in both zones and seasons might be due to the difference in amount of rainfall received during the cropping seasons (Figure 1). The range of cowpea grain and fodder yields obtained agreed with yields of cowpea reported in earlier studies [7,21]. The effect of variety on grain yield in both zones could be partly attributed to the difference in SW and fodder yield. The Padi-Tuya variety matured later than the Apagbaala variety which gave the latter variety more growth period to accumulate enough dry matter to be partitioned into grain size, grain, and fodder yields. Kamara et al. [21] also reported that differences in 100 SW of cowpea varieties contributed to the difference in grain yield among cowpea varieties. The significant effect of N fertilizer seen on grain and fodder yields and NUE in both zones could be due to the efficient use of N fertilizer for maximum economic yield. This agrees with earlier reports that application of starter N fertilizer in different sources of phosphorus fertilizer increased cowpea grain and fodder yields and phosphorus nutrient use efficiency [6]. However, Da Silva et al. [22] reported that application of N fertilizer at higher rate to *Phaseolus vullgaris* inhibit biological N fixation and does not also result in higher yields. Similarly, other studies have reported a decrease in NUE with increased N application to *Phaseolus vulgaris* in different locations of Ethiopia [23].

The significant effect of variety on net return and BCR from both zones was due to differences in grain yield and SW. This agrees with reports from earlier studies that suggest seasonal supply and seed size determines up to about 97% variations of price of cowpea in most markets in West Africa and consumers are willing to pay a premium of up to 2% of the average price on each increase in SW [24]. The effect of N fertilizer on net return and BCR was possibly due to significant increase in grain and fodder yield from the application of N fertilizer which could offset the cost of production. The income accrued from the sale of fodder as livestock feed is considered extra source of income for farmers and has a huge market potential. The sale of fodder may also serve as an incentive for cowpea farmers as they may earn money from both the grain and fodder.

The negative CDFs associated with Apagbaala and the positive CDFs associated with Padi-Tuya when grain only was considered in the analysis was partly due to differences in the grain yield and net returns of the two varieties. This shows that planting Apagbaala without applying starter N fertilizer has about 50% chance of encountering net loss whiles planting Padi-Tuya with or without starter N has no risk of negative net returns. The changes in CDFs of both Apagbaala and Padi-Tuya with the N fertilizer rates under the grain and fodder analysis was due to additional revenue accrued from the sale of the fodder. The application of starter N fertilizer to cowpea reduced the risk associated with net loss which is an important feature of the technology given that most smallholder farmers in developing countries are risk averse [25–28]. The changes in the SERF results under the fodder and grain analysis was due to the positive effect of using higher starter N fertilizer on fodder yield. The confidence premium for applying 15 and 30 kg/ha N is very high which indicates farmers would have strict preference for applying starter N fertilizer at these rates to their cowpea given that other factors are not operating against the adoption of the technologies.

5. Conclusions

The cowpea variety had significant effect on yield and yield components, net return, and BCR in both zones. Padi-Tuya variety significantly increased grain and fodder yields, SW, net return, and BCR compared to Apagbaala in both zones. Similarly, starter N fertilizer increased grain and fodder yields, NUE, net return and BCR in both zones. The risk analysis showed that Padi-Tuya variety with the starter N fertilizer rates was risk efficient compared to Apagbaala variety. The results suggest that, cowpea farmers with interest in only grain yield could plant Padi-Tuya variety with application of 15 kg/ha N while those interested in both grain and fodder could plant Padi-Tuya variety with application of 30 kg/ha N for improved grain and fodder yield production with better net income in both Guinea and Sudan savanna zones of northern Ghana and similar ecologies across West Africa. However, we did not measure the amount of N fixed by these treatments and therefore future research is recommended on that.

Author Contributions: N.A.R. conceived, designed, performed experiment, analyzed data and wrote the agronomic part of the article; A.L. assisted in the conception, design, experiment execution, review and editing of the article; B.K. analyzed the economic data and wrote the economic part of the article; F.M.T. supported in the conception, design, and implementation experiment; I.H.-Z. coordinated financial support for acquiring experimental materials.

Funding: This research was funded by United State Agency for International Development.

Acknowledgments: Support received from USAID-funded Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) West Africa project is duly acknowledged.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Fatokun, C.A.; Tarawali, S.A.; Singh, B.B.; Kormawa, P.M.; Tamo, M. (Eds.) *Challenges and Opportunities for Enhancing Sustainable Cowpea Production, Proceedings of the World Cowpea Conference III Held at IITA, 4–8 September 2000*; International Institute of Tropical Agriculture (IITA): Ibadan, Nigeria, 2002.
2. Fatokun, A.C. Breeding Cowpea for Resistance to Insect Pest: Attempted Crosses between Cowpea and Vignia vexillata. In *Challenges and Opportunities for Enhancing Sustainable Cowpea Production, Proceedings of the World Cowpea Conference III Held at IITA, 4–8 September 2000*; Fatokun, C.A., Tarawali, S.A., Singh, B.B., Kormawa, P.M., Tamo, M., Eds.; International Institute of Tropical Agriculture (IITA): Ibadan, Nigeria, 2002; pp. 52–61.
3. FAOSTAT. Available online: www.fao.org/faostat/en/#data/QC (accessed on 20 February 2017).
4. Singh, B.B.; Chambliss, O.L.; Sharma, B. Recent advances in cowpea breeding. In *Advances in Cowpea Research*; Singh, B.B., Mohan Raj, D.R., Dashiell, K.E., Eds.; International Institute of Tropical Agriculture (IITA): Ibadan, Nigeria, 1997; pp. 30–49.
5. Coulibaly, O.; Lowenerg-DeBoer, J. The economics cowpea in West Africa. In *Challenges and Opportunities for Enhancing Sustainable Cowpea Production, Proceedings of the World Cowpea Conference III Held at IITA, 4–8 September 2000*; Fatokun, C.A., Tarawali, S.A., Singh, B.B., Kormawa, P.M., Tamo, M., Eds.; International Institute of Tropical Agriculture (IITA): Ibadan, Nigeria, 2002; pp. 351–366.
6. Bationo, A.; Ntare, B.R.; Tarawali, S.; Tabo, R. Soil fertility management and cowpea production in the Semi-Arid tropics of West Africa. In *Challenges and Opportunities for Enhancing Sustainable Cowpea Production, Proceedings of the World Cowpea Conference III Held at IITA, 4–8 September 2000*; Fatokun, C.A., Tarawali, S.A., Singh, B.B., Kormawa, P.M., Tamo, M., Eds.; International Institute of Tropical Agriculture (IITA): Ibadan, Nigeria, 2002; pp. 301–318.
7. Abayomi, Y.A.; Ajibade, T.V.; Sam, F. Growth and Yield Response of Cowpea (*Vignia unquiculata* (L.) Walp.) Genotypes to Nitrogen Fertilizer (NPK) Application in Southern Guinea Savanna Zone of Nigeria. *Asian J. Plant Sci.* **2008**, *7*, 170–176. [CrossRef]
8. Dart, P.; Day, J.; Islam, R.A.; Dobereiner, J. Some Effect of Temperature and Composition of the Rooting Medium in Symbiotic Nitrogen Fixation in Plants Synthesis. In *Tropical Grain Legume*; Nutman, R.S., Ed.; Cambridge University Press: Cambridge, UK, 1977; pp. 361–383.
9. Bationo, A.; Ntare, B.R. Rotation and nitrogen fertilizer effects on pearl millet, cowpea, and groundnut yield and soil chemical properties in a sandy soil in the semi-arid tropics, West Africa. *J. Agric. Sci.* **2000**, *134*, 277–284. [CrossRef]
10. Dugje, I.Y.; Omoigui, L.O.; Ekeleme, F.; Kamara, A.Y.; Ajeigbe, H. *Farmers' Guide to Cowpea Production in West Africa*; International Institute of Tropical Agriculture: Ibadan, Nigeria, 2009.
11. Tetteh, F.M.; Larbi, A.; Nketia, K.A.; Senaya, J.N.; Hoeschle-Zeledon, I.; Abdul Rahman, N. Suitability of soils for cereal cropping in Northern Ghana. In *Evaluation and Recommendations*; International Institute of Tropical Agriculture (IITA): Ibadan, Nigeria, 2016; p. 19, ISBN 978-978-8444-72-5.
12. International Union of Soil Sciences (IUSS) Working Group. *World Reference Base for Soil Resources 2014 International Soil Classification System for Naming Soils and Creating Legends for Soil Maps*; World Soil Resource Reports 106; Food and Agriculture Organization: Rome, Italy, 2014.
13. International Institute of Tropical Agriculture (IITA) AgriSTAT. Available online: http://agristat.iita.org/agristat/index.jspx (accessed on 15 May 2018).
14. Fageria, N.K.; Carvalho, M.C.S.; Knupp, A.M.; Moraes, M.F. Nutrient uptake and use efficiency of dry bean in tropical lowland soil. *Commun. Soil Sci. Plant Anal.* **2013**, *44*, 2852–2859. [CrossRef]
15. SBAS. *9.3 Procedure Guide*; SAS Institute Incorporation: Cary, NC, USA, 2011.
16. Gomez, K.A.; Gomez, A.A. *Statistical Procedures for Agricultural Research*, 2nd ed.; John Wiley and Sons: New York, NY, USA, 1984.
17. Hardaker, J.; Richardson, J.W.; Lien, G.; Schumann, K.D. Stochastic efficiency analysis with risk aversion bounds: A simplified approach. *Aust. J. Agric. Resour. Econ.* **2004**, *48*, 253–270. [CrossRef]
18. Anderson, J.R.; Dillon, J.L. *Risk Analysis in Dryland Farming Systems*; Farming Systems Management Series, No. 2; Food and Agriculture Organization: Rome, Italy, 1992.

19. World Bank: Adjusted Savings: Net National Savings (% of GNI). Average for the Period of 2005–2014. Available online: http://data.worldbank.org/indicator/NY.ADJ.NNAT.GN.ZS?locations=GH (accessed on 10 September 2017).
20. Ghana Statistical Service. *Ghana Living Standards survey Round 6 (GLSS 6): Labour Force Report*; Ghana Statistical Service: Accra, Ghana, 2014.
21. Kamara, A.Y.; Tofa, A.I.; Kyei-Boahen, S.; Solomon, R.; Ajeigbe, H.A.; Kamai, N. Effects of plant density on the performance of cowpea in Nigerian savannas. *Exp. Agric.* **2016**, 1–13. [CrossRef]
22. Da Silva, P.M.; Tsai, S.M.; Bonetti, R. Response to inoculation and N fertilization for increased yield and biological nitrogen fixation of common bean (*Phaseolus vulgaris* L.). In *Enhancement of Biological Nitrogen Fixation of Common Bean in Latin America*; Bliss, F.A., Hardarson, G., Eds.; Springer: Dordrecht, The Netherlands, 1993; pp. 123–130.
23. Argaw, A.; Mekonnen, E.; Muleta, D. Agronomic efficiency of N of common bean (*Phaseolus vulgaris* L.) in some representative soils of Eastern Ethiopia. *Cogent. Food Agric.* **2015**, *1*, 1074790. [CrossRef]
24. Langyintuo, A.S.; Lowenberg-DeBoer, J.; Faye, M.; Lambert, D.; Ibro, G.; Moussa, B.; Kergna, A.; Kushwaha, S.; Musa, S.; Ntoukam, G. Cowpea supply and demand in West and Central Africa. *Field Crops Res.* **2003**, *82*, 215–231. [CrossRef]
25. Barr, A. *Risk Pooling, Commitment, and Information: An Experimental Test of Two Fundamental Assumptions*; University of Oxford, Centre for the Study of African Economies: Oxford, UK, 2003.
26. Wik, M.; Kebede, T.A.; Bergland, O.; Holden, S.T. On the measurement of risk aversion from experimental data. *Appl. Econ.* **2004**, *36*, 2443–2451. [CrossRef]
27. Mosley, P.; Verschoor, A. Risk Attitudes and the 'Vicious Circle of Poverty'. *Eur. J. Dev. Res.* **2005**, *17*, 59–88. [CrossRef]
28. Hurley, T. *A Review of Agricultural Production Risk in the Developing World*; University of Minnesota: St. Paul, MN, USA; HarvestChoice: Washington, DC, USA, 2010.