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Comparative Productivity and Profitability of Four Groundnut Varieties with Phosphate Fertiliser in Mbale District, Uganda

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Abstract **- Groundnut (*Arachis Hypogaea*, L.) is important for food, nutrition and income generation. However, productivity in Uganda is low, partly due to low soil fertility, yet fertiliser use is limited amidst uncertain market conditions. This study assessed the profitability of phosphate fertiliser use on four varieties: red beauty, serenut 2, serenut 3 and serenut 4, in Mbale district, Uganda. The objective was to develop optimum P fertiliser rates for different groundnut varieties under prevailing market conditions. Phosphorus was applied as single superphosphate at 0, 4.37, 8.73, 13.10, 17.46 and 34.96 kg P ha^{-1}. Over two seasons (2009-2010), response to P was highest for red beauty followed by serenut 3 then serenut 4, and none for serenut 2. Agronomic response was observed up to 13.1 kg P ha^{-1}; however, highest gross margin (US \$ 47 ha^{-1}) was observed at 4.37 kg P ha^{-1}. Phosphate rates higher than 8.73 kg P ha^{-1} although agronomically beneficial, were not profitable under the prevailing market conditions. Breakeven prices indicated that profitability would be assured with red beauty and serenut 3 varieties if their prices rose by 10% for all P rates. Profitability with serenut 2 and serenut 4 varieties could be assured if their prices rose by 20% for P rates between 4.37 and 13.1 P ha^{-1} only. The study recommends a need for government and other value chain actors to put in place mechanisms that make fertilisers more accessible and affordable for smallholder for enhanced profitability.**

Keywords **– Fertiliser Cost, Phosphate Profitability, Marginal Analysis, Sensitivity Analysis.**

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I. Introduction

Groundnut (*Arachis Hypogaea*, L.) is an important food, feed, fertiliser, oil, fuel and income generating crop in Uganda. It is useful in rotation through its ability to fix free nitrogen into the soil, thereby improving soil fertility. Groundnut kernels are rich in protein and vitamins A, B, and can be eaten raw, roasted, fried, sweetened or boiled. Confectionery products may include cookies, snacks, and butter (*Odi*). The surplus after household consumption is readily sold for cash in local and regional markets and prices are generally high. The oil content of kernels varies from 44 to 50% depending on variety and agronomic conditions [1]. Refined groundnut oil is used in food preparations, soap making, manufacture of cosmetics, lubricants, etc. The residual oil cake contains 7-8% N, 1.5% P_2O_5 and 1.2% K_2O and can be used as fertiliser or as a protein supplement in livestock rations. The haulms (plant stalks) can be fed to livestock and the shells may be used as fuel, manufacture of coarse boards, etc.

Although farmers in Uganda have been growing various groundnut varieties (e.g. Roxo 531, Red beauty, Igola 1), yields are low. In Mbale district, productivity was found as 850 kg ha^{-1}, shelled and marketable surplus at 50 kg per household per season [2]. These low figures are partially attributed to pests and disease damage (e.g. rosette), low yielding varieties, and soil fertility limitations, among others. The National Agricultural Research Organisation (NARO) released three high-yielding, short-duration, rosette-resistant groundnut varieties which meet the specific requirements of different local markets. Serenut 2 (ICGV-SM 90704), an ICRISAT variety, was released in 1999 and rapidly established itself as one of the most popular groundnut varieties. Serenut 3R (ICGV-SM 93530), a red type, and the tan-coloured Serenut 4T (ICG 12991) were released by the Uganda Seed Board in 2002. The short duration of the varieties enabled farmers to grow two crops of groundnut a year and thus to significantly enhance their income potential [3].

A groundnut production manual [4] was compiled in 2002 and distributed to uptake pathways. The manual gives the recommended groundnut production practices, agronomic and post-harvest handling. It also gives a recommendation of Single Superphosphate (SSP) at 100-125 kg ha^{-1} (equivalent to 8.7-10.9 kg P ha^{-1}) (Ministry of Agriculture and Forestry, 1985). Although groundnut is a generally low nutrient demanding crop [5], some studies have revealed that application of higher doses of fertilizer (150 % of the recommended) resulted in increased yield compared to the farmers' practice of manure and fertilizer application [6]. In addition, there is a growing need to improve fertilizer recommendations for different crops to take into consideration, the decline in soil fertility and address nutrient requirements of new crop varieties. However, any revised fertilizer recommendations should also take into consideration the market prices for both the fertilizer and the resulting crop produce. The objectives of this study were: (i) to study the performance of four groundnut varieties (serenut 2, serenut 3, serenut 4 and red beauty) under different phosphorus fertilizer rates, and (ii) assess the profitability of phosphate fertilizer use on groundnuts under prevailing market conditions.

II. Materials and Methods

Description of the study area- This study was conducted in Bungokho sub-county, Mbale district in Eastern Uganda. The sub county stretches from the lowland, 950 m asl to the slopes of Mt. Elgon, typically 1,400 m asl. It is made of two micro-climatic zones: the upper (eastern) part of the sub county which is located on the foot-slopes of Mt. Elgon, lies in the transition zone between Kyoga plains and the "Highland ranges" [7]. It is characterized by an undulating topography with slopes ranging from 8 to 12%, moderately to very deep black volcanic soils derived from granitic gneiss.

The area receives 1270 to 1400 mm of rainfall annually, distributed bi-modally. There are two growing seasons: the first (main) season (March to June) and the second (August to November). Temperature ranges from 7.5 to 27.5°C. Soils are well-drained with good permeability and moderate runoff. The dominant soil type is Haplic Lixisols [8]. Lixisols are strongly weathered soils with low levels of available nutrients and low nutrient reserves. However, the chemical properties of Lixisols are generally better than of Ferralsols and Acrisols because of their higher soil pH (BS > 50 %) and absence of Al-toxicity. Due to low structural stability and moderate chemical fertility conservation of surface soil and SOM is of primary concern. Low plant nutrients and cation retention by Lixisols make recurrent use of inputs such as fertilizers and/or lime a precondition for continuous cultivation [9].

The lower (western) part of the sub county lies in the "Kyoga Plains" [7] and is typically flat, 0-2% slope. The area receives about 1000 to 1200 mm of rainfall annually, distributed in bi-modally with the main peak in April-May and a secondary peak in August-September. One dry season runs from December to about mid-March [7]. Temperature ranges from 15 to 32.5°C. Two dominant soil units were identified: Endopetric Plinthosols and Nitic Lixisols. Plinthosols have high contents of iron and/or aluminium, with proportions varying from more than 80% iron oxides with little aluminium to about 40% of each. Most Plinthosols have poor cation exchange properties and low base saturation but there are exceptions, e.g. Endoeutric soil units. Poor natural soil fertility, water logging in bottomlands and drought on shallow and/or skeletal Plinthosols are serious limitations [10]. Nitic Lixisols are Lixisols with a Nitic horizon (a clay-rich subsurface with moderately to strongly developed polyhedric or nutty structure with shinny ped faces, which cannot or can only partially be attributed to clay illuviation), characterized by diffuse or gradual transition to horizons above or below [11].

Four farmers' groups (20 farmers per group) participated in the study. They groups included: Bubirabi and Namatsale found in the upper (eastern) side, Siira farmers' group in the lower (western) part, and Bunapongo farmers group which lies midway between the upper and lower part of the sub county.

Experimental layout and design- Four groundnut varieties: red beauty, serenut 2, serenut 3, and serenut 4. Each farmer received red beauty and one of the serenut varieties which were randomly distributed to five farmers in each group. The groundnuts were planted at a spacing of (30x10) cm for serenut 3, serenut 4 and red beauty. Serenut 2 was planted at a spacing of (45x30) cm. Plot sizes were (20x10) m and each farmer had four plots which were divided into two each, to form 8 plots. Phosphorus was applied as single superphosphate (SSP) at 0, 4.37, 8.73, 13.10, 17.46 and 34.96 kg P ha^{-1} kg Pha^{-1} (representing 0, 50, 100, 150, 200 and 400 kg SSP ha^{-1}, respectively). The experimental set up was a completely randomized block design (CRBD), with groundnut variety and P rate arranged in a factorial combination, replicated four times (farmers' groups). The crops were sprayed with dimethoate at the recommended dose of 30 ml per 20L of water starting at 2 weeks after planting to control aphids that carry along the rosette virus. Farmers observed proper agronomic practices like timely weeding, spraying, among others.

*Data collection and analysis-*Agronomic data were collected using data sheets prepared to capture for each farmer and experimental plot, the actual area harvested, number of plants harvested, number of pods on representative plants, fresh and dry weight of groundnut pods. Information on the amount of groundnuts sold, eaten or given away between harvesting and drying was also collected from farmers, as a component of the yield. The data were processed using Microsoft excel, yields adjusted for harvested area, plant population, 14% moisture content, and expressed on a hectare basis. Data were analysed using Genstat package version 3.2. Significant differences between treatment means were determined at a 95% Confidence level and means separated using the standard error of difference (sed) procedure. Two means were declared significantly different when the difference between them was greater than twice the sed value. For financial analysis, data on costs that varied including labour, fertiliser, spray, material supplies, transport, etc., groundnut yields and farm-gate prices were collected using formal survey tools such as questionnaires, interviews, data sheets and field observations. The input market prices were obtained from the nearby Mbale market. Data were cleaned using Microsoft excel and analysed using Statistical Package for Social Scientists (SPSS). Partial budget analysis, marginal analysis, dominance analysis, breakeven analysis and sensitivity analysis were used to analyse the data.

Partial budget analysis was used to determine the Financial Net Benefits (FNB) of the alternative production packages.

$$FNB = (YP_y) - CV \qquad (1)$$

where, Y = average groundnut yield, kg ha^{-1}; P_y = average price of a groundnut variety; CV = costs that vary for each production package.

Marginal analysis compared the extra (marginal) costs incurred in investing in a production package with extra net benefits from the investment. A higher net benefit may not be affordable to a poor farmer if it requires very much higher investment. To highlight this scenario for a production package, a net benefit/cost change ratio usually expressed as a percentage known as the *marginal rate of*

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return (MRR) was calculated. Calculation was done by proceeding stepwise from the least costly treatment level to the most costly, in a procedure called marginal analysis [12], where $FNB_1 - FNB_2$ = extra net benefit realised; $CV_1 - CV_2$ = extra cost incurred:

$$MRR = [(FNB_1 - FNB_2)/(CV_1 - CV_2)] * 100 \qquad (2)$$

The MRR actually indicates what one can expect to gain in return for the added investment when one chooses to change from one treatment to another. However, one will rationally compare the MRR with one's acceptable minimum rate of return for such a technology change. The MRR, therefore, should be high enough to repay for one's opportunity cost of working capital and for what one would expect to get for one's time and effort in adjusting to the new technology level [13].

Dominance analysis simply listed the treatments (groundnut varieties with rates of phosphorus) in order of increasing costs that varied along with the net returns for each of the treatments. This was done on the assumption that no farmer would rationally invest in any treatment that had net returns which were less than or equal to those of a treatment with lower costs that vary (a preference for a lot more for a little more). *Breakeven analysis* was done to provide a handy decision support tool for knowing, for example, how high P_y would have to be for additional output to become profitable, where TCV: total costs that vary for each treatment:

$$P_y = TCV/Y \qquad (3)$$

Sensitivity analysis was done to test systematically what would happen to the profitability of a groundnut enterprise if major elements such as yield, price or cost of production changed from those observed. It is a means of dealing with the risk from variability in what one expects to gain from added investment (MRR) under certain conditions. It charts out ranges of levels over which a given investment option would be economically viable. A sensitivity analysis is done by varying one element or a combination of elements and determining the effect of that change on the outcome, which is, in this case, groundnut enterprise profitability, where Δ refers to change in:

$$\Delta P_y = \Delta CV(1+MRR)/Y \qquad (4)$$

III. Results

Experimental site characteristics-Soils: Table I presents the mean soil characteristics at the study sites. The pH in the top 20cm was somewhat lower for upper sites (Bubirabi and Namatsale) compared to the lower one (Siira). However, pH values for all sites were within the range of 5.5 to 6.2 considered favourable for groundnuts [14]. Available soil P was low in the top 20cm of the upper sites, with Bubirabi exhibiting the lowest P levels. Since the groundnut crop is a surface feeder, P addition would be expected to enhance its growth, more so at the P deficient Bubirabi site. Calcium was above the range of 600 to 800 mg kg^{-1} soil considered adequate [14], indicating that it was not limiting at all the sites.

Rainfall distribution for Mbale during 2009 to 2010- During 2009 groundnuts were planted during September and harvested during December to January 2010. Monthly rainfall totals ranged from 30 to 5 mm, with means decreasing during the dry season. During 2010, groundnuts were planted in April and harvested during July to August. Monthly rainfall totals ranged from 30 to 20 mm in June, with a peak of 40mm observed in July. Generally more rainfall was received during the April to July/August 2010 growing season than during September to December/January 2009 season. This is consistent with farmers' observations from the lower village (Siira) who reported prolonged dry spells in 2009. Although groundnuts survive on average rainfall ranging from above 500 to 1,200 mm, moisture shortage during the reproductive stage can drastically reduce yields [14].

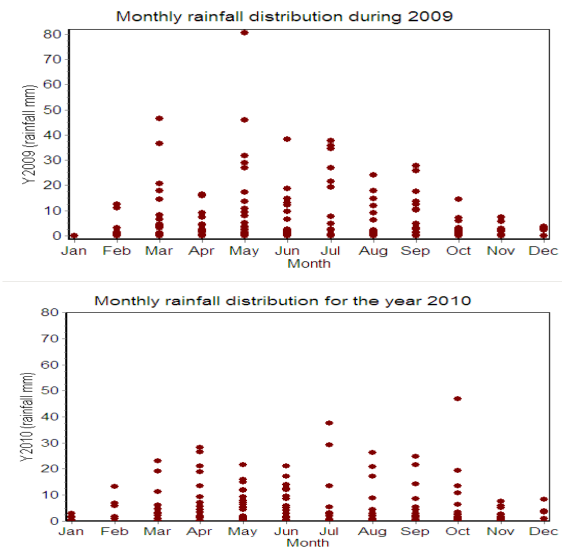

Fig.I. Rainfall distribution for Mbale, 2009-2010.

Effect of phosphorus application on groundnut yield, 2009-2010- There was a significant (P<0.001) main effect of Variety and P rate but no Variety*P rate interaction, meaning that the groundnut varieties did not differ in their response to P. Averaged over all P rates, red beauty gave the highest unshelled groundnut yields followed by serenut 2, serenut 3 then serenut 4 the lowest (Table II). Mean yields for serenut 2, 3 and 4 were not significantly (P>0.05) different. Production costs differed for the varieties. Lowest values were observed for serenut 2 followed by serenut 3, although these were not significantly (P>0.05) different. Low production costs for serenut 2 is consistent with the low price of serenut seeds. On the other hand, production cost for serenut 4 was significantly (P<0.05) higher than the other varieties inspite of the low price for seeds. Production costs for red beauty (unshelled or shelled) were not significantly different from those of serenut 3.

Income realised from the sale of unshelled groundnuts was significantly (P<0.05) higher for red beauty compared to other varieties (Table II). This could be attributed to the higher overall yields observed for this variety compared to other varieties. This was followed by serenut 3 then serenut 2, and lowest for serenut 4. The lowest income from serenut 4 is a combination of both the lowest yield observed, and the fact that this variety fetches the lowest price on the market. In general with the exception of serenut 2, income from shelled groundnuts was higher than that from unshelled. Lower income from shelled serenut 2 is due to its low shelling percentage (60%) and the low market price (US \$ 0.825 per kg for serenut 2 compared to red beauty and serenut 3 with a shelling percentage of 70% and a market price of US \$ 1.025 per kg). The gross margin was significantly ($P<0.05$) higher for red beauty (both unshelled and shelled), but was not different for serenut 3 and serenut 2 (unshelled). Gross margin was lowest for serenut 4. In general, for a given variety, gross margin was higher for shelled than unshelled groundnuts, meaning that a farmer makes more profit from the sale of shelled than unshelled groundnuts. Serenut 2 was an exception to this, because of its high shelling costs due to the high labour cost involved in shelling off the rather hard shell.

Table I: Mean soil characteristics for the study sites

Site	Major Soil unit (s)	Depth cm	pH	OM	N	P	Ca	Mg	K	Sand	Clay	Silt	Textural class
				---- % -----		--------- mg kg^{-1} -----------				----------- % ------------			
Bubirabi	Haplic Lixisols	0-20	6.20	3.90	0.15	1.8	2168	448	456	60.40	27.80	11.80	Sandy clay loam
		20-50	5.80	2.40	0.11	0.7	2439	560	136	44.40	43.80	11.80	Clay
Namatsale	Haplic Lixisols	0-20	6.40	3.10	0.13	6.2	3325	604	537	54.40	30.80	14.80	Sandy clay loam
		20-50	6.25	2.10	0.11	1.6	2580	629	654	49.40	37.80	12.80	Sandy clay
Siira	Endopetric Plinthosols	0-20	6.50	3.20	0.14	16.4	2892	472	632	54.40	33.80	11.80	Sandy clay loam
		20-50	6.15	2.35	0.12	23.4	4074	558	554	35.40	53.80	10.80	Clay
Critical values#			5.2	3.0	0.2		600##						

#Critical values for 0-20 cm layer, for most crops in Uganda [15].
##Critical Ca value of 600 mg kg^{-1} proposed for groundnuts [14].

Table II: Main effect of varieties on groundnut yield and profitability, 2009-2010

	Red beauty	Serenut 2	Serenut 3	Serenut 4	sed	CV, %
Seed price, US \$ kg^{-1}	1.25	1.00	1.25	0.90		
Yield, unshelled, kg ha^{-1}	1012	844	805	718	55.1	46.7
Yield, shelled, kg ha^{-1}	709	507	563	574	38.9	46.9
Production cost, unshelled, US \$ ha^{-1}	525.8	481.5	505.0	564.4	13.0	14.1
Production cost, shelled, US \$ ha^{-1}	544.4	494.6	523.6	584.3	13.8	14.5
Income, unshelled, US \$ ha^{-1}	683.0	464.0	543.0	323.0	33.1	45.5
Income, shelled, US \$ ha^{-1}	726.0	440.0	577.0	476.0	36.5	46.2
Gross margin unshelled, US \$ ha^{-1}	158.0	-17.0	38.0	-241.0	35.0	80
Gross margin shelled, US \$ ha^{-1}	182.0	-55.0	54.0	-109.0	38.2	83

Main effect of Phosphorus on groundnut yield, 2009-2010- The effect of phosphate application on groundnut yield is graphically presented in Fig. II. Data are means of four varieties. Phosphorus application increased groundnut yield, with significant ($P<0.05$) differences over the control observed at 8.73 kg P ha^{-1}. Increasing P rate beyond 8.73 increased groundnut yields, but not significantly. For unshelled groundnut, the relationship was quadratic ($Y=-0.6631X^2+26.493X+689.49$; $R^2=0.9978$, $P<0.05$). Similar trends were observed for shelled groundnuts. It is important to note that observed yields were much lower than the potential yield for groundnuts (3,000 kg ha^{-1}). According to Bashaasha et al [16] actual yields of grain crops in Uganda ranged from 51 to 68 percent of potential crop levels. Clearly, conditions under which this on-farm study were carried out could not enable us realise the full yield potential of the crop. Income realised from groundnut sale increased with P rate, in response to increased groundnut yields, with shelled groundnuts fetching a higher income than the unshelled. Gross margin for unshelled groundnuts grown without P was negative, meaning that under this management

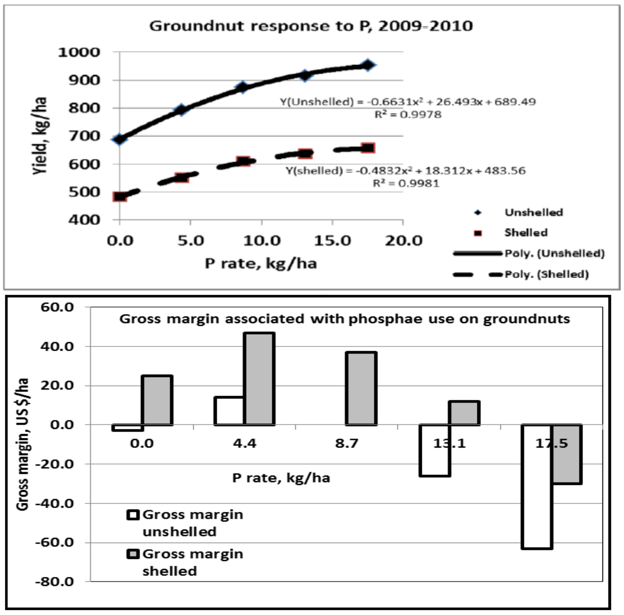

Fig.II. Groundnuts response to P fertiliser, and associated gross margins, Mbale, Uganda, 2009-10.

practice, a farmer would incur a loss by selling unshelled groundnuts. Gross margin was improved on application of 4.37 kg P ha^{-1}, but decreased at higher P rates. Thus, although use of P fertilizer improved the gross margin from the sale of shelled groundnuts, highest benefits were observed at low P rates (Fig. II).

Effect of changes in yield, price and cost of production on groundnut profitability- Table III presents groundnuts yields, costs, breakeven prices and returns for investment in phosphate fertilizer over the two production seasons, summarized in Fig. III. Closely corresponding to the observed differences in agronomic responses to P, only red beauty and Serenut 3 groundnut varieties with phosphorus came up as financially viable treatments. Serenut 2 and Serenut 4 turned up as money losers at any rate of P. Breakeven analysis (Table III) determined the breakeven prices for *red beauty* shelled groundnuts to be between US $ 0.67per kg at 4.37 kg P ha^{-1} and US $ 1.22 per kg at 34.96 kg P ha^{-1}; for Serenut 3 shelled groundnuts between US $ 0.97 per kg at 4.37 kg P ha^{-1} and US$ 0.99 per kg at 34.96 kg P ha^{-1}; for Serenut 2 between US $ 0.89 per kg at 4.37 P kg ha^{-1} and US $ 1.89 kg ha^{-1} at 34.96 kg P ha^{-1}; for Serenut 4 between US $ 0.96 per kg at 4.37 kg P ha^{-1} and US$ 2.18 per kg at 34.96 P kg P ha^{-1}. These were price ranges for the varieties beyond which certain P rates could be financially viable treatments [16]

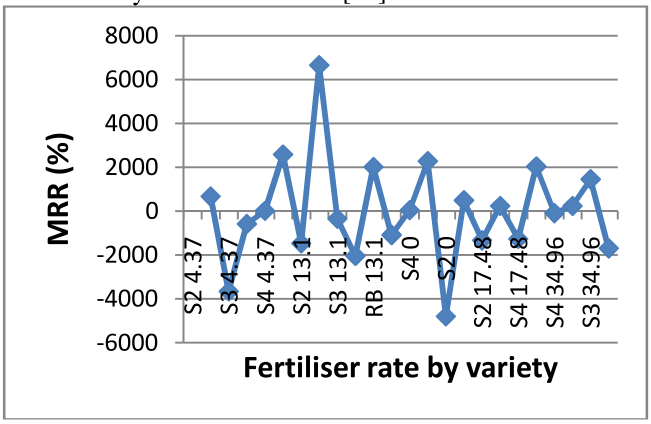

Fig.III. Dominance Analysis across all Groundnut Varieties and P rates (2009–2010) in Mbale District, Uganda. S2=serenut 2; S3=serenut 3; S4=serenut 4; RB=red beauty.

Sensitivity analysis- Table IV complements the above revelation in indicating that sure profitability for Red beauty and serenut 3 varieties could be realized at any level of phosphorus application if groundnut price rose by 10%. For serenut 2 and serenut 4, profitability could only be assured with a groundnut price rise of 20% at phosphorus application between 4.37 and 13.1 kg Pha^{-1}.

IV. Discussion

Groundnut is a relatively low input but high value crop [5]. The greatest cost of production is drawn from the seed, but farmers can preserve seed from a previous crop. Use of phosphate fertilizer adds to the production costs, and this must be justified with additional revenue from increased yields. In the current study, fertilizer P contributed between 18 to 40% of the production cost. Production costs were higher for shelled groundnuts compared to the unshelled. Income from shelled groundnuts was higher than the unshelled, with the exception of serenut 2 where no difference in income (unshelled vs shelled) was realized. The lack of a financial benefit to shelling serenut 2 could be attributed to the high labour cost involved in shelling off the rather hard serenut 2 shell, the low shelling percentage (60%) and the low market price for serenut 2.

Phosphate application increased groundnut yields but no varietal differences were observed. Pod yields levelled off between P ranges of 13.1 and 17.48 kg P ha^{-1}, which is equivalent to 150 and 200 kg SSP ha^{-1} respectively (Fig. II). These rates are higher than the earlier recommended rates of 100 to 125 kg SSP ha^{-1} that were developed in the 1970s [18]. Considering the generally low P status of the soils where the study was undertaken (Table I), this observation may suggest a higher P requirement for groundnut production compared to the rates previously recommended. In Viet Nam, Tran [19] reported increased groundnut yield on both the poor alluvial and sandy soils following P fertilization, with yield significantly higher than the control at 26.2 kg P ha^{-1} in the alluvial soil, while the sandy soil required 39.3 kg P ha^{-1} to produce a significantly higher yield.

Table III: Mean Groundnut yields, Costs, Returns and Breakeven prices for Investment in P use in Mbale District, Uganda, 2009 – 10.

Groundnut Variety	P- rate, kg ha^{-1}	Av. Yield, kg ha^{-1}	Av. Output, US $ ha^{-1}	Av. CV, US $ ha^{-1}	Av. NFB, US $ ha^{-1}	MRR, %	Breakeven price, US $ kg^{-1}
S2 4.37	04.37	482.80	420.00	430.70	-10.70		0.89209
RB 4.37	04.37	700.00	714.00	469.00	245.00	667.62	0.67000
S3 4.37	04.37	485.40	500.00	475.00	25.00	-3666.67	0.97857
S2 8.73	08.73	478.20	416.00	492.50	-76.50	-580.00	1.02990
S4 4.37	04.37	546.90	454.00	525.40	-71.40	15.50	0.96069
S3 8.73	08.73	623.30	642.00	532.40	109.60	2585.71	0.85416
S2 13.1	13.10	556.00	484.00	543.90	-59.90	-1473.91	0.97824
RB 8.73	08.73	746.10	761.00	548.00	213.00	6656.10	0.73449
S3 13.1	13.10	653.30	672.70	583.50	89.20	-348.73	0.89316
S4 8.73	08.73	597.70	496.10	592.60	-96.50	-2040.66	0.99147
RB 13.1	13.10	720.60	735.00	603.90	131.10	2014.16	0.83805

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S4 13.1	13.10	618.10	513.00	626.40	-113.40	-1086.67	1.01343
S4 0	00.00	691.00	604.85	688.90	-84.05	46.96	0.99696
RB 0	00.00	751.80	869.80	700.05	169.75	2276.23	0.93117
S2 0	00.00	479.70	458.50	708.80	-250.30	-4800.57	1.47759
S3 0	00.00	677.40	790.50	765.15	25.35	489.17	1.12954
S2 17.48	17.48	564.00	580.25	782.20	-201.95	-1333.13	1.38688
S3 17.48	17.48	764.95	898.00	877.45	20.55	233.60	1.14707
S4 17.48	17.48	779.30	679.85	896.15	-216.30	-1266.58	1.14994
RB 17.48	17.48	908.95	1039.00	912.95	126.05	2037.80	1.00440
S4 34.96	34.96	594.40	1070.00	1299.00	-229.00	-91.97	2.18540
RB34.96	34.96	1149.60	1437.00	1408.00	29.00	236.70	1.22477
S3 34.96	34.96	1435.20	1794.00	1431.00	363.00	1452.17	0.99707
S2 34.96	34.96	787.00	787.00	1494.00	-707.00	-1698.41	1.89835

Table IV: Sensitivity Analysis Report for groundnuts Mbale District, Uganda, (2009 – 2010).

	Average prices, red beauty (US \$ kg^{-1})										
Red Beauty	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
P rates, $kgha^{-1}$	0.56	0.67	0.78	0.89	1.01	1.12	1.23	1.34	1.45	1.57	1.68
0	-279.58	-195.48	-111.39	-27.30	56.80	140.89	224.99	309.08	393.17	477.27	561.36
4.37	-77.50	0.80	79.10	157.40	235.70	314.00	392.30	470.60	548.90	627.20	705.50
8.83	-130.72	-47.26	36.20	119.65	203.11	286.57	370.02	453.48	536.94	620.39	703.85
13.1	-200.88	-120.27	-39.67	40.93	121.54	202.14	282.75	363.35	443.96	524.56	605.16
17.48	-404.59	-302.91	-201.24	-99.57	2.10	103.78	205.45	307.12	408.79	510.47	612.14
34.96	-765.05	-636.45	-507.86	-379.27	-250.68	-122.09	6.50	135.09	263.68	392.27	520.86
	Average Prices Serenut 2 (US \$ kg^{-1})										
Serenut 2	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
P rates, $kgha^{-1}$	0.46	0.56	0.65	0.74	0.83	0.93	1.02	1.11	1.20	1.30	1.39
0	-486.77	-442.36	-397.95	-353.55	-309.14	-264.73	-220.33	-175.92	-131.52	-87.11	-42.70
4.37	-207.23	-162.54	-117.85	-73.15	-28.46	16.23	60.93	105.62	150.32	195.01	239.70
8.73	-271.16	-226.89	-182.63	-138.36	-94.09	-49.82	-5.56	38.71	82.98	127.25	171.51
13.1	-286.55	-235.08	-183.61	-132.14	-80.67	-29.20	22.27	73.74	125.21	176.68	228.15
17.48	-521.15	-468.94	-416.73	-364.52	-312.31	-260.10	-207.89	-155.68	-103.47	-51.26	0.95
34.96	-1129.73	-1056.88	-984.02	-911.17	-838.32	-765.46	-692.61	-619.76	-546.90	-474.05	-401.19
	Average Prices Serenut 3 (US \$ kg^{-1})										
Serenut 3	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
P rates, $kgha^{-1}$	0.56	0.67	0.79	0.90	1.01	1.12	1.24	1.35	1.46	1.57	1.69
0	-384.35	-308.20	-232.04	-155.88	-79.72	-3.56	72.60	148.76	224.92	301.08	377.24
4.37	-202.14	-147.56	-92.99	-38.42	16.16	70.73	125.30	179.87	234.45	289.02	343.59
8.73	-182.02	-111.94	-41.86	28.21	98.29	168.37	238.44	308.52	378.60	448.67	518.75
13.1	-216.25	-142.80	-69.35	4.10	77.55	151.00	224.45	297.90	371.34	444.79	518.24
17.48	-447.44	-361.44	-275.43	-189.43	-103.43	-17.43	68.57	154.58	240.58	326.58	412.58
34.96	-624.21	-462.86	-301.50	-140.14	21.22	182.57	343.93	505.29	666.65	828.00	989.36
	Average Prices Serenut 4 (US \$ kg^{-1})										
Serenut 4	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
P rates, $kgha^{-1}$	0.43	0.52	0.60	0.69	0.77	0.86	0.95	1.03	1.12	1.20	1.29
0	-391.77	-332.34	-272.92	-213.49	-154.07	-94.64	-35.21	24.21	83.64	143.06	202.49
4.37	-290.23	-243.20	-196.17	-149.13	-102.10	-55.07	-8.03	39.00	86.03	133.07	180.10
8.73	-335.59	-284.19	-232.78	-181.38	-129.98	-78.58	-27.18	24.23	75.63	127.03	178.43
13.1	-360.62	-307.46	-254.30	-201.15	-147.99	-94.83	-41.68	11.48	64.64	117.79	170.95
17.48	-561.05	-494.03	-427.01	-359.99	-292.97	-225.95	-158.93	-91.91	-24.89	42.13	109.15
34.96	-1043.41	-992.29	-941.17	-890.05	-838.93	-787.82	-736.70	-685.58	-634.46	-583.34	-532.22

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Averaged over all four varieties, groundnut agronomic response to P was observed up to 13.1 kg P ha^{-1} (equivalent to 150 kg SSP ha^{-1}); however, highest Gross Margin (US \$ 47 ha^{-1}) was realised at 4.4 kg P ha^{-1} (equivalent to 50 kg SSP ha^{-1}). With respect to particular varieties, highest gross margin was observed for red beauty (US \$ 182 ha^{-1}) followed by serenut 3 (US \$ 54 ha^{-1}). Highest MRR was obtained with red beauty followed by serenut 3, both fertilised with 8.73 kg P ha^{-1}. Higher profitability for red beauty and serenut 3 is partly due to the higher market prices for these two varieties (Table II). For serenut 2 and serenut 4, negative gross margins of US \$ -55 and -109 ha^{-1}, respectively were obtained, in response to a similar trend in market prices of the four varieties. Further dynamic profit prospects were explored using breakeven analysis and sensitivity analysis. Narrower breakeven price ranges (US \$ 0.67 - US \$ 1.18 per kg at 4.37 – 34.96 kg P ha^{-1}) were possible for red beauty and serenut 3 varieties than for serenut 2 and serenut 4 varieties (US 0.89 – 2.58 at 4.37 – 34.96 kg P ha^{-1}). Thus, red beauty and serenut 3 rather than serenut 2 and serenut 4 stood out as surer profitable enterprises with changes in groundnut prices (10% increase for the former pair and 20% increase for the latter pair).

V. Conclusion

Under the market conditions of this study, red beauty fertilised with 8.73 kg P ha^{-1} was a more profitable investment, followed by serenut 3 at the same rate of P. For serenut 2 and serenut 4, negative gross margins of US \$ -55 and -109 ha^{-1}, respectively were obtained, suggesting that they may not be viable investments. For planning purposes, sensitivity analysis proved useful in charting out ranges of phosphorus rates over which a given groundnut variety would be profitable. Profitability would be assured with red beauty and serenut 3 varieties if their prices rose by 10% for all rates of P. Profitability with serenut 2 and serenut 4 varieties could be assured if their prices rose by 20% for P rates between 4.37 and 13.1 P ha^{-1} only. Considering that fertiliser cost contributes 18-40% of the production costs, there is need for Governments & other chain actors to put in place mechanisms to increase fertiliser access, affordability and use by smallholder farmers.

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