Productive impact of residual nutrients (N and P) in maize and soybean rotation

ABSTRACT

Agricultural intensification has resulted in severe soil nutrient depletion in Africa. Alternative agricultural practices have been promoted to restore and sustain soil fertility. Use of mineral fertilizer alongside different cropping systems has been particularly promising. This study was conducted in the Guinea savannah zone of Ghana during the 2015 and 2016 cropping season (July to November) to assess the performance of soybean and maize in a rotation system. In season one, using randomized complete block design the treatments were, sole-soybean, inoculated soybean, soybean with phosphorus application, inoculated soybean with phosphorus application and maize. During the second season, the first season experimental plots served as main-plots and divided into four sub-plots on which maize planted and treated with four nitrogen rates in a split plot design. The results show that soybean production leads to significant increase in residual soil nitrogen content of about 16kg/ ha to 55kg/ ha, which is about 8 to 28 folds higher than that observed in maize fields. The level of Residual N was enhanced with inoculation. Phosphorus application during the first season of maize cultivation led to increases in residual P levels, which had a positive impact on yield of soybean in the second season. Grain yield of maize that followed soybean in a rotation system performed better than maize that followed maize at various fertilizer rates. This shows that the residual N and P help maize and soybean respectively in a rotation system which makes it highly economical.

Keywords: Impact, Inoculation, N, residual nutrients, P, rotation,

1.0 INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a legume plant belonging to the botanical family *leguminosae*. Is an economically important leguminous crop worldwide and also the most important legume in Ghana (Plahar, 2006). According to Dugje *et al*. (2009), soybean is more protein-rich than any of the common vegetable or legume food sources in Africa. Soybean contains is of 20-25 % edible oil, and 42-45 % of protein (Alam *et al*., 2009). Cultivation of Maize is also done worldwide and represents a staple food for a significant proportion of the world's population. Maize is highly nutritive and the seed contains; starch (78%), protein (10%), oil (4.8%), fiber (8.5%), sugar (3.1%) and ash (1.7%) (Chaudhary,1993). Maize is a staple food in sub-Saharan Africa for an estimated 50% of the population and provides 50% of the basic calories. Nitrogen is the most abundant element on the earth and about 78 % of the earth's atmosphere is nitrogen gas. There are hundreds of tons of nitrogen over every hectare of land surface. Despite the abundance of nitrogen in the atmosphere, plants are unable to use it directly because it is present in an inert form (N_2) and the nitrogen in the soil is lost through microbial denitrification, soil erosion, leaching, chemical volatilization, removal of nitrogen containing crop residues from land. Sangakara *et al* reported in 2003 that, nitrogen is therefore most limiting plant nutrient for crop production in West Africa. Most legumes, through symbiosis with rhizobia have the ability to reduce N_2 through biological nitrogen fixation (BNF) into a form usable for growth. Phosphorus is also an essential ingredient for Rhizobia bacteria to carry out BNF processes. Inadequate P restricts root growth, the process of photosynthesis, translocation of sugars and other such functions which directly influence N fixation by legume plants. The phosphorus serves as an energy source during the physiological processes taking place in the plant (Anonymous, 1999). Studies have demonstrated positive response of rhizobia inoculation on nodulation, dry matter yield and grain yield. Dorivar et al. (2009) reported that the application of rhizobia inoculation increased soybean grain yield by an average of 130 kg/ha and that of plant dry matter, N concentration, N accumulation and grain N were also increased in soybean with soybean seed inoculation. Also, a study conducted on three legume (ground nut) cultivar in a sandy loamy soil observed that rhizobia inoculation increased the amount of N_2 fixed by 46 % over the un-inoculated control. Studies have shown that some legumes can grow well before cereal crops, producing large amounts of residues and fixing atmospheric N_2, leading to considerable increase in yields of succeeding cereal crops (McDonagh *et al*., 1995). Rotation of cereals with legumes has been extensively studied in recent years. Use of rotational systems involving legumes is gaining importance throughout the region because of economic and sustainability considerations. The beneficial effect of legumes on succeeding crops is normally exclusively attributed to the increased soil N fertility as a result of N_2 fixation.

Despite the numerous benefits of the soybean, the grain yield per unit area is low in Ghana, The average soybean yield for northern Ghana (Northern, Upper West and Upper East regions) was about 1.5t/ha on the farmers' field compared to that of USA which was 4.6 t / ha (Lawson *et al*., 2008). The significant increase in the grain yield of soybean in U.S.A. has been partly attributed to the development and improvement of cultural practices. In spite of the great potentials of the crop, soybean production is still inadequate owing to low yields, resulting in a wide gap between what is currently produced and what is needed. As a way of improving production level, one of the major areas to consider is the improved cultural management practices. Currently, BNF contribution on majority of small holder farms rarely exceeds 5 kg N/ ha / year with nitrogen fixing legumes in Ghana (Mapfumo *et al*., 2001). A measure of more than 240 kg N / ha of fixed N_2 in soybean in southern Africa on small holder farms with associated grain yield of more than 3.5 t / ha has been recorded (Giller, 2001). The average soybean yield for northern Ghana is about 1.5 t/ha on the farmers' field compared to that of USA which is 4.6t/ha (Lawson *et al*., 2008). Currently, Biological Nitrogen Fixation (BNF) contribution on majority of small holder farms rarely exceeds 5 kg N/ ha / year with nitrogen fixing legumes in Ghana (Mapfumo *et al*., 2001) whiles measure of more than 240 kg N / ha of fixed N_2 in soybean in southern Africa on small holder farms with associated grain yield of more than 3.5 t / ha has been recorded (Giller, 2001).

Recent research shows that maize yields increase when grown in crop rotations with soybean but the residual N after soybean cultivation with different production techniques have not been quantified and this makes it difficult for farmers to apply the right amount of nitrogen to augment with what was fixed by soybean the previous cropping season to reduce cost of production whiles yield of maize is increased. Also, it is not known if the soybean plants that follow maize production could benefit from residual P resulting from P application to the preceding maize crop. Due to the problems and cost involved in the production of these two important crops, this study was to identify the best production technology to increase soybean and maize production using the rotation system to reduce the cost of production.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study was carried out in the experimental field of the Faculty of Agriculture of the University for Development Studies at Nyankpala in the Northern Guinea savannah ecological zone during 2014 and the 2015 cropping season. The site is located at longitude 0^o 58' W and latitude 91^o 25 N and at an altitude of 183m above sea level The area experience a unimodal rainfall of 1000-1200mm from April to November. The temperature distribution is uniform with a monthly mean value of 21^{o}C and a maximum of 34.1^{o}C. It has a relative humidity of 53%-80% (SARI, 2008).

2.2 Experimental design and treatment

The experiment comprised two cropping seasons, the 2014 and 2015 cropping seasons.

2.2.1 *Experiment 1*

For the first cropping season, Randomized Complete Block design was used. The experiment was replicated three times with each plot measuring 10m x 10m, with 2m alley between replications and 1m alley within replications or between plots. The treatments used were:

1. Sole Soybean (S)
2. Inoculated soybean (SI)
3. Soybean with P application (SP)
4. Inoculated soybean with P application (SPI)

Note: Two maize plots were established to make way for the quantification of residual P after maize cultivation and also access it impact on both maize(continuous cropping) and soybean(rotation) that follows in the farming system.

2.2.2 *Experiment 2*

The same field used for the first cropping season was used for the second cropping season. Split plot design was used in season two, where the plots in season one served as the main plots. Each main plot was divided into four sub-plots, each sub plot measuring 4m x 4m and 2m alley left between plots and reps. Where soybean was cropped in the first season, maize was cropped in the second season on the sub-plots, at an N fertilizer rate of 30N, 60N, 90N and 120Nkg/ha. On the maize main plots in the first season, soybean was cropped on the sub-plots in the second season with the treatments: sole soybean, Inoculated soybean, Soybean with P application, and Inoculated soybean with P application.

2.3 Seed inoculation

Soybean seeds (Jenguma variety) were inoculated with *Bradyrhizobium japonicum* (legume fix), using the Slurry method. 5g of *Bradyrhizobium japonicum* legume fix inoculant was used for 1kg of seeds. The inoculum was poured over the 1kg seeds of soybean seeds in the bowl after sprinkling water over the seeds. The seeds and inoculum in the bowl were mixed carefully until seeds were coated with black film of inoculants. The inoculants-coated seeds were allowed to dry for 30 minutes, after which they were planted.

2.4 Land preparation and planting

The land was ploughed and harrowed by tractor. Planting was done at a planting distance of 60 cm x 10 cm for soybean and 80 cm x 40 cm for maize. Three seeds per hill were planted and later thinned to two. Jenguma soybean variety and Aburohemaa maize variety were used for the experiment. Soybean seeds that were not inoculated were planted before inoculating seeds to avoid contamination with the inoculants. During second season each plot in the first season served as main plot and they were tilled using a hoe. A main plot was split into four subplots measuring 4 x 4 m with 2 m alley between sub plots

2.5 Fertilizer application

Soybean plots that were to receive P treatment were applied with 60 kg/ha of phosphorus. After application, the fertilizer was incorporated into the soil manually with the use of the hoe. This was done 5 days before planting. NPK at 60-30-30 kg/ha was also applied to all experimental units that received sole maize treatments for the first cropping season in split application. NPK (15-15-15) compound fertilizer at a rate of 30-30-30 kg/ha NPK was applied 2 weeks after planting (WAP). A top dressing of the remaining 30 kg/ha N was done 20 days after the first application by the use of urea. In the second cropping season, rate of fertilizer application was undertaken based on the various treatments.

2.6 Weeding

Weeding was done on the 2, 4 and 6 (WAP) weeks after planting for both cropping seasons.

2.7 Measurement of soybean variables

2.7.1 *Nodule number and effectiveness per plant*

At 8 WAP, ten plants from the two middle rows were randomly selected and gently dug out. The plants were then washed through a fine sieve with water to remove soil particles and organic debris. The number of nodules on each plant was then determined and the average nodules per plant calculated. Nodules were then sliced open to check their effectiveness. The presence of red or pink colour showed effectiveness whilst white and black colour showed ineffective nodules.

2.7.2 ***Pod number per plant***

Ten plants were randomly selected (every 5th plant was picked in the two middle rows) from the net harvest area and their pods counted to obtain the number of pods per plant. The pods from the ten plants were then added and average number taking.

2.7.3 Grain *Yield*

After threshing the pods of soybean on plot basis, grains were weighed on an electronic balance.

2.8 Maize variables

2.8.1 ***Cob length***

Cob length was measured from the point of cob's attachment to the plant point of silk formation. Five harvested cob lengths were measured and the average recorded for various treatments.

2.8.2 ***Grain yield***

Harvested cobs were threshed manually with the hand on plot basis when grains were dried to 13% moisture content. Weight was then determined using an electronic scale.

2.9 Soil sampling, preparation and analysis

2.9.1 Sampling

The double diagonal method was used for soil sampling. Initial soil samples were taken to know the available nutrient content of the soil before planting in season one. Samples were taken again after harvest and before the second planting. Soils were taken from six different places in a particular field at a depth of 0 to 30 cm using the auger. The soils were then mixed and composite samples taken at each sampling time.

2.9.2 Sample preparation

Soil samples were air-dried at room temperature for three days. All debris, plant residues, gravels and stones were removed by sieving. They were then disaggregated using porcelain pestle and mortar, and sieved with a 2 mm nylon mesh sieve to give the fine earth fraction which was used (< 2 mm) for the various soil chemical analysis. Residual nutrients left in the soil after harvest, and which could be made available to the next season crop was estimated as the difference between the initial soil nutrient and the final soil nutrient after harvest.

2.9.3 *Soil pH analysis*

Soil pH of the fine earth fraction (< 2 mm) of each air-dried soil sample was determined in a 1:1 soil to distilled water ratio (McKeague, 1978; McLean, 1982).

2.9.4 *Soil organic carbon*

The organic carbon content of the soil was determined using the wet combustion method of Walkley and Black (1934).

2.9.5 *Total nitrogen*

The total N in the samples was determined using modified Kjedahl method as described by Bremner (1996).

2.9.6 *Exchangeable potassium (K)*

Procedure described by Chapman (1965) was used for determination of soil K.

2.10. Statistical Analysis

All data collected were subjected to statistical analysis using SPSS statistical package (Version 16). The analysis of variance procedure was followed to determine differences in mean distribution of the treatments. Significant differences observed were compared using Duncan's multiple Range test at 5 % level of significance. Differences in mean between two treatments were compared using the pairwise t test at 5% probability level. Results are presented in Tables and Figures for comparison.

3.0 RESULTS

3.1. Experiment One (season one)

3.1.1. *Nutrients content of soils at the beginning and end of the experiment in season 1*

The soils, prior to planting, had pH ranging from 5.1 to 5.5 and low initial nitrogen and phosphorus levels (Table 1 and 2). After harvest, Inoculated soybean with P application (SIP) had the highest nitrogen followed by inoculated soybean (SI), Soybean with P application (SP) and Soybean only respectively (S). Residual P from soybean fields with phosphorus application was also higher than maize fields (Table 1). There was a slight increment in terms of nitrogen, organic matter and organic carbon levels of the soil before second planting

(Table 2). Generally, the soil parameters, prior to planting in season one were adequate for the growth of maize and soybean. The low level of essential plant nutrients present in the soil could be attributed to continuous cropping of the land with maize which is a heavy feeder crop that rapidly depletes plant available nutrients and results in low soil nutrients states (Grant, 1970). The low initial nitrogen levels of the soil might encourage nodule formation to enhance biological nitrogen fixation (Vesterager *et al*., 2008). The observed soil pH was suitable for nodule formation, which led to nitrogen fixation as previously reported by Bordeleau and Prevost, 1994. Van Jaarsveld *et al,* (2002) reported that, nitrogen fixation could be inhibited by very low soil pH. The insignificant differences that existed in the initial nutrient concentrations of the soil prior to planting in season one implied that any differences observed in post-harvest soil parameters are attributable to differences in treatments imposed on the soils. After harvest, plots that received the soybean seeds, inoculated with P application (SIP) had the highest fixation of nitrogen followed by Soybean with inoculation, soybean with P (SP) and Soybean only (S) respectively. Residual P from soybean field with P application was also higher than maize fields which also received similar P fertilization and this may be due to soybean seeds receiving high amount of P (60kg/ha) than maize fields (30kg/ha). There was slight increase in organic matter content of the soil from first cropping season, attributable to the plant residues left on the field after harvest (Larson, 1972). The observation of N increases in the soils of the soybean–maize rotations was anticipated because of the positive N balance in soybean production (Sarkodie Addo et al., 2006). This increase in N fixation may be the consequence of enhanced growth of the legume plants that fix the nitrogen (Sanginga et al., 2000; Jemo et al., 2010) The high P residues from soybean fields than maize fields confirms the works of Zingore et al. (2008) and Kihara et al. (2010) that, targeting P to the soybean phase of a soybean–maize rotation may increase levels of N fixation and lead to increased benefits to the maize crop in terms of N nutrition.

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Table 1: Initial, after harvest and residual N, P and pH contents of soils during the experiment at Nyankpala in the Guinea savanna zone of Northern Ghana. Same letters denotes no difference between treatments whilst different letters shows difference between treatments.

	N (kg/ha)			P (kg/ha)			pH	
Treatments	Initial	After harvest	Residual N	Initial	After harvest	Residual P	Initial	After
(SI)	3.39	**46.8**^{b}	**43.4**^{b}	**8.8**	**5.4**^{c}	**3.4**^{c}	5.4	4.8
(M1)	3.49	**5.45**^{e}	**1.96**^{e}	**6.6**	**11.0**^{bc}	**4.4**^{b}	5.3	5.3
(M2)	3.43	**4.49**^{e}	**1.06**^{e}	**7.0**	**13.2**^{b}	**6.2**^{b}	5.4	5.2
SIP	3.8	**57.3**^{a}	**54.56**^{a}	**7.3**	**13.8**^{b}	**6.5**^{b}	5.5	4.8
SP	3.86	**35.7**^{c}	**31.84**^{c}	**7.8**	**21.6**^{b}	**13.8**^{a}	5.5	4.9
S	3.5	**19.3**^{d}	**16.3**^{d}	**7.3**	**5.2**^{c}	**-2.0**^{c}	5.1	4.9
P value	0.827	**0.00**	**0.00**	**0.355**	**0.00**	**0.01**	0.827	0.195

Table 2: Nutrients content of soil prior to the second season planting in a two season soybean/maize rotational field in the Guinea savanna zone of Northern Ghana. Same letters denotes no difference between treatments whilst different letters shows difference between treatments.

Treatments	pH	N(kg/ha)	P(mg/kg)	K(mg/kg)	Organic carbon (%)	Organic matter (%)
(SI)	4.8	46.7b	2.7c	51.67	0.553	0.95
(M1)	5.3	5.45e	5.5bc	63.70	0.470	0.82
(M2)	5.2	5.44e	6.68b	64.70	0.50	0.86
SIP	4.8	57.3a	6.91b	51.33	0.523	0.90
SP	4.9	35.67c	10.80a	49.67	0.520	0.90
S	4.9	19.3d	2,62c	47.33	0.560	0.96
P value	0.195	0.00	0.01	0.002	0.16	0.16

3.1.2 Effect of inoculation and P application on grain yield and pod number of soybean

There was significant difference in grain yield among the various treatments (*P=0.006*). Inoculated soybean with Phosphorus application significantly increased grain yield more than sole application of the two (Figure 1). The effect of phosphorus application on grain yield was not significantly different from that of rhizobium inoculation.

The ttreatments significantly affected the number of pods formed (*P<.001*). Inoculated soybean with phosphorus application recorded the highest pod number. Phosphorus greatly impacted on podding more than inoculation. The results also shows that application of either phosphorus or inoculum and in combination enhances podding more than sowing soybean alone (Figure 2). The results show that inoculation was not as important as phosphorus on number of pods. Phosphorus in combination with inoculation had synergistic effect and led to higher number of pods than phosphorus alone. This results agreed with Bhuiyan *et al*. (2008) and Malik *et al*. (2006) who reported that pod number of soybean significantly increased by inoculating with Bradyrhizobium and phosphorus application. Similar to this result, Shahid *et al*. (2009) reported that seed inoculation of soybean produced more pods per plant than un-inoculated seeds. Rao *et al*. (1997) submitted that higher number of pods will be achieved when phosphorus is applied. As number of pods is an important factor to grain yield, observed difference in grain yield is attributed to the differences in the mean number of pods per plant. The high number of pods recorded in the inoculated soybean with P treatment contributed to the observed high yield. This is in agreement with the work by Bekere and Hailemariam (2012), who reported that the yield of soybean can be increased by inoculation and phosphorus application. The works by Stefanescu and Palancius (2000), Jain and Trivedi (2005), Shahid *et al.* (2009) and, Bakere and Hailemariam (2012) also show that seed yield of soybean increase with pod number, attributable to inoculation and higher levels of phosphorus.

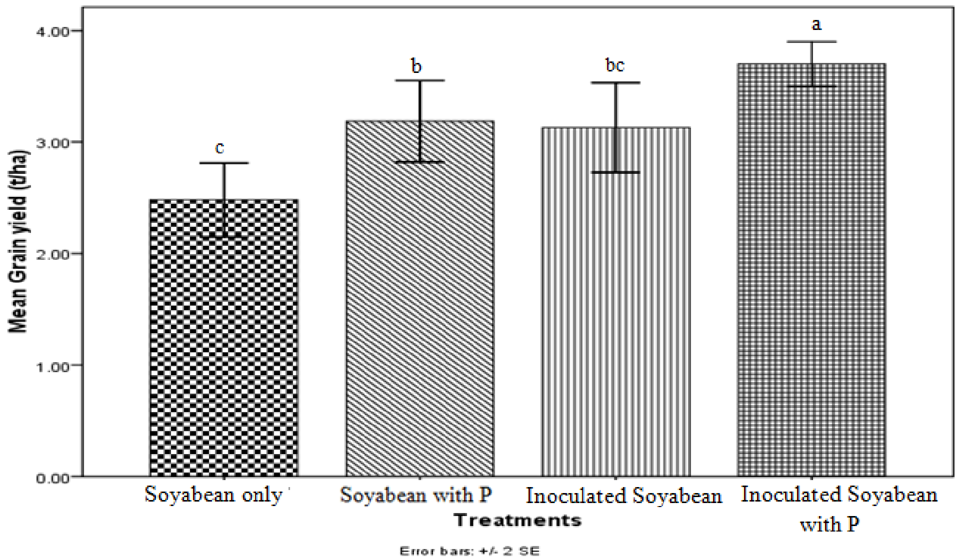

Figure 1: Effects of phosphorus fertilization and rhizobium inoculation on soybean grain yield in the Guinea Savanna zone of Ghana. Same letters denotes no difference between treatments whilst different letters shows difference between treatments.

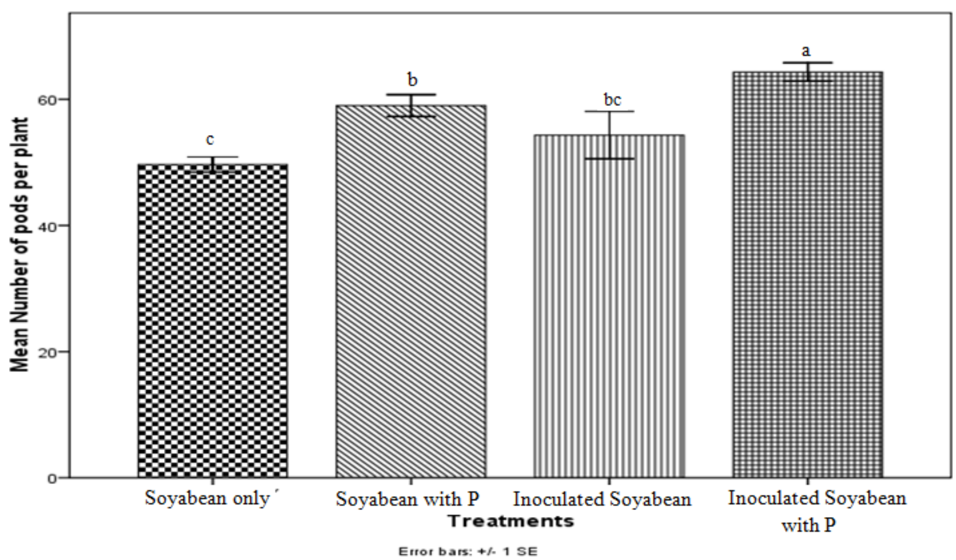

Figure 2: Effect of phosphorus fertilization and rhizobium inoculation on number of pods in the Guinea Savanna zone of Ghana. Same letters denotes no difference between treatments whilst different letters shows difference between treatments.

3.1.3 *Impact of inoculation and P application on* Number of nodules and effectiveness

Nodule number was significantly affected by the different treatments (*P=0.015*). Inoculated soybean with phosphorus application treatment was at par with inoculated soybean alone (Figure 3). Soybean with phosphorus application was not significantly different from untreated control or sole soybean. The treatments also had significant influence on nodule effectiveness among the treatments (*P=0.037*). The application of both inoculants with phosphorus application on soybean (SIP) was significantly different from the untreated control. However, individual application of inoculant and phosphorus on soybean was not significantly different from the untreated control (Figure 4). The observed significant difference in nodule number and effectiveness among different treatments could be attributed to the impact of phosphorus and rhizobium on nodule initiation and development. Phosphorous is known to initiate nodule formation, increase number of nodule primordial and is essential for the development and functioning of nodules (Waluyo *et al.,* 2004; Tagoe *et al*., 2008). Inoculating soybean with the appropriate strain of Bradyrhizobia is also known to increases the number of nodules formed by soybean (Okereke *et al*. 2000). Inoculated seeds resulted in higher nodule numbers than un-inoculated seeds. Since phosphorus is considered as one of the major factors that lead to nodule formation and effectiveness, a combined treatment of P and inoculation may explain the observed high effectiveness in nodule number, effectiveness and dry weight. This observation may go to confirm the report of Singleton *et al*. (1984) that, in addition to enhancing nodule formation, deficiency of phosphorus in legume markedly affects the development of effective nodules and the nodule leghaemoglobin content.

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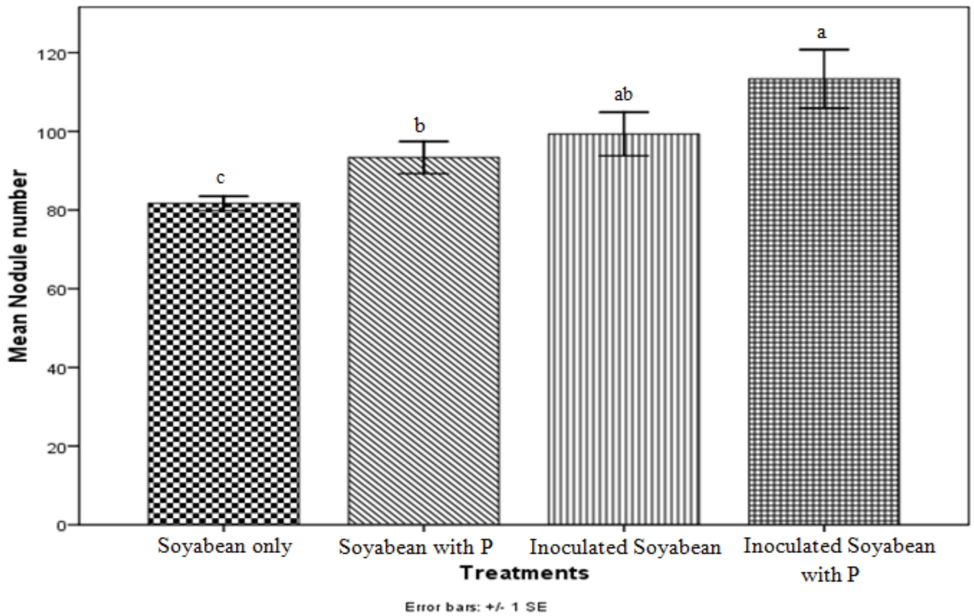

Figure 3: Effect of phosphorus fertilization and rhizobium inoculation on soybean nodule number in the Guinea Savanna zone of Ghana. Same letters denotes no difference between treatments whilst different letters shows difference between treatments.

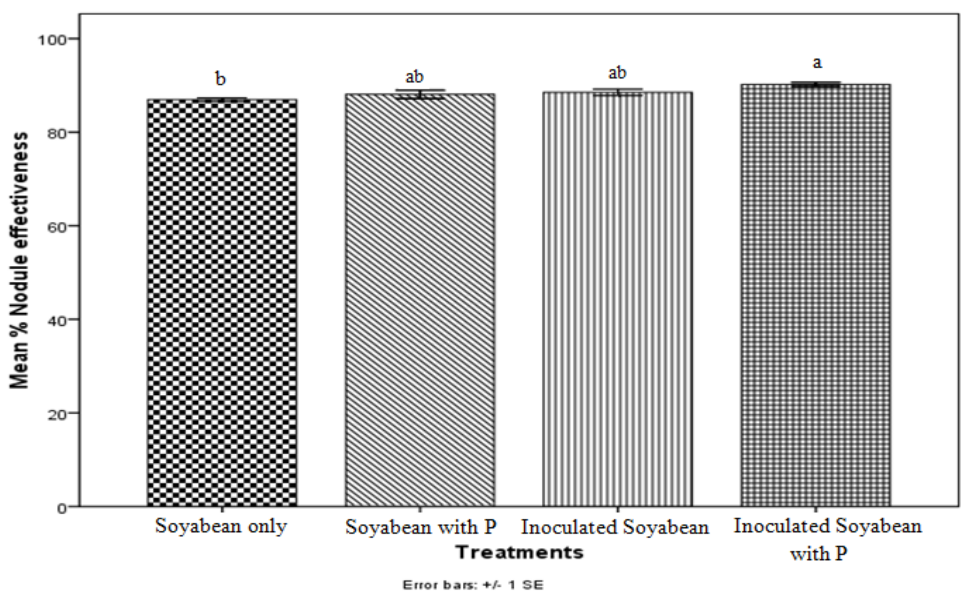

Figure 4: Effect of phosphorus fertilization and rhizobium inoculation on nodule dry weight in the Guinea Savanna zone of Ghana. Same letters denotes no difference between treatments whilst different letters shows difference between treatments.

3.2 Experiment Two (Season 2)

3.2.1 Impact of residual P from first season maize on soybean in a rotation system

Number of pods per plant was also affected by the various treatments (*P=0.004*). Inoculated soybean seeds with phosphorus application (SIP) recorded the highest number of pods followed by soybean with phosphorus application (SP), inoculated soybean (SI) and Soybean only respectively. Statistically there was no difference between inoculated soybean and soybean with P application (Figure 5). There was significant difference ($P < 0.001$) in grain yield among the various treatments. Inoculation and Phosphorus application individually was not significantly different from when the two were combined (figure 6). The treated soybean yielded better than the untreated control (soybean alone). Irrespective of season, the yield of soybean in the SIP was similar. The insignificant difference in yield of soybean between SIP, SI and SP in the second season of the maize-soybean rotation system was not realized in the first season of soybean production. In the second season of soybean production in the maize-soybean rotation system, the comparable yield of SIP, SI and SP are higher than that of SIP, SI and SP in the first season. . The observed significant differences in number of pods between treatments (Figure 5), confirms the work of Bhuiyan et al. (2008) and Malik *et al*. (2006) who concluded that pod number of soybean significantly increased by inoculating with Bradyrhizobium. Similar to this result and in the first season soybean production (Figure 3), Shahid *et al*. (2009) reported that seed inoculation of soybean produced more pods per plant than un-inoculated seeds. This result supports, also, the finding of Rao *et al*. (1997) that higher number of pods will be achieved when phosphorus is applied. The comparable (P=0.168) number of pods in the first season for SI (52) and that of SI in the second season of maize-soybean rotation system (55) indicates that number of pods did not benefit from the residual effect of the first season P application on the preceding maize crops. Irrespective of season, the yield of soybean in the SIP was similar. The insignificant difference in yield of soybean between SIP, SI and SP in the second season of the maize-soybean rotation system was not realized in the first season of soybean production. In the second season of soybean production in the maize-soybean rotation system, the comparable yield of SIP, SI and SP are higher than that of SIP, SI and SP in the first season. Since SI and SP in the first and second seasons were given the same treatments, the increase in yield of SI may be attributed to residual P left on the field after the first season maize cropping. The residual P may have provided enough available P in the second season, to increase performance of SIP and SI in the second season compared to their yields in the first season. This observation is in line with the observed high post-harvest soil P observed in the first season maize plots. Similar observations of yield increases in second season soybean crop in a maize-soybean rotation system have been reported by Pedersen and Laurer (2003). The residual soil P thus provides readily available P in the second season for increasing yield of inoculated seeds to levels that are comparable to treatments that received SIP treatment. While similar increases in yield of about 15% were observed for SP in the second season of the maize-soybean rotation system, the 15% increase in yield realized in the SI treatment, and the high benefit/cost ratio of SI compared to SIP and SP makes the SI technology in a maize-soybean production system the most productive, economical and efficient system for soybean production in northern Ghana.

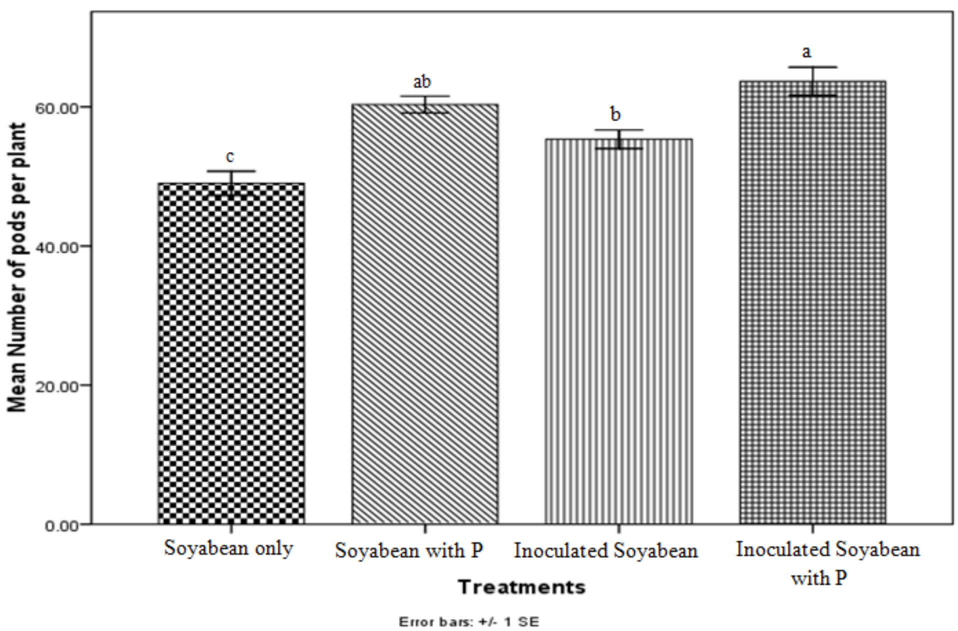

Figure 5: Effect of phosphorus fertilization and rhizobia inoculation on number of pods per plant after maize production in a rotation system in the Guinea Savanna zone of Ghana

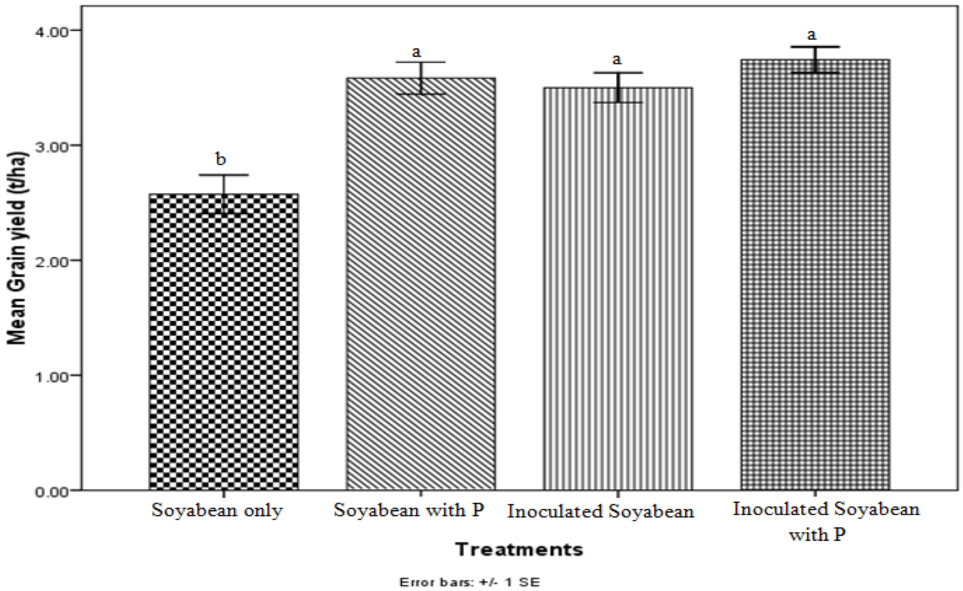

Figure 6: Effect of phosphorus fertilization and rhizobia inoculation on grain yield of soybean after maize production in a rotation system in the Guinea Savanna zone of Ghana

3.2.2 Impact of Residual Nitrogen from soybean production on maize

There was no significant interaction effect between rotation type and fertilizer rate on the cob-length of maize during the second season (Figure 7). Cob length was significantly influenced by fertilizer rate with 120 kg/ha N recording the highest value. Cropping system as sole treatment also had significant influence on the cob length with soybean-maize rotation system performing better than continuous cropping of maize that is maize followed by maize. Grain yield was significantly influenced by fertilizer rate (and rotation system however their interaction was not significant (figure 8). Inoculated soybean field with P application on which maize was planted (SIPM) recorded the highest yield at all N application rates, followed by soybean with P application preceding maize in a rotation system (SPM), inoculated soybean field followed by maize (SIM), soybean only followed by maize (SM) and maize followed by maize (MM) respectively. The highest yield of 4.3 t/ha was recorded at a fertilizer rate of 90 kg/ha N under SIPM rotation. The observed trend in cob length of the soybean production systems, followed by maize (Figure 7) show that under low N rate (30kg N/ha), maize following soybean treatments performed better than maize following maize in a rotation system. With all other soybean-maize treatments, the cob lengths were comparable higher to the sole maize cropping system. This results for the low N rate show that the second season maize crops in the soybean–maize rotation system benefits from some extra N which could not be obtained in the sole maize-maize rotation system (figure 8). This observation confirms the work of Bationo *et al*. (2000), who reported that maize that follows legume in a rotation system benefits from N which was fixed by the legume in the preceding year. The certainty associated with this observation is more pronounced in the SIPM and the SIM treatment than the other treatments: indicating a more contribution of SIPM and SIM on fixing nitrogen into the soil for the second season maize production. This observation has also been noted by some other authors (Kamh *et al*., 2002). Grain yield was significantly influenced by the interaction of rotation system and fertilizer rate SIPM at 90kgN/ha and at 60kgN/ha recorded the highest yield of 4.3 t/ha while MM at 30 kg N/ha recorded the lowest yield of about 1t/ha. Generally, soybean-maize rotation system performed better than maize-maize rotation system. This observation is similar to that of Wilhelma and Wortmann (2004), who noted that rotation of corn (Zea mays) and soybean is preferred to continuous corn production system. The rotational effect was more pronounced at the lower N rate of 30kg/ha compared to the higher N rates of 60, 90 and 120 kg/ha (Figure 8). At the lower N rate and under the Maize-Maize rotation system, less than optimum rate of nitrogen is supplied to the growing crop. This affects the grain yield of maize. The increase in yield observed at the lower rate of 30kg N /ha under the soybean-maize rotation as compared with maize-maize rotation systems is due to availability of more nutrients to the maize crop in soybean-maize rotational system. The high response to yield under the low fertilizer rate in the soybean-maize rotation systems show that the second season maize crops benefit from some extra N which could not be obtained in the sole maize-maize rotation system which confirms the work of Yusuf *et al*., (2009) who reported that, cereals benefit from N fixed into the soil whey it follows legume in a rotation system. Increases of about 130% of maize grain yield was realized in SIPM, SIM and SPM compared to the MM rotation under 30 kg/ha N. The observation in this study confirms the work of Zingore *et al*., 2008 and Kihara *et al*., 2010 that, targeting P to the soybean phase of a soybean–maize rotation may increase levels of N fixation and lead to increased benefits to the maize crop. In terms of P nutrition, it has also been shown that a maize crop can largely benefit from residual P applied to a legume in the previous season (Sanginga *et al*., 2002; Pypers *et al*., 2007). In addition to the rotation effects related to improved N uptake and to residual P effects, other rotation effects may have an impact on productivity in a soybean–maize rotation. Sanginga *et al.* (2002) and Pypers *et al*. (2007), showed that the rotation effect of mucuna on a subsequent maize results in beneficial effects in the soil that play critical role in the crops productivity.

The fore going show that SIPM at 60 kg/ha N will be the most effective system of fertility management in the northern region of Ghana. Though all production systems at 30 kg N/ha are associated with lower cost, SIPM at 60 results in more than 100% increases in yield compared to the 30 kg /ha N fertilizer levels and is associated with lower cost of production compared to the higher fertilizer levels of 90 kg /ha and 120kg /ha of N.

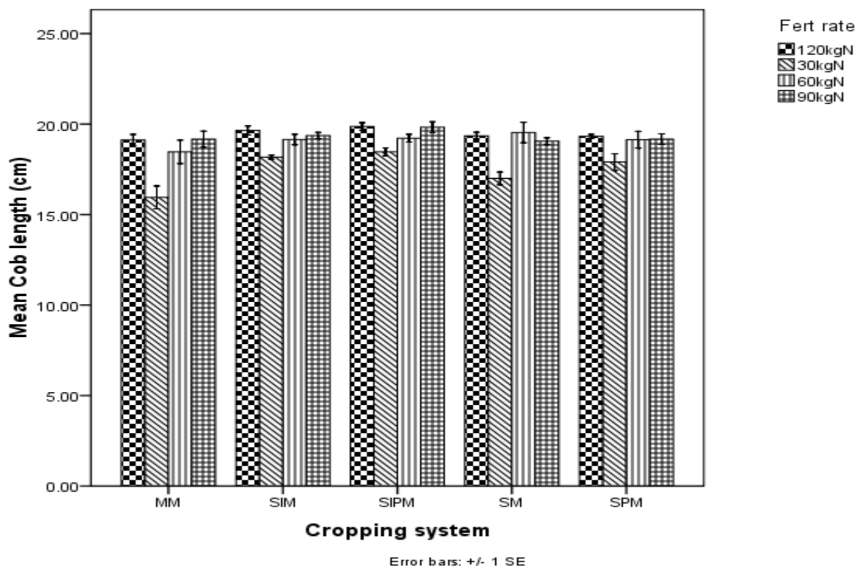

Figure 7: Effect of cropping system and nitrogen application on cob length of maize after soybean cultivation in a rotation system in the Guinea Savanna zone of Ghana

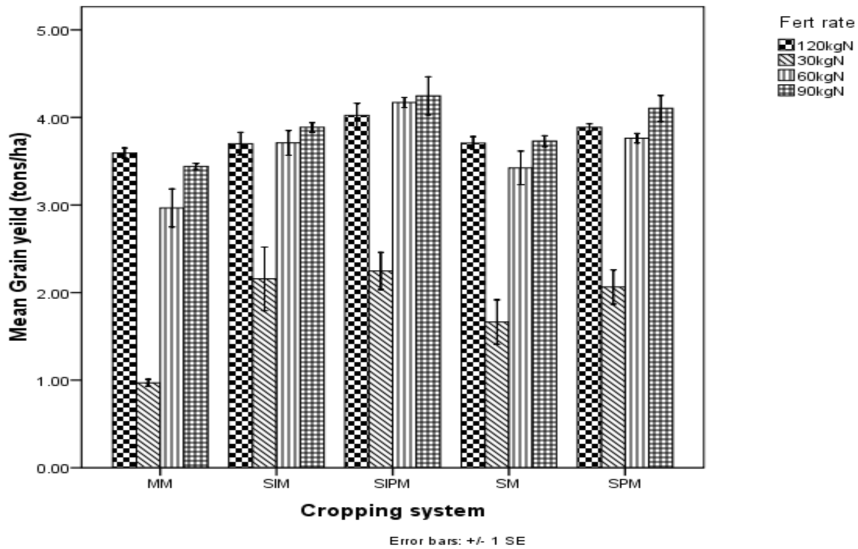

Figure 18: Effect of cropping system and nitrogen application on grain yield of maize after soybean cultivation in a rotation system in the Guinea Savanna zone of Ghana

Conclusions

Soybean production lead to an increase in soil N contents after harvest and the fixing is enhanced with inoculation and P application. This effect **affects** helps to enhance yield of maize that follows soybean in a rotation system at a lower N application rate. The application of P to maize during the first cropping season of maize-soybean rotation also leads to increase in P levels of soils after harvest, which has a positive impact on yield of soybean that is grown in the second season. Due to the above reason, it is economically appropriate to inoculate soybean seeds and avoid P application to soybean during the second season production in a maize–soybean rotation system.

Comment [M10]: What do you mean? Effect or what?

References

Alam, MA, Siddiqua A, Chowdhury MA, and Prodhan HM. Nodulation, yield and quality of soybean as influenced by integrated nutrient management. Bangladesh Agriculture University 2009; 7(2): 229-234

Bationo, A, and 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. The Journal of Agricultural Science 2000;134 (03): 277-284.

Bekere W, and Hailemariam A. Influence of inoculation methods and phosphorus rates on nitrogen fixation attributes and yield of soybean (Glycine max L.) at Ham, Western Ethiopia. African Journal of Agricultural Research 2012; 13(6): 27-69.

Bekere W, Wolde-meskel E, and Kebede T. Growth and nodulation response of soybean (Glycine max L) to Bradyrhizobium inoculation and phosphorus levels under controlled condition in South Western Ethiopia. African Journal of Agricultural Research 2012; 7(30): 4266-4270.

Bhuiyan MM, Rahman H, Afroze MM, Sutradhar F, and Bhuiyan GNC. Effect of phosphorus, molybdenum and Rhizobium inoculation on growth and nodulation of mungbean. Journal of Soil Nature.2008; 2 (2):25-30

Bordeleau, LM, and Prevost D. Nodulation and nitrogen fixation in extreme environments. In Symbiotic Nitrogen Fixation pp. 115-125. Springer Netherlands, 1994.

Bremner JM. Total Nitrogen. In Methods of soil analysis. Part 3 - Chemical methods. (D. L. Sparks, ed.), pp. 1065-1121. Soil Science Society of America Book Series 1996, Madison, USA.

Chaudhary A.R. Maize in Pakistan. Punjab Agriculture Resarch Cord. Board, University of Agriculture. Faisalabad, Pakistan 1983, pp: 312-317

Chapman, H. D. Cation Exchange Capacity. In Black, C. A., Evans, D. D., White, J. L., Ensminger, L. E., and Clark, F. E. (Eds.), Methods of soil analysis, part 1. Physical and mineralogical properties, including statistics of measurement and sampling. American Society of Agronomy, Inc. 891-901, 1965 .

Dorivar A, Ruiz D, Pedersen J. and Sawyer JE. Soybean response to inoculation and nitrogen application following long-term grass pasture. Agronomy Journal 2009; 49(3) : 1058-1062

Dugje, IY, Omoigui L0, Ekeleme F, Bandyopaolhyay, Lava Kumar RP, and Kamara AY. Guide to soybean production in northern Nigeria 2009. UTA, Ibadan. 21 pp

Giller KE. Nitrogen fixation in tropical cropping systems. Cabi. (No. 631.84 G481n). Oxon, GB: CAB International, 2001.

Jain PC, and Trivedi SK. Response of soybean {Glycine max (L.) Merrill} to phosphorusand biofertiuzers. Legume Research-An International Journal 2005; 28(1): 30-33.

Jemo M, Nolte C, Tchienkoua M, and Abaidoo RC. Biological nitrogen fixation potential by soybeans in two low-P soils of southern Cameroon. Nutrient cycling in Agroecosystems, 2010; 88(1): 49-58.

Kamh M, Abdou M, Chude V, Wiesler F, and Horst WJ. Mobilization of phosphorus contributes to positive rotational effects of leguminous cover crops on maize grown on soils from northern Nigeria. Journal of Plant Nutrition and Soil Science, 2002; 165(5): 566-572.

Kihara J, Vanlauwe B, Waswa B, Kimetu JM, Chianu J and Bationo A. Strategic phosphorus application in legume-cereal rotations increases land productivity and profitability in Western Kenya. Experimental Agriculture 2010; 46(01): 35-52

Larson, W., Clapp, C. E., Pierre, W. H., and Morachan, Y. B. (1972). Effects of increasing amounts of organic residues on continuous com: II. Organic carbon, nitrogen, phosphorus, and sulfur. Agronomy Journal, 64(2):204-209

Lawson IYD, Mensah EA, and Yeboah EN. Improving the establishment and yield of soybean through planting depth and land preparation methods in northern Ghana. West African Journal of Applied Ecology 2008; 14(1):142-167

Malik, AM, MA Cheema, HZ Khan, and MA Wahid. Growth and Yield Response of Soybean to Seed Inoculation varying P Level. Agriculture Research 2006; 44 (1): 47-56

Mapfumo P, Campbell BM, and Mpepereki S. Legumes in soil fertility management: the case of pigeonpea in smallholder farming systems of Zimbabwe. African Crop Science Journal, 2001; 9(4): 629-644.

McDonagh, JF, Toomsan B, Limpinuntana, V, and Giller, KE. Grain legumes and green manures as pre-rice crops in Northeast Thailand. Plant and Soil, 1995; 177(1): 111-126

McKeague, JA. Manual on soil sampling and methods of analysis. Ottawa, Canada: Canadian Society of Soil Science 1978. pp 72-104

McLean EO. Soil pH and lime requirement. In A. L. Page, R. H. Miller, and D. R. Keeney (Eds.), Methods of Soil Analysis, Part 2: Chemical and microbiological properties (2nd ed., pp. 199-224). Madison, Wisconsin USA: American Society of Agronomy and Soil Science Society of America, 1982.

Okereke GU, Onochie,m CC, Onyeagba E. and Ekejindu GO (2000). Response of introduced Bradyrhizobium strains infecting a promiscuous soybean cultivar. World Journal of Microbial Biotechnology 2000; 16: 43-8

Plahar WA. (2006). Overview of the soybean industry in Ghana. CSIR-food research institute. Workshop on soybean protein for human nutrition and health. Accra, 2006.34-57.

Pypers P, Huybrighs M, and Diels J. Does the enhanced P acquisition by maize following legumes in a rotation result from improved soil P availability? Soil Biology and Biochemistry 2007; 39:2555-2566

Rao IM, Borrero V, Ricaurte, J, Garcia R, and Ayarza MA. Adaptive attribute of tropical forage species to acid soils. Differences in phosphorus acquisition and utilization as influences by varying supply and soil types. Journal of Plant Nutrition 1997; 20: 155-180Research, 44 (1): 47-56

Sangakara, U. R., Richner., W., Schnelder, M. K., and Stamp, P. (2003). Impact of ntercropping beans (Phaseolus vulgaris L.) and sun hemp (Crotalariajuncea L.) on growth, yields and nitrogen fixation of maize (Zea mays L.) grown in the humid and tropics during the minor season. Maydike, 48:233-238

Sanginga N, Lyasse O and Singh BB. Phosphorus use efficiency and nitrogen balance of cowpea breeding lines in a low P soil of the derived savanna zone in West Africa. Plant Soil, 2000; 220: 119-128.

Sanginga N, Okogun J, Vanlauwe B, and Dashiell K. The contribution of nitrogen by promiscuous soybeans to maize based cropping the moist savanna of Nigeria. Plant Soil, 2002; 18(2):223-231

Sarkodie -Addo J, Adu - Dapaah, HK, Ewusi-Mensah N and Asare E. Evaluation of Medium Maturing Soybean Lines for their Nitrogen Fixation Potentials. Journal of Science and Technology 2006; 26 (2): 34 - 39.

Shahid, QM, Saleem, M.F, Khan, H.Z, and Anjum SA. Performance of soybean (Glycine max 1.) under different phosphorus levels and inoculation. Pakistan Journal of Agriculture Science, 2009; 46(4): 34-49

Stefanescu M, and Palanciuc V, (2000). Efficiency of bacterial inoculation and mineral nitrogen and phosphorus fertilization in rainfed soybean. Roma. Agriculture Research 2000; 13-14: 75-83.

Tagoe, SO, Horiuchi T, and Matsui T. (2008). Effects of carbonized and dried chicken manures on the growth, yield and N content of soybean. Plant Soil 2008; 306: 211-220

Van Jaarsve1d CM, Srnit MA, and Kruger GHJ. Interaction amongst soybean [Glycine max (L.) Merrill] genotype, soil type and inoculants strain with regards to N2 fixation. Journal of Agronomy and Crop Science 2002; 188: 206-211

Vesterager JM, Nielsen NE, and Hegh-Jensen H. Effects of cropping history and phosphorus source on yield and nitrogen fixation in sole and intercropped cowpea-maize systems. Nutrient Cycling in Agroecosystems 2008; 80(1): 61-73.

Walkley A, and Black IA. An examination of the Degtjaref method for determining soil organic matter, and a proposed modification of the chronic acid titration method. Journal of Soil Science, 1934; 37: 2-11

Waluyo, S. H., Lie, T. A. and Mannetjie, L. (2004). Effect of soybean (Glycine max) in acid soils in rhizotron experiments. Indian. Journal of Agriculture Science, S:27-44pp

Yusuf, AA, Abaidoo RC, lwuafor EN0, Olufajo OO, Sanginga N. Rotation effects of grain legumes and fallow on maize yield, microbial biomass and chemical properties of an Alfisol in the Nigerian savanna. Agriculture, Ecosystem and Environment 2009; 129:325-331

Zingore, S, Murwira HK, Delve RJ, and Giller KE. Variable grain legume yields, responses to phosphorus and rotational effects on maize across soil fertility gradients on African smallholder farms. Nutrient Cycling in Agro-ecosystem 2008; 80: 1-18