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RESEARCH ARTICLE

Productivity of Lima Bean (*Phaseolus Lunatus* L.) Cultivars Using NPK Compound Fertilizer Rates and Training Practice in the Nigerian Savanna

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ABSTRACT

Lima bean (*Phaseolus lunatus* L.) is a legume crop grown for its edible beans. Field trials were performed at the research farm Samaru, Bagauda sub-station during the wet season of 2018 (Duration month-month). The treatment consisted of two lima bean cultivars (Ex-Manchok Brown and Ex-Manchok Cream), preparation (trained and untrained) and four fertilizer levels of NPK 15:15:15 (control, 150, 300, and 450 kg ha^{-1}). Data showed that in Bagauda, Ex-Manchok Brown gave significantly higher in LAI at 6 WAS than Ex-Manchok Cream, while Ex-Manchok Brown outperformed in the number of seeds pod^{-1}, at Samaru Ex-Manchok Cream. Trained lima bean at Samaru resulted in significantly higher LAI at 9 WAS and branch numbers at 12 WAS. NPK The application of 450 kg ha^{-1} in Samaru and Bagauda resulted in the highest seed yield. The outcome of this study verified that training with 9 DAS and 450 kg ha^{-1} of NPK 15:15:15 is needed to obtain a maximum of Ex-Manchok Cream lima bean cultivar in Nigerian savanna beans.

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INTRODUCTION

Lima bean is a pulse crop normally grown for its enlarged seeds and cultivated mainly for its immature and dry seeds (Van der Maeseen and Sadikin, 1989). This bean have protein ($7.8g^{-100}$) and vitamins which, in rural areas of developing countries, can alleviate malnutrition. Dried bean seeds can be canned, according to Oliveira et al. (2004). In addition, it can be grilled, boiled and even fried in oil. The large pods and leaves are eaten in Ghana and Malawi as vegetables (Broughton et al., 2002). In addition, beans are an excellent food source for their high protein, carbohydrates, fibers and vitamins and minerals (Batista et al., 2010). But this nutritious crop was restricted to production in homestead gardens. Rapheal (2013) previous studies revealed relatively high labor input for staking. Weak agronomic practices, low soil infertility and high labor costs, lack of high yields, short term and pest/disease resistant cultivars less vulnerable to shattering, insufficient knowledge of training practices and equipment, and improper application of fertilizer are factors responsible for low yields in lima bean production.

No research institute has been charged with its genetic improvement, considering the growing knowledge and interest in lima bean. Despite their inadequacies, growers continuously rely on the local cultivars accessible. The broad variety in morphology and physiology of the available cultivars requires exploring the best-adapted cultivars to improve yields. The superiority of lima bean training over non-trained ones has been well known. However, challenged by the growing scarcity of staking content and the related training costs, the possibility of improving crop yields in non-trained crops by screening available cultivars and fertilizing crops should be explored. Lima bean reliance on nitrogen fertilizer is substantially greater than that of soy bean fertilizer (Matsushiro, 1971). The low nitrogen fixation observed in *Phaseolus* spp. can lead to three factors: delay in the appearance of root system nodule, a low root system nodule weight, and the root system nodule formation efficiency (De Jauregui, 2019). No fertilizer recommendations are currently available for the crop, with practically no focused research on the crop. There is a need to evaluate the adequate fertilizer requirement of the crop for increased yields, given the low soil fertility status in the Nigerian savanna.

In addition to the suitable cultivar/variety, the yield of beans could be accelerated by agronomic manipulation such as vine training practice and judicious application of fertilizer. Training requires controlling the shape of vines, resulting in variations in the percentage of total leaf area and leaf area well-exposed to sunlight. Consequently, the potential of leaves for photosynthesis and the resulting light microclimate could be enhanced effectively. Training programs help strike a balance between the vigour of the vine and the yield. It has led to split canopy systems that, by optimizing canopy light microclimate, could simultaneously increase yield and enhance fruit composition. There is a need to resolve these three crucial issues through rigorous research to address the incredible increase in productivity. There is a need to resolve these three important issues by rigorous research to address the unprecedented increase in productivity. The aim of this study was to govern the optimal NPK fertilizer rate and the need for training practice in order to obtain the maximum yield of lima bean cultivars in Nigerian Savanna.

MATERIALS AND METHODS

Experimental site, season and edaphic and climatic condition

The studies were performed simultaneously at two locations during the 2018 cropping season, namely Bagauda. The treatments were repeated three times in the RBD. Meteorological data were obtained from both locations during the investigation time (data not shown). Planting was performed immediately after the preparation of the ground.

Experimental treatments

Seeds were dressed with Mefenaxon-200 g kg^{-1}, Difenoconazole-20g $kg^{-1}$and Thiamethoxam-200 g kg^{-1}) at the rate of one sachet (10 grams) per 4 kg of seed. Sowing was done on 30 May 2018. At two WAS the crop were thinned to 2 plants per stands. A pre-emergence herbicide, pendimethelin (Stomp®455 gL^{-1}), at 4.0 L ha^{-1} was mixed with paraquat (Gramoxone®200 gL^{-1}) at 4.0L/ha was applied on the day of sowing. The crop was fertilized basal, according to treatment, using NPK @15:15:15 in holes 5 cm deep made between each two stands. The stakes were installed according to treatment at six weeks after sowing and connected with polyethene rope. The lima bean was trailed to the polyethene rope and poles using plastic twines. Every plot had nine stakes each 2 m long. The poles were placed on the stakes while polyethene rope was used to connect the poles. At 6 WAS the crop was given a prophylactic spray of a mixture of recommended insecticides and fungicides at recommended rates. Further sprays were done at fortnightly intervals until completion of the harvest.

Measurements and Data analysis

In order to collect data on yield and yield components, the crop was continuously harvested as a mature pod, dried and processed. For each net plot, the number of branches originating from the main vine was counted from 3 tagged plants and the mean was computed and reported at 3, 6, 9 and 12 WAS. Two plants were randomly selected in each net plot at 3, 6, 9 and 12 WAS and cut from the ground level. The mean dry weight was calculated and recorded. Leaf area index was assessed at 3, 6, 9 and 12 WAS using a Ceptometer. As stated by Blanco and Folegatti (2003), the LAI-2200 calculates leaf area index. From the third picking (the peak of operation), the number of seeds from 10 randomly selected pods. Seed wight was determined by extrapolating the seed yield per net plot to a kilogram ha^{-1}(kg ha^{-1}). The DMRT has been used to distinguish the value of the means. All statistical procedures have been determined for windows using SAS (SAS Institute, 2011).

RESULTS

Cultivar differences and training of lima bean at Samaru and Bagauda show non-significant on the number of branches throughout the study in both locations except the training at 12 WAS in Samaru which recorded a higher number of branches than non-trained (Table 1). Varying NPK fertilizer rate caused significant differences in the number of branches in both locations except at 3 WAS in Bagauda. Only the interaction between cultivar and training at 3 WAS in Bagauda significantly influenced number of branches plant^{-1}. NPK fertilization of 450 kg ha^{-1} provide greater amount of branches/plant at all sampling stages, followed by 300 kg ha^{-1} at 3 WAS in Samaru and 9 WAS in Bagauda. Both 150 and 300 kg ha^{-1} gave the comparable number of branches plot^{-1} at all stages except at 9 and 12 WAS at Bagauda when the higher rate produced significantly more branches/plants. Each cultivar produced more branches in trained condition than non-trained (Table. 2).

Non-significant differences in shoot dry weights among cultivars of lima bean were observed at both locations (Table 3). Similarly, training did not significantly influence shoot dry weights. Application of NPK @ 450 kg ha^{-1} in Samaru and Bagauda resulted in the highest increase in shoot dry weight of lima bean at all sampling stages except at 12 WAS in Bagauda where the 450 kg ha^{-1} was similar to 300 kg ha^{-1}. The 300 kg ha^{-1} NPK resulted in statistically similar shoot dry weight with 150 kg ha^{-1} at 3, 6 and 9WAS in both locations. Only the interaction between cultivar and training as well as training and NPK application, both at 9 WAS in Samaru, caused significant differences in shoot dry weight of lima bean. Shoot dry weight of only Ex-Manchok Cream significantly increased with training. (Table. 4); both cultivars gave similar shoot dry weight in each location, trained and non-trained. Application of 450 kg ha^{-1} of NPK produced higher shoot; other rates were statistically at par in each condition, trained and non-trained did not significantly influence shoot dry weight at each NPK level (Table. 5). The effect of training and NPK application on LAI of lima bean cultivars is presented in Table 6. Cultivar differences had no significant effect on LAI except at 6 WAS in Bagauda where Ex-Manchok Brown gave higher LAI than the other. Similarly, training had no significant effect in both locations except at 9 WAS in Samaru when its enhanced LAI. Application of NPK in Samaru and Bagauda each at 450 kg ha^{-1} provide greater LAI.

Table 1. Effect of training and NPK fertilizer rates on number of branches plant^{-1}

	Samaru				Bagauda			
Treatment	3 WAS	6 WAS	9 WAS	12 WAS	3 WAS	6 WAS	9 WAS	12 WAS
Cultivar (C)								
Ex-Manchok Brown	3.17	5.75	8.63	12.21	2.88	5.25	6.54	10.13
Ex-Manchok Cream	3.13	5.67	8.54	11.88	2.67	5.29	6.58	10.00
SE±	0.167	0.194	0.206	0.167	0.126	0.135	0.132	0.237
Training (T)								
Trained	3.17	5.86	8.88	12.42a	2.83	5.33	6.63	10.08
Non-trained	3.13	5.54	8.29	11.67b	2.71	5.21	6.50	10.04
SE±	0.167	0.194	0.206	0.167	0.1261	0.135	0.132	0.237
Rates of NPK 15:15:15 fertilizer (F)								
0.00 kg ha^{-1}	2.50^{c}	4.67^{c}	7.92^{b}	10.50^{c}	2.67	4.67^{c}	5.92^{c}	8.67^{c}

150 kg ha^{-1}	3.17^{b}	5.58^{b}	8.08^{b}	11.67^{b}	2.75	4.83^{bc}	6.25^{bc}	9.42^{c}
300 kg ha^{-1}	3.25^{b}	5.83^{b}	8.58^{b}	11.75^{b}	2.75	5.25^{b}	6.83^{b}	10.42^{b}
450 kg ha^{-1}	3.67^{a}	6.75^{a}	9.75^{a}	14.25^{a}	3.08	6.33^{a}	7.25^{a}	11.75^{a}
SE$\pm$	0.236	0.275	0.291	0.236	0.178	0.190	0.186	0.335
Interaction								
C x T	NS	NS	NS	NS	*	NS	NS	NS
C x F	NS	NS	NS	NS	NS	NS	NS	NS
T x F	NS	NS	NS	NS	NS	NS	NS	NS
C x T x F	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Interaction between training and NPK fertilizer rates on number of branches per plant of lima bean at 3WAS at Bagauda

Cultivar	Trained	Non-trained
Ex-Manchok Brown	3.00^{a}	2.75^{bc}
Ex-Manchok Cream	2.92^{ab}	2.42^{c}
SE$\pm$	0.264	0.152

Table 3. Effect of training and NPK fertilizer rates on shoot dry weight

	Samaru				Bagauda			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Cultivar(C)								
Ex-Manchok Brown	5.69	8.27	10.28	18.69	4.75	7.43	9.87	12.75
Ex-Manchok Cream	5.75	8.82	10.53	18.86	5.21	7.25	9.73	12.45
SE$\pm$	0.173	0.338	0.259	0.636	0.163	0.1857	0.218	0.340
Training(T)								
Trained	5.74	8.39	10.65	19.33	5.06	7.48	9.85	12.94
Non-trained	5.66	8.70	10.16	18.23	4.89	7.19	9.74	12.26
SE$\pm$	0.173	0.338	0.259	0.168	0.163	0.185	0.217	0.340
Rates of NPK 15:15:15 fertilizer (F)								
0.00 kg ha^{-1}	4.20^{c}	5.93^{c}	9.22^{b}	15.38^{c}	3.83^{c}	6.21^{c}	8.97^{c}	11.58^{b}
150 kg ha^{-1}	5.70^{b}	8.19^{b}	9.62^{b}	15.95^{c}	4.81^{bc}	7.06^{bc}	9.18^{bc}	11.53^{b}
300 kg ha^{-1}	5.98^{b}	8.72^{b}	10.02^{b}	19.86^{b}	5.13^{b}	7.18^{b}	9.76^{b}	13.21^{a}
450 kg ha^{-1}	6.99^{a}	11.36^{a}	12.74^{a}	23.91^{a}	6.15^{a}	8.91^{a}	11.28^{a}	14.08^{a}
SE$\pm$	0.245	0.479	0.367	0.899	0.231	0.262	0.308	0.481
Interaction								
C x T	NS	NS	*	NS	NS	NS	NS	NS
C x F	NS	NS	NS	NS	NS	NS	NS	NS
T x F	NS	NS	*	NS	NS	NS	NS	NS
C x T x F	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Interaction between cultivars and training on shoot dry weight of Lima bean

Cultivar	Trained	Non-trained
Ex-Manchok Brown	10.43^{a}	9.90^{b}
Ex-Manchok Cream	11.15^{a}	10.14^{ab}
SE$\pm$	1.17	

Table 5. Interaction between training and NPK fertilizer rates on shoot dry weight of Lima bean

Rates of NPK 15:15:15 fertilizer	Trained	Non-trained
0.00 kg ha^{-1}	9.43^b	9.53^b
150 kg ha^{-1}	9.86^b	9.43^b
300 kg ha^{-1}	9.83^b	9.33^b
450 kg ha^{-1}	12.56^a	12.26^a
SE±	0.734	0.721

Table 6. Effect of training and NPK fertilizer rates on leaf area index (LAI) of lima bean cultivars

	Samaru				Bagauda			
Treatment	3WAS	6WAS	9WAS	12WAS	3WAS	6WAS	9WAS	12WAS
Cultivar (C)								
Ex-Manchok Brown	0.66	1.12	1.99	2.76	0.59	1.02a	1.44	2.48
Ex-Manchok Cream	0.67	1.14	1.97	2.92	0.62	0.94b	1.36	2.45
SE±	0.020	0.024	0.046	0.059	0.024	0.026	0.070	0.066
Training (T)								
Trained	0.65	1.11	2.08a	2.85	0.62	0.98	1.43	2.55
Non-trained	0.68	1.15	1.88b	2.83	0.59	0.97	1.37	2.39
SE±	0.020	0.024	0.046	0.059	0.024	0.026	0.070	0.066
Rates of NPK 15:15:15 fertilizer (F)								
0.00 kg ha^{-1}	0.44^d	0.92^c	1.73^c	2.42^c	0.36^d	0.80^c	1.19^b	2.27^{bc}
150 kg ha^{-1}	0.56^c	0.98^c	1.85^c	2.68^b	0.48^c	0.85^c	1.20^b	2.14^c
300 kg ha^{-1}	0.74^b	1.11^b	2.04^b	3.07^a	0.66^b	1.03^b	1.48^{ab}	2.44^b
450 kg ha^{-1}	0.94^a	1.52^a	2.31^a	3.19^a	0.66^a	1.25^a	1.70^a	3.04^a
SE±	0.029	0.038	0.065	0.083	0.034	0.036	0.099	0.112
Interaction								
C x T	NS	NS	NS	NS	NS	NS	*	NS
C x F	NS	NS	NS	NS	NS	NS	NS	NS
T x F	NS	NS	NS	NS	NS	NS	NS	*
C x T x F	NS	NS	NS	NS	NS	NS	NS	NS

Table 7. Interaction between cultivars and training on leaf area index of lima bean

Cultivar	Trained	Non-trained
Ex-Manchok Brown	1.56^a	1.31^{bc}
Ex-Manchok Cream	1.43^{ab}	1.29^c
SE±	0.141	0.134

Application of 300 kg ha^{-1} of NPK gave significantly higher LAI than the lower rates except at 9 WAS in Bagauda where it is at par with all lower rates. The only interaction between cultivar with training and NPK on LAI at 9 and 12 WAS at Bagauda, respectively, were significant. With training both cultivars outperformed their non-trained form (Table. 7), and in each condition, both cultivars had similar values. At NPK rates of 300 and 450 kg ha^{-1} training significantly increased LAI differences were not significant (Table. 8). In trained, both 300 and 450 kg NPK gave comparable LAI, each further decrease in rate resulted in a significant fall in LAI. In non-trained condition, the control significantly differed in LAI with all other rates except 150 kg ha^{-1} with which it was comparable.

The effect of training and NPK fertilizer rates on the number of seeds pod^{-1} of lima bean cultivars is presented in Table 9. At Samaru Ex-Manchok Cream gave higher number of $seedpod^{-1}$ seeds $plot^{-1}$ than Ex-Manchok Brown while in Bagauda differences between cultivars were non-significant. Training had no significant effect on the number of seeds $plot^{-1}$ seed pod^{-1} in both locations. NPK @ 450 kg ha^{-1} pointedly increased number of seeds $plot^{-1}$ $seedpod^{-1}$ at Samaru but was at par with 300kg ha^{-1}, also 300kg ha^{-1} was similar to 150kg ha^{-1}, and the control have comparable number of seeds pod^{-1} to 150kg ha^{-1}. Interaction between the factors caused no significant difference in number of seeds plot^{-1} seedpod^{-1}at both locations.

Ex-Manchok Cream gave significantly higher 100-seed weight than Ex-Manchok Brown at both locations (Table. 9). The trained crop gave significantly heavier seeds than the non-trained in Bagauda while in Samaru the differences were not significant. Application NPK fertilizer rate at 150 kg ha^{-1} did not considerably alter 100-seed weight compared with control, but each further rate increases significantly increased 100-seed weight at both locations. Interaction between cultivar and training at both locations as well as cultivar and fertilization at Samaru significantly influenced 100-seed weight. Ex-Manchok Cream gave significantly higher 100-seed weight with or without training than Ex-Manchok Brown except in non-trained at Bagauda when they were similar (Table.10). Training significantly increased 100-seed weight of Ex-Manchok Brown at both locations compared to non-trained, with Ex-Manchok Brown the difference was not significant in both locations. Interaction between cultivar and NPK rate (Table. 11) shows that at each NPK level, except the control, the NPK increase caused a significant increase in 100-seed weight. At each Ex-Manchok Cream gave higher seed weight than Ex-Manchok Brown. Ex-Manchok Cream gave highest 100-seed weight at 450 kg ha^{-1} of NPK. With each cultivar, each decrease in the rate of NPK significantly reduced 100-seed weight.

Ex-Manchok Cream gave significantly higher seed yield than Ex-Manchok Brown in both locations. The trained crop gave higher seed yield than non-trained in Bagauda while in Samaru the differences were not significant. NPK application substantially influenced seed yield only at Bagauda. Seed yield were observed only in the interaction lima bean cultivar and NPK levels at Bagauda. Ex-Manchok Cream that received 450 kg ha^{-1} of NPK gave the least yield without fertilizer (Table 11). Ex-Manchok Brown showed no significant yield changes with change in NPK rate, but with Ex-Manchok Cream, the control gave comparable yield to 150 kg ha^{-1} of NPK, comparable to 300 kg ha^{-1}. At each NPK level, both cultivars did not differ in yield except when treated to 450 kg ha^{-1} of NPK when Ex-Manchok Cream out-yielded Ex-Manchok Brown.

DISCUSSION

The lima bean cultivars used in the study differed in their potential productivity, as their growth and yield characteristics differed significantly. Ex-Manchok Cream, which had comparatively larger seeds than Ex-Manchok Brown, showed consistent substantial differences for pod^{-1}, weight of 100 seeds and yield of seeds. Such differences can be due to variations in genetic composition and environmental interaction (training, moisture, abundant sunshine, soil fertility). Ambika et al. (2014) reported similar findings for seed size (Jerlin and Vadivelu, 2004).

The highest results yield traits and seed yield were obtained by the trained crop as it facilitated vigorous crop growth and creation of larger vegetative sections.

Table 8. Interaction between training and NPK fertilizer rates on leaf area index at 12WAS of lima bean at Bagauda, 2018 wet season

Rates of NPK 15:15:15 fertilizer	Trained	Non-trained
0.00 kg/ha	2.35^{c}	2.47^{c}
150 kg/ha	2.71^{b}	2.64^{bc}
300 kg/ha	3.16^{a}	2.98^{b}
450 kg/ha	3.41^{a}	2.99^{b}
SE±	0.12	0.10

Table 9. Effect of training and NPK fertilizer rates

	Samaru			Bagauda		
Treatment	Number of seeds pod^{-1}	100seed weight (g)	Seed yield (kg ha^{-1})	Number of seeds pod^{-1}	100-seed weight (g)	Seed yield (kg ha^{-1})
Cultivar (C)						
Ex-Manchok Brown	3.17^{b}	25.88^{b}	1730.40^{b}	3.00	24.38^{b}	118.89^{b}
Ex-Manchok Cream	3.71^{a}	28.65^{a}	1790.90^{a}	3.08	25.58^{a}	219.49^{a}
SE±	0.069	0.320	159.00	0.071	0.297	23.270
Training (T)						
Trained	3.50	27.41	1986.70	3.08	25.64a	237.83a

Non-trained	3.38	27.12	1534.60	3.00	24.32b	100.55b
SE±	0.083	0.320	159.00	0.072	0.297	23.270
Rates of NPK 15:15:15 fertilizer (F)						
0.00	3.17[c]	25.13[c]	1630.00	2.92	23.01[c]	66.02[c]
150	3.33[bc]	25.28[c]	1667.90	3.00	23.71[c]	93.28[c]
300	3.50[ab]	27.98[b]	1800.40	3.08	25.62[b]	210.36[b]
450kg/ha	3.75[a]	30.68[a]	1944.40	3.17	27.58[a]	307.08[a]
SE±	0.099	0.453	224.860	0.102	0.420	32.901
Interaction						
C x T	NS	**	NS	NS	**	NS
C x F	NS	**	NS	NS	NS	**
T x F	NS	NS	NS	NS	NS	NS
C x T x F	NS	NS	NS	NS	NS	NS

Table 10. Interaction between cultivars and training on 100-seedseeds weight of lima bean at Samaru and Bagauda include SE for non-trained

Cultivar	Trained	Non-trained
	Samaru	
Ex-Manchok Brown	25.46[c]	26.31[c]
Ex-Manchok Cream	29.36[a]	27.93[b]
SE±	0.45	0.34
	Bagauda	
Ex-Manchok Brown	24.48b	24.28[b]
Ex -Manchok Cream	26.80a	24.36[b]
SE±	0.42	0.40

Table 11. Interaction between cultivars and NPK 15:15:15 fertilizer rates on 100-seed weights of lima bean at Samaru and seed yield of lima bean at Bagauda include SE for Cream

Rates of NPK 15:15:15 fertilizer	Ex-Manchok Brown	Ex-Manchok Cream	Ex-Manchok Brown	Ex-Manchok Cream
0.00 kg ha^{-1}	25.33[ef]	24.92[fg]	69.22[c]	62.82[c]
150	23.78[gh]	26.78[cd]	63.19[c]	123.38[bc]
300	26.43[de]	29.52[b]	189.57[bc]	231.15[b]
450	27.98[bc]	33.37[a]	153.56[bc]	460.60[a]
SE±	0.64	0.52	46.53	52.46

This is further verified by the low output of the non-trained seedlings due to the shading effect of some leaves, resulting in a decrease in growth and yield characteristics, possibly due to light competition, which is a growth and development necessity. In line with Takusewanya et al. (2018), sticks and polyethene rope were used for these experiments at 6 WAS, which stated that bean staking is accomplished at different growth stages. Staking in the production of climbing beans is a very useful agronomic approach (Lwakuba et al., 2003). The thin, long branches encouraged by stakes. It increases the aeration of qualified beans, which, compared to bush beans, decreases the impact of pests and diseases.

Some growers show half of the fertilizer and place the other half next to the planting row. When plants start to climb, side dress with 20 to 25 kg of N ha^{-1} and again when the first blooms set fruit. Where leaching rains occur, additional side dressing can be required. Beans are very vulnerable to injury from fertilizer. Kamara et al. (2011) who suggested that N contributes to the photosynthetic activities, vigorous growth, and the leaves' dark green (Bown, et al., 2010; Zhao et al., 2008). According to (Bargaz et al., 2012), nodular numbers and plant production are increased by phosphorus fertilization.

CONCLUSION

Results of this study confirm that the cultivation of trained Ex-Manchok Cream under 450 kg ha^{-1} of NPK could be the best practice for the highest productivity of Lima bean in the Nigerian Savanna.

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