International Journal of Environment, Agriculture and Biotechnology
Vol-9, Issue-3; May-Jun, 2024
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Prospects and strategies for enhancing Phosphorus efficiency in Soybean production in the Nigerian savannah Regions: A review

D.A. Adeshina[1]*, S.E. Adeboye[1], H. Garba[2], B. Hanis[1], O.F. Osisami[1], E. Ighedosa[1]

[1]Agricultural Biotechnology Department, National Biotechnology Research and Development Agency (NBRDA), Abuja.
[2]Department of Extension services, Niger State Agricultural and Mechanization Development Authority (NAMDA), Minna.
Corresponding author: dollyadeshina@yahoo.com

Received: 29 Mar 2024; Received in revised form: 05 May 2024; Accepted: 15 May 2024; Available online: 24 May 2024

Abstract— *Low crop production negatively affects most farming systems in Sub-Saharan Africa (SSA). Grain legumes like soybeans (Glycine max (L.) Merrill) tend to have lower yields in SSA due to various biological and environmental factors. Soybean is susceptible to low soil Phosphorus (P) levels and requires large amounts of P for adequate biological nitrogen fixation through its root nodules. Unfortunately, most small-scale African farmers face difficulties affording the exorbitant costs of mineral fertilizers as over 75% of the fertilizers used are imported, which puts a significant strain on local currencies. This research study has examined previous and ongoing interventions in phosphorus application, explicitly focusing on soybean cultivation in the savannah ecological zones of Nigeria. The aim is to identify the most effective ways to advise farmers on enhancing production and encouraging the adoption of efficient Phosphorus application methods to achieve optimal yields in the face of climate change challenges. The study's significant findings include the following key points: (1) Understanding the crop's morphology to guide appropriate varietal selection. (2) Identifying the soil qualities necessary for successful Soybean cultivation. (3) Determining the appropriate rate of Phosphorus application for optimal results. (4) Selecting the most efficient method of Phosphorus application. (5) Timing the application of Phosphorus correctly to maximize its effectiveness.*

Keywords— ***biological nitrogen fixation, internal use efficiency, Phosphorus deficiency, Phosphorus efficiency.***

I. INTRODUCTION

Grain legumes are leguminous plants that produce dry, edible seeds. Soybean (*Glycine max* (L.) Merrill) holds global economic importance among these legumes. They are known for their substantial economic value as they contain a high oil content of around 18% and high-quality proteins of approximately 40%. In addition to its economic value, Soybean is crucial in enhancing soil fertility, promoting high productivity, and ensuring profitability in agricultural systems. Due to these remarkable attributes, experts often call Soybeans a "miracle crop" (Rajni *et al.*, 2020). Phosphorus (P) is a crucial nutrient limiting biomass production in legumes as it plays vital roles in various aspects of plant development. It is a key component of nucleic acids, proteins, ATP (adenosine triphosphate), genetic material, and energy storage and transfer. It is also essential for important plant processes such as photosynthesis, regulation of enzymatic activities, root development, and seed formation. Hence the application of P is reported to affect most Soybean growth and yield parameters (Tehulie *et al.*, 2021). This point was buttressed as Phosphorus absorption created a direct stimulation of cellular exercise in roots and leaves because it is a constituent of enzymes and proteins; adenosine diammonium phosphate (ADP), adenosine triphosphate (ATP), ribonucleic acids (RNA) and deoxyribonucleic acids (DNA). However, the extra addition of Phosphorus negatively influences soybean boom parameters such as leaf area, number of leaves per plant, leaf location index, number of nods per plant and spread of plants and others (Tehulie *et al*., 2021). The availability of Phosphorus is a critical factor that influences nitrogen fixation and the overall nitrogen economy in various tropical ecosystems (Bello, 2015). Yang *et al*. (2022) observed from their study that Leaf area index and plant height were generally increased with P in plants as it enhances leaf expansion, increasing light interception for photosynthesis and greater assimilating accumulation, they buttressed that P is an indispensable nutrient requirement for Soybean. In legumes, a deficiency of P has a substantial negative impact on growth and biomass accumulation. Insufficient P levels can constrain the proliferation of a population of free-living rhizobia in the rhizosphere consequently affecting nodulation and impairing nodule function. Ultimately, this limitation on nodulation and impaired nodule function hampers the overall growth of the host plant (Bello, 2015). Furthermore, Phosphorus (P) can enhance plant resistance by influencing the activation of genes related to resistance and defense characteristics through the jasmonate signalling pathway reducing susceptibility to various fungal diseases. Similar findings in other crops support this notion, as studies have shown that phosphorus application induces systemic resistance in Cucumber plants against *Colletotrichum legendarium* (the pathogen causing anthracnose) and in beans against *Uromyces viciae fable* (the pathogen causing rust) (Tchemadon *et al*., 2021).

Phosphorus efficiency is a plant's capacity to uptake phosphorus from the soil and efficiently employ it in the production of biomass or the development of harvestable organs (Tehulie *et al*., 2021). The Nigerian Savannas have experienced a significant boost in Soybean production due to the introduction of improved varieties. However, this production's sustainability could increase by improving the soil's prevalence of low phosphorus (P) levels. Compared to cereal crops, Soybean is more susceptible to Phosphorus insufficiency and drought, which prevents the attainment of their potential yield (Tehulie *et al*., 2021). In the tropical and subtropical regions where Soybean cultivation is widespread, the soils typically have a high capacity for phosphorus fixation, resulting in limited availability of Phosphorus for crops (Yang *et al*., 2022). Research has highlighted P-level variations across distinct Savannah regions in Nigeria. Soil phosphorus (P) levels in the Sudan and Guinea savannas of Northeast Nigeria are found to be majorly insufficient. P levels varied between 0.3 and 10.4 mg/kg in the Southern Guinea Savanna (SGS) in the Sudan Savanna (SS) spanned from 0.3 to 7 mg/kg. While in the Northern Guinea Savanna (NGS), the range was 1.4 to 9.5 mg/kg. Significantly, the study reported that most fields surveyed in these regions had P levels below the critical values (5-7 mg/kg) recommended for the Nigerian Savanna. Phosphorus deficiency was observed in 78% of fields in the Southern Guinea Savanna (SGS), 93% in the Sudan Savanna (SS) and 92% in the Northern Guinea Savanna (NGS) (Bello, 2015).

II. MATERIALS AND METHODS

This research was conducted as a review work. It was based on a systematic review of research publications where Phosphorus efficiency in Soybean fields played a central role. The literature analysis was first contextualized by presenting a brief overview of related scholarly articules, presenting a descriptive methodological analysis of field approaches in the production of Soybean. The review is descriptive and follows an integrative synthesis approach, which "attempts to summarize the contents of multiple studies and minimizes any interpretation on the reviewer's part". Several peer-reviewed journals and articles reporting the results of quantitative and qualitative research studies in Soybean production were utilized (Krippendorff, 2018).

This research was conducted as a review work. It was based on a systematic review of research publications where Phosphorus efficiency in Soybean fields played a central role. The literature analysis was first contextualized by presenting a brief overview of related scholarly articles and a descriptive methodological analysis of field approaches in Soybean production. The review is descriptive and follows an integrative synthesis approach, which "attempts to summarize the contents of multiple studies and minimizes any interpretation on the reviewer's part." Several peer-reviewed journals and articles reporting the results of quantitative and qualitative research studies in Soybean production were utilized (Krippendorff, 2018).

2.1 Collation and analysis of articules

Data from peer-reviewed journal articles were systematically selected and analyzed. This approach provides valuable insights into the effectiveness and impact of Phosphorus in Soybean production. This method conformed to the one Snelson (2016) used in selecting and analyzing reports, which proceeded through four stages: pre-research, search, data cleaning, and analysis.

2.1.1 Stage 1: Pre research

A thorough pre-research was conducted to conceptualize the topic and develop a clear and focused research plan by *defining the Scope*: The specific terminologies in Phosphorus efficiency in Soybean cultivation were thoroughly researched. *Literature Review***:** An extensive literature review to understand the existing research and theories identifying key concepts, trends, and gaps. *Timeline and Resources***:** A timeline was developed for the research project, identifying resources needed, such as access to literature databases. *Potential Impact***:** the potential impact of the research and how the findings contribute to efficient Soybean cultivation theory, practice, and policies were observed.

2.2.2 Stage 2: Search

Google Scholar was included as one of the databases searched for during this literature review due to its broad reach across interdisciplinary academic scholarship indexed on the Internet and its use in prior literature review studies (Snelson, 2016).

2.2.3 Stage 3: Data Cleaning

The eligibility of articles for the review was determined by reviewing both abstracts and full-text copies. Selection criteria included publication in a peer-reviewed journal or academic literature, relevance to Soybean cultivation research, and the availability of a full-text English version of the article (Snelson, 2016).

2.2.4 Stage 4: Analysis

A qualitative content analysis methodology, based on a multiphase approach, was used to review the content at different time points and cross-check results for consistency. The articles had all been reviewed for eligibility for the study during the data-cleaning stage, but the actual analysis of content began with a round of review and tagging (Snelson, 2016).

III. RESULTS AND DISCUSSION

3.1 Achieving Phosphorus Efficiency in Soybean Production in The Savanna Regions of Nigeria.

Depending on the fertilisation method, tillage system, and variety employed, the response of soybeans to P fertilisation can vary. The high cost of P fertiliser in SSA restricts its use, while organic inputs' low P content prohibits them from releasing sufficient P for optimal crop growth (Bello, 2015). Phosphorus is immobile in soil; therefore, plant uptake of Phosphorus may additionally be low in the first year after application (Tehulie *et al*., 2021). Studies have shown that using phosphate sources with associated technologies increased the soybean crop's relative agronomic efficiency and productivity (Soares *et al*., 2021). The following should be considered to achieve phosphorus fertilizer efficiency;

3.1.1 Varietal Selection

The selection of the appropriate Soybean variety significantly impacts the efficiency of P. Different Soybean cultivars exhibit varying responses to factors like flood irrigation, and the root system of the plants plays a crucial role in adapting to adverse conditions such as dry regions or poorly drained soils (Nunes *et al*., 2021). The interaction between varieties and Phosphorus on the yield of Soybeans planted on a field in the Gwagwalada area (North Guinea Savannah) of Nigeria is presented in Table 1. The V x P interaction significantly impacted the yield (Kg/ha), indicating that all varieties exhibited higher yields with Phosphorus than the control. Moreover, there was variability among the different varieties at the same Phosphorus application rate, with certain varieties demonstrating notably higher yields. This pattern was consistent in the in two trial locations in Borno State (Sudan Savannah) during the 2004 and 2005 cropping seasons (Table 2). as well as the Lafia (North Guinea Savannah) during the 2018 and 2019 cropping seasons (Table 3),

Table 1: Interaction between Varieties and Phosphorus on the Yield (Kg/ha) of Soybean in 2022 at the University Research farm, Gwagwalada, Abuja

Yield (Kg/ha)			
	Phosphorus levels (Kg/ha)		
Varieties	**0**	**20**	**40**
TGX 1485-1D	2054.1e	2322.9d	2633.9bc
TGX 1448 -2E	2148.7e	2484.3cd	2971.5a
TGX 1987-10F	2413.4d	2711.6b	2972.2a
SE± 59.87			

Means followed by the same letter(s) are not significantly different at 5% level of probability (DMRT), SE=Standard error

Culled from effects of Rhizobium (*Bradyrhizobium japonicum*) inoculation and phosphorus fertilizer rate on the nodulation, growth and yield parameters of soybean [*Glycine max* (l.) Merrill] varieties in the Southern Guinea Savanna of Nigeria by Adeshina (2023).

Table 2. The yield (kg/ha) of four Soybean varieties assessed under three P fertilizer rates in two trial locations in Borno State in 2004 and 2005 cropping seasons.

	Phosphorus levels (Kg/ha)		
Variety	**0**	**20**	**40**
TGX 1448 -2E	1200	1850	2110
TGX 1904 -6F	1280	1890	2180
TGX 1485 -1D	1190	1870	1960
TGX 1830 -20E	1280	1910	1810
Mean	1240	1880	2020
SED (Phosphorus)		70	
SED (Variety x Phosphorus)		140	

(r =0.82, $p \leq 0.001$), number of pods per plant (r =0.67, $p \leq 0.001$), and seed weight (r =0.66, $p \leq 0.001$). Grain yield was also weakly but significantly associated with harvest index.

Culled from Phosphorus effects on yield of Soybean by Kamara *et al*., 2007.

Table 3. Impact of Phosphorus and Variety on Seed yield of Soybean during the 2018 and 2019 cropping seasons in Lafia.

	Seed Yield (Kg/ha)		
Treatment	**2018**	**2019**	**Combined**
Phosphorus (Kg/ha)			
0	949.0[d]	958.0[d]	953.5[d]
13	1068.7[c]	1110.0[c]	1089.4[c]
26	1289.0[b]	1306.0[b]	1297.5[b]
39	1561.3[a]	1606.7[a]	1584.0[a]
LSD (0.05)	0.46	0.42	0.8
Variety			
TGX 1985 -10F	834.0[c]	853.3[c]	843.7[c]
TGX 1987 -10F	1126.0[c]	1160.7[c]	1143.4[c]
TGX 1448 -2E	949.3[d]	952.0[d]	950.7[d]
TGX 61987 -62F	1543.3[b]	1526.7[b]	1535.0[b]
TGX 1989 -19F	1591.7[a]	1624.0[a]	1607.9[a]
TGX 1835 -10E	786.7[f]	803.0[f]	794.9[f]
LSD (0.05)	0.56	0.51	0.9
Interactions			
P x V	NS	NS	NS

Values of the same letter (s) in each column of treatment group are not significantly different at 5% level of significance. NS – Not significant.

Culled from Seed yield and economic returns of Soybean (*Glycine max* (L.) Merill) influenced by Phosphorus fertilizer rates and varieties at Lafia, Nasarawa State by Jibrin *et al*., 2021.

These results buttress the point that several Soybean varieties have been developed to thrive in different environmental conditions to ensure proper absorption of soil P, optimal growth, and long-term crop productivity. The interaction between soil P and roots occurs primarily through diffusion; it is essential to have roots capable of effectively absorbing the nutrient, thus emphasizing the importance of a robust root system for P availability (Nunes *et al*., 2021).

Soybeans employ various strategies to acquire P, which involve a combination of below-ground morphological, physiological, and symbiotic traits (Wang *et al*., 2022). The roots display a high degree of plasticity, both physiologically and morphologically, in response to the availability of nutrients in the soil. It is essential to avoid high concentrations of P in a small volume of soil, as it can harm the apical meristem of the roots (Nunes *et al*., 2021). Therefore to achieve optimal yields it is imperative that the variety suitable for a region should be used.

3.1.2 Rate of fertiliser applied

Phosphorus fertilizer administration poses significant challenges in many tropical soils due to their low native content and the high immobilization within the soil. It is a reactive element which does not exist in its elemental form in the soil; as such most of the P in most soils is present in insoluble forms that are inaccessible to plants. Excess and under-application of Phosphorus will adversely affect soybean growth, yield and yield components (Tehulie *et al*., 2021). From an agronomic perspective, it is essential to employ crop management strategies that increase P efficiency and decrease the demand for fertilizers (Ibrahim and Ibrahim, 2019). In fertile soil, an extensive element of the total Phosphorus is in slightly soluble forms, which act as a "ready reserve" to fill up the pool of soluble Phosphorus as it is depleted by other organisms (Ibrahim and Ibrahim, 2019). Continuous application of P fertilizers to soybeans may lead to a build-up of available P in the soil, reducing the subsequent P application rate. Several studies have evaluated the response of Soybeans and other crops to applied and residual P in the soil (Bello, 2015).

Scientists agree that Soybean responds to P readily, but the optimum level has remained in contention, hence, figuring out the ranges of Phosphorous fertilizer is an essential consideration for maximizing crop yield. The recommended rates for phosphorus use vary by location and are determined by the local soil conditions (Tehulie *et al*., 2021). In the survey in Gwagwalada 2022 to evaluate different Soybean varieties at varying phosphorus rates, 40KgP/ha rate showed the highest yield for all varieties studied (Table 1). In Borno, a rate of 40KgP/ha resulted in the highest yield across all varieties (Table 2), while for the case of Lafia, the optimal rate was 39KgP/ha (Table 3) under examination. These results can be attributed to the notable role Phosphorus plays in improving soybeans' growth yield and quality. Findings showed that the nodule formation of Soybeans is directly dependent on applying P fertilizer. However, though the application of Phosphorus increases the yield of soybeans, on the other hand, the application of surplus quantity will lead to adverse effects on the yield of soybeans (Khan *et al*., 2020). This position was supported by Soares *et al*. (2021) who suggested that applying Phosphorus (P) fertilizer resulted in a positive response in Soybean grain yield as it facilitated the biological nitrogen fixation process by nodules in legumes, which depend on an ample Phosphorus supply. However excessive application of Phosphorus can restrict plant nodulation. Accurate estimation of crop nutrient demand, seed nutrient removal, and the availability of nutrients from native soil sources is essential for sustainable fertilization and balanced nutrition. Achieving these objectives requires optimizing nutrient use efficiency (Bomeisl *et al*., 2020).

3.1.3 Internal Use Efficiency

The commonly employed metric for guiding fertilizer recommendations is internal use efficiency, defined as the total nutrient uptake or removal with seeds per unit of seed yield. This approach operates under the assumption that replenishing seed nutrient removal is necessary to maintain nutrient budgeting (Salvagiotti *et al*., 2021). Beyond nutrient uptake, it is crucial to consider the proportion of seed nutrient removal and the nutrients remaining in residues to effectively quantify fertilizer repositioning and estimate nutrient recycling within the system (Salvagiotti *et al*., 2021). Based on the local soil conditions, different regions have different suggested rates for using Phosphorus (Tehulie *et al*., 2021). The application of a phosphorus fertilizer showed an increase in agronomic efficiency at 40 and 80 kg/ha P_2O_5, and the highest values of agronomic efficiency were obtained at doses above 80 kg/ha P_2O_5. Usage of the appropriate phosphorus fertilizer rates promotes the growth of Soybean significantly (Soares *et al*., 2021, Tehulie *et al*., 2021).

3.2 Method of Phosphorus application.

Aside from determining the optimal rate for each region, the application method is critical to success. Given that phosphorus is recognized as a non-mobile nutrient in the soil the fertilizer placement strategy can greatly improve nutrient use efficiency for different soybean varieties consequently affecting their productivity (Rosa *et al*., 2020). Ensuring sufficient phosphorus uptake, promoting crop growth, and achieving optimal grain yield over the long term requires the implementation of management systems that enhance the bioavailability of phosphorus in the soil and facilitate its accessibility by plant roots. Some application methods used for fertilizer placement include broadcast and incorporation, pinnacle dress, seed-positioned Phosphorus, and aspect banding phosphorus. Under the no till system of cropping using the broadcast and band placement methods is advantageous. This is due to the advantage in labour, cost and time of application. It has also been observed that applying P to the surface makes it more accessible to plant increasing access to the roots as P is a highly immobile nutrient (Rosa *et al*., 2020). In non-tillage systems, there is a notable difference in the depth distribution of Phosphorus, with P accumulating in the fertilizer application zone. This zone is typically within 0-5 cm deep for broadcast application, while for row application, it extends to 5-10 cm deep. In contrast, traditional tillage results in a more uniform dispersion of phosphorus throughout the soil profile, exhibiting relatively higher concentrations below 10 cm deep. Despite these disparities in distribution, the average phosphorus content in the 0-20 cm profile remained comparable across both soil management systems and application modes (Nunes *et al*., 2020). Applying phosphate fertilizer in rows reduces soil contact, leading to a smaller fertilized area. However, this method enhances phosphorus availability compared to broadcast application and reduces the depth gradient (Nunes *et al*., 2020). Research findings indicated that the application of phosphorus in bands near soybean seeds produced superior outcomes compared to broadcast treatment in soils characterized by low phosphorus levels (Rosa *et al*., 2020).

3.2.1 Timing of Phosphorus application

The timing of application plays a significant function in the proper development of crops, as some strategies are more environmentally friendly than others (Tehulie *et al*., 2021). Band applications of P fertilizer aid in optimizing P availability during Soybeans' early growth and reproductive (Rosa *et al*., 2020). Research has indicated that around 75% of Soybeans' P concentration in the seeds and the yield are greatly influenced by its uptake during the reproductive stages as the highest P uptake occurs at this period and employing management strategies that improve P uptake is crucial during this growth stage.

3.3 Choice of soil used for planting

The soil used for planting is a critical factor in achieving Phosphorus efficiency as the soil pH., Soil type, Soil Cation exchange capacity (CEC), and availability of Organic materials play a significant role.

3.3.1 Soil pH

Soil pH is the degree of hydrogen ions present in the soil and is represented by a negative logarithm of hydrogen ions concentration; it indicates the general chemical environment in the soil. It is a measure of relative acidity and alkalinity. A soil of pH 7.0 is neutral; *acid soils* are defined as soils with pH below 7.0 and above seven are alkaline. The pH of the soil influences the nutrient available to plants as it plays a crucial role in influencing the availability of P, plant nutrients, and microbial activity, including atmospheric nitrogen (N) fixation by nodules. Limited phosphorus availability in tropical soils poses a notable constraint to soybean production. Studies indicate that optimal phosphorus availability occurs within a pH range of 6 to 7. In ferrasols, the pH typically ranges from 5.0 to 6.0, and several other soil properties can impact nutrient availability (Philips, 2021). Phosphorus is readily available in soils with slightly acidic to near-neutral pH levels. However, P is a nutrient that exhibits low mobility in soil and is naturally deficient in acidic soils. Its availability is regulated by solubility and the propensity to become fixed in the soil through reactions between aluminium and phosphorus, forming insoluble phosphate precipitates. P-fixing soils are common in tropical regions, and highly weathered tropical soils possess a high capacity to adsorb P, consequently reducing the availability of P inputs for crops (Bomeisl *et al*., 2020).

Soybean roots take up Phosphorus primarily in the ionic structure of either H_2PO_4 or HPO_4 (orthophosphate). The ionic form that is predominantly absorbed depends on soil pH; H_2PO_4 is easily absorbed in low-pH soils, whereas PHO_4 is preferentially absorbed in high-pH soils. There are two forms in which Phosphorus can exist in water: dissolved (soluble) and particulate (affixed to or a part of particulate particles). Ortho phosphorus is the principal dissolved phosphorus structure accessible to algae and aquatic plants. Most Phosphorus discharged from wastewater remedy services is dissolved (Tehulie *et al*., 2021). Soil's acidity hinders the symbiotic fixation of N_2, limits Rhizobium survival in the soil, decreases nodulation, and leads to nutrient imbalance. Challenges with soil acidity constitute a significant factor in low yields, weak plant vigour, and nodulation of legumes. At a pH of 4.3, Rhizobium rhizosphere growth and nodulation were inhibited (Dabessa and Tana, 2021). When the soil pH is 7.0, both types of P exist in equal quantities. However, as the pH level increases beyond 7.0, the dominance of P shifts towards the secondary orthophosphate ion. Its uptake is frequently constrained under very low solubility in the soil (Tehulie *et al*., 2021). The pH of the soil plays a crucial role in influencing the survival and longevity of beneficial microorganisms, such as Rhizobia, and their interactions with plant roots; It influences the function and association of arbuscular mycorrhizal (AM) fungi with plant roots. In acidic soils, there tends to be an abundance of acidobacteria, which are potential antagonists of fungi, including AM fungi, suppressing their activity (Wang *et al*., 2022). In the Western and Eastern Wollega Zones of Ethiopia, farmers had to temporarily or permanently abandon their land (fallowing) in certain areas due to the challenges of poor fertility and soil acidity However, with increasing population pressure, abandoning farmland is no longer feasible. As a result, farmers are adopting soil fertility management practices to sustain productivity and address the challenges of soil acidity and low fertility (Dabessa and Tana, 2021). It is not recommended to utilize highly soluble Phosphate fertilizer sources that have a higher capacity for P adsorption in acidic tropical soils. These soils can quickly convert P to less available forms and decrease fertilizer efficiency. Instead, it is advisable to use reactive natural P sources that promote gradual phosphorus solubilization. This approach limits specific adsorption by clays and enables greater fertilizer efficiency, which is more desirable (Nunes *et al*., 2021).

3.3.2 Soil Cation exchange capacity (CEC) and availability of Organic materials in soil

Despite large amounts of P in a soil it may still be unavailable for absorption to the plants due to challenges of dissolved P fixation and low solubility. Aluminum (Al), iron (Fe), calcium (Ca), potassium (K), and magnesium (Mg) can undergo reactions with phosphorus fertilizer, resulting in the formation of compounds that are not readily soluble (Faozi *et al*., 2019). Studies indicate that phosphorus is most accessible within a pH range of 6 to 7, but this accessibility is influenced by its solubility and how readily it becomes fixed in the soil due to aluminium reacting with phosphorous to form insoluble phosphate precipitates (Philips, 2021). In acidic soils characterized by elevated levels of aluminum (Al), iron (Fe), and manganese (Mn), phosphorus fixation takes place in the form of aluminum-phosphate (Al-P), iron-phosphate (Fe-P), and manganese-phosphate (Mn-P). These compounds are poorly soluble, rendering phosphorus unavailable to plants (Dabessa and Tana, 2021). In response to various environmental conditions, particulate Phosphorus can switch from one structure to another (a process known as cycling). The component is found in organic matter such as algae, plant and animal tissue, waste solids, or other naturally occurring materials that can be counted (Tehulie *et al*., 2021). Phosphorus is introduced into the biosphere as microorganisms and plants absorb it, and its release into the soil occurs during the decomposition of organic materials. The amount of phosphorus in the soil can be influenced by organic matter, as approximately 20-80% of its overall phosphorus comes from alterations in organic matter. Fertilization in the form of manure, mineral fertilizer, and sewage sludge is recommended to enhance the availability of phosphorus in the soil. However, it's important to note that the distribution of the phosphorus element can be influenced by soil and environmental conditions, which can lead to either concentration or leaching (Faozi *et al*., 2019). Microbial decomposition of natural compounds can convert natural particulate P to dissolved Phosphorus. Some of the Phosphorus in soil mineral particles can additionally be transformed to dissolve P both in the water column and at some stage in chemical and physical modifications in backside sediment (Tehulie *et al*., 2021).

3.3.3 Soil type

P-fixing soils are common in tropical regions, and highly weathered tropical soils have a solid ability to adsorb P, resulting in reduced P availability for crops. In soils with higher R_2O_3 and clay materials there was a decrease in yields Soybean yields. As opposed to this, yields in sandier soils containing higher soil test P levels were unaffected by lower P inputs even in severely worn and P-fixing soils, as residual soil P can support crop output. They recommend lowering reliance on phosphate rock fertilisers (Bomeisl *et al*., 2020).

IV. CONCLUSION

Despite recent improvements in P management, more research is required to determine the environmental suitability of varieties and recommended rates for different regions based on their local soil situation (Rosa *et al*., 2020). Farmers need to have a thorough understanding of the precise determination of crop nutrient requirements, seed nutrient removal, contribution of nutrients by indigenous soil sources, and the optimization of nutrient use efficiency in achieving sustainable fertilization. Utilizing residual Phosphorus (P), often referred to as "legacy P," present in the soil and accumulated over time, can be crucial in supporting crop yields. By harnessing this residual P, it is possible to reduce the reliance on P fertilizers to sustain the future global food system. This approach helps conserve valuable non-renewable P resources and enhances the effectiveness of P fertilization, maintaining a balanced nutrition to promote a healthier environment in agriculture (Bomeisl *et al*., 2020).

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author (s).

DATA AVAILABILITY STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

REFERENCES

[1] Adeshina, D. A. (2023). Effects of Rhizobium (*Bradyrhizobium japonicum*) inoculation and phosphorus fertilizer rate on the nodulation, growth, and yield parameters of soybean [*Glycine max* (L.) Merrill] varieties in the Southern Guinea Savanna of Nigeria (Unpublished PhD thesis). University of Abuja, Nigeria.

[2] Bello, J.S. (2015). Response of Soybean (*Glycine max* [L.] Merr.) Varieties to sowing methods and Phosphorus fertilizer application at Samaru, Nigeria. A dissertation submitted to the school of postgraduate studies in the Agronomy Department of the Faculty of Agriculture Ahmadu Bello University Zaria, Nigeria. https://kubanni.abu.edu.ng/items/490fab08-52ab-4c1d-964f-38d8eab1eaa7 [Cross ref]

[3] Bomeisl, L., Neill, C., Porder, S., Cerri, C., Brando, P & Roy, E. (2020). Tropical soybean yield response to reduced or zero phosphorus fertilization depends on soils. *Agrosystems Geosciences & Environment. 3. 10.1002/agg2.20113.* [Google Scholar]

[4] Dabessa, A., & Tana, T. (2021). Response of Soybean (*Glycine max* L. (Merrill) to Bradyrhizobium Inoculation, Lime, and Phosphorus Applications at Bako, Western Ethiopia. *International Journal of Agronomy. 2021. 1-12. 10.1155/2021/6686957.* [Google Scholar]

[5] Faozi, K., Yudono, P., Indradewa, D & Ma'as, A. (2019). Effectiveness of phosphorus fertilizer on soybean plants in the coastal sands soil. IOP Conference Series: Earth and Environmental Science. 250. 012060. 10.1088/1755-1315/250/1/012060.PAGE 1-8 [Google Scholar]

[6] Ibrahim, N., & Ibrahim, M. (2019). Comparative Assessment of *Bradyrhizobium japonicum* Inoculant and Phosphorus on Growth and Yield of Soybeans (*Glycine max* L.) Genotypes. *Journal of Applied Sciences. 19. 10.3923/jas.2019.782.788.* [Google Scholar]

[7] Jibrin, I.M., Haruna, I.M. Ogara, I.M., Ibrahim, A.J & Adamu, M.B. (2021). Seed Yield and Economic returns of Soybean (Glycine max. l. Merill) as influenced by Phosphorus Fertilizer rates and Varieties at Lafia, Nasarawa state. Presented at Nigerian Association of Agricultural Economists 21st National Conference 18th – 22 October, 2021 at Faculty of Agriculture Shaba, Lafia campus, Nasarawa State University Keffi, Nigeria. https://www.researchgate.net/publication/360067028 [Cross ref]

[8] Kamara, A. Y., Abaidoo, R., Kwari, J., & Omoigui, L. (2007). Influence of phosphorus application on growth and yield of soybean genotypes in the tropical savannas of northeast Nigeria. *Archives of Agronomy and Soil Science*, *53*(5), 539-552. [Google Scholar]

[9] Khan, M. S. A., Karim, M. A., Haque, M. M., Islam, M. M., Karim, A. J. M. S., & Mian, M. A. K. (2016). Influence of Salt and Water Stress on Growth and Yield of Soybean Genotypes. *Pertanika Journal of Tropical Agricultural Science*, *39*(2). [Google Scholar]

[10] Krippendorff, K. (2018). "Content Analysis: An Introduction to Its Methodology." Sage Publications. [Google Scholar]

[11] Nunes, R., Sousa, D., Goedert, W., Zancanaro, L. E., & Pinheiro,T. (2021). Crops' Yield and Roots Response to Soil Phosphorus Distribution Resulting From Long-Term Soil and Phosphate Fertilization Management Strategies. Frontiers in Agronomy. 3. 10.3389/fagro.2021.757100. [Google Scholar]

[12] Philip, S. (2021). The effect of Triple Super Phosphate, Urea, and Lime on Soybean (*Glycine max*) growth rate and yield in ferrasols of Kombewa, Kisumu County. A dissertation submitted to the Department of Soil Science Maseno University Published: 1st December 2021. https://www.researchgate.net/publication/356972232 [Cross ref]

[13] Rajni, M., Beenu, T., Ankit, G., & Vikas, K. (2020). Soybean (*Glycine max*). Oil seeds: Health Attributes and Food Applications Springer Publishers, Singapore *10.1007/978-981-15-4194-0_1.* [Google Scholar]

[14] Rosa, A.T., Ruiz D.A and Fernando, D.H. (2020). Phosphorus fertilizer optimization is affected by soybean varieties and placement strategy. *Journal of Plant Nutrition. 43. 1-14. 10.1080/01904167.2020.1771583.* [Google Scholar]

[15] Salvagiotti, F., Magnano, L., Ortez,O., Enrico, J ., Barraco, M., Barbagelata, P.,Condori, A., Di Mauro, G., Manlla, A., Rotundo, J., Garcia, F., Ferrari, M., Gudelj, V & Ciampitti, I. (2021). Estimating nitrogen, phosphorus, potassium, and sulfur uptake and requirement in soybean. *European Journal of Agronomy. 127. 126289. 10.1016/j.eja.2021.126289.* [Google Scholar]

[16] Snelson, C. L. (2016). Qualitative and Mixed Methods Social Media Research: A Review of the Literature. *International Journal of Qualitative Methods*, *15*(1). https://doi.org/10.1177/1609406915624574 [Google Scholar]

[17] Soares, R.V., Gonçalves, L., Santos, H., Souza, C & Martins, N.M. (2021). Agronomic Efficiency of Phosphorus Fertilizers with Associate Technology in Soy Crop in Cerrado Soil. *Journal of Agricultural Science. 13. 61-69. 10.5539/jas.v13n10p61*. [Google Scholar]

[18] Tchemadon, G., Valerien, A., Valerien, Z., Tovihoudji, P., Fanou, A., Experat, P & Tchakpa, D. (2021). Effects of application of *Bradyrhizobium japonicum*, Phosphorus and Potassium fertilization on Soybean bacterial leaf pustule caused by *Xanthomonas axonopodis* pv. glycines. *Journal of Animal and Plant Sciences. 49. 8920-8932. 10.35759/JAnmPlSci.v49-3.4.* [Google Scholar]

[19] Tehulie, N., Ayehu, A., & Nuru, A. (2021). Review on the effect of phosphorus fertilizer rates on growth and yield of soybean (*Glycine max* L.). *International Journal of Current Research. 31-34* [Google Scholar]

[20] Wang, Q., Sheng, J., Pan, L., Cao, H., Li, C., Lambers, H & Wang, X. (2022). Soil property determines the ability of rhizobial inoculation to enhance nitrogen fixation and phosphorus acquisition in soybean. *Applied Soil Ecology. 171. 104346. 10.1016/j.apsoil.2021.104346.* [Google Scholar]

[21] Yang, J., Richards, A.R., Yi, J., & Jin, H. (2022). Both biomass accumulation and harvest index drive the yield improvements in soybean at high and low phosphorus in South-west China. *Field Crops Research. 277. 108426. 10.1016/j.fcr.2021.108426.* [Google Scholar]