

Soil Chemical Properties and Their Implications for Sugar Beet (*Beta vulgaris* L.) Cultivation in Kabianga, Kenya

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ABSTRACT

Sugar beet (*Beta vulgaris* L.) is an important industrial crop cultivated primarily for sucrose production, with additional applications in livestock feed, bioethanol production and integrated biorefinery systems. Its adaptation to relatively cool growing conditions makes it a potential complementary sugar crop for selected highland environments in Kenya. However, its suitability for cultivation in Kabianga, Kericho County, requires assessment of local soil conditions and crop nutrient requirements. This study evaluated the chemical properties of soil from Kabianga to identify potential constraints to sugar beet production and propose appropriate soil management interventions. The assessment was based on soil analytical results from Imara Analytical Laboratories and relevant agronomic literature. The reported results indicated strongly acidic soil conditions, with a pH of 5.09, and a phosphorus concentration of 4.07 ppm. Calcium and sulphur were classified as low, while manganese and iron concentrations were reported as elevated. Nitrogen and organic matter were classified as adequate, and potassium as high. These findings suggest that soil acidity and nutrient imbalances may constrain crop establishment, root development and nutrient uptake. However, the interpretation of individual nutrient concentrations requires confirmation of the laboratory methods, units and reference ranges, particularly for calcium, sulphur, micronutrients and cation exchange capacity (CEC). Agricultural liming, phosphorus supplementation and targeted nutrient management are potential interventions for improving soil conditions. Indicative amendment and fertilizer rates should be confirmed through laboratory lime-requirement testing and crop-specific nutrient recommendations before application. Field trials are also necessary to evaluate root yield, sucrose concentration, crop maturity and the effectiveness of the proposed treatments. The findings provide a preliminary basis for investigating sugar beet cultivation in Kabianga but do not, on their own, establish commercial suitability. Further agronomic and economic evaluation is required to determine whether the area can support productive and commercially viable sugar beet cultivation.

Keywords: Sugar beet; soil acidity; nutrient availability; soil fertility; lime requirement; Kabianga; Kenya.

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1. Introduction

Sugar beet (*Beta vulgaris* L.) is one of the world's two principal commercial sugar crops, alongside sugarcane (*Saccharum officinarum* L.). It is cultivated primarily for sucrose production and also contributes to livestock feeding, bioethanol production and the utilization of agricultural by-products. Sugar beet is particularly important in temperate agricultural systems, where relatively cool growing conditions can support storage-root

development and sucrose accumulation. Under favorable environmental conditions and appropriate agronomic management, modern cultivars can produce substantial root yields with commercially useful sugar concentrations. Its potential for multiple industrial applications has encouraged interest in sugar beet as an alternative or complementary crop in regions seeking to diversify agricultural production and strengthen domestic sugar supply chains.

In Kenya, sugar production has traditionally depended on sugarcane, which is cultivated mainly in the western sugar belt and selected coastal areas. Dependence on a single principal sugar crop presents challenges associated with land suitability, production costs, climatic variability, agricultural productivity and access to processing infrastructure. Sugar beet may provide an alternative source of sucrose in selected agroecological zones, particularly highland areas with relatively cool temperatures and suitable soil conditions. Nevertheless, its potential contribution to the national sugar industry depends on more than successful crop establishment. Root yield, sucrose concentration, harvesting costs, transportation, processing technology and access to reliable markets must also be considered.

Previous sugar beet investigations in Kenya provide a basis for examining the crop's adaptability under local conditions. Historical trials in Nyandarua and western Kenya reported successful crop establishment and variable root yields across locations and growing seasons. These findings suggest that selected Kenyan environments may support sugar beet cultivation. However, the differences in soil properties, rainfall distribution, temperature, cultivar performance and management practices among sites mean that results from one location cannot automatically be applied to another. Site-specific evaluation is therefore necessary before recommending sugar beet for commercial production in new areas.

Kabianga, in Kericho County, presents an opportunity to investigate sugar beet cultivation because of its highland setting and relatively cool environmental conditions. These characteristics may be favorable for the crop, although their suitability must be confirmed using local climatic data and field observations. Soil physical and chemical properties are also important determinants of germination, root development, nutrient uptake, sucrose accumulation and final yield. Deep, well-drained soils with adequate nutrient availability and a suitable pH generally provide favorable conditions for sugar beet production. Strong soil acidity, nutrient deficiencies and imbalances may restrict crop performance even where climatic conditions are otherwise favorable.

The soil analysis from Kabianga, conducted by Imara Analytical Laboratories, reported a soil pH of 5.09 and a phosphorus concentration of 4.07 ppm. Calcium and sulphur were classified as low, while manganese and iron were reported at elevated concentrations. Nitrogen and organic matter were classified as adequate, and potassium as high. These results identify potential constraints that warrant further investigation, particularly the implications of soil acidity for nutrient availability and the possibility of excessive manganese availability. However, the laboratory's analytical methods, nutrient reference ranges and reporting units must be verified before all classifications can be considered conclusive.

Agricultural liming, balanced fertilization and appropriate crop management may improve the soil conditions required

for sugar beet establishment. The effectiveness of these interventions depends on the soil's lime requirement, buffering capacity, nutrient availability, amendment quality and the response of the selected cultivar. Proposed lime and fertilizer rates should therefore be based on confirmatory laboratory recommendations and, where possible, field trials. Such trials would help establish whether soil amendments can improve root development, yield and sucrose accumulation under Kabianga conditions.

In addition to agronomic suitability, the introduction of sugar beet requires consideration of seed availability, production inputs, water supply, harvesting and transportation arrangements, processing facilities and market access. The use of beet pulp, molasses and other processing by-products could provide additional economic opportunities, but their value would depend on the scale and organization of production and processing. Evaluating these requirements is essential for distinguishing the potential for successful crop growth from the broader feasibility of establishing a sustainable sugar beet value chain.

Against this background, the present study evaluates the chemical properties of Kabianga soils in relation to the potential cultivation of sugar beet. It identifies reported soil fertility constraints, examines their possible implications for crop growth and proposes soil amendment and nutrient management interventions for further evaluation. The study also identifies the additional laboratory analyses, field experiments and economic assessments required to establish the agronomic and commercial feasibility of sugar beet cultivation in the Kericho highlands.

The overall objective was to provide an evidence-based foundation for determining whether corrective soil management can improve the suitability of Kabianga soils for sugar beet production and whether the area warrants further agronomic and commercial investigation.

The specific objectives were to:

- i. Characterize the reported chemical properties of Kabianga soil using available laboratory results.
- ii. Identify potential soil acidity, nutrient deficiency and nutrient imbalance constraints relevant to sugar beet cultivation.
- iii. Propose soil amendment and fertilizer management interventions for testing under local conditions.
- iv. Identify the additional research required to assess crop performance and commercial feasibility.

2. Literature Review

2.1 Global Importance of Sugar Beet and Industrial Applications

Sugar beet is a major commercial source of sucrose and contributes substantially to sugar production in temperate regions. Its share of global sugar production varies among years according to weather conditions, crop yields, market conditions and the performance of sugarcane-producing regions. The crop is widely cultivated in Europe, North America and parts of Asia, where environmental conditions and agricultural management support the development of storage roots with high sucrose concentrations.

A major characteristic of sugar beet is its capacity to accumulate sucrose in an enlarged storage root during a relatively short growing period. Root yield and sugar concentration vary with cultivar, temperature, water availability, soil fertility, disease pressure and crop management. Published yields of approximately 50–90 tonnes of roots per hectare and sucrose concentrations of around 15–20% represent indicative ranges under suitable production conditions rather than guaranteed outcomes. Commercial performance depends on both root biomass and the proportion of sugar that can be recovered efficiently during processing.

Sugar beet can contribute to agricultural diversification because its climatic requirements differ from those of sugarcane. In environments where sugarcane is less suitable, sugar beet may offer an alternative source of industrial sugar if adequate root yields can be achieved and processing infrastructure is available. However, the existence of successful sugar beet industries elsewhere does not demonstrate that the crop will be equally productive or profitable in all regions with relatively cool climates.

The crop also has value beyond conventional sugar production. Sugar beet roots contain fermentable carbohydrates that can be converted into bioethanol. Beet pulp may be used as livestock feed, while molasses can serve as a fermentation substrate or an input for other industrial processes. Residual biomass may also be utilized for energy generation, including biogas production. These applications can improve resource utilization and create additional revenue streams where appropriate processing systems exist.

An integrated biorefinery approach seeks to recover value from different components of the crop while reducing waste. Its feasibility depends on the quantity and quality of available feedstock, processing efficiency, energy requirements, market demand and the cost of transporting raw materials. For Kenya, these industrial applications may provide opportunities for diversification, but they should be assessed alongside the more immediate requirements of crop establishment, root yield, sugar recovery and processing economics.

The global experience with sugar beet therefore provides a rationale for investigating the crop in suitable Kenyan environments. Its potential contribution to domestic sugar production must, however, be evaluated through site-

specific agronomic research and realistic assessments of processing and market requirements.

2.2 Sugar Beet Production Requirements

Sugar beet performance is influenced by the interaction of climate, soil physical properties, nutrient availability, cultivar characteristics and management practices. The crop generally benefits from a sufficiently long growing period, moderate temperatures, adequate moisture and soils that allow unrestricted root development. Temperature and moisture conditions influence leaf growth, root expansion, sucrose accumulation and the timing of crop maturity.

Soil depth and drainage are important because sugar beet develops a substantial storage root. Compaction, water logging and other physical restrictions may interfere with root expansion, reduce nutrient uptake and complicate harvesting. Field assessment should therefore complement chemical analysis when evaluating the suitability of a proposed production site.

Soil reaction also influences nutrient availability. Sugar beet is commonly associated with soils that are near neutral, although the appropriate target pH depends on soil type, nutrient status and the production system. Strong acidity can increase the availability of manganese and certain other metals, restrict phosphorus availability through reactions with iron and aluminium compounds, and reduce calcium availability. These effects may impair crop establishment and root development.

Phosphorus is particularly important during early crop development because it supports energy transfer, cell division and root growth. Calcium contributes to cell-wall development and membrane stability, while sulphur is required for the synthesis of sulphur-containing amino acids and proteins. Nitrogen supports leaf development and photosynthesis, but excessive nitrogen can delay maturity and adversely affect sugar concentration and processing quality. Potassium is involved in enzyme activation, osmotic regulation and carbohydrate transport, although the appropriate application rate depends on the existing soil supply and crop demand.

Nutrient management should therefore be based on soil testing and an assessment of crop requirements rather than on the automatic application of a standard fertilizer package. This is particularly important in soils where some nutrients are reported as deficient while others are present at relatively high concentrations. Balanced management can reduce unnecessary input costs while addressing the factors most likely to constrain productivity.

2.3 Potential for Sugar Beet Cultivation in Kenya

Kenya's highland environments provide a basis for investigating sugar beet as a complementary industrial crop. Parts of the western highlands and other elevated

areas experience relatively cool conditions that may support the crop. However, altitude and rainfall alone are insufficient indicators of suitability. Temperature variation, rainfall distribution, drainage, soil depth, soil fertility and the availability of suitable cultivars must also be considered.

Historical trials in Nyandarua reportedly recorded sugar beet root yields ranging from approximately 40 to 80 tonnes per hectare, with an average yield of about 70 tonnes per hectare and a reported sugar content of 17% in the study attributed to Mandere and colleagues. The results indicate that substantial root yields may be achieved under selected Kenyan conditions. However, differences among trial sites and seasons, including drought-related yield reductions, demonstrate that performance is dependent on environmental and management conditions. The absence of a reliable market was also identified as a potential constraint to adoption.

Trials at Mumias in western Kenya reportedly evaluated the cultivars Posada and Dorotea on approximately 10 hectares in July 2005, at an altitude of about 1,314 metres above sea level. The crop was reported to have established successfully and reached maturity within approximately five to six months. These observations suggest that sugar beet can develop under some Kenyan conditions outside its conventional temperate production regions. The original publication should be consulted to verify the trial details, yield results and the extent to which the findings can be generalized.

Earlier experiments by Elmer, Gosnell and Smith (1963) examined sugar beet growth in several western Kenyan locations, including Turbo, Soy, Kipkabus and Nandi Border. Their findings were mixed, with better growth reported on certain soils associated with comparatively higher pH and calcium status. Responses to phosphorus and nitrogen were also observed. These findings are relevant to Kabianga because they highlight the importance of soil chemical properties and nutrient management in determining crop performance.

At the national scale, Mandere et al. (2010), in their study on sugar beet land evaluation under Kenyan conditions, estimated that approximately 27% of Kenya's land area had some degree of suitability for sugar beet cultivation. The study classified about 5% as highly suitable, 5% as moderately suitable and 17% as marginally suitable. These figures indicate potential opportunities for further investigation but do not establish the suitability of any individual farm or locality without site-specific evaluation.

Collectively, the Kenyan studies provide a rationale for investigating sugar beet in Kabianga. They also demonstrate that crop performance varies among locations and that soil fertility, climatic conditions, water availability and market access can influence production outcomes. The current assessment builds on this evidence by examining the reported soil chemical properties of Kabianga and

identifying the interventions that should be evaluated before commercial recommendations are made.

2.4 Research Gap and Relevance to Kabianga

Existing Kenyan trials indicate that sugar beet can grow under selected local conditions, but evidence from other locations cannot establish the suitability of Kabianga soils. Differences in soil acidity, nutrient availability, and drainage and crop management may result in substantially different outcomes.

The available Kabianga soil analysis identifies several potential constraints, including strong acidity, low reported phosphorus, low calcium and sulphur classifications, and elevated manganese and iron concentrations. However, the effectiveness of corrective management and its influence on sugar beet yield and sucrose accumulation have not been established by the laboratory results alone.

The present assessment therefore addresses a preliminary information gap by relating the reported soil characteristics to sugar beet production requirements and identifying the tests and field experiments needed to evaluate potential interventions. It provides a starting point for subsequent agronomic research rather than a definitive classification of the site as commercially suitable.

3. Materials and Methods

3.1 Study Area

The assessment concerns Kabianga in Kericho County, Kenya (0.4458°S, 35.1381°E). The area is situated within the Kenyan highlands, where relatively cool conditions provide a basis for investigating crops adapted to moderate growing temperatures.

3.2 Soil Sampling and Laboratory Analysis

Soil sampling for the Kabianga sugar beet (*Beta vulgaris* L.) study was conducted using a systematic zigzag sampling design across a one-acre plot (approximately 4,047 m²). Twenty soil cores were collected from evenly distributed sampling points using a clean soil auger at a depth of 0–20 cm for routine soil fertility assessment. Additional samples were collected separately from a depth of 20–40 cm to assess subsoil acidity and potential root-zone constraints. Sampling locations were selected to ensure representative coverage of the plot while avoiding field margins, manure heaps, fertilizer bands, drainage channels and waterlogged areas. The samples were subsequently air-dried under clean conditions, gently crushed, passed through a 2 mm sieve and homogenized before laboratory analysis.

Laboratory analyses were conducted to determine soil pH, organic matter, total nitrogen, available phosphorus, exchangeable potassium, calcium and magnesium,

sulphate-sulphur, extractable manganese, iron, zinc, copper and boron, as well as cation exchange capacity (CEC). Soil pH was determined potentiometrically using a calibrated pH meter; while available phosphorus and exchangeable bases were assessed using appropriate validated extraction procedures. Elemental concentrations were determined using suitable instrumental techniques, including atomic absorption spectrometry or inductively coupled plasma optical emission spectrometry, depending on the analytical procedure employed by the laboratory.

3.3 Data Interpretation

The soil results were interpreted in relation to the general requirements of sugar beet and the potential influence of soil acidity and nutrient imbalance on crop development. Particular attention was given to soil pH, phosphorus, calcium, sulphur, nitrogen, organic matter, potassium, manganese, iron and CEC. The classifications of low,

adequate, high or optimal were retained as reported in the supplied laboratory results. They should not be treated as independently validated classifications until the laboratory's analytical methods and crop-specific reference ranges have been confirmed. The interpretation also considered whether the reported conditions might justify liming, phosphorus supplementation, sulphur application or adjustments to nitrogen and potassium management. The proposed interventions are preliminary and require confirmation through laboratory recommendations and field trials.

4. Results and Discussion

4.1 Soil Chemical Characteristics

The soil analysis from Kabianga identified a combination of acidic soil reaction, reported nutrient deficiencies and potentially elevated concentrations of certain elements. Table 1 presents the available results.

Table 1. Reported chemical characteristics of soil from Kabianga

Parameter	Unit as reported	Mean result	Standard deviation	Reported status
pH	pH units	5.09	0.05	Acidic
Nitrogen	%	0.32	0.02	Optimal
Organic matter	%	8.49	0.15	High
Phosphorus	ppm	4.07	0.20	Low
Potassium	ppm	417	5.00	High
Calcium	Ppm	808	10.00	Low
Sulphur	Ppm	90.2	2.00	High
Sodium	Ppm	138	3.00	Optimal
Magnesium	Ppm	311	4.00	High
Manganese	Ppm	359	5.00	High
Iron	Ppm	176	3.00	High
Zinc	Ppm	10.7	0.30	High
Copper	Ppm	4.42	0.10	High
Boron	Ppm	4.21	0.10	High
CEC	meq/100g	8.30	0.20	Low

Source: Imara Analytical Laboratories,

Kericho, Kenya.

4.2 Soil Acidity and Its Agronomic Implications

The measured pH of 5.09 indicates an acidic soil reaction. This is an important potential constraint because sugar beet generally performs better in soils with a less acidic reaction, often within a near-neutral range. Soil acidity can influence nutrient availability in several ways. Phosphorus may become less available through reactions with iron and aluminium compounds, while calcium availability may be restricted. Under some conditions, acidity also increases the solubility of manganese and iron, potentially exposing plants to excessive concentrations of these elements. The

reported pH therefore provides a sound basis for investigating whether liming would improve the rooting environment. However, the amount of lime required cannot be determined from pH alone. Soil buffering capacity, texture, exchangeable acidity, and incorporation depth and amendment quality must be considered. A laboratory lime-requirement test is necessary before a definitive rate is recommended. Historical sugar beet trials in western Kenya reported differences in crop performance among soil types and associations between better growth and comparatively higher soil pH and calcium status. These findings support the relevance of soil acidity assessment but do not demonstrate that liming will produce a particular yield response in Kabianga. That response must be evaluated experimentally.

4.3 Phosphorus Availability

The reported phosphorus concentration of 4.07 ppm was classified as low. This result indicates a potential constraint to early sugar beet establishment. Phosphorus supports energy transfer, cell division and root development. Inadequate phosphorus availability during early growth may restrict root expansion and reduce the crop's capacity to explore the soil for water and nutrients. The consequences for final yield depend on the severity and duration of the deficiency, soil moisture, cultivar and other environmental conditions. Diammonium phosphate (DAP) is one possible source of phosphorus. Nevertheless, the appropriate application rate should be determined from the laboratory's crop-specific recommendation and the contribution of DAP-derived nitrogen to the overall nutrient budget. Because soil acidity can influence phosphorus availability, phosphorus fertilization should be considered alongside acidity correction rather than as an isolated intervention. A field trial comparing phosphorus rates, with suitable controls and consistent management, would help establish whether phosphorus supplementation improves crop establishment and yield under Kabianga conditions.

4.4 Calcium and Sulphur Status

Calcium was reported at 808 ppm and classified as low. Calcium is important for cell-wall development, membrane stability and the maintenance of healthy growing tissues. Calcium deficiency may contribute to restricted root development or other nutritional imbalances. Agricultural lime can supply calcium while neutralizing soil acidity. However, the amount of calcium supplied will depend on the material's composition and application rate. Where magnesium is adequate, calcitic lime may be appropriate; where magnesium deficiency is confirmed, dolomitic lime may be considered. The selection should be based on the complete soil analysis and the lime requirement.

The soil analysis indicated a sulphur concentration of 90.2 ppm, which was classified as high for the Kabianga soil. This concentration suggests that the soil may contain a substantial reserve of sulphur to support plant growth, particularly if the measured value represents plant-available sulphate-sulphur. Sulphur is an essential secondary macronutrient involved in the synthesis of sulphur-containing amino acids, proteins and enzymes, and it contributes to efficient nitrogen utilization and overall plant development. For sugar beet (*Beta vulgaris* L.), adequate sulphur nutrition supports healthy growth and metabolic processes associated with root development and sucrose production. However, the actual contribution of the measured sulphur concentration to crop nutrition depends on the analytical extraction method, the form of sulphur measured and the laboratory's reference ranges.

Despite the reported high sulphur concentration, its availability to sugar beet should be confirmed before additional sulphur fertiliser is applied. If the value of 90.2 ppm represents extractable sulphate-sulphur, it would

generally indicate that sulphur supplementation may not be necessary, subject to the soil-testing method and crop-specific recommendations. Applying additional sulphur without confirming a deficiency could increase production costs and contribute to nutrient imbalances. Furthermore, gypsum, although a source of both calcium and sulphur, does not effectively neutralize soil acidity, whereas agricultural lime is primarily used to correct low soil pH and supply calcium. Ammonium sulphate supplies both nitrogen and sulphur but may contribute to further soil acidification with repeated use.

Consequently, the reported sulphur concentration of 90.2 ppm should be treated as a potentially favourable soil fertility characteristic rather than an established nutrient limitation. Given the strongly acidic soil pH of 5.09, priority should be given to determining the lime requirement and correcting soil acidity, while phosphorus management should be guided by the confirmed low phosphorus status. The need for additional sulphur should only be established after verifying the laboratory's analytical method and reference range. This approach would promote balanced nutrient management, avoid unnecessary fertilizer application and improve the prospects for evaluating sugar beet production under the soil conditions prevailing in Kabianga.

4.5 Nitrogen and Organic Matter

Nitrogen was reported at 0.32% and classified as optimal, while organic matter was reported at 8.49% and classified as high. Crop availability depends on the rate of organic matter mineralization, microbial activity, leaching, immobilization and plant uptake. Consequently, the total nitrogen requirement should be determined using the laboratory results, expected nutrient release and crop demand. Organic matter can improve soil aggregation, water retention and nutrient cycling. However, its contribution to sugar beet production should be assessed in relation to the soil's physical condition, nutrient supply and organic matter quality. The reported value alone does not establish that the soil has an ideal physical structure or that additional organic amendments are unnecessary. Nitrogen management is especially important for sugar beet because excessive nitrogen can promote prolonged vegetative growth, delay maturity and adversely affect sucrose concentration or processing quality. Fertilizer applications should therefore be based on the crop's total requirement and adjusted for the nitrogen supplied by basal fertilizers such as DAP.

4.6 Potassium, Magnesium and Sodium

Potassium was reported at 417 ppm and classified as high. Potassium contributes to enzyme activation, osmotic regulation and carbohydrate transport. However, the recommendation to withhold potassium should be conditional on confirmation that the measured value represents an appropriate plant-available or exchangeable fraction. Crop removal, nutrient interactions and changes in

soil fertility over time should also be considered. Magnesium was reported at 311 ppm and classified as high, while sodium was reported at 138 ppm and classified as optimal. The balance among calcium, magnesium and potassium may influence nutrient uptake, but concentrations alone do not establish that an antagonistic interaction is occurring. Further soil analysis should therefore be used to assess the balance among exchangeable cations and to determine whether any corrective intervention is justified. Unnecessary potassium, magnesium or sodium-related amendments should be avoided until a specific requirement has been established.

4.7 Manganese, Iron and Other Micronutrients

Manganese and iron were reported at 359 ppm and 176 ppm, respectively, and classified as high. Zinc, copper and boron were also classified as high. The potential risk depends on the chemical forms of the elements, the analytical extraction method, soil pH, drainage, redox conditions and crop-specific thresholds. Total or extractable concentrations should not automatically be interpreted as evidence of plant toxicity. If elevated plant-available manganese is confirmed, appropriately calculated liming may reduce its availability by increasing soil pH. However, liming should not be assumed to correct every micronutrient imbalance, and iron availability may respond differently depending on soil conditions. The appropriate next step is to confirm the laboratory methods and assess the results against suitable crop-specific thresholds. Field observations and, where necessary, plant tissue analysis should then be used to determine whether nutrient toxicity is occurring under actual growing conditions.

4.8 Cation Exchange Capacity

The reported CEC value was 8.30 meq/100g, with the unit given as ppm. This unit requires correction or clarification because CEC is ordinarily reported in charge-based units, such as cmol(c)/kg. CEC describes the soil's capacity to retain exchangeable cations and is influenced by clay content, organic matter and mineral composition. A confirmed low CEC may indicate a greater need for careful nutrient management, especially where nutrient leaching is substantial. However, the implications for fertilizer timing cannot be determined reliably until the reported unit and analytical method are verified. The original laboratory report should be consulted before this value is used to support a conclusion about the soil's nutrient-retention capacity.

4.9 Overall Assessment of Soil Constraints

The Kabianga results identify several potential soil fertility constraints relevant to sugar beet cultivation. The most immediate concerns are the acidic soil reaction, the reported low phosphorus concentration and the reported calcium and sulphur classifications. Elevated manganese and iron concentrations also require investigation. Other reported results, including nitrogen, organic matter,

potassium and magnesium, may provide useful information for designing a nutrient management program. However, their contribution to crop performance cannot be established conclusively without confirming the laboratory methods and reference ranges. The findings therefore justify further evaluation of acidity correction and balanced nutrient management. They do not demonstrate that the soil is already suitable for commercial sugar beet production or that any particular amendment rate will produce a satisfactory crop response. These questions require confirmatory laboratory analysis and field experimentation.

5. Proposed Soil Amendment and Nutrient Management Program

5.1 Management Principles

The proposed management program aims to address the potential soil constraints identified in the Kabianga analysis while avoiding unnecessary or excessive fertilizer applications. It emphasizes laboratory-guided acidity correction, phosphorus management, confirmation of sulphur requirements, balanced nitrogen supply and monitoring of potentially excessive micronutrients. The rates presented below are preliminary treatment options for evaluation, not validated recommendations for the entire Kabianga area. Before implementation, the soil analysis should be confirmed, the lime requirement determined, and the total crop nutrient budget established. Where possible, the proposed interventions should be evaluated through replicated field trials.

5.2 Pre-Planting Soil Assessment and Land Preparation

Before planting, representative soil samples should be collected from the intended field using the documented sampling design. Sampling depth, the number of sampling points and whether samples are composited should be appropriate to the field's variability and the objectives of the assessment. The laboratory should analyze soil pH, lime requirement or buffer pH, texture, organic matter, available phosphorus, exchangeable potassium, calcium and magnesium, sulphur, exchangeable acidity and CEC. Extractable manganese and iron should also be assessed using appropriate methods. Additional analyses should be included where indicated by the laboratory findings or field conditions. Land preparation should aim to establish a suitable rooting environment and a uniform seedbed. Field inspection should identify compaction, poor drainage, erosion risk and other physical constraints. Deep tillage should be undertaken only where a restrictive layer is confirmed and the operation is agronomically justified. The objective is to provide adequate root-zone depth without unnecessarily disturbing the soil.

5.3 Agricultural Liming

Agricultural lime is a potential amendment for correcting soil acidity and supplying calcium. The reported pH of 5.09 indicates that the lime requirement should be evaluated

before sugar beet establishment. An indicative rate of 600 kg/acre, equivalent to approximately 1.48 tonnes/ha, may be included as a preliminary treatment in a field trial. The wider range of 600–800 kg/acre, equivalent to approximately 1.48–1.98 tonnes/ha, should be considered only as a provisional planning range until the laboratory lime requirement has been determined. Neither rate should be adopted as a final prescription solely from the measured pH. The final application rate should account for exchangeable acidity, soil buffering capacity, texture, incorporation depth and the effective neutralizing value of the lime material. Where lime is justified, it should be spread uniformly and incorporated into the intended rooting zone sufficiently early to allow it to react. The required interval will depend on soil moisture, lime fineness and the incorporation method. Calcitic lime may be suitable where calcium supply and acidity correction are required and magnesium is adequate. Dolomitic lime should be considered only where the soil analysis establishes a need for additional magnesium. Soil pH should be reassessed after treatment where practicable to determine whether the intended correction has been achieved.

5.4 Basal Phosphorus Fertilization

The reported phosphorus concentration of 4.07 ppm suggests that phosphorus supplementation may be required, subject to confirmation of the analytical method and laboratory recommendation. An indicative DAP treatment of 75 kg/acre, equivalent to approximately 185 kg/ha, may be evaluated in a field trial. Standard 18-46-0 DAP supplies approximately 18% nitrogen and 46% phosphorus pentoxide (P_2O_5). At 75 kg/acre, it would supply approximately:

- i. 13.5 kg nitrogen/acre, equivalent to about 33.3 kg N/ha.
- ii. 34.5 kg P_2O_5 /acre, equivalent to about 85.2 kg P_2O_5 /ha.
- iii. 15.1 kg elemental phosphorus/acre, equivalent to about 37.1 kg P/ha.

These calculations describe the nutrient content of the proposed treatment; they do not establish that the rate is optimal for Kabianga. The final application rate should follow the laboratory's phosphorus recommendation and the crop's nutrient requirements. The nitrogen supplied by DAP must be included in the overall nitrogen budget. Fertilizer placement should provide access to developing roots while avoiding direct contact between concentrated fertilizer and the seed. The appropriate placement distance and depth should follow locally validated agronomic guidance.

5.5 Nitrogen Management

The nitrogen program should be based on the confirmed soil nitrogen status, anticipated mineralization, crop demand and nitrogen supplied by basal fertilizers. The reported nitrogen concentration of 0.32% should not be

interpreted as a direct measure of plant-available nitrogen unless the analytical method establishes that interpretation. Additional nitrogen should not be prescribed automatically. Where crop demand and soil analysis justify supplementation, the rate and timing should be determined using a nutrient budget and adjusted to local conditions. Split application may be considered where it improves synchronization between nutrient supply and crop demand or reduces the risk of nutrient loss. However, excessive or late nitrogen application should be avoided because it may prolong vegetative growth, delay maturity and reduce sugar concentration or processing quality. Calcium ammonium nitrate and urea are possible nitrogen sources, but their application rates should be based on the required amount of elemental nitrogen, the product formulation and the total fertilizer budget. A standard top-dressing rate should not be adopted without field evidence.

5.6 Potassium and Other Micronutrients

Additional potassium fertilizer should not be included automatically because potassium was reported as high. The need for application should be assessed using the confirmed exchangeable potassium concentration, the laboratory recommendation and expected crop removal. The reported magnesium, zinc, copper, boron, manganese and iron classifications should also be verified. No additional micronutrient fertilizer should be applied routinely without evidence of deficiency. Similarly, corrective treatment for elevated micronutrients should be based on confirmed plant-available concentrations and crop-specific thresholds rather than on unverified classifications. Where excessive manganese availability is confirmed, liming may help reduce its availability under suitable conditions. The effectiveness of this intervention should be assessed through soil testing and field observations.

5.7 Field Validation and Monitoring

A field experiment should be established to determine whether the proposed interventions improve sugar beet performance under Kabianga conditions. A preliminary trial could compare an untreated control with selected lime and phosphorus treatments, adding sulphur or nitrogen treatments where confirmatory laboratory analysis justifies their inclusion. The design should include appropriate replication, consistent crop management and a clearly documented treatment structure. If several nutrients are to be investigated simultaneously, the trial design should allow the individual and combined effects of the treatments to be distinguished. Measurements should include crop establishment, canopy development, root growth, root yield, sucrose concentration and crop maturity. Where possible, the assessment should also include recoverable sugar, nutrient uptake and production costs. Soil pH and relevant nutrient concentrations should be measured before and after the trial to evaluate changes in soil conditions. Plant tissue analysis may help distinguish nutrient deficiency from toxicity or other environmental stress. Records of rainfall, soil moisture, drainage, pest pressure and management operations should also be maintained to

support interpretation of the crop response. The results would provide a basis for refining amendment and fertilizer recommendations and determining whether further agronomic trials are justified.

6. Commercial and Environmental Considerations

Soil correction is only one component of sugar beet production. Even if field trials demonstrate satisfactory crop growth, commercial production will depend on whether yields, sucrose concentration and sugar recovery justify the costs of cultivation, harvesting, transport and processing. The relatively short production cycle reported in some Kenyan trials may offer opportunities for crop diversification, but its value will depend on the suitability of local cultivars, seasonal water availability, labor requirements and the timing of harvest relative to processing capacity. Sugar beet processing can generate products such as beet pulp and molasses, which may have value in livestock feeding and industrial applications. Their economic contribution depends on reliable markets, processing efficiency and the scale of production. Transporting bulky roots over long distances may also affect profitability, making the location of processing facilities and the organization of supply chains important considerations. Environmental management should be integrated into any future production program. Liming and fertilizer applications should be based on verified requirements to avoid unnecessary input use. Nitrogen management should account for the risk of leaching, while phosphorus applications should reflect soil-test results and the risk of nutrient loss. Crop rotation, appropriate drainage and erosion control can contribute to longer-term soil management. A complete feasibility assessment should therefore combine agronomic performance, input costs, labor, water requirements, processing technology, market access and potential environmental effects. Until these factors have been evaluated, sugar beet cultivation in Kabianga should be regarded as an opportunity for investigation rather than an established commercial proposition.

7. Conclusion

This assessment examined the reported chemical properties of soil from Kabianga, Kericho County, in relation to the potential cultivation of sugar beet (*Beta vulgaris* L.). The laboratory results indicated strongly acidic soil conditions, with a pH of 5.09, and a low phosphorus concentration of 4.07 ppm. Calcium was classified as low, while sulphur was reported at 90.2 ppm and classified as high, suggesting that additional sulphur fertilization may not be necessary, subject to confirmation of the analytical method and laboratory reference ranges. Manganese and iron concentrations were also reported as elevated, warranting further assessment of their potential availability and phytotoxic effects under acidic conditions. Nitrogen and organic matter were classified as adequate or high, while potassium was reported as high. These findings highlight potential soil fertility constraints that could affect sugar beet establishment, root development and nutrient uptake.

The results suggest that correcting soil acidity and addressing phosphorus deficiency should be the primary priorities in developing a soil management programme for sugar beet cultivation in Kabianga. Agricultural lime may improve soil pH, enhance calcium availability and reduce the solubility of certain potentially harmful elements. Given the reported high sulphur concentration, routine sulphur supplementation should not be recommended unless further soil testing establishes a deficiency. Similarly, additional potassium fertiliser should be applied only where justified by confirmed crop requirements and laboratory recommendations. The proposed lime and fertilizer application rates should be determined using appropriate soil tests, including a lime-requirement assessment, rather than relying on soil pH or nutrient classifications alone. Verification of the analytical methods, reporting units and reference ranges, particularly for sulphur, calcium, micronutrients and cation exchange capacity (CEC), is also necessary to strengthen the reliability of the recommendations.

Overall, Kabianga may warrant further investigation as a potential location for sugar beet production, provided that the identified soil constraints are addressed through appropriate management and validated under local growing conditions. Field trials should evaluate the effects of liming and phosphorus supplementation on crop establishment, root yield, sucrose concentration and nutrient uptake. Further assessment of the reported manganese and iron concentrations would also help establish whether they pose practical risks to crop performance. In addition, commercial feasibility should be evaluated in relation to production costs, suitable cultivar availability, harvesting and transportation requirements, processing infrastructure and market access. The study therefore provides a preliminary basis for further agronomic investigation, but confirmation of sugar beet's productivity and commercial viability in the Kericho highlands will require replicated field trials and an accompanying economic assessment.

8. Recommendations

Based on the available soil analysis and the identified information gaps, the following recommendations are proposed:

- i. Conduct an appropriate lime-requirement test that considers exchangeable acidity, soil buffering capacity, soil texture and incorporation depth before selecting an application rate.
- ii. Obtain a crop-specific phosphorus fertilizer recommendation before adopting the proposed DAP rate of 75 kg/acre.
- iii. Establish the total nitrogen requirement using confirmed soil information, anticipated mineralization, crop demand and the nitrogen supplied by basal fertilizers.
- iv. Do not apply additional potassium or micronutrient fertilizers routinely without evidence of a crop requirement. Confirm the reported high nutrient classifications before making management decisions.

- v. Compare untreated soil with selected lime and nutrient-management treatments using a replicated experimental design and consistent crop management.
- vi. Record crop establishment, root yield, sucrose concentration, crop maturity and relevant soil and plant nutrient measurements.
- vii. Assess compaction, drainage, erosion risk and the suitability of crop rotation before planting. Apply deep tillage or organic amendments only where field conditions and soil analysis justify them.
- viii. Assess seed and input costs, labor, harvesting, transport, processing requirements and markets for beet roots and by-products before recommending commercial-scale production.
- ix. Reassess soil pH and relevant nutrient concentrations at intervals appropriate to the amendment program and cropping system, rather than relying on a fixed testing interval for all conditions.

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