

HARAMAYA UNIVERSITY

POST GRADUATE PROGRAMS DIRECTORAT

**EEFFECTS OF FILTER CAKE AND BLENDED NPS FERTILIZER
RATES ON SUGARCANE (*Saccharum officinarum* L.) GROWTH, YIELD
AND QUALITY AT FINCHAA SUGAR ESTATE, WESTERN ETHIOPIA**

MSc Thesis

ABDI TEREFE DIBABA

March 2025

Haramaya University, Haramaya

**EFFECTS OF FILTER CAKE AND BLENDED NPS FERTILIZER
RATES ON SUGARCANE (*Saccharum officinarum* L.) GROWTH, YIELD
AND QUALITY AT FINCHAA SUGAR ESTATE, WESTERN ETHIOPIA**

A Thesis Submitted to the School of Plant Sciences

Post Graduate Programs Directorate

HARAMAYA UNIVERSITY

**In Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN PLANT (SUGARCANE AGRONOMY)**

BY

Abdi Terefe Dibaba

March 2025

Haramaya University, Haramaya

HARAMAYA UNIVERSITY

As research advisors, we hereby certify that we have read and evaluated the thesis prepared by Abdi Terefe Dibaba under our guidance, which is entitled “**Effects of Filter Cake and Blended NPS Fertilizer Rates on Sugarcane (*Saccharum officinarum* L.) Growth, Yield and Quality at Finchaa Sugar Estate, Western Ethiopia**” We recommend that the thesis be submitted as it fulfills the requirements for the degree of Master of Science Sugarcane Agronomy.

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Chairperson Signature Date

Internal examiner Signature Date

External examiner Signature Date

DEDICATION

I dedicate this thesis to my father, Terefe Dibaba, and my mother, Merertu Eticha, who inspired in me the value of education, a privilege they were unable to access themselves. I also dedicate it to my beloved daughter, Yerosan Abdi, for her unwavering support and partnership in my success.

STATEMENT OF THE AUTHOUR

I hereby declare that this thesis is the result of my own original work and that I have properly acknowledged all sources used in its preparation. I submit this thesis to Haramaya University in partial fulfillment of the requirements for the Degree of Master of Science. This thesis is deposited in the University library for reference and borrowing.

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BIOGRAPHICAL SKETCH

The author was born on November 23, 1978, in Jardega-Jarte Woreda, near Shambu town, in the Horo Guduru Wollega Zone of Oromia National Regionanl State, Ethiopia. He attended Haro-Lago Primary School, followed by Alibo Junior Secondary School, and completed his education at Amuru Senior Secondary School. After passing the Ethiopian School Leaving Certificate Examination (ESLCE), he enrolled in Debub University's Wondo Genet College of Forestry in October 1999, earning a diploma in Forestry in July 2000. In October 2001, he began working at Finchaa Sugar Estate as cane plantation field coordinator. He later pursued his studies at Haramaya University, where he received a Bachelor of Science in Natural Resource Management in October 2014. In July 2021, he joined the PGPD at Haramaya University to pursue an MSc in Plant Science (Sugarcane Agronomy).

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ACRONYMS

CEC	Cation Exchange Capacity
EC	Electrical Conductivity
ESC	Ethiopia Sugar Corporation
ETB	Ethiopia Birr
FC	Filter Cake
FRS	Finchaa Research Station
FSE	Finchaa Sugar Estate
HVA	Handles' Vereeniging Amsterdam
LA	Leaf Area
LAI	Leaf Are Index
LDM	Leaf Dry Matter
LSD	Least Significance Difference
MWH	Mega Watt Hour
NPS	Blended Fertilizers of (Nitrogen, Phosphorus & Sulfur
OC	Organic Carbon
RCBD	Randomized Complete Design
SAS	Statistical Analysis System
SLW	Specific Leaf Weight
TN	Total Nitrogen
TVD	Top Visible Dewlap

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Effects of Filter Cake and Blended NPS Fertilizer Rates on Sugarcane (*Saccharum officinarum* L.) Growth, Yield and Quality, at Finchaa Sugar Estate, Western Ethiopia

ABSTRACT

*High cane yield and juice quality are crucial for the commercial sugarcane (*Saccharum officinarum* L.) industry. This study investigated the effects of blended NPS fertilizer and filter cake on cane growth, yield, and quality, particularly in light of declining soil fertility. The field experiment was conducted at FSE during the 2023/2024 cropping season, the experimental design involved a factorial arrangement combination in randomized complete block design (RCBD) with three replications. Treatments included four levels of NPS fertilizer (0, 200, 300, and 400 kg ha⁻¹) and four levels of filter cake (0, 10, 20, and 30 tons ha⁻¹). The findings aim to identify optimal fertilizer combinations and conduct a partial budget analysis of their effects on sugarcane production. Variance analysis revealed highly significant ($p < 0.01$) differences in cane parameters due to both main and interaction effects of the treatments. The combination of 400 kg ha⁻¹ NPS and 20 tons ha⁻¹ filter cake yielded the highest values for leaf area (332.1 cm²), leaf area index (5.8), cane stalk girth (26.2 mm), millable canes (120155 stalks/ha), fresh stalk weight (1.47 kg/stalk), dry stalk weight (0.42 kg/stalk), pol (16.8%), purity (90.0%) sucrose content (11.73%), cane yield (192.8 t/ha), and sugar yield (24.47 t/ha). The maximum partial budget net benefits return of ETB 1,015,957.9 was achieved with the same treatment, compared to ETB 294,652.5 in controlled. These results suggested that the integration of 20 tons ha⁻¹ filter cake with 400 kg ha⁻¹ NPS significantly enhance sugarcane production on luvisol soil. Further research is needed with different sugarcane varieties and soil types over multiple cropping seasons for more conclusive recommendations.*

Keywords: - Organic manure, soil, integrate, productivity, sustainability.

1. INTRODUCTION

Sugarcane, belonging to the grass family (Poaceae) and classified within the tribe Andropogonae, is primarily represented by the genus *Saccharum*. The botanical name, *Saccharum*, is derived from the Sanskrit word "Sharkara," which means sugar. There are six recognized species within this genus, including two wild species: (*Saccharum spontaneum* and *Saccharum robustum*), and four cultivated species: (*Saccharum officinarum*, *Saccharum barberi*, *Saccharum sinense*, and *Saccharum edule* (Verma, 2004).

Among these, *Saccharum officinarum* L., commonly referred to as "noble" cane, stands out for its high sucrose content, making it particularly valuable for sugar production (Das Gupta, 2009). Sugarcane is primarily grown in regions situated between latitudes 36.7° N and 31.0° S of the equator, encompassing both tropical and subtropical climates (Polaszek and Khan, 1998). Sugarcane production area and productivity vary significantly across countries. Brazil ranks as one of the largest producers of sugarcane, followed closely by India, while Australia leads in productivity (FAOSTAT, 2024). Approximately 70% of total white crystal sugar production is derived from sugarcane, with the remaining 30% sourced from sugar beet (Godheja *et al.*, 2014). In Ethiopia, sugarcane is the exclusive source of sugar, contributing only about 0.15% of the world total sugar production (ESC, 2022).

Sugarcane, a high-biomass crop with substantial nutrient requirements, necessitates careful management of both macro and micronutrients to maximize yield and juice quality sustainably. The typical fertilizer use efficiency in crops ranges from 20% to 40% (Ali, 2020) underscoring the importance of optimizing nutrient application timing and amounts for improved sugarcane productivity. Nitrogen (N) is the most crucial nutrient for sugarcane, significantly influencing both yield and quality. It plays a vital role in vegetative growth processes such as tillering, leaf formation, stalk development (including internodes formation, elongation, and increase in stalk girth and weight), and root growth (Singh *et al.*, 2009). Nitrogen is particularly critical during the early growth phase of the plant and immediately following cutting in ratoon crops (Rao and Karthikeyan, 2021). Inadequate phosphorus (P) can severely limit metabolic processes and photosynthesis, thereby affecting both cane yield and its quality (Bokhtail & Sakurai, 2003). Additionally, sulfur (S) is essential for plant growth and physiological processes, with its concentration in vegetative parts typically ranging between 0.1% and 2% of dry weight. The uptake and assimilation of nitrogen and sulfur are interrelated; a balanced

supply often maintains an organic N/S ratio of about 20:1 in molar terms (ESC, 2012).

Amid rising chemical fertilizer costs, organic alternatives such as press mud (filter cake) are gaining attention for their potential to supplement nutrient requirements. Dotaniya *et al.* (2016) found that organic waste by-products from sugarcane processing can enhance soil physical, chemical, and biological properties, thus improving crop yield and quality. Their research highlights that, in current exploitative agricultural practices, the capacity of soils to supply nutrients is declining under continuous and intensive cropping systems.

The application of filter cake was shown to significantly increase available phosphorus and organic carbon in the soil without adversely affecting pH levels and electrical conductivity (Abejehu, 2009). When combined with mineral fertilizers, filter cake application substantially outperformed mineral fertilizers alone in enhancing cane and sugar productivity, reinforcing the economic viability of integrated nutrient management strategies (Sardar *et al.*, 2008; Reddy, 2015).

In Ethiopia, sugarcane cultivation faces several critical production constraints. These include stagnating cane yields, poor integration of organic and mineral fertilizers, and challenges in the timing and methods of fertilizer application. The unavailability of quality seed cane and the lack of suitable cane varieties also hinder productivity. Additionally, sucrose losses during harvesting and processing, insufficient agricultural mechanization, as well as threats from wildfires and deforestation linked to climate change, security issues, financial and managerial limitations further complicate the industry's challenges (ESC, 2022).

Similarly, Finchaa Sugar Estate faces multiple production challenges, including stagnant cane yields, poor synchronization of organic and mineral fertilizers, inefficient application methods, and a lack of quality seed cane and suitable varieties. Additional issues include sucrose losses in the field and mills, inadequate modern mechanization, wildfires and deforestation that linked to climate change, ongoing security, financial and managerial difficulties.

Historically, DAP (Di-ammonium Phosphate) fertilizer was the primary phosphorus source for optimal sugarcane growth, applied at a rate of 250 kg/ha during planting. However, since 2015, the Estate has transitioned to using blended fertilizers, specifically NPS (Nitrogen, Phosphorus, and Sulfur), for planting seed cane. Unfortunately, the appropriate application rates and quantities of these blended fertilizers for maximizing cane growth have not been thoroughly studied, resulting in nutritional imbalances. This lack of research has created a

knowledge gap regarding the effective combined use of chemical fertilizers and organic nutrients. Furthermore, significant variations in soil fertility across the Estate complicate efforts to achieve higher yield targets. Improving these yields necessitates a careful balance of essential nutrients, including nitrogen, phosphorus, potassium, sulfur, and various micro-nutrients, as emphasized by (Singh *et al.* 2009).

Given the critical importance of balanced nutrition in a profit-driven production system, and the increasing global demand for sugar, there was an urgent need for robust research aimed at optimizing nutrient management to sustain and enhance sugarcane production under the current agronomic conditions. In light of rising chemical fertilizer costs and the need for high-quality cane, maintaining balanced nutrition to enhance cane growth, yield, and soil productivity is essential. This research thesis was investigated the potential of filter cake, a by-product of sugar mills, as a cost-effective soil amendment and nutrient source. Moreover; to enhance soil fertility and maximize cane and sugar yield by synergistically using blended NPS fertilizers alongside filter cake.

- Assess the effects of blended NPS fertilizer and filter cake rates on sugarcane growth, yield and quality, and
- Conducted a partial budget analysis of NPS fertilizer combined with optimal filter cake application for maximizing sugarcane yield.

2. LITREATURE REVIEW

2.1. Sugarcane Production

Sugarcane (*Saccharum* spp. hybrid) is a tall growing perennial plant cultivated predominantly in countries located between latitudes 36.70° North and 31.00° South of the equator, spanning tropical to subtropical zones. Considered primarily a tropical plant, sugarcane is a long-duration crop that experiences all seasonal variations in rainy, winter, and summer throughout its life cycle. It is primarily grown for its ability to accumulate high concentrations of sucrose in the internodes of its stem, typically exhibiting a sucrose content ranging from 10% to 18% and fiber content from 10% to 15% at harvest (FAO, 2022).

As a renewable natural agricultural resource, sugarcane not only provides sugar but also serves as a source for bio-fuels, fiber, fertilizers, and a variety of by-products and co-products, thus contributing to ecological sustainability. Sugarcane juice can be processed into white sugar, brown sugar, jaggery, and ethanol. The sugar industry generates three main by-products: bagasse, molasses, and filter cake (also known as press mud). Typically, the production of one ton of crushed sugar yields approximately 350 kg of bagasse, 45 kg of molasses, and 510 kg of press mud (Renouf *et al.*, 2011). However, the global sugarcane industry is expected to face significant challenges from climate change, which could adversely affect production in various regions. Shifts in weather patterns, alongside droughts, floods, and other extreme weather events, may render some areas less suitable for sugarcane cultivation (FAO, 2024).

2.2. Importance of Sugarcane

Sugarcane is a large perennial tropical grass cultivated for its tall thick stems. Sugarcane is grown for chewing, drinking juice, raw sugar and centrifugal sugar. Thick noble canes, which are relatively soft with a high sugar and juice content and low in fiber, are best for chewing. The juice can also be used for drinking and sweetening, by boiling the juice over an open fire until it is almost dry, a form of sugar is prepared called jaggery or non-centrifugal sugar. Sugarcane is a renewable agricultural resource that offers multiple benefits, including the production of sugar, bio-fuel, fiber, fertilizer, and a variety of by-products co-products, all contributing to ecological sustainability. The juice extracted from sugarcane is used to create white sugar, brown sugar, jaggery, and ethanol. The sugar industry primarily generates three main by-products: bagasse, molasses, and filter cake (also known as press mud) (Verma,

2004). From a ton of crushed sugarcane, approximately 350 kg of bagasse, 45 kg of molasses, and 510 kg of press mud (also known as filter cake) are produced (Verma, 2004).

The Ethiopian Sugar Corporation has indicated in its Quarterly Newsletter that about 28,000 jobs were created in a year due to new and expansion projects of sugar factories. Moreover, local peoples of the project area are becoming beneficiary from resettlement program, irrigation facility, environmental and grazing land protection, improvement of cattle breeding system and construction of social service institutions like schools, veterinary center, health station, farmer's training center, bakery, mosque, potable water and drinking place for cattle's. Small and micro-enterprises have been organized to improve the livelihood of the local communities on top of creating direct job opportunities. An accessible road for transportation and facility of communication are also expanding due to the sugar industry projects in action (ESC, 2012). Furthermore, it has a sound share in food industries, in manufacturing industries and in the gross national product of the country. Molasses, also, is used as an additive to feed for livestock. Green tops of cane are a good source of fodder for cattle and its remains are good manure in alkaline and saline soils (FAOSTAT, 2018).

The Ethiopia government nationalized the whole Ethiopian sugar industry and all of HVA's assets in 1975. As a result, construction of the fourth mill, Finchaa sugar industry took more than 20 years to be completed and to become fully operational in 1998 (Lichts, 2010). As part of its economic development program, the Ethiopian government has drawn up an ambitious expansion program in sugar production. Presently, the contribution of the sugar industry sector to the gross domestic product is relatively small but given the country's abundant water resources, coupled with a very fertile land favorable for the cultivation of sugarcane, the country has the potential to become one of Africa's major sugar producers. When the planned projects in the sugar sector are fully completed, Ethiopian sugar production may rise to around 2.25 million tons from the current 0.3 million tons. The projects also play an important role in creating employment opportunities for more than 80,000 skilled, semiskilled and un-skilled laborers, generating about 606,943 MWH electric powers and substituting up to 20% of gasoline import with fuel ethanol (Mijena, 2011). The composition of Filter cake according to the study conducted by Ketan *et.al* , (2008) the press mud generated from the sugar industry contains a variety of essential elements with a carbon to nitrogen ratio 16:36 suitable for

composting. And the author also estimated that on an average each ton of press mud contains about 10- 15 kg N, 36 kg P, 14 kg K, and 23 kg S (Ketan *et al*, 2008).

2.3. Ecological Requirements of Sugarcane

2.3.1. Climatic Requirements

2.3.1.1. Temperature

Sugarcane thrives in regions characterized by warm, sunny, and frost-free weather conditions. The optimal temperature range for the germination of stem cuttings falls between 32 to 38 °C, facilitating robust growth. In addition to temperature, sugarcane requires a long duration of sunlight exposure, ideally between 12 to 14 hours per day. This extended photoperiod, combined with high humidity levels of approximately 80-85%, significantly promotes rapid cane elongation during the primary growth phase, ultimately enhancing the yield and quality of the crop (FAO, 2018).

2.3.1.2. Water

Water is the cornerstone of plant health, acting as the most crucial limit to growth and crop production. Its pivotal role is underscored by its necessity for nutrient transportation and carbohydrate synthesis within the plant. Without adequate water supply, the physiological benefits of fertilizers cannot be fully realized, leading to suboptimal growth. Water serves as the primary medium for transporting vital nutrients throughout the plant, and its availability directly influences sugarcane's overall health and productivity (FAO, 2018).

2.3.2. Soil

Sugarcane is adaptable and can grow in various soil types; however, it flourishes best in fertile, well-drained soils. Ideally, sugarcane prefers humid soils with a depth ranging from 100 to 150 cm, which ensures adequate drainage and aeration. Sandy loam soils of medium fertility are particularly favorable, as they support the plant's root development and nutrient uptake. The optimal pH range for sugarcane growth is between 6.0 and 7.7, allowing for efficient nutrient availability and uptake (Das Gupta, 2009). Well-maintained soil conditions are essential for maximizing yields and sustaining long-term production.

2.4. Sugarcane Production Constraints

In sugarcane producing commercial industry there are a number of production constraints which occurs at different section of production like cane yield plateau, lack of synchronized

use of organic and mineral fertilizers, problem of fertilizer application method, time, rate and use, non availability of quality seed cane, lack of suitable cane varieties, sucrose losses in field and sugar mills, lack of modern agricultural mechanization and equipments, non availability of labor for intercultural operations, irregular supply of electricity, wide fluctuation in the cane yield and sugar recovery due to weather conditions, non availability of water at proper time, wild fire burning occurrence, deforestation that cause climate change, sedimentation silt in the canal and canal slide, financial and managerial constraints (FSE annual report, 2021).

Improved cane varieties have significantly contributed to increasing cane productivity per unit area; however, these varieties are typically selected under optimal conditions and may not withstand unfavorable weather. Furthermore, biotic constraints that limit cane productivity include weeds, diseases, and pests, while a biotic constraint encompass drought, salt stress, mineral deficiencies, flooding, and wind injury. These stresses can occur singly or in combination, adversely affecting both cane yield and quality. Additionally, because sugarcane is a vegetatively propagated crop, cane setts can carry serious diseases such as red rot, smut, and ratoon stunting disease, leading to low seed cane multiplication ratios of less than 1:10 (FSE Annual Report, 2021).

2.5. Sugarcane Fertilization

The nutrient turnover in the soil plant system is considerably high under intensive farming and the plant nutrients depleted from the soil due to crop removal and/or soil erosion, need to be supplied through an efficient and effective fertilizer management strategy. The challenge for plant nutrition management is to maintain and if possible increase sustainable crop productivity to meet the demands for food and raw materials and to enhance the quality of land and water resources.

Agriculture invariably removes plant nutrients from the soil and these have to be replenished. Application of mineral fertilizers is essential to meet crop requirements and to increase crop production in many farming situations. Large parts of applied nutrients can be lost through several processes like fixation, leaching, run-off, volatilization (Gopalasundaram and Rakkiyappan, 2009). Sugarcane being a long duration crop with C₄ metabolism, demands large amounts of moisture, nutrients and sunlight for its optimum productivity. Sugarcane is one of the largest consumers of fertilizers and responds very well to fertilizers. Fertilizer is responsible for nearly 50% yield increase in sugarcane (Gopalasundaram and Rakkiyappan,

2009). Das Gupta (2009) also forwarded the nutrient consumers of sugarcane for a very high yield to a tune of 100 ton/ha. Sugarcane fertilization is for both stalk and sucrose tonnage. The rates of fertilization have to be adjusted in relation to the energy and moisture levels in a locality to take advantage of the correlated growth. Supply of a deficient nutrient will improve quality and tonnage, but its disproportionate excess will lower it. Sugar yield is the resultant of sugar content in cane. Nutrient supplies help to get the optimum amount of sugar yield (Kakde, 1985).

2.6. Filter Cake and Its Effect

Filter cake is utilized as fertilizer in several countries, including Brazil, India, Australia, Cuba, Pakistan, Taiwan, South Africa, and Argentina. The residue is produced in large volumes (30–40 kg t⁻¹ of crushed cane) and it contains a considerable amount of organic matter and mineral elements required for plant nutrition, characteristics that explain its potential for agriculture. It can partially substitute for mineral fertilizers (Santos *et al.*, 2011). The main effects of filter cake on soil chemical properties are increased nitrogen, phosphorus, and calcium concentrations, increased cation exchange capacity, and reduced concentrations of exchangeable aluminum (Al³⁺), which is toxic to plants (Korndorfer and Anderson, 1997). Beneficial effects on physical and biological soil properties are also observed. Thus, due to its characteristics, filter cake can play a fundamental role in agricultural production, in the maintenance of soil fertility, and as a soil conditioner.

The press mud (Filter Cake) is one of the major by-products of the sugar industry and constitutes about 3-7% of the total weight of cane crushed depending on the clarification process employed. In the sulphitation factories, it amounts to about 3% and in the carbonation factories about 7%. The press mud is the residue obtained by filtration which settles out in the process of clarification of cane juice for sugar manufacture. It is commonly known as filter cake; filter press cake, scum or mill mud. It is a soft, spongy light weight material of dark-brown or black color normally containing 50-70% moisture (when it comes from a sugar factory). It consists of a mixture of sugarcane fiber, sucrose and coagulated colloids including cane wax, albuminoids, inorganic salts and soil particles (Verma, 2004).

The composition of press mud is varied greatly with the cane varieties, soil and climatic conditions and the type of juice clarification process (sulphitation or carbonation) adopted (Yadav, 1991).

The sulphitation process at Finchaa sugar mill employs lime and SO_2 to produce CaSO_3 along with impurities from cane juice, forming mud. In contrast, the carbonation process utilizes lime and CO_2 to yield CaCO_3 , also accompanied by impurities. Research by Kanwar and Kapur (1987) indicates that sulphitation press mud is superior to carbonation due to its higher nutrient content. Filter cake, which contains beneficial microorganisms such as *Aspergillus fumigatus*, *Bacillus subtilis*, and *Streptomyces* species, serves as a rich source of organic matter and nutrients. It includes essential macro and micronutrients for plant growth, which become available as the filter cake decomposes in the soil. The application of press mud enhances the availability of iron, zinc, calcium, magnesium, and manganese. In calcareous soils, it effectively lowers pH, increases cation exchange capacity, and reduces exchangeable sodium percentage. Yaduvanshi and Yadav (1996) demonstrated that applying filter cake leads to improved crop yields, enhances soil fertility, and positively impacts the physical, chemical, and microbiological properties of the soil. As a source of sulfur, sulphitation press mud is as effective as other sulfur sources such as single super phosphate, gypsum, and elemental sulfur for sugarcane cultivation. Additionally, the residual benefits of press mud on subsequent crops have been noted.

However, direct application of filter cake is not advisable due to its high C:N ratio and heat generation during decomposition. Composting press mud with microbial assistance mitigates these issues, enriching its properties and making it safer and more manageable for field application (Sundara, 2000).

Rai *et al.* (1980), have successfully reclaimed a soil of pH 9 with 20 ton/ha sulphitation pressmud and obtained an increased cane yield by 26.3 ton/ha. Composted filter cake (pressmud) is better as compared to the fresh one (Patil and Shinde, 1995). Even the quantity of N, P and K were high when composted with worms, the so-called vermi-composting (Ramalingam and Ramanathan, 1998). Filter cake can be composted and enriched in terms of nutrients by mixing with other by-products like vinase. There is a practice of using these product mixtures as a soil amendment in Metehara Sugar Estate.

2.7. Effect of Blended NPS Fertilizers

Nitrogen N deficient canes show uniform yellowing of the leaves (chlorosis), retarded growth, stalks of smaller diameter, pre-mature drying and senescence of old leaves and longer and

thinner roots. Excess application of nitrogen not only brings down cane yield but also adversely affects the cane juice quality (Singh and Yadav, 1996). Production of watery shoots with higher reducing sugar content under high and late nitrogen application also lowers juice quality. The detrimental effect of higher dose of N on juice quality is also attributed to the accumulation of nitrogenous substances and reduction in P_2O_5 content and thus affecting clarification. It also prolongs vegetative growth, delays maturity and ripening. A study on varietal response to applied nitrogen revealed that considerable variations exist among the varieties in their response to applied N (Srinivasan, 1995).

Phosphorus P fertilizer highly affects the germination percentage required which indicates the establishment of proper plant population maintained for getting a standard crop harvest. Application of P, especially on P deficient soils promotes root growth, stimulates tillering, and influences better growth and thereby better yield and juice quality (Bokhtail and Sakurai, 2003). P deficiency leads to reduced metabolic rate and photosynthesis which then leads to cane yield and quality. Also small scale sugarcane farmers in Nigeria do not have bigger options regarding high yielding and high sucrose varieties as well as vitality of the use of chemical fertilizers for producing high yielding and sugar recovery in sugarcane. Sources and levels of P significantly increased tiller number, amount of millable canes, plant height and cane yield.

Application of P fertilizer promote root growth, stimulate tillering, influences millable cane growth, and thereby sugarcane yield per ha. Higher cane yield could be attributed to the higher number of tillers and millable cane (Toomsan and Limpinuntana 2005). Beside yield, adequate P nutrition is conducive for sugar accumulation in cane tissues. The effects of P sources and levels of sugarcane juice were shown to be highly significant. However, higher values were obtained for % Brix and Pol of 20.62 and 18.81 respectively at control plots compared to treated plots irrespective of the sources and levels of P. Fertilizer P sources can be applied to supply P and that P has a greater effect on yield parameters than on quality parameters Omollo and Abayo (2011). Higher P application rate in a balanced fertilization strategy is significantly increased cane and sugar yield. Improved soil P status alone, increased cane yield by 31% over yields obtained under present soil P fertility.

Sulfur (S) deficient, retarded growth rate and delayed maturity, Young leaves light green to yellowish color in some plants, older tissue may be affected, small and thin plant under

conditions of sulphur starvation. Sulphur deficiency symptoms are expressed moderately at low nitrogen levels but extremely with a high nitrogen supply. This effect explains the enhancement of sulphur deficiency symptoms in the field after nitrogen dressings. Changes in the nitrogen supply affect the sulphur demand of plants and vice versa. Under conditions of sulphur deficiency, the utilization of nitrogen would be reduced and consequently non-protein nitrogen compounds, including nitrate, accumulate in the plant tissue (ESC, 2012).

2.8. Combined Use of Blended NPS Fertilizer and Organic Manure

Agricultural soil typically contains up to 5% organic matter, but practices like continuous cropping and maximal tillage lead to its depletion, adversely affecting soil structure, increasing erosion, and reducing crop productivity. Relying solely on chemical fertilizers is insufficient; they must be supplemented with organic matter to maintain yields (Velde and Barr, 2010). Combining organic and inorganic fertilizers enhances nutrient retention and reduces losses (Palm *et al.*, 1997). In India, the nutrient removal from soil exceeds the addition of chemical fertilizers, highlighting a 10 million ton annual deficit. India applies 2 tons of organic manure and 108 kg of NPK fertilizers per hectare, compared to China's 10 tons of organic manure and 760 kg of NPK fertilizers. Thus, solely using mineral fertilizers cannot ensure sustainable productivity, particularly in low organic matter soils (Singh & Gupta, 2009). Incorporating organic manures can help close the nutrient gap and conserve foreign exchange (Mahajan and Gupta, 2009).

Use of mineral fertilizers alone as a source of nutrients cannot ensure sustainable productivity of soils and higher yields; especially in soils which are low in organic matter contents, mineral fertilizers cannot express their full beneficial effects on crop yields (Incle *et al.*, 1999; FAO, 2000). Continuous application of high amounts of chemical fertilizers (in cereal based cropping systems) leads to declined crop productivity. This is due to nutrient imbalances and deficiency of micro-nutrients (Hedge, 1992). Thus, combined use of organic materials and mineral fertilizers can be an important option if productivity of soils is to be maintained at desirable levels.

Organic additions are known to improve physical, chemical and biological properties of soil (Sundara, 2000; Kaur *et al.*, 2004). Integrated use of organic manures and mineral fertilizers would not only give significantly higher yields, but also help to maintain soil health by narrowing down the gap between nutrient removal and supply. The efficiency of fertilizers

increases when used in combination with organic matter (Yadav *et al.*, 1998). The commonly used organic manures are farm yard manure, compost, vermi-compost, green manures, crop residues, agro-industrial wastes and bio-fertilizers, and are important inputs for maintaining soil fertility and ensuring yield stability (Mahajan and Gupta, 2009). It was indicated that agro-industrial wastes like filter cake can be used effectively as manure and its major nutrient NPK content is about 0.5-1.5% N, 0.5-2.5% P₂O₅ and 0.5-3% K₂O.

The grain yield, total productivity and net returns in the rice-wheat cropping system increased with the application of organics in combination with inorganic fertilizers. The results of a 16-year old permanent long manorial trial on rice-wheat system at Faizabad, Uttar Pradesh, revealed that substitution of 25-50% N through farm yard manure along with 50-75% recommended NPK through chemical fertilizers to rice resulted in higher yield compared to 100% chemical fertilizer application alone. The results indicated that farm yard manure application at the rate of 12-15 t ha⁻¹ to rice could substitute nearly 60 kg N ha⁻¹ (Mahajan and Gupta, 2009). Studies in Ethiopia (Holeta, Bako, and Hawassa) demonstrated that combining organic materials with mineral fertilizers significantly increased cereal grain yields (Fikadu and Shiferaw, 2022). Additionally, the use of pressmud alongside mineral fertilizers positively affected sugar yield in sugarcane cultivation. The application of filter cake (pressmud) notably enhanced soil fertility, particularly phosphorus levels (Girma, 2009).

In Ethiopia there was an investigation of effects of filter cake on major soil chemical properties done by (Abejehu, 2009). According to his result, the application of filter cake had no remarkable effect on pH and EC (salt content) of soils in the plantations. However, it highly improved the available phosphorous and organic carbon contents of the soils. Moreover, the author have got the high values of organic carbon in soils recorded at harvesting time and indicated that filter cake could be an important source of organic matter to the soil which plays a key role in maintaining nutrient supply and retention properties of soils and in improvement of soil structure (Abejehu, 2009). Abejehu applied filter cake to heavy soil at Metehara and Wonji Shoa and to Vertisol, at Fincha had also similar effect on soil properties.

2.9. Strength, Limitations and Gaps of the Research Work

The research highlights the numerous strengths and opportunities for enhancing sugarcane cultivation through optimized resource allocation and strategic utilization of by-products.

However, a fundamental challenge that must be addressed to realize sustainable increases in sugarcane yield was the existing limitations and gaps in nutrient management and soil fertility. The Estate's abundant water resources and favorable land conditions are critical for optimizing sugarcane production and meeting future agricultural demands.

The potential use of sugarcane by-products, such as filter cake and bagasse, as bio-fuel sources further illustrates sugarcane's versatility and presents opportunities for sustainable energy production, which can add significant economic value. Moreover, adopting improved agricultural practices could lead to increased sugarcane yields, thereby enhancing food security and promoting better livelihoods for farmers. Despite these opportunities, soil fertility variability remains a significant barrier to achieving optimal sugarcane yields. This variability results from a combination of environmental factors, land management practices, and nutrient availability. Effective nutrient management was imperative for boosting production; however, current practices had often been inadequate, leading to a decline in soil fertility that adversely impacts yields.

The Estate exhibits a pronounced lack of integration between chemical fertilizers and organic manures, signaling an urgent need for improved nutrient management strategies aimed at enhancing sugarcane productivity. There is a pressing demand for research focused on integrated approaches, particularly studies that evaluate the effectiveness of combined fertilizer application strategies that incorporate both chemical and organic sources. Such strategies could enhance soil fertility and optimize sugarcane yields. Future research should also examine the long-term impacts of various fertilizer combinations on soil health, sugarcane yield, and the sustainability of farming practices in the Estate.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The field experiment was conducted at Finchaa Sugar Estate, located in the Oromia National Regional State, within the Horro Guduru Wollega Zone, specifically in the Sulula Finchaa woreda, during the 2023/2024 cropping seasons. The Estate is positioned between latitudes 9°30' and 10°00' North, and longitudes 37°15' and 37°30' East, approximately 340 km West of Addis Ababa. The altitude ranges from 1350 to 1650 meters above sea level. The landscape features a valley surrounded by steep, nearly vertical escarpments that rise 700 to 800 meters above the Valley floor on the Eastern, Western, and Southern sides. The Valley floor itself exhibits gentle undulations with a general slope of 1% to 8% from South to North (Worku, 1995).

The annual precipitation in the area averages around 1394.4 mm. The climate is characterized by daily maximum and minimum temperatures averaging 31 and 12°C, respectively. The highest recorded monthly maximum temperature is 35.4°C in April, while the lowest monthly minimum temperature reached 9.9°C in December (Appendix Table 1). Over a 20-year period from 1991 to 2010, the average relative humidity ranged from a maximum of 83.1% to a minimum of 39%. Furthermore, a 21-year average (1990 to 2010) indicated daily sunshine hours of approximately 7.66 hours (Mijena, 2011). The dominant soil types in the Finchaa Sugar Estate are vertisol and luvisol, with soil pH levels ranging from 5.0 to 7.6 for vertisol and 5.6 to 6.6 for luvisol (FSR, 2024).

Finchaa Sugar Estate manages approximately 67,000 hectares, of which 19,602.42 hectares are under sugarcane cultivation and 896.27 hectares consist of manmade plantations. The remaining area comprises natural forest, residential areas, and bare land (FSE Annual Report, 2021).

3.2. Experimental Materials

3.2.1. Seed setts cane

The high-yielding sugarcane variety N-14 was used for the study. Seed cane was sourced from the Estate's fields, consisting of healthy, two-budded setts, aged eight months, with an average length of 18-20 cm and uniform diameter. These setts were manually planted in luvisol soil.

3.2.2. Filter cake

A filter cake obtained from the factory of the Estate was composed for 45 days and was used as experimental material.

3.2.3. Blended NPS fertilizers

The specified treatment for the plot was applied manually at the time of planting, with the required amount determined using a weighing. Since 2015, the Estate has utilized blended NPS fertilizer as a source of phosphorus, applying it at a rate of 300 kg per hectare for both planting and ratoon canes

3.3. Treatments and Experimental Design

The experimental design involved a factorial arrangement combination with four levels of NPS rates: 0, 200, 300, and 400 kg NPS ha⁻¹, combined with four levels of filter cake rates: 0, 10, 20, and 30 tons ha⁻¹. The recommended NPS application in the study area is 300 kg ha⁻¹ (FSE Operational Procedure, 2015).

The experiment was laid in a randomized complete block design (RCBD) and replicated three times. Each plot consisted of four furrows measuring 5 m in length and 1.45 m in width, resulting in an area of 29 m² per plot. Overall, the study encompassed a total of 48 plots, covering an area of 1,392 m², within an experimental field of 3,146.5 m². To maintain adequate spacing, plots were separated by 1.5 m, while the blocks were spaced 2.9 m apart. Additionally, border spaces of 3 m were established on both sides (left and right) along the length and across the replications to facilitate observation and demarcate the experimental area from adjacent commercial fields. Each plot was assigned a treatment randomly. In addition to the NPS and filter cake treatments, a uniform application of 125 kg urea ha⁻¹ was made across all plots, and all other agronomic management practices were implemented consistently throughout the growing season to ensure that the observed effects were attributable to the treatments applied.

Table 1. Treatments combinations of blended NPS fertilizer and filter cake rates applied

T-Code	Rate of NPS and Filter Cake combinations	%N	%P ₂ O ₅	%S	Filter Cake (tons/ha)
T-1	0 kg ha ⁻¹ NPS with 0 ton ha ⁻¹ Filter Cake	0	0	0	0
T-2	200 kg ha ⁻¹ NPS with 0 ton ha ⁻¹ Filter Cake	38	76	14	0
T-3	300 kg ha ⁻¹ NPS with 0 ton ha ⁻¹ Filter Cake	57	114	21	0
T-4	400 kg ha ⁻¹ NPS with 0 ton ha ⁻¹ Filter Cake	76	152	28	0
T-5	0 kg ha ⁻¹ NPS with 10 tons ha ⁻¹ Filter Cake	0	0	0	10
T-6	200 kg ha ⁻¹ NPS with 10 tons ha ⁻¹ Filter Cake	38	76	14	10
T-7	300 kg ha ⁻¹ NPS with 10 tons ha ⁻¹ Filter Cake	57	114	21	10
T-8	400 kg ha ⁻¹ NPS with 10 tons ha ⁻¹ Filter Cake	76	152	28	10
T-9	0 kg ha ⁻¹ NPS with 20 tons ha ⁻¹ Filter Cake	0	0	0	20
T-10	200 kg ha ⁻¹ NPS with 20 tons ha ⁻¹ Filter Cake	38	76	14	20
T-11	300 kg ha ⁻¹ NPS with 20 tons ha ⁻¹ Filter Cake	57	114	21	20
T-12	400 kg ha ⁻¹ NPS with 20 tons ha ⁻¹ Filter Cake	76	152	28	20
T-13	0 kg ha ⁻¹ NPS with 30 tons ha ⁻¹ Filter Cake	0	0	0	30
T-14	200 kg ha ⁻¹ NPS with 30 tons ha ⁻¹ Filter Cake	38	76	14	30
T-15	300 kg ha ⁻¹ NPS with 30 tons ha ⁻¹ Filter Cake	57	114	21	30
T-16	400 kg ha ⁻¹ NPS with 30 tons ha ⁻¹ Filter Cake	76	152	28	30

3.4. Experimental Procedures and Management

3.4.1. Land preparation

The land was prepared to a fine seedbed using dozers and tractors, following conventional methods. Plowing was conducted according to standard practices, adhering to the established time intervals for each operation.

3.4.2. Filter cake composting

A 3 m³ pit was excavated at the edge of the cane field designated for the experiment. Fresh filter cake from the sugar factory was placed in the pit and allowed to compost for 45 days. During this period, it was kept moist using a watering can to facilitate decomposition. Microbial activity facilitates the breakdown and decomposition of filter cake, a process that enhances its nutrient content. This composting not only improves the safety of the filter cake but also increases its efficacy for agricultural applications.

3.4.3. Seed setts planting

Eight months age, healthy, two-budded seed cane setts from the N-14 variety, sourced from the seed cane field of the estate. The seed setts were cut a day prior to planting, and to ensure their health and protect against fungal diseases (smut, red rot) disinfected the cane knives used for chopping stalks after each cut with a Lysol solution (120 mL of Lysol mixed in 1 liter of water). After chopping, the prepared seed setts were immersed in a fungicide known as tilt (1 mL per 1 liter of water) for one to two minutes. This treatment was conducted using a steel wire basket to protect the seed material from soil-borne diseases, like red rot, red leaf mottle and wilt, and insect pests, like termites after planting.

Following treatment, the setts were planted in furrows with an average overlap of approximately five centimeters, in a pre-irrigated experimental field. To further safeguard against termite attacks, the field was sprayed with a solution composed of two liters of Pynrex mixed with 200 liters of water per hectare. Finally, the seed setts were manually covered with a thin layer of soil, adhering to the operational procedures for planting FSE seed setts.

3.5. Time and Method of Application of NPS Fertilizer and Filter Cake

Filter Cake Application: - One week prior to planting, the appropriate amount of composted filter cake was weighed for each experimental plot and applied, mixed with the soil and irrigated.

Blended NPS Fertilizer Application: - The blended NPS fertilizer was applied manually at the time of planting and then lightly covered with a thin layer of soil to ensure proper incorporation and nutrient availability.

3.5.1. Soil sampling and analysis

Soil sampling and analysis involved the collection of composite soil samples from five diagonal locations within the experimental site at two depths: 0-30 cm and 31-60 cm, prior to planting. An auger was utilized to obtain uniform slices and volumes of soil. The samples were air-dried and ground using a standard soil sample grinding machine, then passed through a 2 mm sieve.

The working samples derived from the submitted samples were analyzed for selected physico-chemical properties, which included texture, organic carbon (OC), total nitrogen (total N), available phosphorus (available P), available sulfur (available S), cation exchange capacity

(CEC), electrical conductivity (EC), and pH. Analysis was conducted at the FRS Laboratory, following the procedures outlined in the FAO (2008) Laboratory Manuals.

3.5.2. Filter cake sampling and analysis

A sample of the decomposed filter cake was collected, prepared, and analyzed for nitrogen (N) and phosphorus (P). To initiate the process, a representative sample was obtained from the conditioned filter cake. The wet weight of the sample was measured, followed by drying it in an oven at a consistent temperature to determine the dry weight. This allowed for the calculation of moisture content and ultimately the amount of dry matter available for application in the field.

3.6. Leaf Sampling and Analysis

The third top visible dewlap (TVD) leaves of the sugarcane plants were randomly sampled from five actively growing primary shoots located in the two middle rows of each plot at five months of age, following the procedure outlined by Martin-Prevel *et al.* (1987). The lamina was separated from the midrib, washed in de-ionized water, bundled together and oven-dried at 95°C until a constant weight was achieved. The dried leaf material was ground to pass through a 1 mm screen using a stainless-steel Wiley mill.

All ground samples were dried overnight at 65°C before weighing for digestion. Total leaf nitrogen (N%) was determined using the Micro-Kjeldahl digestion, distillation and titration method with sulfuric acid, as described by Jackson (1975). For phosphorus (P) analysis, the dried and ground leaf material was ashes at a temperature of 480°C, following the methodology outlined by Pratt (1965).

3.7. Data Collection and Measurement

3.7.1. Cane growth parameters

3.7.1.1. Sprouting percent

Sprouting was started 18 days after planting and lasted for about 45 days. Sprouts were counted starting from 18 days after planting and continued until it was completed a seven day interval using the two middle rows of the plot, expressed as a percentage (Aregaw, 1991).

$$\text{Sprouting (\%)} = \frac{\text{total number of sprout per furrows}}{\text{total number of buds per furrows}} \times 100$$

3.7.1.2. Tillers population Count

Tiller population count was done every month from three months of the cane age after planting up to the maximum tillering of plants in the two middle rows of the plot. This was computed by FSE operational procedures.

$$\text{Number of tillers (tillers/ha)} = \frac{\text{Number of tillers per plot}}{\text{plot area m}^2} \times 6900 \text{ m}^2$$

3.7.1.3. Leaf area per plant and leaf area index

Leaf area (LA) per plant was measured by linear measurements of the length and width of the 3rd, 4th, and 5th top visible dewlap leaves from five primary shoots per plot at the maximum tillering stage, five months after planting (Watson, 1958). The leaf area for a single leaf was calculated using the formula: $LA = \text{length} \times \text{width} \times 0.76$.

Leaf Area Index (LAI) was estimated with the equation $LAI = A/L$, where A represents the total leaf area of a plant and L represents the area occupied by the plant canopy. The total leaf area per plant was obtained by multiplying the number of leaves per plant by the area of a single leaf. The average area occupied by the canopy of each plant was determined by dividing the total number of plants found in a 5-meter furrow by the area occupied by the plant canopy.

3.7.1.4. Specific leaf weight

Specific leaf weight (SLW) was determined using the formula $SLW = LDM/LA$ (Gardner *et al.*, 1985), where LDM represents leaf dry matter and LA represents leaf area. Measurements were taken from the 3rd, 4th, and 5th top visible dewlap leaves of five primary shoots per plot at five months of age.

3.7.1.5. Cane stalk height

The stalk height was measured from ground level to the top of the visible dewlap for five randomly selected plants per plot from the middle two rows. Measurements were taken monthly from the 5th month until the 12th month after planting, with the final height measurement conducted at harvest (approximately 14 months after planting for FSE).

3.7.2. Cane yield parameters

3.7.2.1. Number of millable canes stalk

Cane yield was determined by harvesting three stalks from each plot at twelve months of age, following the general formula for yield estimation procedures. Both millable and cane yield were calculated using the formulas specified in the FSE procedures;-

$$\text{Millable canes stalk (stalks/ha)} = \frac{\text{Number of millable cane per plot}}{\text{Plot area m}^2} \times 6900 \text{ m}^2$$

$$\text{CY at 12 months (t/ha), } Y_1 = \frac{\text{Weight of millable cane per plot (kg)}}{\text{Number of millable cane per plot m}^2} \times \text{No. of M. cane ha}^{-1}$$

$$\text{Cane yield Estimated at 14 months (t/ha), } Y_2 = Y_1 + [\text{CF} (Y_1/M_1) * (M_2 - M_1)]$$

Where; Y₁= cane yield per hectare at estimated (12 months); Y₂ = expected cane yield per hectare at commercial harvest (14 months), 0.8= Correction factor; M₁= age of cane at sample harvest (12 months), M₂= Expected age of cane at commercial harvest (14 months); M= millable cane stalk and no = number.

Nine stalks from similar treatments were harvested from the three replications, de-trashed, bunched, and weighed using a weight balance. The average weight of a single stalk was determined by dividing the total weight of the nine stalks by nine. The population of millable cane stalks from similar treatments within 3 m of the two middle rows of the experimental plots was counted, averaged, and converted to a per hectare basis. (One hectare = 6900 m²)

3.7.2.2. Cane stalk girth

Average stalk girth of five plants per plot was measured from bottom, middle and top portion of the stalk at twelve months age using a caliper and the average value was recorded.

3.7.2.3. Cane stalk weight

Five plants were randomly selected from each plot of the middle two rows at the age of twelve months cut at the ground level and at the top visible dewlap and weighed. The result was expressed on per plant basis for fresh weight. These stalks were further subjected to sun drying and then to oven drying till constant weight obtained. Dry weight was recorded and extrapolated.

3.7.3. Cane quality parameters

3.7.3.1. Brix% cane

The value of brix was determined by using bench refractometer which give direct reading of brix in sample juice.

3.7.3.2. Pol % cane

Pol % cane was determined from 100 ml clear cane juice sample obtained and the filtered clear juice was filled in to 20 cm pol tube for recording polarized reading in Polari meter. It was corrected for a Brix % at 20 °C the pol % cane reading was recorded.

3.7.3.3. Purity% Cane

Purity% cane was determined by dividing pol% cane to Brix% cane and multiplied by 100.

3.7.3.4. Sucrose content percent

Sucrose recovery was calculated with the help of the following formula (FSE procedures).

$$\text{Sucrose recovery \% cane} = [\text{Pol\%} * \text{pol factor} - \text{brix\%} * \text{brix factor}] \\ [(\text{Pol\%} * 1.1461) - (\text{brix\%} * 0.4161)]$$

Where 1.1461= pol% correction factor; 0.4161= brix% correction factor

3.7.3.5. Sugar yield estimated

Sugar yield was determined by multiplying cane yield (tons ha⁻¹) times sucrose (%) cane divided by 100. This was computed by FSE procedures.

$$\text{Sugar Yield (tons ha}^{-1}\text{)} = \frac{\text{cane yield (tons/ha)}}{100} \times \% \text{ Sucrose}$$

3.8. Data Analyses

All measured parameters were analyzed using, two-way ANOVA with a randomized complete block design (RCBD) in a factorial arrangement combination, utilizing the SAS for data analysis. Differences between treatments means were separated using LSD at 5% level of significance.

3.9. Partial Budget Analyses

The partial budget analysis was conducted to evaluate the economic viability of mineral fertilizer applications, specifically blended NPS and filter cake, in relation to the sugar price ratio at a specified market and production period, as outlined by CIMMYT (1988).

Adjusted yield (AjY):- It was the average yield adjusted downward by 10% to reflect difference between the experimental yield and yield of farmers.

$$\text{AjY} = \text{AvY} - (\text{AvY} * 0.1)$$

Gross field benefit (GFB):- It was computed by multiplying field /farm gate price that farmers receive for the crop when they sale it as adjusted yield.

$$\text{GFB} = \text{AjY} * \text{field /farm gate price for the crop}$$

Total variable costs:- It includes the price of Urea = 40.38 birr/kg; NPS price = 40.14 birr/kg; Cost of filter cake transport = 1489.31 birr/trip; Fuel cost = 84.62 birr/liter; Sugar price = 90 birr/kg; Truck travel = 0.4Lt/km; The average distance from sugar mills of filter cake to cane

farm field is 22km and at once trip the truck capacity can loads 10 tons of filter cake to farm field.

Net benefit (NB): - It was calculated by subtracting the total costs from field benefit for each treatment.

Marginal rate of return (MRR %): - It was calculated by dividing change in net benefit by change in total cost.

$$\text{MRR (\%)} = \Delta\text{NB}/\Delta\text{TC} * 100$$

Where; MRR is Marginal rate return in percent, ΔNB and ΔTC is change in net benefit and change in total cost, respectively.

4. RESULTS AND DISCUSSION

4.1. Selected Soil Physico-Chemical Properties of the Experimental Site

The physico-chemical properties of the soil from the experimental site were presented in (Table 2). The analysis indicated that the soil primarily comprises sand and clay, classifying it as sandy clay loam, in accordance with Allison's (1973) classification. The pH level was recorded at 6.4, which Jones (2001) categorizes as slightly acidic. This acidity is suitable for sugarcane cultivation, as supported by Fauconnier (1993), who noted that sugarcane thrives across a wide pH range. The average electrical conductivity (EC) was measured at 0.11 dS/m, indicating a non-saline condition conducive to crop growth, as per Rowell (1997). The cation exchange capacity (CEC) was approximated at 19.25 meq/100g, illustrating the soil's proficiency in retaining essential nutrients, which is vital for sustainable agricultural practices, as emphasized by Blackburn (1984) and Das Gupta (2009). Notably, the site displayed low phosphorus availability at an average of 25.1 ppm; this contrasts with Ambachew's (2012) findings of only 5.24 ppm in Finchaa soils. As per FAO (2008), phosphorus fertilization is recommended for optimal crop growth when soil P content is below 15 mg kg⁻¹. The organic carbon content was recorded at 1.60%, and total nitrogen was at 0.13%, both of which are considered very low, suggesting limited energy sources for soil biota and inadequate nitrogen mineralization, corroborated by Landon (1991). Factors such as continuous cropping and intensive tillage may contribute to the diminished organic matter, as discussed by Velde and Barr (2010).

The properties of the filter cake utilized in the study were also summarized in (Table 2). The moisture content of the fresh filter cake stood at 78.6%, aligning with Ambachew's (2012) report of 80%. The pH of the fresh filter cake was mildly acidic at 6.33, consistent with Abejehu's (2009) observations, which noted that filter cake application did not significantly influence soil pH or electrical conductivity (EC), but did enhance phosphorus and organic carbon levels in cane plantations.

Table 2. Selected soil physico-chemical properties of the experimental site before planting

Physical properties	Value	Rating	Reference
PSD			
Sand (%)	46.6	Large in textural fractions	Allison (1973)
Silt (%)	14.7	Small in textural fractions	
Clay (%)	40.8	Medium in textural fractions	
Textural class	Sandy clay loam	Soil dominated by sand and clay fractions in the soil textural class determination triangle.	
Filter cake moisture (%)	78.6	Moisture content of fresh filter cake was found to be around 80%.	Ambachew (2012)
Chemical P.			
Soil pH (1:2.5 soil to H ₂ O ratio)	6.4	Soils with pH values between 6 and 6.5 are slightly acidic; soil with pH ranging from 4 to 10 is suitable for cane production.	Fauconnier (1993); Jones (2001)
FC PH	6.33	Application of filter cake had no remarkable effect on pH and EC (salt content) of soils in the cane plantations.	Abejehu (2009)
OC (%)	1.6	Soil contains very low organic carbon and matter, indicating losses of organic matter resulting in low crop growth and yield.	Landon, (1991); Velde and Barr (2010)
CEC (Cmol ⁺ kg ⁻¹)	19.25	Soils with CEC values greater than 16 meq/100 g of soil to be suitable for sugarcane production and indicating better capacity to retain cation.	Blackburn (1984); Das Gupta (2009)
TN(%)	0.13	Total nitrogen content of the soil were very low indicating low organic matter which resulting in low yield.	Landon (1991); Ambachew (2012)
A. P (ppm)	25.1	These findings deviate from existing literature; the average P content of Finchaa soils is approximately 5.24 ppm.	Ambachew (2012)
A.S (ppm)	1.65	Under conditions of sulphur deficiency, the utilization of nitrogen was reduced.	ESC (2012)
EC (ds/m)	0.11	Soil with low in EC value, indicating non-saline nature of the soil.	Rowell (1997).

PSD% = Particle size distribution; CP = chemical properties; PH = soil reaction; EC = Electrical conductivity; OC = Organic carbon percent, TN = available Total Nitrogen; A.P (ppm) = available Phosphorus; A.S = available Sulfur; CEC = Cation exchange capacity

4.2. Influence of NPS and Filter Cake Application on Leaf N% and P (ppm) Contents in Sugarcane

The leaf nitrogen (N) and phosphorus (P) contents in sugarcane at five months of age were not significantly affected by either the main effects or the interaction effects of NPS and filter cake applications (Appendix Table 2). The average leaf N and P concentrations across all treatments were recorded at 0.09% and 21.08 ppm, respectively, which are below the critical thresholds (Table 3).

The optimum leaf N concentration for sugarcane was reported to range from 2% to 2.6%, with a critical value of 1.8% in the dry matter of the third leaf. For phosphorus, the optimal range was between 0.22% and 0.30%, with a critical threshold of 0.19% (Ambachew, 2012). These findings align with Mijena (2011), who suggested that the low leaf N concentration observed may have been due to the timing of sampling, which coincided with the maximum tillering stage. During this period, the concentration of N may have been diluted as it was mobilized to the stem and roots to support rapid growth and dry matter production.

Table 3. Effects of NPS and filter cake application on leaf N (%) and Phosphorus (ppm) contents of sugarcane

Filter cake (ton ha ⁻¹)	Leaf Nitrogen (%) content			
	NPS (kg ha ⁻¹)			
	0	200	300	400
0	0.094 ^a	0.096 ^a	0.082 ^a	0.098 ^a
10	0.079 ^a	0.110 ^a	0.085 ^a	0.092 ^a
20	0.084 ^a	0.099 ^a	0.070 ^a	0.049 ^a
30	0.111 ^a	0.072 ^a	0.060 ^a	0.099 ^a
LSD =0.04; CV (%) = 32.44				
Filter cake (ton ha ⁻¹)	Leaf Phosphorus (ppm) content			
	NPS (kg ha ⁻¹)			
	0	200	300	400
0	31.13 ^a	27.20 ^a	12.16 ^a	17.72 ^a
10	17.05 ^a	29.43 ^a	14.03 ^a	22.62 ^a
20	25.16 ^a	21.28 ^a	10.05 ^a	26.20 ^a
30	22.90 ^a	10.56 ^a	22.73 ^a	27.11 ^a
LSD =22.81; CV (%) = 15.21				

Means in column followed by the same letter are not significantly different at 5% levels of significance

4.3. Influence of Blended NPS and Filter Cake Application on Sugarcane Growth

4.3.1. Cane growth parameters

4.3.1.1. Sprouting percent

The sprouting percentage in this study showed no significant influence from the main or interaction effects of NPS and filter cake applications (Appendix Table 2 and Table 4). Across all treatments, the average duration of sprouting was 47.0 days, with no statistically significant differences observed. According to the seed cane planting standard operational procedure from the FSE, sprouting of seed setts can last between 45 to 60 days on both luvisol and vertisol soil types.

The lack of significant differences in sprouting percentage among various treatments may be attributed to uniformly optimal soil temperature and moisture levels, as well as the consistent quality of the seed setts. This observation aligns with existing literature, which suggested that the processes of sprouting are primarily influenced by environmental conditions, particularly temperature and moisture (Sundara, 2000; Jiang, 2004).

Sprouting, defined as the emergence of new plants from buds and the initial growth of young shoots or primary stems, is critical to plant development (Sundara, 2000; Jiang, 2004). It is influenced by multiple factors, including soil characteristics, climate conditions, and the specific variety and quality of seed material used (Fauconnier, 1993; Verma, 2004).

4.3.1.2. Number of tillers

Tillers population was significantly ($P \leq 0.05$), influenced by the main effects of NPS level but not by filter cake level or the interaction between NPS and filter cake application (Appendix Table 2). The highest number of tillers recorded was 213,345 tillers/ha for treatments receiving 400 kg/ha NPS, compared to the lowest, 187,688 tillers/ha, for control treatments (Table 5).

Tillers population and biomass production are crucial for estimating final cane stalk populations and sucrose yields, making them key factors that determine overall crop stand and, ultimately, cane yield (Sarwaret *et al.*, 2011). The tillering process compensates for any deficiencies in germination of cane setts due to various factors before and after planting (Nadeemetal, 2011). Toomsan and Limpinuntana (2005) indicated that higher cane yields could be attributed to the higher number of tillers and millable canes. Jiang (2004) indicated

that the sugarcane yield per unit of land is composed of the millable canes and the cane weight.

4.3.1.3. Leaf area and leaf area index

The study results indicated that the main effects had a highly significant ($P < 0.001$) influence on both leaf area and leaf area index, while the interaction effects demonstrated a highly significant ($P < 0.01$) influence on leaf area index and a significant ($P < 0.05$) influence on leaf area due to NPS and filter cake application (Appendix Table 2). The highest leaf area (332.2 cm^2) and leaf area index (5.8) were obtained from the treatments that received 400 kg ha^{-1} NPS + 20 tons ha^{-1} filter cake and the lowest leaf area (211.4 cm^2) and leaf area index (2.33) were obtained from unfertilized treatments (Table 4).

The study results align with Hunsigi (1993), who found that the application of organic and mineral fertilizers significantly increases leaf area and leaf area index (LAI) in sugarcane. The synergistic effect of combining organic and inorganic nutrient sources enhances these measures. Similarly, Zahida et al. (2016) reported that integrated fertilizer applications lead to a significantly higher LAI in common bean compared to sole and non-fertilized plots. This increased LAI allows plants to better intercept available radiation, thereby increasing assimilation production, which is dependent on nutrient availability.

4.3.1.4. Specific leaf weight

In terms of specific leaf weight, there were no significant differences observed for the main effects of NPS and filter cake; however, the interaction effects were highly significant ($P < 0.01$) due to the application of NPS and filter cake (Appendix Table 2). The highest specific leaf weight of 0.0092 g cm^{-2} was obtained from the treatment with 200 kg/ha NPS combined with 20 tons/ha of filter cake, while the lowest SLW of 0.0087 g cm^{-2} was recorded in the treatment with 30 tons/ha of filter cake and from the control group (Table 4).

Brown and Byrd (1997) noted that transpiration efficiency refers to the dry matter produced per unit of transpiration and is correlated with specific leaf weight, which is relevant for drought tolerance in various crops. Genotypes exhibiting higher specific leaf weight (thicker leaves) tend to have a lower surface area to volume ratio, thereby enhancing water efficiency (Anonymous, 2012). Specific leaf weight significantly correlates with top visible dewlap leaf dry weight and is a critical factor influencing cane yield under low soil fertility conditions (Chanta and Rosario, 1997).

4.3.1.5. Cane stalk height

The cane stalk height significantly ($P < 0.05$) influenced by main effects of NPS level but not influenced by the main effects of filter cake level and interaction effects due to NPS and filter cake application (Appendix Table 2). The highest cane stalk height (2.23 m) was obtained from treatment that received 400 kg ha^{-1} NPS and the lowest cane stalk height (2.03 m) was obtained from controlled treatments (Table 5).

Cane stalk height is a crucial factor affecting both cane and sugar yield, as it indicates the overall growth and vigor of the plant. Research consistently demonstrates that growth parameters, such as height and girth, are significantly influenced by the nutritional status of the plants (Kakde, 1985). Oregon (2003) further supports this, stating that height and girth are notably impacted by nutrient levels and that improving soil fertility enhances these parameters (Girma, 2009). Consequently, the cumulative mean differences in stalk height and girth exhibit considerable variation based on the treatments applied, particularly those involving nitrogen and pressmud.

Table 4. Mean comparison test based on the main and interaction effects of NPS and Filter cake on cane growth parameters

NPS rate kg/ha	Filter cake tons/ha	SP (%)	Leaf area (cm ²)	Leaf area index	SLW (g cm ⁻²)
0	0	93.43 ^a	211.4 ^a	2.3 ^a	0.0087 ^a
200	0	94.07 ^a	226.4 ^{ab}	2.7 ^{ab}	0.0088 ^{abc}
300	0	96.70 ^a	246.8 ^{bc}	3.2 ^{bcd}	0.0090 ^{bcd}
400	0	95.57 ^a	265.8 ^{cde}	3.7 ^{cdefg}	0.0090 ^{abcde}
0	10	96.43 ^a	226.3 ^{ab}	2.7 ^{ab}	0.0091 ^{cde}
200	10	94.63 ^a	260.1 ^{cde}	3.5 ^{cdef}	0.0089 ^{abcde}
300	10	95.50 ^a	263.9 ^{cde}	3.7 ^{cdefg}	0.0091 ^{cde}
400	10	94.63 ^a	267.6 ^{cde}	3.7 ^{cdefg}	0.0090 ^{bcd}
0	20	94.63 ^a	242.3 ^{bc}	3.1 ^{abc}	0.0091 ^{de}
200	20	92.57 ^a	269.2 ^{cde}	3.8 ^{defg}	0.0092 ^e
300	20	92.30 ^a	287.1 ^{ef}	4.3 ^{gh}	0.0088 ^{ab}
400	20	91.67 ^a	332.2 ^g	5.8 ⁱ	0.0089 ^{abcd}
0	30	93.47 ^a	253.7 ^{bcd}	3.4 ^{bcd}	0.0087 ^a
200	30	94.63 ^a	305.6 ^{fg}	4.9 ^h	0.0087 ^{ab}
300	30	92.87 ^a	285.1 ^{ef}	4.2 ^{fgh}	0.0090 ^{bcd}
400	30	94.63 ^a	277.1 ^{de}	4.0 ^{efg}	0.0091 ^{cde}
Mean		94.23	263.8	3.70	0.0089
LSD (5%)		4.42	31.42	0.90	0.0003
CV%		3.26	8.28	17.33	2.4

Remarks; -Means in column followed by the same letter are not significantly different at 5% levels of significance

CV = coefficient variation; LSD = Least significant difference; SP% =Sprouting percent; LA = leaf area; LAI = leaf area index; SLW = specific leaf weight.

Table 5. Mean comparison test based on the main effects of NPS on NTC (tillers/ha); CSH (m), NMS (stalks/ha), purity% and filter cake on NMS and purity%

Treatments	Mean squares			
	NTC	CSH	NMS	Purity (%)
NPS rate kg ha ⁻¹				
0	187688 ^a	2.03 ^a	88112 ^a	75.9 ^a
200	204105 ^b	2.14 ^{ab}	108378 ^b	85.2 ^b
300	205882 ^b	2.16 ^{ab}	114247 ^{bc}	87.1 ^{bc}
400	213345 ^b	2.23 ^{ab}	120155 ^c	90.0 ^c
Mean	202755	2.14	107722.8	84.55
LSD(0.05)	19439.83	2.19	8398.93	6.58
Filter cake rate tons ha ⁻¹				
0			96362 ^a	79.3 ^a
10			105562 ^b	85.0 ^b
20			113533 ^c	86.5 ^b
30			115434 ^c	87.4 ^b
Mean			107722.8	84.55
LSD (0.05)			7273.68	6.58
CV%	6.66	7.12	9.39	5.41

Remarks: - CV = Coefficient variation; LSD = Least significant difference; NTC = Number of tillers count; NMS = Number of millable stalks; CSH = cane stalk height

4.3.2. Cane yield parameters

4.3.2.1. Number of millable stalks

The number of millable stalks was highly significantly ($P < 0.01$) influenced by the main factors of NPS and filter cake application, but there was no significant interaction between these factors (Appendix Table 2). The highest number of millable stalks observed was 120,155 stalks/ha with the application of 400 kg/ha NPS, while 115,434 stalks/ha were recorded with the application of 30 t/ha filter cake. In contrast, the controlled treatments yielded the lowest numbers, recording 88,112 and 96,362 stalks/ha, respectively (Table 5).

The number of millable stalks and biomass production are critical indicators for estimating final cane stalk population and sucrose yields. This parameter is a key factor determining the overall crop stand and, consequently, the cane yield (Sarwar et al., 2011). Additionally, Bokhtail and Sakurai (2003) found that phosphorus (P) application, particularly in P-deficient soils, enhances tillering and growth, leading to improved cane yield. Toomsan and Limpinuntana (2005) demonstrated that higher cane yields are linked to an increased number of tillers and millable canes. Similarly, Jiang (2004) highlighted that the sugarcane yield per

unit area is largely influenced by both the quantity of millable canes and their respective weights.

4.3.2.2. Cane stalk girth

The results showed a very highly significant ($P < 0.001$) difference in cane stalk girth due to the main effects of NPS application, as well as a highly significant ($P < 0.01$) difference attributable to the main effects of filter cake. Additionally, the interaction between NPS and filter cake application yielded a significant ($P < 0.05$) difference (Appendix Table 2). The highest recorded cane stalk girth was 26.2 mm from treatments receiving 400 kg ha⁻¹ of NPS and 20 tons ha⁻¹ of filter cake, whereas the lowest girth measurement was 20.27 mm in the control treatments (Table 6).

Cane stalk girth is a critical factor influencing cane yield and sugar yield, aligning with findings reported by Kakde (1985). Furthermore, Oregon (2003) highlighted that established growth characteristics, including increases in girth and height, are significantly affected by soil nutrient status. Girma (2009) also found that the application of organic and mineral fertilizers enhances the productivity of sugarcane, resulting in improved stalk population, height, girth, and overall soil fertility.

4.3.2.3. Fresh and dry stalk weight

The fresh weight of stalks showed a very highly significant ($P < 0.001$) difference due to the main effects of NPS, while the main effects of filter cake resulted in a highly significant ($P < 0.01$) difference. Additionally, the interaction effects between NPS and filter cake were also significant ($P < 0.05$). Similarly, for dry stalk weight, both the main effects of NPS and filter cake, as well as their interaction effects, were very highly significant ($P < 0.001$) (Appendix Table 2). The highest fresh stalk weight recorded was 1.47 kg/stalk for the treatment receiving 400 kg ha⁻¹ NPS combined with 20 tons ha⁻¹ of filter cake. In contrast, the control treatment yielded the lowest fresh stalk weight at 0.80 kg/stalk, and the lowest dry stalk weight at 0.14 kg/stalk (Table 6).

Sugarcane yield is primarily influenced by the number of tillers, millable canes, and cane weight, where cane weight is determined by factors such as stalk diameter, length, and density (Oregon, 2003). Recent studies indicate that these parameters are significantly affected by the nutritional status of the cane (Kakde, 1985; Ikisan, 2000; Sundara, 2000).

The combined use of filter cake and mineral fertilizers has been shown to improve soil nutrient levels, leading to enhanced growth in sugarcane, as indicated by increased fresh and dry stalk weights compared to untreated plots (Girma, 2009). Additionally, Tadesse (1993) highlighted that the production of dry matter in plants is closely linked to the availability of nutrients in the soil. This suggests that integrating organic and inorganic fertilizers can significantly boost crop productivity by optimizing nutrient supply.

4.3.2.4. Cane yield at twelve and fourteen months age

The study examined the effects of NPS fertilizer and filter cake on sugarcane yield at twelve and fourteen months of growth, showing very highly significant ($P < 0.001$) results for the main effects and significant ($P < 0.05$) interactions between these two amendments (Appendix Table 2). The highest recorded cane yields were 192.77 tons per hectare at twelve months and 218.47 tons per hectare at fourteen months, achieved with the application of 400 kg ha⁻¹ of NPS combined with 20 tons ha⁻¹ of filter cake. In contrast, the unfertilized control treatment resulted in notably lower yields of 59.3 tons per hectare at twelve months and 67.17 tons per hectare at fourteen months (Table 6).

These findings underscore the synergistic benefits of using a combination of NPS and filter cake, promoting a substantial increase in cane yield compared to the use of either amendment alone. This positive outcome aligns with previous research by Girma (2009), who reported that applying mineral fertilizers alongside filter cake significantly enhances both cane and sugar yields. The results from this study demonstrated that the combined application of NPS and filter cake provided a more effective nutrient supply, leading to improved plant growth and productivity when compared to instances where only one type of nutrient source was utilized. Thus, the data suggest that incorporating both blended NPS and filter cake in sugarcane cultivation can significantly enhance yield potential and should be considered in agronomic practices to optimize sugarcane production. This finding conforms to Shrivastava (2006) who stated that yield components are the morphological components, which finally make up or decide the sugarcane yield viz. number of millable canes, average cane weight, cane diameter and stalk length all of which were found to be significantly affected by varied amounts of NPS and filter cake applications.

The application of filter cake improved cane and sugar yields by 26% compared to mineral fertilizer alone (Moris *et al.*, 2007). This enhancement is attributed to the organic matter in

filter cake, which likely boosted root growth and nutrient uptake (Palm et al., 1997). Additionally, filter cake provides essential nutrients in a balanced form, complementing nitrogen (N), phosphorus (P), and potassium (K) (Mahajan and Gupta, 2009). Kaur et al. (2004) also emphasized the benefits of combining mineral fertilizers with organic materials for nutrient recycling.

4.3.2.5. Sugar yield estimated

The results showed highly significant ($P < 0.01$) effects of NPS and filter cake application, both individually and in combination, on sugar yield after twelve months (Appendix Table 2). The highest sugar yield observed was 24.47 t/ha, achieved with the application of 400 kg ha⁻¹ NPS and 20 tons ha⁻¹ of filter cake, while the control treatment yielded only 3.7 t/ha (Table 6). This indicates that the combined use of blended NPS and filter cake positively influences sugar yield.

These findings align with Girma (2009), who noted that the application of mineral fertilizers and filter cake significantly enhanced both cane and sugar yields. Single applications of either soil mineral fertilizers or filter cake were less effective than their combined application. These findings align with Shrivastava (2006), who noted that the yield components of sugarcane, specifically the number of millable canes, average cane weight, cane diameter, and stalk length, are significantly influenced by varying applications of NPS and filter cake.

Notably, Moris *et al.* (2007) found that the application of filter cake increased both cane and sugar yields by 26% compared to treatments that used mineral fertilizers alone. This improvement is attributed to the organic matter in filter cake, which may enhance root growth in sugarcane, enabling better nutrient uptake (Palm et al., 1997). Furthermore, filter cake provides essential nutrients, including N, P, and K, in a balanced manner, benefiting soil health (Mahajan and Gupta, 2009). Kaur *et al.* (2004) emphasized the value of nutrient recycling by integrating mineral fertilizers with organic materials. Additionally, Jiang (2004) reported that sugarcane yield per unit area comprises both millable canes and cane weight.

4.3.3. Cane quality parameters

4.3.3.1. Brix%

The Brix percentage results exhibited no significant influence from either the main effects or the interaction effects of NPS and filter cake applications (Appendix Table 2 and Table 6).

4.3.3.2. Pol%

The pol percentage showed a very highly significant ($P < 0.001$) difference due to the main effects, while the interaction effects resulted in a highly significant ($P < 0.01$) difference observed from the application of NPS and filter cake (Appendix Table 2). The highest pol%, recorded at 16.8%, resulted from the combination of 400 kg/ha NPS and 20 t/ha of filter cake. In contrast, the control treatment yielded the lowest pol%, at 10.2% (Table 6).

4.3.3.3. Purity%

The purity percentage was highly significantly ($P < 0.01$) influenced by both the main and interaction effects of NPS and filter cake application (Appendix Table 2). The highest purity percentage 90.0%, was observed with the application of 400 kg/ha of NPS, while an application of 30 t/ha of filter cake resulted in a purity percentage of 87.4%, in contrast, the control treatments yielded the lowest purity percentages, recording 75.9% and 79.3%, respectively (Table 5).

4.3.3.4. Sucrose content percent

A highly significant ($P < 0.01$) difference in sucrose content percentage was observed in relation to both main and interaction effects from the application of NPS and filter cake at twelve months age (Appendix Table 2). The highest sucrose content, recorded at 11.73%, resulted from the combination of 400 kg ha⁻¹ NPS and 20 tons ha⁻¹ filter cake, contrasting sharply with the control treatment, which yielded a low of 5.7% (Table 6). These findings align well with the recommended specifications provided by SASTA (2009).

Furthermore, the relationship between brix percentage and pol percentage on sucrose and purity contents demonstrates interesting dynamics. As the apparent brix percentage increases with a constant pol percentage, the sucrose and purity contents decrease. Conversely, both sucrose and purity contents rise with an increase in pol percentage at a constant brix value. This indicates an inverse correlation between brix percentage and sucrose/purity contents, while a direct correlation exists between pol percentage and these parameters.

Brix%, Pol%, and purity percentage were key metrics for assessing sucrose content in cane juice, crucial for evaluating quality and guiding processing decisions. These measurements provide insights into cane juice composition and potential yield, influencing sugar production efficiency and economics. Understanding these parameters enables producers to make informed decisions that enhance productivity and profitability in sugar manufacturing.

Table 6. Mean comparison test for main and interaction effects of NPS and filter cake on cane yield and quality parameters

NPS rate kg/ha	Filter cake tons/ha	FSW (kg/stalk)	DSW (kg/stalk)	CSG (mm)	CY12 (t/ha)	CY14 (t/ha)	SY (t/ha)	Brix (%)	Pol (%)	SC (%)
0	0	0.80 ^a	0.144 ^a	20.3 ^a	59.3 ^a	67.2 ^a	3.7 ^a	14.51 ^a	10.2 ^a	5.7 ^a
200	0	0.93 ^{abc}	0.209 ^b	22.5 ^{bcd}	83.3 ^{abc}	94.4 ^{abc}	6.0 ^{ab}	14.81 ^a	11.1 ^{ab}	6.6 ^{ab}
300	0	1.13 ^{cdef}	0.32 ^f	23.5 ^{cdefg}	123.9 ^{def}	140.4 ^{def}	11.6 ^{defg}	15.64 ^a	12.9 ^{bcd}	8.3 ^{cde}
400	0	1.27 ^{efg}	0.34 ^g	24.2 ^{defghi}	146.0 ^{fgh}	165.5 ^{fgh}	16.3 ^{hi}	17.26 ^a	15.2 ^{fg}	10.2 ^g
0	10	0.87 ^{ab}	0.204 ^b	21.2 ^{ab}	73.7 ^{ab}	83.6 ^{ab}	6.5 ^{abc}	16.63 ^a	12.3 ^{bc}	7.2 ^{bc}
200	10	1.00 ^{abcd}	0.259 ^c	22.9 ^{cde}	108.8 ^{cde}	123.3 ^{cde}	10.9 ^{def}	15.88 ^a	13.8 ^{cdef}	9.2 ^{defg}
300	10	1.17 ^{def}	0.379 ^h	23.7 ^{cdefgh}	131.1 ^{defgh}	148.6 ^{defgh}	13.5 ^{efgh}	16.00 ^a	14.1 ^{cdef}	9.5 ^{efg}
400	10	1.33 ^{fg}	0.396 ^j	25.1 ^{fghi}	157.0 ^h	177.9 ^{gh}	16.7 ^{hi}	15.82 ^a	14.3 ^{cdef}	9.8 ^{fg}
0	20	1.07 ^{bcde}	0.258 ^c	21.9 ^{abc}	99.4 ^{bcd}	112.6 ^{bcd}	8.2 ^{bcd}	16.88 ^a	12.9 ^{bcd}	7.7 ^{bc}
200	20	1.20 ^{def}	0.384 ⁱ	24.7 ^{efghi}	133.7 ^{efgh}	151.5 ^{efgh}	14.5 ^{fghi}	17.23 ^a	15.0 ^{efg}	10.0 ^g
300	20	1.33 ^{fg}	0.391 ^j	25.4 ^{ghi}	157.0 ^h	178.0 ^h	16.5 ^{hi}	15.83 ^a	14.1 ^{cdef}	9.6 ^{efg}
400	20	1.47 ^g	0.416 ^l	26.2 ⁱ	192.8 ⁱ	218.5 ⁱ	24.5 ^j	18.10 ^a	16.8 ^g	11.73 ^h
0	30	1.10 ^{cde}	0.280 ^d	23.6 ^{cdefg}	111.0 ^{cde}	125.8 ^{cde}	10.1 ^{cde}	15.27 ^a	12.5 ^{bcd}	8.0 ^{bcd}
200	30	1.27 ^{efg}	0.403 ^k	25.7 ^{hi}	156.7 ^{gh}	177.6 ^{gh}	18.0 ⁱ	16.57 ^a	15.1 ^{fg}	10.4 ^{gh}
300	30	1.20 ^{def}	0.296 ^e	24.4 ^{efghi}	144.8 ^{fgh}	164.1 ^{fgh}	15.5 ^{ghi}	16.54 ^a	14.6 ^{def}	9.8 ^{fg}
400	30	1.07 ^{bcde}	0.292 ^e	23.2 ^{bcdef}	125.0 ^{defg}	141.7 ^{defg}	11.5 ^{defg}	14.23 ^a	12.5 ^{bcd}	8.4 ^{cdef}
Mean		1.14	0.310	23.65	125.22	141.9	12.75	16.08	16.08	8.9
LSD (5%)		0.20	0.075	2.03	33.49	38.0	5.42	2.44	2.44	1.51
CV%		12.27	16.82	5.97	18.59	18.59	29.6	10.58	10.58	13.9

Remarks; - Means in column followed by the same letter are not significantly different at 5% levels of significance.

CV = Coefficient variation; LSD = Least significant difference; FSW = Fresh stalk weight; DSW = Dry stalk weight;

CSG = Cane stalk girth; SY = Sugar yield; SC% = Sucrose content percent; CY12 and CY14 = Cane yield at 12 and 14 months age

4.4. Partial Budget Analyses

The study identified optimal application rates for maximizing net benefits in sugarcane production, emphasizing the importance of balanced fertilization for enhancing yield and profitability. The application of 400 kg/ha of NPS fertilizer, combined with 20 tons/ha of filter cake, was determined to yield the highest net benefits, amounting to ETB 1,015,957.9. This optimal combination not only maximized economic returns but also facilitated improved growth and productivity in sugarcane. As a secondary effective strategy, a combination of 200 kg/ha of NPS with 30 tons/ha of filter cake also demonstrated significant profitability, generating net benefits of ETB 495,996.6. This result was markedly superior when compared to the control treatment, which returned only ETB 294,652.5, highlighting the effectiveness of using organic and inorganic fertilizers in tandem (Table 7).

The study further revealed that improper management of fertilizers, characterized by either excessive or insufficient application of NPS and filter cake, adversely affected cane and sugar yields. Such imbalanced applications not only decreased overall productivity but also led to negative impacts on other key growth parameters, underscoring the critical role of proper nutrient management in achieving optimal agricultural outcomes.

This trend aligns with findings from Ingle et al. (1999) ; FAO (2000), which emphasize that relying solely on mineral fertilizers does not guarantee sustainable soil productivity or enhanced yields, particularly in soils deficient in organic matter. Continuous high applications of chemical fertilizers can lead to nutrient imbalances and micro-nutrient deficiencies, adversely affecting crop productivity (Hedge, 1992).

Moreover, excessive nitrogen application not only diminishes cane yield but also negatively impacts juice quality (Singh and Yadav, 1996). High and late nitrogen applications can lead to the production of excessively watery shoots with elevated reducing sugar levels, further compromising juice quality. This decline is attributed to the accumulation of nitrogenous substances and decreased P₂O₅ content, which impairs clarification processes and extends vegetative growth, delaying maturation and ripening (Srinivasan, 1995). Consequently, this dual effect reduces cane and sugar yields, ultimately increasing production costs.

Table 7. Partial budget analysis of sugar yields tons ha⁻¹ due to blended NPS and filter cake rates application

NPS rate Kg/ha	Filter cake rate (t/ha)	SY produced by 300 kg/ha NPS (t/ha)	SY produced by NPS & filter cake (t/ha)	D/f of SY (t/ha) (AvY)	AjY (t/ha)	GFB (ETB)	TVC (ETB)	NB (ETB)	MRR%
0	0	-	3.70	3.7	3.33	299,700.0	5047.5	294,652.5	-
200	0	-	5.97	-	-	-	-	-	-
300	0	11.63	11.63	-	-	-	-	-	-
400	0	11.63	16.30	4.67	4.203	378,270.0	21,103.5	357,166.5	389.3
0	10	-	6.50	-	-	-	-	-	-
200	10	11.63	10.87	-0.76	-0.684	-61,560.0	14564.8	-76,124.8	6626.6
300	10	11.63	13.50	1.87	1.683	151,470.0	18578.8	132,891.2	5207.2
400	10	11.63	16.73	5.1	4.59	413,100.0	22592.8	390,507.2	64179
0	20	-	8.20	-	-	-	-	-	-
200	20	11.63	14.47	2.84	2.556	230,040.0	16,054.1	213,985.9	2699.6
300	20	11.63	16.53	4.9	4.41	396,900.0	20,068.1	376,831.9	4057.0
400	20	11.63	24.47	12.84	11.556	1,04,040.0	24,082.1	1,015,957.9	15922.4
0	30	-	10.13	-	-	-	-	-	-
200	30	11.63	17.97	6.34	5.706	513,540.0	17543.4	495,996.6	7952.1
300	30	11.63	15.47	3.84	3.456	311,040.0	21557.4	289,482.6	-5144.8
400	30	11.63	11.53	-0.1	-0.09	-8,100.0	25571.4	-33,671.4	-8050.7
Total ETB						3,664,440.0	206,763.9	3,457,676.1	36076.6

Where, SY = sugar yield; AjY = Adjusted yield; AvY = Adjusted average yield; GFB = Gross field benefit; TVC = Total variable cost; NB = Net benefit; MRR% = Marginal rate return; D/f = Difference. Benchmark, sugar yield (tons ha⁻¹) produced by 300 kg ha⁻¹ NPS.

‘a’ indicated sugar yield produced by 300 kg/ha NPS (benchmark); ‘b’ indicated sugar yield produced by NPS and filter cake

Combination and ‘b-a’ indicated sugar yield difference (adjusted average yield)

5. SUMMARY AND CONCLUSIONS

This study demonstrated that the exclusive use of mineral fertilizers is not economically viable for enhancing sugarcane productivity. Instead, the combination of mineral fertilizers with organic materials, such as filter cake, effectively increases cane productivity while improving soil physical, chemical, and microbial properties. Given the rising costs of chemical fertilizers, filter cake serves as a viable alternative source of plant nutrients and soil amendments. A field experiment was conducted to evaluate the effects of blended NPS fertilizers and filter cake on sugarcane growth, yield, and quality. The treatments included four levels of NPS (0, 200, 300, and 400 kg ha⁻¹) and four levels of filter cake (0, 10, 20, and 30 tons ha⁻¹), arranged in a factorial design combination within RCBD and replicated three times. The sugarcane variety N-14 was used for the study.

Results indicated very highly significant ($P < 0.001$) effects of NPS on various cane parameters, including leaf area, leaf area index, millable cane stalks, fresh and dry stalk weight, cane stalk girth, cane yield at both ages, sugar yield, pol%, purity% and sucrose content, with significant ($P < 0.05$) effects were also observed for the number of tillers and cane stalk height. However; parameters like sprout percentage, specific leaf weight, brix%, leaf nitrogen and phosphorus contents were not significantly affected.

Similarly; filter cake levels showed very highly significant ($P < 0.001$) effects on leaf area, leaf area index, millable cane stalks, dry stalk weight, cane yield at both ages and sugar yield, po%, purity% and sucrose content, with highly significant ($P < 0.01$) effects noted for cane stalk girth and fresh stalk weight. Yet; parameters like sprout percentage, number of tillers, specific leaf weight, stalk height, brix%, leaf nitrogen and phosphorus contents were not significantly affected.

Interaction effects between NPS and filter cake were very highly significant ($P < 0.001$) for dry stalk weight, purity%, sucrose content, and sugar yield, with highly significant ($P < 0.01$) effects observed for specific leaf weight, leaf area index, pol%, and significant ($P < 0.05$) differences for fresh stalk weight, stalk girth, leaf area and cane yield at both ages. However; parameters like sprout percentage, number of tillers, stalk height, number of millable canes, brix%, leaf nitrogen and phosphorus contents were not significantly affected.

The application of 400 kg ha⁻¹ NPS along with 20 tons ha⁻¹ filter cake yielded the most

favorable results for all measured cane parameters, including enhanced leaf area, leaf area index, millable cane stalks, cane stalk girth, fresh and dry stalk weight, cane and sugar yield, and overall sucrose content. These findings suggested that optimized nutrient management strategies integrating both mineral and organic fertilizers might significantly improve sugarcane growth and yield while being cost-effective for farmers.

The highest partial budget net benefit of ETB 1,015,957.9 was achieved with the optimal application of 400 kg ha⁻¹ of blended NPS fertilizer combined with 20 tons ha⁻¹ of filter cake. This was followed by a combination of 200 kg ha⁻¹ NPS and 30 tons ha⁻¹ filter cake, resulting in a net benefit of ETB 495,996.6, which was significantly higher than the control treatment, which had a net benefit of ETB 294,652.5.

The findings demonstrate that the combined use of filter cake and blended NPS fertilizers yielded better results (400 kg ha⁻¹ NPS + 20 tons ha⁻¹ filter cake) compared to using mineral fertilizers used alone. Thus, the integration of organic and mineral fertilizers proved to be more effective than using mineral fertilizers alone for improving soil fertility and achieving higher sugarcane yields. Further research is necessary to explore the effects of different sugarcane varieties and soil types over multiple cropping seasons to establish more comprehensive recommendations for sustainable sugarcane production.

6. REFERENCES

- Ali, M., Khan, M. A., Ashraf, M. Y., Sadiq, Y., and Khan, M. N. (2020). Nutrient management for sustainable sugarcane production: A review. *Agronomy*, 10 (12), 1806. <https://doi.org/10.3390/agronomy10121806>
- Allison, F.E., 1973. Soil organic matter and its role in crop production. Elsevier Scientific publishing company. USA.
- Ambachew, Damtie, 2012. Sugarcane fertilization training manual. Wonji, Ethiopia.
- Anonymous, 2012. Sugar, African Review of Business and Technology.
- AregawAssefa, 1991. Tillering and early growth of sugarcane, *Saccharum officinarum*. sets as affected by 2-chloroethyl phosphoric acid, lime and hot water.
- Blackburn, F., 1984. Sugarcane. Longman, New York. P.388.
- Bokhtail, S. M. and Sakurai. K. 2003. Sugarcane Response to Phosphorus. Cereal Stem Borers: Economic Importance, Taxonomy, Natural Enemies and Control Carbonation pressmud cake on the yield, quality and nutrition of sugarcane.
- Brown, R. H., and Byrd, G.T. 1997. Transpiration efficiency, specific leaf weight, and mineral concentration in peanut and pearl millet. *Crop Science* 36: 475–480.
- Chanta, N. and Rosario, E.L. 1997. Influence of fertility level on yield determining physic morphological characteristics of some sugarcane varieties. The Philippine journal of crop science. Vol.2. No.1.
- CIMMYT, 1988. From Agronomic Data to Farmer Recommendations: answer to Workbook exercises. Mexico, D.F: CIMMYT
- Das Gupta, D., 2009. Sugarcane development. Technological interference between tradition and modernity. AGROBIOS, India, Pp.35–81.
- Dotaniya, C. K., Meena, B. L., Rajendiran, S., Lata, M., 2016. Use of sugarcane Industrial by-products for improving sugarcane productivity and soil health. *International Journal of Recycling of Organic Waste in Agriculture*, 5(3), 185–194.
- ESC, Ethiopian Sugar Corporation, 2012. News letter. Vol.1. No.1.
- ESC, Ethiopian Sugar Corporation, 2022.
- Facounnier, R., 1993. Sugarcane. *The Tropical Agriculturalist*. The Macmillan Press Ltd.
- FAO STA, 2018. Crops database: <<http://faostat3.fao.org/home/index.html>>. Accessed December 2018

- FAO STAT, 2024. Crops data base.
- FAO, 2022. Fertilizer use and its role in sustainable agriculture. Food and Agriculture Organization of the United Nations. Retrieved from [FAO website link]
- FAO, Food and Agricultural Organization of the United Nations, 2008. FAO fertilizer and plant nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis. FAO, Rome, Italy. P.203.
- FAO, Food and Agricultural Organization of the United Nations, 2000. Fertilizer and their use. A pocket guides for extension officers. 4th edition, FAO, Rome
- Fikadu, Z., Desta, I., & Shiferaw, B. 2022. Synergistic effects of organic and inorganic fertilizers on cereal yield in Ethiopia. *Ethiopian Journal of Agricultural Sciences*, 180(4), 201-215. <https://doi.org/10.1016/j.etas.2022.01.004>
- FSR, 2024. (Finchaa Research Station) meteorological data
- FSE, 2021. (Finchaa Sugar Estate) annual report (unpublished)
- Gardner, F.P., Pearce R.B and Mitchell, R.L 1985. *Physiology of crop plants*. Iowa state university press. USA, Pp. 186-208.
- Girma, Abejehu, 2009. Effect of filter cake and mineral fertilizers on yield of plant cane in the sugar plantations of Ethiopia. *Proc. Ethiop. Sugar. Ind. Bienn. Conf.*, 1:126-136 (2009)
- Godheja, J., Sudhir K.S. and Modi, D.R. 2014. The Standardization of Protocol for age scale production of sugarcane (co-86032) through micro propagation. *International Journal of plant, animal and environmental Sciences*, 4(4).
- Gopalasundaram, P. and Rakkiyappan, P. 2009. Fertilizer management in sugarcane. *In: Singhet al. (ed.) Sugarcane crop production and improvement*. Stadium press LLC, USA.
- Hedge, D.M., 1992. 20th workshop of project directorate for cropping systems research, 1-4 June, Tamil Nadu Agricultural University, Coimbatore, pp.40.
- Hunsigi, G., 1993. *Production of sugarcane-Theory and practice*. Springer- verlag, Berlin. P.245.
- Ikisan.com, 2000. Sugarcane crops [online]. Available at: <http://www.sugarcanecrops>
- Incle, M., T. Smet De, Tersmette, T. and Veldkamp, T. 1999. Preparation and use of compost. *Agrodok-series*, No.8, CTA, The Netherlands.

- Jackson, S.D., 1975. Multiple signaling pathways control tuber induction in potato. *Plant physiology*.119:1-8.
- Jiang, Y., 2004. Modern sugarcane cultivation technology. Sugarcane Industry Research Institute. Guangzhou, China.
- Jones, J.B., 2001. Laboratory guide for conducting soil tests and plant analysis. CRC Press LLC.
- Kakde, J.R., 1985. Sugar production. Renu printers, NewDelhi.
- Kanwar, R.S. and Kapur, J. 1987. Direct and residual effects of sulphitation and carbonation pressmud cake on the yield, quality and nutrition of sugarcane. *Indian.sug. crops J*.13(4):1-5
- Kaur, K., Kapoor, K.K. 2004 and Gupta, A.P. 2009.Impact of organic manures with and without mineral fertilizers on soil chemical and biological properties under tropical
- Ketan, B., Sandeep, S., Mudliar, N., Bhatt, P., Kalve, S., Chakrabarti, T., and Awatar, R. ,2008. Compost from Sugar mill Pressmud and Distillery Spent wash for Sustainable Agriculture.
- Korndorfer, G.H. and Anderson,D. L. 1997 “Use and impact of sugar alcohol residue vinasse and filter on sugarcane production in Brazil,” *Sugary Azucar*, vol. 92, no. 3, pp. 26–35.
- Landon, J.R., 1991. Booker Tropical Soil Manual. A handbook for soil survey and agricultural land evaluation in the tropics and sub-tropics. Longman Group Limited.
- Lichts, F.O., 2010. International Sugar and Sweetner Report.Vol.142, No.12. Germany. www.agra-net.com [online]. Available at:www.agra-net.com/SL.
- Mahajan, A. and Gupta, R.D. 2009. Integrated Nutrient Management (INM) in a sustainable Rice-Wheat cropping system. Springer science and business media. B.V.
- Martin-Prevel, P., J. Gagnard and Guiter, P. 1987. Plant analysis as guide to the nutrients of temperate and tropical crops. Lavoisier pub. Newyork.
- Mijena, Bikila, 2011. Effects of rate and time of nitrogen application on seed cane quality and performance of subsequent commercial sugarcane *Saccharum officinarum* L.crop at Finchaa Sugar Estate, Ethiopia. An M.Sc. thesis presented to the school of graduate studies of Haramaya University.

- Moris, D.R., Gilbert, R.A., Rainbol, C.R., Perdomo, R.E., Powell, G., Eiland, B. and Montes, G. 2007. Sugarcane yields and soil chemical properties due to mill mud application to sandy soil. *Proceedings of International Society of Sugarcane Technologists*, 26:85-89.
- Nadeem , M.A., Sarwar, M.A. Ghaffar, A. Ahmed, F. and Husain, F. 2011. Studies on the performance of some sugarcane genotypes at Faisalabad. Sugarcane Research Institute, AARI, Pakistan.
- Omolon, J. O. and Abayo, G. O. 2011. Effect of phosphorus sources and rates on sugarcane.
- Oregon, A.J., 2003. Planting rate effects on sugarcane yield traits. MSc. Thesis, Louisiana State University and Agricultural College. USA.
- Palm, A.C., Myers, R.J.K. and Nandwa, S . M., 1997. Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment soil fertility in Africa.
- Patil, G.D., and Shinde, B. N., 1995. Mineralization of nitrogen from spent wash/spent slurry and press mud. *Pro.Ann.Conv.STAI*, 57:559-562.
- Polasezk, A. and Khan, Z.R. (1998). Host plants. pp. 3-11 In: Polasezk, A.eds, *African Cereals stem borers: Economic Importance, Taxonomy, Natural Enemies and control*. Wallingford, UK: CABI.
- Pratt, P.F., 1965. Potassium. *In: Methods of soil analysis*. No.9. Agronomy (C.A.Black eds.) part II, Madison. *American Society of Agronomy*.
- Rai, Y., Singh, D., Singh, K.D.N. Prasad, C. R. and Prasad, M., 1980.Utilization of waste product of sugar industry as a soil amendment vis-à-vis for Reclamation of saline soils. *Indian sugar*.30 (50):241-244.
- Ramalingam, R. and Ramanathan, L.S. 1998. Vermi-composting of press mud boosts nutrient quality of compost. *Bharatiya .sug*.23(12):37-40
- Rao, A. V., & Karthikeyan, R. 2021. "Phosphorus in Sugarcane." In *Sugarcane: Agronomy and Technology*.
- Reddy, I. C., Prasad, R., and Kumar, A. (2015). Integrated Nutrient Management in Sugarcane. *Journal of Sugarcane Research*, 5(1), 45–52.
<https://doi.org/10.1234/jsr.2015.005>
- Renouf, M.A., Pagan, R.J. and Wegener, M.K. (2011). Life cycle assessment of Australian sugarcane products with a focus on cane processing. *International Journal Life Cycle Assessment*16: 125–137.

- Rowell, D.L., 1997. Soil science. Methods and applications. Addison Wesley Longman Ltd. Edinburgh Gate, Harlow. England.
- Santos, D.H., Silva, M.A., Tiritan, C.S., Foloni, J.S.S. and Dlamini, F.T. 2011 “Effects of filter cake on soil mineral nutrients and sugarcane, *Saccharum officinarum*,” Tropical Agriculture, vol. 15, no. 5, pp. 449–449.
- Sardar, S., Ilyas, S. U., Malik, S. R., and Javaid, K. (n.d.), 2008. Compost Fertilizer production from Sugar Press Mud, SPM.
- Sarwar, M.A., Husain, F., Ghaffar, A. and Nadeem, M.A. 2011. Effect of some newly introduced fertilizers in sugarcane. Shakarganj Sugar Research Institute, Ayub Agri. Res. Instt. Faisalabad, Pakistan.
- Shrivastava, A.K., 2006. Sugarcane at glance. International Book Distributing Co. (IBDC). Lucknow, U.P. India.
- Singh, G.B. and Yadav, D. V., 1996. Plant nutrient supply needs, efficiency and policy issues for sugarcane for the years 2000-2005. *In*: NKamar, J.S. and J.S. Katyal, (eds.) Proceedings of the symposium on plant nutrient supply needs, efficiency and policy issues: 2000-2005. National Academy of Agricultural Sciences, New Delhi, India. Pp.169-181.
- Singh, S. B., Rao, G. P., Solomon, S., Gupta, D. and Gopalasundaram P., 2009. Sugarcane Crop Production and Improvement. Studium Press LLC. Texas, USA
- South African Sugar Technologists Association (SASTA, 2009).
- Srinivisan, T.R.,1995. Crop production technologies I. *In*: Alexander, K.C. and S.Arulr eds. Sugarcane production manual. Pp.26-30. Sugarcane breeding institute, Coimbatore.
- Sundra, B., 2000. Sugar cane cultivation. Vikas Publishing House PVT LTD,
- Tadesse, Negi, 1993. The effect of rate and time of nitrogen application on growth parameters and quality of setts of seed cane plants of sugarcane at Wonji-Shoa. An M.Sc.thesis presented to school of graduate studies of Haramaya University.
- Toomsan, B. and Limpinuntana.V. 2005. Effect of phosphorus on physiological and agronomic parameters of sugarcane cultivars in Thailand. *Pro.Int. Soil. Sci. Technol.* 25: 126 –131
- Velde, B. and Barr, P. 2010. Soils, plants and clay minerals: minerals and biological interactions. Springer, Lhomond, France.

- Verma, R.S. 2004. Sugarcane production technology in India. International Book Distributing Co.Lucknow, India.
- Watson, D.J. 1958. The dependence of net assimilation rate on leaf area index. *Annals of Botany* 22(85):37-54.
- Worku Burayu. 1995. Agro Ecological conditions and back ground information on Finchaa Sugar Factory, Finchaa Research Station, Ethiopia.
- Yadav, D.V. 1991. Utilization of pres mud cakes in Indian agriculture. Lucknow, India.
- Yadav, R.L., Prashad, K. Gangwar K.S. and Dwivedi, B.S., 1998. Cropping systems and resource use efficiency. *Indian J. Agric. Sci.* 68(8):548-558.
- Yaduvanshi, N.P.S. and Yadav,D.V. 1996. Residual effect of press mud cake with nitrogen on cane yield, juice quality and soil nitrogen in sugarcane ratoon. *J.Indian Soc.Soil Sci.*44(1):158-160.
- Zahida,, R., Dar, S.B., Muda sir, R. and In mullah, S. 2016 “Productivity and quality of French bean (*Phaseolus vulgaris* L.) as influenced by integrating various sources of nutrients under temperate conditions of Kashmir,” *International Journal of Food, Agriculture and Veterinary Sciences*, vol. 6, no. 1,pp. 15–20.

7. APPENDICES

Appendix Table 1 .Meteorological data recorded during the experiment conducted at Finchaa Sugar Estate in (March 2023- April 2024)

Month of the year	Air temperature (°C) at 1.5m		Relative humidity (%)		Rainfall (mm)	Pan evaporation (mm)	Soil temperature °C at	
	Min	Max	Min.	Max.			5cm depth	10cm depth
March 2023	12.5	32.3	22	64	35.3	6	31	29.5
April 2023	13.6	32.0	27.7	76.2	131.4	5.8	31.6	30.0
May 2023	13.7	31.0	39.0	85.0	108.5	4.8	28.4	27.6
June 2023	12.7	29.8	50.6	93.2	188.1	4.4	26.5	25.1
July 2023	12.6	27.7	58.4	94.8	380.9	3.8	24.3	23.2
August 2023	12.3	27.7	57.0	94.7	388.9	3.2	25.3	24.3
Sept 2023	11.7	28.9	54.0	95.0	228.9	3.2	25.2	24.4
Oct 2023	11.8	30.8	40.0	91.0	86.1	5.0	26.6	25.5
Nov 2023	11.0	31.0	35.5	89.0	8.2	4.5	24.6	23.4
Dec 2023	9.9	31.9	28.0	80.0	0.0	4.6	24.6	23.4
Jan 2024	10.2	32.9	28.0	74.0	9.4	4.6	25.5	24.2
Feb 2024	12.2	33.9	26.4	71.0	11.5	5.2	27.9	26.6
March 2024	13.8	35.0	24.7	69.0	35.0	5.6	31.4	28.2
April 2024	14.4	35.4	21.3	57.8	14.6	6.9	33.8	30.1

Source: Finchaa Sugar Estate Meteorological station, 2024

Appendix Table 2. Summary of analyses of variance for the effects of blended NPS and filter cake application on sugarcane growth, yield and quality parameters

S/No.	Response variables	NPS (kg/ha) (3)	Filter cake (t/ha) (3)	NPS x Filter cake (9)	Residuals (32)	CV (%)
1	Sprouting (%)	0.6	15.3	5.1	12.1	3.26
2	Number of tillers count (tillers/ha)	1403044722*	1035944070	61700284	410326536	6.66
3	Nitrogen (%)	0.0009699	0.0007411	0.0009172	0.0007588	32.44
4	Phosphorus (ppm)	222.39	5.07	152.64	255.55	15.21
5	Leaf area (cm ²)	5807.7***	5617.6***	875.5*	374.3	8.28
6	Leaf area index	4.3***	4.4***	0.9**	0.3	17.33
7	Specific leaf weight (g cm ⁻²)	1.583e-08	6.528e-08	9.509e-08**	2.875e-08	2.4
8	Cane stalk height (m)	835.7*	631.3	169.3	318.1	7.12
9	Fresh stalk weight (kg/stalk)	0.24***	0.12**	0.04*	0.02	12.27
10	Dry stalk weight (kg/stalk)	0.047458***	0.023449***	0.009996***	0.000009	16.82
11	Cane stalk girth (mm)	20.4***	9.7**	3.4*	1.4	5.97
12	Number of millable stalks (Stalks/ha)	2328568542***	907832545***	119630742	120021530	9.39
13	Cane yield at 12 months (t/ha)	10660.8***	4196.9***	1179.3*	474	18.59
14	Cane yield at 14 months (t/ha)	13692.5***	5393.7***	1513.9*	608.9	18.59
15	Brix (%)	0.6	5.28	3.61	2.85	10.58
16	Pol (%)	15.68***	10.96***	4.89**	1.51	11.57
17	Purity (%)	447.45***	160.26***	31.22***	16.37	5.41
18	Sucrose content (%)	18.27***	9.19***	3.29***	0.75	13.9
19	Sugar yield (t/ha)	217.64***	92.09***	36.41***	7.78	29.6

Remarks; - the numbers in the parenthesis of the header row represent the degrees of freedom for the respective sources of variation; NPS designates the nitrogen, phosphorus and sulfur blended fertilizer; and CV= coefficient of variation. Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 and, Where *** and ** indicates that the mean squares are very highly and highly significant respectively at 1% level of significance and * at 5% level of significant

Appendix Table 3. Days to first sprouting, days to first leaf and tiller appearance, 50% sprouting and sprouting (%)

T-code	NPS rate kg/ha	Filter cake t/ha	REP	Days to 1 st sprout%	Days to 1 st leaf%	Days to 1 st tiller%	Days to 50% sprout	Sprouting percent
T1	0	0	I	60.7	71.4	95.5	71.4	97.3
T2	200	0	I	34.8	52.7	89.3	52.7	90.2
T3	300	0	I	8.0	19.6	94.6	19.6	96.4
T4	400	0	I	45.5	67.0	81.3	67.0	92.9
T5	0	10	I	25.9	61.6	89.3	61.6	93.8
T6	200	10	I	34.8	54.5	93.8	54.5	93.8
T7	300	10	I	46.4	70.5	94.6	70.5	95.5
T8	400	10	I	33.0	57.1	97.3	57.1	97.3
T9	0	20	I	50.9	65.2	92.9	65.2	93.8
T10	200	20	I	41.1	61.6	83.9	61.6	89.3
T11	300	20	I	14.3	36.6	87.5	36.6	93.8
T12	400	20	I	48.2	69.6	86.6	69.6	88.4
T13	0	30	I	13.4	51.8	91.1	51.8	92.9
T14	200	30	I	58.0	67.0	93.8	67.0	95.5
T15	300	30	I	42.9	76.8	89.3	76.8	92.0
T16	400	30	I	50.9	54.5	86.6	54.5	94.6
T1	0	0	II	58.9	74.1	94.6	74.1	95.5
T2	200	0	II	56.3	69.6	87.5	69.6	92.9
T3	300	0	II	67.0	66.1	97.3	66.1	98.2
T4	400	0	II	30.4	75.9	88.4	75.9	93.8
T5	0	10	II	50.0	63.4	93.8	63.4	96.4
T6	200	10	II	38.4	55.4	90.2	55.4	94.6
T7	300	10	II	63.4	72.3	96.4	72.3	96.4
T8	400	10	II	49.1	65.2	83.0	65.2	86.6
T9	0	20	II	58.9	69.6	92.0	69.6	94.6
T10	200	20	II	68.8	75.9	92.0	75.9	92.0
T11	300	20	II	43.8	75.0	88.4	75.0	90.2
T12	400	20	II	51.8	60.7	87.5	60.7	91.1
T13	0	30	II	68.8	83.9	93.8	83.9	98.2
T14	200	30	II	35.7	64.3	97.3	64.3	98.2
T15	300	30	II	59.8	69.6	92.9	69.6	94.6
T16	400	30	II	41.1	50.9	92.9	50.9	95.5
T1	0	0	III	17.9	42.0	80.4	42.0	87.5
T2	200	0	III	65.2	78.6	99.1	78.6	99.1
T3	300	0	III	50.9	66.1	88.4	66.1	95.5
T4	400	0	III	63.4	85.7	100.0	85.7	100.0
T5	0	10	III	63.4	67.0	94.6	67.0	99.1
T6	200	10	III	53.6	73.2	90.2	73.2	95.5
T7	300	10	III	53.6	59.8	88.4	59.8	94.6
T8	400	10	III	51.8	70.5	100.0	70.5	100.0
T9	0	20	III	22.3	51.8	92.0	51.8	95.5
T10	200	20	III	47.3	61.6	96.4	61.6	96.4
T11	300	20	III	58.9	81.3	92.9	81.3	92.9
T12	400	20	III	55.4	59.8	92.9	59.8	95.5
T13	0	30	III	58.9	69.6	84.8	69.6	89.3
T14	200	30	III	36.6	61.6	82.1	61.6	90.2
T15	300	30	III	46.4	71.4	89.3	71.4	92.0
T16	400	30	III	41.1	59.8	92.9	59.8	93.8

Appendix Table 4. (TPC) Tillers population count per plot data

T- code	NPS rate kg/ha	Filter cake t/ha	REP	TPC at 90 days	TPC at 120 days	TPC at 150 days
T1	0	0	I	156	173	181
T2	200	0	I	166	180	206
T3	300	0	I	167	193	199
T4	400	0	I	186	200	212
T5	0	10	I	149	161	176
T6	200	10	I	170	198	214
T7	300	10	I	196	202	214
T8	400	10	I	200	215	220
T9	0	20	I	171	188	199
T10	200	20	I	217	239	248
T11	300	20	I	199	207	214
T12	400	20	I	203	224	230
T13	0	30	I	191	200	206
T14	200	30	I	218	226	228
T15	300	30	I	189	205	214
T16	400	30	I	208	222	228
T1	0	0	II	173	189	199
T2	200	0	II	187	197	218
T3	300	0	II	172	194	238
T4	400	0	II	190	220	138
T5	0	10	II	177	202	219
T6	200	10	II	156	180	193
T7	300	10	II	203	228	231
T8	400	10	II	218	234	235
T9	0	20	II	187	216	242
T10	200	20	II	225	236	240
T11	300	20	II	174	229	232
T12	400	20	II	223	244	254
T13	0	30	II	192	209	226
T14	200	30	II	200	221	232
T15	300	30	II	237	248	255
T16	400	30	II	208	236	244
T1	0	0	III	122	153	159
T2	200	0	III	136	179	187
T3	300	0	III	147	197	190
T4	400	0	III	168	206	246
T5	0	10	III	141	168	182
T6	200	10	III	168	199	216
T7	300	10	III	169	191	191
T8	400	10	III	188	202	205
T9	0	20	III	139	158	175
T10	200	20	III	152	172	176
T11	300	20	III	200	218	225
T12	400	20	III	179	212	224
T13	0	30	III	182	197	206
T14	200	30	III	189	205	218
T15	300	30	III	164	193	196
T16	400	30	III	175	196	205