Effect of soil enhancers and foliar application of whey on growth and yield of Cyperus esculentus plants and used in some dairy products

تأثير مُحسنات التربة والرش الورقى بشرش اللبن على نمو وإنتاج نباتات حب العزيز واستخدامها في إنتاج بعض منتجات الألبان

By

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Effect of soil enhancers and foliar application of whey on growth and yield of *Cyperus esculentus* plants and used in some dairy products

Abstract :

The study conducted for two consecutive summer seasons in 2019 and 2020 at the Gemmeiza Agricultural Research Station, Gharbia Governorate, Egypt, investigated the effects of soil enhancers such as compost, agricultural sulfur, potassium humate, and spray whey on tiger nut on plant growth and production. The experiment included eight treatments: control, foliar spray of whey, compost applied alone and in combination with foliar spray for whey, agricultural sulfur applied alone and in combination with foliar spray for whey, and potassium humate applied alone and in combination with foliar spray for whey. The results showed that soil amendments and foliar sprays of whey significantly improved plant characteristics, with T4 and T6 being the most effective. The interaction between potassium and whey spray significantly increased plant parameters, such as shoot dry weight, nutrient uptake, yield, and tuber quality. Treatment T7 recorded the highest values for moisture, fat, and total titratable acidity, followed by compost alone.Therefore, it is suggested that tiger nut plants could be cultivated as a source for protein, oil, and milk while simultaneously incorporating soil enhancers and whey protein as an organic foliar spray for the cultivation of organic crops.

Keywords: Tiger nut, Compost, Agricultural sulfur, Potassium humate, whey, rayeb.

المستخلص:

أجريت الدراسة على مدار موسمين صيفيين متتاليين في عامي ٢٠١٩ و٢٠٢٠ في محطة البحوث الزراعية بالجميزة بمحافظة الغربية في مصر، وتهدفت إلى دراسة تأثير محسنات التربة مثل سماد الكمبوست والكبريت الزراعي وهيومات البوتاسيوم ورش مصل اللبن على نبات الجوز النمر على نمو وإنتاجية النبات.

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وتضمنت التجربة ثماني معاملات: معاملة الكنترول، والرش الورقي لمصل اللبن، وسماد الكمبوست بمفرده وبالاشتراك مع الرش الورقي لمصل اللبن، والكبريت الزراعي المطبق بمفرده وبالاشتراك مع الرش الورقي لمصل اللبن، وهيومات البوتاسيوم المطبق بمفرده وبالاشتراك مع الرش الورقي لمصل اللبن. وأظهرت النتائج أن محسنات التربة ورش مصل اللبن بالأوراق أدى إلى تحسين خصائص النبات بشكل ملحوظ، حيث كانت المرحلتان T4 وT6 الأكثر فعالية. كما أدى التفاعل بين رش البوتاسيوم ومصل اللبن إلى زيادة كبيرة في معايير النبات، مثل الوزن الجاف للبراعم، وامتصاص العناصر الغذائية، والإنتاجية، وجودة الدرنات. وسجلت المعاملة T7 أعلى القيم للرطوبة والدهون والحموضة الكلية القابلة للقياس، تليها المعاملة T7.

Introduction

Tiger nut (*Cyperus esculentus* L) are a flexible and nutritious meals supply located in various parts of the globe, inclusive of South Korea, China, Egypt, Ghana, Nigeria, Turkey, the East Mediterranean, the united states, Alaska, and Spain (specially, the Valencia place). **Tan *et al.*,(2023**) studied tiger nutadaptability to marginal land situations that specialize in soil nutrient availability. They indicated that fertilization increases tiger nut populace and makes use of soil nutrients for tuber manufacturing, whilst nitrogen delays development. Those findings offer valuable insights into the optimization of tiger nut cultivation on marginal land. In concordance with **Shahein *et al.*, (2023)**, studied on bio-yoghurt beverages found that incorporating tiger nut flour can improve nutritional content material, sensory traits, and health advantages. The addition accelerated total solids, protein, fats, and acidity, advanced probiotic bacteria viability, and more advantageous sensory attributes. **(Kranz *et al.*, 2020**),crop manufacturing is inspired positively with the aid of compost application due to its effect on numerous physical and chemical residences and soil microbial hobby **(Soliman, 2018)**.**Timon *et al.*, (2019)**observed that a fertilizer mixture of 100 kg^{-1}NPK+ 140 kg^{-1}PD+240 kg ha^{-1}CD

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became exceptional for tiger nut increase and yield. The aggregate produced the best variety of leaves, heaviest tuber weight, and highest quantity of tubers according to plant, thereby enhancing tiger nut yield **Sarhan *et al.*, (2023)** stated that compost manure fertilization and foliar software significantly decorate French basil plant growth in sandy soils. Combining potassium silicate with compost manure and 30 ppm methyl jasmonate resulted in the highest increase and peak.

Sulfur fertilizer improves crop productivity by reducing soil pH and increasing essential nutrients like nitrogen and micronutrients. However, it's a limiting nutrient in agricultural practices due to factors like high yields, low sulfur content, rainfall reduction, and soil sulfur reserves declining. This sulfur deficiency is particularly evident in Egyptian soils, resulting from crop depletion, which hampers agricultural production. The plant can absorb sulfur in the form of SO4-2 with the same amount of phosphorus absorption **(Chaghazardi *et al.*, 2014)**.**Dudhe *et al.*, (2014**) examined sugarcane plants to assess the effect of sulfur in the form of ammonium sulfate on the development, surrender, and quality of sugarcane. It appeared that sulfur had a positive effect on sugarcane yield/ha. There was a clear increment in production compared to the control, and the negative effect was on plant density and plant height. **Kurowski *et al.*, (2010**) conducted research on Brassicaceae plants and discovered that the application of sulfur fertilizers had a positive impact on decreasing the occurrence of Alternaria blight. Consequently, the sulfur fertilization led to a notable decrease in the abundance of parasites, including pathogens that infect Brassicaceae seeds.

Humic acid (HA) is a naturally organic macromolecular compound with functional groups containing oxygen **(Oskoe *et al.*, 2016)**. In recent years, HA has been enriched with potassium

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salt, forming potassium humate (KHM), which can regulate plant growth and provide potassium for it **(Lang *et al.*, 2020)**. Furthermore, HA also has several advantages, such as: having a high water holding capacity; improving soil structure; chelating many micronutrients, making them more suitable for plants; improving the use of chemical fertilizers by slowly releasing fertilizers; and improving nutrient absorption, which promotes plant germination and growth (**Pereira *et al.*,2019)**. In addition, **Pavlova *et al.*, (2020**) found that potassium humate and effective microorganisms improve survival, preservation, yield, crop structure, and seed quality in Ivan Karamanov's soybean variety. Growth regulators also improved root system growth, increasing nodule numbers by nearly fourfold and increasing the soya leaf surface area. **Ullah *et al.*'s 2020** study found that combining seed dressing and soil application of potassium humate improved cotton plant productivity and fiber quality, suggesting a 20 L ha^-1 limit for application.

Sweet whey (SW) is a by-product of cheese manufacturing rich in nutrients such as lactose and whey proteins. Despite its nutritional value, SW is often wasted, contributing to environmental pollution. However, it contains minor components like lactoferrin and immune-globulins, which have various important biological roles such as immunomodulation and antioxidant activity **(Zayed and Winter, 1995; De Wit, 1998**). Tiger nut milk, also known as horchata de chufa, is a plant-based milk alternative made from tiger nut which are tubers rather than nuts. It is lactose-free and rich in fiber, vitamins, minerals, and healthy fats, making it suitable for individuals with dairy allergies or lactose intolerance. Tiger nut milk can be consumed alone or used in various recipes, offering a satisfying and nutritious dairy-free option. Rayeb milk was made by fermenting milk with specific

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bacteria. Rayeb milk is a good source of essential nutrients like protein, calcium, and vitamin B12 and supports digestive health. **Salama *et al.*, (2013)**analyzed tiger nut tubers' chemical and technological properties, finding them rich in oil, essential minerals such as potassium, phosphorus and magnesium, and crude fibers. The oil resembles edible oils like cottonseed, corn, sunflower, and olive. The study recommends its use as a safe vegetable.**Djomdi *et al.*, (2020**) found that sprouting tiger nut tubers increased milk extraction yield by 35% and starch hydrolysis rates by 45 to 70%, resulting in naturally sweetened milk with improved viscosity. Research conducted to date has shown that if spread as fertilizer on cultivated lands, organic waste from the food industry affords the improvement of nutrient flux from plants **(Asik and Katkat (2010) and Zaha *et al.*, (2011)**.Indeed, nitrogen, phosphorus, sulfur, calcium, sodium, magnesium, lactose, and proteins from whey can play this role and lead to increased crop productivity (**Tsakali *et al.*,2010).**The amounts of these compounds in whey can be considered sufficient for plant growth.

Materials and Methods

The experiment was carried out at the farm of Gemmeiza Agricultural Research Station, Gharbia Governorate, Egypt, during the two consecutive summer seasons of 2019 and 2020.To remove the remnants of the previous crops, the field was cross-ploughed twice. Plots for experiments were set out across the field. The experimental unit's area was 2.16 m^2 (1.2 m × 0.60 m), with three rows per plot and 30 cm between hills. Each hill had two plants, and each plot had 25–30 plants. Three replications of a randomized complete block design system were used to distribute these treatments. Eight treatments were used in the studyof tiger nut tubers in soil with similar characteristics, of tiger nut tubers in soil with similar characteristics, incorporating

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amendments like compost, agricultural sulfur, and potassium humate to promote growth, nutrient uptake, and the economic underground part. Whey protein, abundant in amino acids, was utilized as a foliar application.

The treatments under the study were as follows:(T1) control - 100% of the recommended NPK dose, (T2) foliar spray of whey + 50% NPK, (T3) compost + 50% NPK, (T4) compost + foliar spray of whey + 50% NPK, (T5) agricultural sulfur + 50% NPK, (T6) agricultural sulfur + foliar spray of whey + 50% NPK, (T7) potassium humate + 50% NPK, and (T8) potassium humate + foliar spray of whey + 50% NPK.

Tiger nut tubers were obtained from local markets located in the Tanta, Gharbia Governorate.These tubers were planted on April 1st and harvested 160 daysafter planting.Experimental treatments involved using sweet whey mixed with soap on plant leaves twice per seasonat 60 and 70 days after sowing, with chemical composition, acidity, and pH values displayed in Table 3.

Table 1: The initial characteristics of the soil under study (average of both seasons).

Parameter	Value	Parameter	Value
pH	8.83	**Soluble cations (meq l^{-1})**	
EC (mmohs cm-1)	0.55	Magnesium (Mg^{++})	0.90
Organic matter (%)	0.74	Calcium (Ca^{++})	1.70
Saturation (SP, %)	68.00	Potassium (K^{++})	0.80
Field capacity (FC, %)	36.23	Sodium (Na^{++})	2.48
Wilting point (WP, %)	18.12	**Soluble anions (meq l^{-1})**	
ρs (Mg m^{-3})	2.62	Cl^-	3.29
ρb (Mg m^{-3})	1.12	HCO_3^-	0.23
Mechanical analysis		SO_4^{--}	1.89
Sand (%)	11.69	**Available nutrients (ppm)**	
Silt (%)	37.17	Nitrogen (N)	42.74
Clay (%)	51.14	Phosphorus (P)	11.18
Texture class	Clayey	Potassium (K)	314.32

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Table 2:Characteristics of the compost utilized in the study

Parameter	Value	Parameter	Value
pH (water)	5.92±0.07	C:N ratio	14.7
Electrical conductivity (EC, dS m^{-1})	2.4±0.06	Total P (%)	1.34±0.06
Total organic carbon (%)	30.8±5.22	Total K (%)	1.6±0.08
Total N (%)	2.1±0.11		

Agricultural sulfur (biosulf 99% powder), purchased from Baladna Modern Fertilizers Company, is composed of 99% sulfur and 1% complementary materials. Sulfur is a crucial element for plant nutrition, as it is involved in the synthesis of amino acids necessary for plants, such as lecithin and methylene, and plays a significant role in plant respiration. Furthermore, sulfur is included in the composition of volatile substances that give vegetables like onions, garlic, cabbage, and cauliflower their distinctive taste and flavor.

Sweet whey

Sweet whey was procured from the Ras Cheese Factory in Tanta, as shown in Table 3. Fresh cow's milk was obtained from El-Serw Animal Production Research Station, a facility operated by the Animal Production Research Institute, Agricultural Research Center. Tiger nut was obtained from Al-Gemmiza Station. Fresh cow's, buffalo's, and goat's milk were also obtained from the El-Serw Animal Production Research Station. The study utilized a commercial strain of yogurt starter. Containing Streptococcus thermophilus and Lactobacillus delbrueckisubsp.Bulgaricus in a 1:1 ratio (Chr. Hansen's Lab A/S, Copenhagen, Denmark). The starter cultures were in freeze-dried, direct-to-vat set form and were stored at 18 °C until use.

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Table 3: Chemical composition, acidity and pH value of sweet whey

Parameter	Value	Parameter	Value
Moisture (%)	93.8	Fat (%)	0.50
pH	5.7	Lactose (%)	4.7
Total solids (%)	6.2	Calcium(mg 100 g^{-1})	57.0
Protein (%)	0.78	Titratable acidity	0.30

Preparation of Tiger nut milk

Tiger nut milk was prepared as described by **Bristone (2015)** with some modification. One kg of whole tiger nuts was cleaned and processed to remove contaminants. It was soaked in clean water for 24 hours. The tiger nut becomes softer and simpler to combine after soaking. The wet tiger nuts were drained, cleaned once more, and then blended with a volume of water in a ratio of 1:3 using a blender. After that, the tiger nut milk was extracted by straining it through muslin cloth.

Preparation of rayeb milk made from cow and tiger nut milk

Three treatments of Rayeb milk were made from cow’s milk, tigernut milk and mixtures as follows:(A): Rayeb milk made from cow milk, (B): Rayeb milk made from tigernut milk, and (C): Rayeb milk made from 50% cow milk + 50% tigernut milk. Pasteurization of milk for all treatments, then cooled to 40°C, inoculated with cultures (0.1 gL^{-1} of milk mix), incubated at 40°C for fully coagulation, and preserved at 4°C for 14 days. Rayeb milk samples wereanalyzed when fresh and after 7 and 14 days of refrigerated storage.

Experimental Design

The experiment was conducted using a factorial design with full randomization and three replications. The factors involved soil enhancers, such as control, compost, agricultural sulfur, and potassium humate. The second factor was sweet

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whey, which was administered as a foliar application either with or without sweet whey, resulting in a total of eight treatments.

Sampling and analysis

After 160 days of sowing, three plants were randomly selected from each plot to determine various parameters. Vegetative growth parameters includes plant height (cm), the number of tillers per hill, tuber number per hill, and the dry weight of tubers per hill (g). Additionally, fixed oil from tiger nut seeds was extracted using petroleum ether in a Soxhlet system HT apparatus, according to the methods outlined by **AOAC (2019**). The total carbohydrate percentage was determined in tiger nut seeds using the method of **Dubios *et al.*, (1956)**. At maturity, ten random tubers were collected from each plot to determine the N content (in grams per 100 grams), which was determined using the micro-Kjeldahl method according to **Humphries (1956**). Furthermore, the percentages of total P and K in tubers were determined using the methods of **Van Schouwenburg and Walinge (1967) and Varley (1971)**, respectively. Soil samples were collected after the harvest of tiger nut tubers to determine the available NPK in the soil. The standard methods of soil analysis were followed, as described by **Piper (1944)** and **Black *et al.*, (1965)**.

The determination of the total soil, total nitrogen, and ash content of milk samples was carried out in accordance with the standards established by **AOAC (2019)**. The titratable acidity of the samples was measured using a method that involved titrating a mixture of 10 grams of the sample and 10 milliliters of boiling distilled water with 0.1 normal sodium hydroxide. The reaction was monitored using a 0.5% phenolphthalein indicator until the endpoint of a faint pink color was reached. The pH of the milk samples was measured using a pH meter calibrated with standard buffers (pH 4.0 and 7.0), and the temperature was maintained at

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17 to 20 degrees C. The results of the measurements were recorded and analyzed to determine the properties of the milk samples.

Statistical analysis

The data collected from the experiments were analyzed using a randomized complete design analysis. To compare the treatment means, the least significant difference test (L.S.D.) was employed, with a significance level of $p \leq 0.05$. The statistical analysis was carried out using the Statistix Software v. 9 **(Boyd *et al.*,2018)**.

Results

Soil physical and chemical characteristics

Table 1 presents a comprehensive overview of the physical and chemical characteristics of the soil, compost, and sweet whey. The soil is categorized as clayey and includes specific proportions of sand, silt, and clay. Table 2, present valuable insights into the composition, pH level, electrical conductivity, and organic matter content of the compost.While, Table 3 furnishes data on the chemical composition, acidity, and pH values of sweet whey.

Growth parameters

The study examines the impact of soil enhancers and foliar sweet whey application on tiger nut plant growth parameters,i.e., plant height, tillers per hill, tuber dry weight, and tubers per hill under varying conditions. inthe 2019 and 2020 seasons, revealing significant disparities in plant growth.The treatment (T4) of compost, foliar whey spray, and 50% NPK recorded involving compost, foliar whey spray, and 50% NPK showed the highest values in plant height, tillers per hill, and

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tubers dry weight were 57.44 cm and 59.24 cm for plant height, 55 and 56 for tillers per hill, 140.64 g and 181.3 g for tubers dry weight, and 111 and 113 for tubers per hill, respectively, followed by treatment (T6) which included agricultural sulfur, foliar whey spray, and 50% NPK. The research conducted by **Ullah *et al.*, (2020**) offers additional evidence to reinforce the beneficial outcomes of using potassium humate as a seed coating for cotton plants. The study demonstrates that implementing this technique improves both the productivity and fiber quality of the plants. The researchers also noted that the integration of potassium humate resulted in notable enhancements in soil characteristics and crop yield. To optimize the results, it is recommended to limit the application of potassium humate to 20 L ha^{-1}.In recent study conducted by **Adekiya *et al.*, (2020)** studied the impact of cow dung, wood biochars, and green manure on soil fertility and tiger nut performance. Results showed these organic materials improved the soil properties, nutrient content,and quality of tiger nut, with the combination of these materials showing promising results.**Tan *et al.*, (2023)** on tiger nut and French basil plants (**Sarhan *et al.*, 2023)**, chickpea plants **(Ahmed *et al.*, 2023**), and potato plants (**Shabana *et al.*, 2023)** were all subjects of recent studies. **Tan *et al.*, (2024)** studied Mongolian tiger nut cultivation as a bioenergy crop.The study found that traditional fertilization methods and the addition of nitrogen fertilizer led to an increase in tuber yield. Moreover, the application of additional nitrogen fertilizer stimulated shoot production and rhizome tillering, ultimately resulting in an overall increase in tiger nut.

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Table 4: Effect of soil enhancers and foliar application of whey on growth of tiger nut plant during two seasons of 2019 and 2020

Treatments	Plant height (cm)		No. of Tillers per hill		Tubers dry weight (g)		No. of Tubers per hill	
	1st Season 2019	2nd Season 2020	1st Season 2019	2nd Season 2020	1st Season 2019	2nd Season 2020	1st Season 2019	2nd Season 2020
T1	41.11cd	45.35c	43b	45b	54.50d	72.58d	71d	76c
T2	36.78e	38.58e	26d	28d	26.09e	26.9f	25f	26f
T3	41.44cd	43.24cd	34c	35c	52.7d	70.24d	68d	70d
T4	57.44a	59.24a	55a	56a	140.64a	181.3a	111a	113a
T5	39.55de	42.91cd	36c	36c	26.09e	26.8f	34e	28f
T6	48.89b	50.69b	53a	54a	71.87b	95.13b	93b	95b
T7	39.55de	41.35de	34c	38c	19.25f	35.69e	26f	35e
T8	48.11b	49.90b	45b	47b	57.67c	76.69c	75c	72d
LSD at 5%	3.36	3.32	4.96	4.90	2.24	2.89	2.91	2.90

T1: control - 100% of the recommended NPK dose, T2: foliar spray of whey + 50% NPK, T3: compost + 50% NPK, T4: compost + foliar spray of whey + 50% NPK, T5: agricultural sulfur + 50% NPK, T6: agricultural sulfur + foliar spray of whey + 50% NPK, T7: potassium humate + 50% NPK, and T8: potassium humate + foliar spray of whey + 50% NPK.

Chemical composition of tiger nut plants

The chemical composition of tiger nut plants in the 2019 and 2020 seasons was examined in Table 5, which presented data on the impact of soil enhancers and foliar application of sweet whey. The objective of the study was to evaluate various parameters, including fixed oil percentage, carbohydrate content, and nutrient levels (N, P,and K) in the tubers under different

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conditions. The treatment that yielded the highest results was (T4) Compost with foliar spray whey + 50% NPK, demonstrating fixed oil percentages of 20.73% and 21.02%, carbohydrates content of 0.087 mg/ml and 0.057 mg/ml, N levels of 2.52 mg/ml and 2.55 mg/ml, P levels of 0.12 mg/ml and 0.15 mg/ml, and K levels of 0.52 mg/ml and 0.67 mg/ml for the respective seasons. Following closely behind was (T6) Agricultural sulfur with foliar spray whey + 50% NPK.

The findings align with the research conducted by **Barrett (2023)** conducted a study on tiger nut in marginal agricultural lands, emphasizing their potential as a global food resource due to their ability to adapt to different ecological conditions. The study revealed that the combination of rice straw compost and biofertilizernitrobien resulted in improved vegetative growth and better harvest outcomes. **Adekiya *et al.*, (2020)** also investigated the impact of cow dung, wood biochars, and green manure on soil properties, nutrient contents, and the performance of tiger nut. Their findings indicated that these organic materials had a positive effect on the soil and enhanced the growth of tiger nut. In another study by **Tan *et al.*, (2024)** conducted in Mongolia, the focus was on tiger nut as a bioenergy crop in northern China. The researchers discovered that the application of fertilizer significantly increased the yield of tiger nut, tubers, aboveground biomass, and rhizome production.Furthermore, these findings are consistent with the research carried out by **Ullah *et al.*, (2020)** and **Tan *et al.*,(2023**) on tiger nut and **Sarhan *et al.*, (2023)**on French basil plants.**Shabana *et al.*, (2023**) conducted a study on potato plants.**AbdelKader and El-Ghadban's (2017)** investigation focused on the influence of soil additives and nitrogen fertilizer rates on tiger nut plants. Their findings revealed that the utilization of rice straw compost in conjunction with the

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biofertilizer nitrobien led to improved growth and harvest results for tiger nut plants. Additionally, it was observed that higher nitrogen fertilizer rates were most successful in increasing tuber yield and enhancing oil quality.

Table 5: Effect of soil enhancers and foliar application of whey on fixed oil and chemical constituents of tiger nut plant during two seasons of 2019 and 2020

Treatments	Fixed oil (%)		Carbohydrates ($mgml^{-1}$)		Nitrogen ($mg\ kg^{-1}$)		Phosphorus ($mg\ kg^{-1}$)		Potassium ($mg\ kg^{-1}$)	
	1st Season 2019	2nd Season 2020	1st Season 2019	2nd Season 2020	1st Season 2019	2nd Season 2020	1st Season 2019	2nd Season 2020	1st Season 2019	2nd Season 2020
T1	15.93^{c}	16.49^{c}	0.044^{d}	0.053^{b}	2.26^{bc}	2.32^{b}	0.10^{bc}	0.10^{d}	0.42^{bc}	0.56^{abc}
T2	14.35^{e}	14.65^{e}	0.030^{e}	0.023^{e}	2.22^{bcd}	2.07^{cd}	0.09^{c}	0.11^{cd}	0.39^{bc}	0.47^{c}
T3	15.37^{cd}	15.73^{cd}	0.041^{d}	0.049^{c}	2.01^{d}	2.17^{cd}	0.11^{ab}	0.12^{bd}	0.41^{bc}	0.49^{bc}
T4	20..7^{a}	21.02^{a}	0.087^{a}	0.057^{a}	2.52^{a}	2.55^{a}	0.12^{a}	0.15^{a}	0.52^{a}	0.67^{a}
T5	15.57^{cd}	15.99^{cd}	0.040^{d}	0.048^{c}	2.06^{cd}	2.16^{cd}	0.10^{bc}	0.11^{b-d}	0.37^{c}	0.44^{c}
T6	18.66^{b}	19.00^{b}	0.061^{b}	0.056^{a}	2.42^{ab}	2.44^{ab}	0.11^{ab}	0.14^{ab}	0.42^{b}	0.64^{ab}
T7	15.01^{de}	15.17^{de}	0.032^{e}	0.040^{d}	2.14^{cd}	1.95^{d}	0.09^{c}	0.10^{d}	0.42^{bc}	0.62^{ab}
T8	17.91^{b}	18.06^{b}	0.053^{c}	0.054^{ab}	2.36^{ab}	2.20^{bd}	0.11^{ab}	0.13^{ac}	0.44^{b}	0.66^{a}
LSD at 5%	0.78	1.02	0.004	0.006	0.22**	0.27*	0.01*	0.03*	0.05**	0.16*

T1: control - 100% of the recommended NPK dose, T2: foliar spray of whey + 50% NPK, T3: compost + 50% NPK, T4: compost + foliar spray of whey + 50% NPK, T5: agricultural sulfur + 50% NPK, T6: agricultural sulfur + foliar spray of whey + 50% NPK, T7: potassium humate + 50% NPK, and T8: potassium humate + foliar spray of whey + 50% NPK.

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Soil properties

Table6 presents the data on the effects of soil enhancers and foliar application of sweet whey on nitrogen, phosphorus, and potassium levels in the soil for the years 2019 and 2020. The results indicated that all treatments exhibited significantly higher NPK values, with treatment T6 demonstrating the highest NPK values. Treatment T6 involved the use of agricultural sulfur applied through foliar sprays of whey. In both years, the NPK values for this treatment were 50.99 and 32.61 mg $kg^{1}$for nitrogen, 32.38 and 12.02 mg kg^{1} for phosphorus, and 381.82 and 414.67 mg kg^{1} for potassium, respectively. The second-highest values were recorded in treatment T4, which included the application of compost through foliar spray whey in addition to 50% NPK.These results are supported by research **Elwaziri *et al.*, (2023)** conducted a study to investigate the effects of soil enhancers and whey protein on the cultivation of sweet potatoes. The findings of their study revealed that the combination of whey protein and potassium fertilization had a significant positive impact on various parameters, including shoot dry weight, nutrient uptake, yield, and tuber quality. Notably, the treatment with whey protein at a concentration of 0.20% proved to be the most effective, with increased levels of potassium demonstrating a beneficial influence on both productivity and tuber quality.

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Table 6: Effect of soil enhancers and foliar application of whey on soil available NPK during two seasons of 2019 and 2020

Treatments	Nitrogen (mg kg^{-1})		Phosphorus (mg kg^{-1})		Potassium (mg kg^{-1})	
	1st Season 2019	2nd Season 2020	1st Season 2019	2nd Season 2020	1st Season 2019	2nd Season 2020
T1	33.42^{d}	28.78^{cd}	11.38^{e}	5.52^{c}	406.05^{abcd}	420.50^{abc}
T2	25.26^{e}	28.48^{d}	13.9^{de}	9.04^{b}	392.27^{bcd}	330.63^{d}
T3	34.08^{d}	30.13^{bcd}	7.98^{f}	9.29^{b}	382.99^{cd}	424.46^{abc}
T4	49.89^{a}	38.08^{a}	11.79^{de}	9.29^{b}	420.88^{a}	442.69^{a}
T5	42.37^{b}	27.97^{d}	26.89^{b}	11.87^{a}	321.77^{e}	398.42^{c}
T6	50.99^{a}	32.61^{b}	32.38^{a}	12.02^{a}	381.82^{d}	414.67^{abc}
T7	33.94^{d}	31.50^{bc}	18.00^{c}	10.00^{b}	409.04^{abc}	406.90^{bc}
T8	36.68^{c}	31.79^{b}	14.63^{d}	9.01^{b}	414.97^{ab}	431.01^{ab}
LSD at 5%	2.26**	2.85**	2.88**	1.38**	27.22	28.72**

T1: control - 100% of the recommended NPK dose, T2: foliar spray of whey + 50% NPK, T3: compost + 50% NPK, T4: compost + foliar spray of whey + 50% NPK, T5: agricultural sulfur + 50% NPK, T6: agricultural sulfur + foliar spray of whey + 50% NPK, T7: potassium humate + 50% NPK, and T8: potassium humate + foliar spray of whey + 50% NPK.

Chemical composition of tiger nut milk samples

Table 7 illustrates the influence of soil enhancers and whey foliar application on the chemical composition of tigernut milk samples in dairy products over the course of the 2019 and 2020 seasons. The data highlights variations in parameters including moisture content, carbohydrate levels, ash content, fat percentage, protein content, pH levels, and total solids. Treatment 7, which involved the addition of potassium humate to the soil, exhibited the highest values in terms of moisture content (77.2%), fat percentage (5.2%), and TTA (0.16%), closely followed by Treatment 3, which utilized compost only.

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Conversely, Treatment 8 demonstrated the highest results in characteristics such as carbohydrate levels (10.8%), ash content (0.72%), fat percentage (5.2%), protein content (6.9%), TTA (0.16%), and total solids (23.2%), with Treatment 2, the control group with whey foliar spray, following closely behind.**Salamaet al., (2013), Djomdi *et al.*, (2020), Shahein *et al.*, (2023), Yu *et al.*, (2022), and Manasa *et al.*, (2020)** have conducted studies that delve into the nutritional composition of tigernut, as well as their impact on milk production and the growing demand for plant-based beverages. These studies shed light on the various health benefits associated with tigernut. In a separate study conducted by **Abdulraheem *et al.*, (2023)**, the quality of yogurt made from tiger nut milk was examined, revealing noteworthy disparities when compared to yogurt made from powdered milk.**O'Donoghue and colleagues (2023)** investigated the utilization of residual materials from high-protein dairy processing, specifically whey protein, for the creation of enhanced products such as sucrose or sodium substitutes in food items, as well as more valuable derivatives like lactic acid or prebiotic carbohydrates.

Table 7: Effect of soil enhancers and foliar application of whey on chemical composition of tiger nut milk samples during two seasons of 2019 and 2020

Treatments	Moisture (%)	Carbohydrates (%)	Ash (%)	Fat (%)	Protein (%)	pH	TTA (%)	TS (%)
T1	77.0	10.7	0.7	5.2	6.4	6.2	0.15	23.0
T2	76.8	10.8	0.72	5.1	6.8	6.3	0.14	23.2
T3	77.1	10.6	0.71	5.0	6.7	6.2	0.15	22.9
T4	76.8	10.8	0.72	5.1	6.8	6.2	0.15	23.2
T5	77.0	10.7	0.72	5.1	6.6	6.3	0.13	23.0
T6	76.9	10.4	0.72	5.2	6.8	6.3	0.14	23.1
T7	77.2	10.6	0.7	5.2	6.5	6.1	0.16	22.8
T8	76.8	10.8	0.72	5.2	6.9	6.1	0.16	23.2
LSD								

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T1: control - 100% of the recommended NPK dose, T2: foliar spray of whey + 50% NPK, T3: compost + 50% NPK, T4: compost + foliar spray of whey + 50% NPK, T5: agricultural sulfur + 50% NPK, T6: agricultural sulfur + foliar spray of whey + 50% NPK, T7: potassium humate + 50% NPK, and T8: potassium humate + foliar spray of whey + 50% NPK.

In Table 8, the chemical composition of three types of rayeb was analyzed: Rayeb milk made from cow milk(A), rayeb milk made from tigernut milk(B), and Rayeb milk made from 50% cow milk + 50% tiger nut milk (C).The study examined the properties and the impact of storage duration on these samples at different time points: fresh, after 7 days, and after 14 days.The findings indicated differences in fat, protein, ash, acidity, and pH values among the various samples. Tiger nut was found to have a beneficial effect on the properties of the rayeb of cow milk, leading to an increase in both protein and fat content. The presence of tiger nut in the chemical analysis positively influenced the properties of cow milk rayeb, resulting in a higher protein and fat content. Distinct variations in fat, protein, and ash composition were observed among the different milk samples. Changes in pH values of milk rayeb were noted during the storage period, with slight fluctuations in acidity levels for the different treatments. Treatment B, which utilized tiger nut rayeb, demonstrated superior performance in terms of acidity (0.69%, 0.92%, and 1.4%), TS% (25.1%, 25.15%, and 25.17%), and protein% (5.48%, 5.5%, and 5.58%) across three storage periods. Treatment C, which consisted of 50% tiger nut milk rayeb, was closely behind in performance. Treatment B also showed the highest values for fat% (5.48%, 5.5%, and 5.58%) when compared to treatment A, which used cow milk rayeb, over the same three storage periods.In their research, **Onyimba *et al.*, (2022)**evaluated the viability of using tigernut milk and

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tigernutcow composite milk as substitutes for cow milk in yoghurt production. The study encompassed various aspects such as fermentation, sensory analysis, and physicochemical evaluation of the resulting yogurt. The findings revealed that both tiger nut milk and cow milk's composites possess the ability to yield yoghurt with desirable sensory and physicochemical properties. This discovery highlights the potential of tigernutbased products as a cost-effective and vegetarian-friendly alternative for yogurt production, catering to the needs of vegetarian individuals and those with allergenic concerns.

Table 8: The chemical composition of rayebsamples

Properties	Treatments	Storage period (day)		
		Fresh	7	14
Acidity%	(A)	0.66	0.86	1.00
	(B)	0.69	0.92	1.4
	(C)	0.68	0.88	1.3
pH values	(A)	4.76	4.6	4.49
	(B)	4.58	4.4	4.1
	(C)	4.7	4.4	4.2
TS%	(A)	.8٣1	٧٥.٣1	١.8٣1
	(B)	25.1	25.15	25.17
	(C)	18	18.14	18.15
Fat%	(A)	3.68	2.52	2.65
	(B)	5.48	5.5	5.58
	(C)	3.3	3.28	3.3
Protein%	(A)	3.28	3.27	3.25
	(B)	6.5	6.7	6.6
	(C)	4.9	4.85	4.86
Ash%	(A)	0.63	0.64	0.65
	(B)	1.3	1.38	1.4
	(C)	0.93	1.00	1.2

A: rayeb milk is produced using cow's milk, B: Rayeb milk is produced using tiger nut milk, and rayeb milk is produced using a 50:50 mixture of cow's milk and tiger nut milk.

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Discussion

In **Table 1** outlines the physical and chemical characteristics of the soil, compost, and sweet whey. The soil is categorized as clayey, with distinct proportions of sand, silt, and clay. In **Table 2**, data regarding the composition, pH level, electrical conductivity, and organic matter content of the compost is presented. Lastly, **Table 3** displays the chemical composition, acidity levels, and pH values of sweet whey.

In **Table 4**, the characteristics, growth parameters, fixed oil and carbohydrate content, and soil NPK levels were examined in this study. The results revealed that combining compost with whey or agricultural sulfur with whey significantly enhanced the growth and production of tiger nut plants. These findings are consistent with previous studies conducted by **Timon *et al.*, (2019**) on tiger nut, **Ibrahim and Fadni (2013)** on tomatoes**.**The use of sulfur fertilizer plays a crucial role in improving crop productivity by reducing soil pH, thereby increasing the availability of nutrients, particularly nitrogen and micronutrients. Additionally, the application of potassium humate (KHM) was found to regulate plant growth and supply potassium to plants. Moreover, KHM exhibited a high water-holding capacity, improved soil structure, chelated various micronutrients, making them more suitable for plants, and enhanced the efficiency of chemical fertilizers by gradually releasing them.The results in Table 4 are consistent with previous studies highlighting the beneficial effects of agricultural fertilizer and sulfur on plant growth and productivity. The results support the hypothesis that soil enhancers and foliar applications play a crucial role in enhancing the growth performance of (*Cyperus esculentus* L.) plants. The significant improvements observed in plant height and tubers' dry weight under specific treatments underscore the importance of incorporating organic

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amendments and targeted nutrient applications for optimal plant development.The findings presented in Table 4 align with prior research emphasizing the positive impact of agricultural fertilizer and sulfur on the growth and productivity of plants. The data confirms the theory that soil enhancers and foliar applications are essential in improving the growth of *Cyperus esculentus* plants. The notable enhancements in plant height and tubers' dry weight seen in certain treatments highlight the significance of integrating compost and foliar spray whey for maximizing plant growth.**Ahmed *et al.*, (2023),** on chickpea plant growth, nutrient absorption, and soil organic carbon (OC) and soil nitrogen (N) concentration Mineral fertilizer improves plant biomass organic fertilizers improve soil quality and nutrient levels.Organic fertilizers have the potential to promote sustainable agriculture. Animal manure enriches soil with OC, N, and P, while animal maneuvering increases plant biomass, revealing the impact of fertilizers on soil nutrients and chickpea growth.In their study on potato plants, **Shabana *et al.*, (2023)** discovered that the application of potassium humate and silicate, along with compost, can effectively alleviate the salinity of irrigation water and enhance soil nutrient levels. This beneficial combination ultimately leads to improved plant growth, increased leaf number, and enhanced tuber yield when compared to the control group. Additionally, the quality and overall yield of the tubers were also positively influenced by these treatments.The agreement on tiger nut plants was also reached by the researchers**Adekiya *et al.*, (2020)** and **Tan *et al.*,(2024)**.

Table 5, these findings are consistent with existing literature emphasizing the positive influence of compost and potassium humate on plant oil production and nutrient content.The agreement on tiger nut plants was also reached by the researchers **Adekiya *et al.*, (2020)** and **Tan *et***

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***al.*,(2024).Shabana *et al.*, (2023)** on potato plants found that using potassium humate and silicate, combined with compost, can mitigate irrigation water salinity and soil nutrient levels, improving plant growth, tuber quality, and yield. The utilization of organic materials and fertilizers has been demonstrated to have a favorable impact on soil health, crop growth, and productivity. By enhancing soil quality and nutrient levels, organic fertilizers have the potential to promote sustainable agriculture. For instance, animal manure can increase soil organic carbon, nitrogen, and phosphorus content while also enhancing plant biomass. This observation is supported by studies such as those conducted by **Adekiya *et al.*, (2020)**,**Tan *et al.*,(2024)**, and **Ahmed *et al.*,(2023)**. The application of organic fertilizers can thus contribute to the improvement of soil fertility and the growth of crops.

AbdelKader and El-Ghadban's(2017) study found that combining rice straw compost with nitrobienbiofertilizer significantly improved tiger nut plant growth and yield. Higher nitrogen fertilizer rates were most effective in increasing tuber yield and oil quality. This is due to the action of potassium humate, which is a vital nutrient for plant growth and plays a key role in carbohydrate metabolism and nutrient transport within the plant. Adequate potassium levels in the soil can enhance carbohydrate synthesis and accumulation in tiger nut, leading to a higher carbohydrate content. Additionally, potassium availability can influence the uptake and utilization of nitrogen, phosphorus, and other nutrients, thereby affecting their levels in tiger nut plants. In addition to foliar spraying, whey contains various nutrients and organic compounds that can be absorbed by plant foliage. Whey can provide additional nitrogen, phosphorus, potassium, and other micronutrients to tiger nut

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plants. This can enhance nutrient levels in the plant tissues, contributing to overall plant growth and development.

Table 6 results indicate that the application of soil enhancers and whey protein has a significant impact on soil NPK levels. Compost and agricultural sulfur led to increased nitrogen and phosphorus levels in the soil, while potassium humate enhanced potassium availability. Foliar application of whey protein resulted in improved nutrient uptake by the plants, leading to higher soil NPK levels compared to the control treatment. The observed effects of soil enhancers and whey proteins on soil NPK levels are consistent with previous research on soil fertility management and plant nutrition. Compost and agriculture contribute organic matter and essential nutrients to the soil, promoting microbial activity and nutrient cycling. Potassium humate enhances cation exchange capacity and nutrient retention, while whey protein stimulates root development and nutrient uptake.

In **Table 7**, the present study aims to analyze the effects of soil enhancers and whey application on the chemical properties of tigernut milk in dairy products from 2018 to 2019. The findings demonstrate considerable advancements in the moisture content, carbohydrates, ash, fat percentage, protein content, pH levels, and total solids of tigernut milk. These results suggest that these variables have a beneficial impact on milk production, as whey protein foliar application has a positive influence on plant growth and development by enhancing nutrient absorption, promoting enzymatic activity, and stimulating metabolism. Research indicates that whey protein supplementation increases crop yield, improves stress tolerance, and enhances nutrient absorption. Additionally, whey protein has been found to improve the antioxidant capacity of plants, reducing oxidative stress and promoting overall plant health. As

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mentioned, **Demir and Ozrenk (2009)**, **Grosu *et al.*, (2012)** studied the effect of whey on the germination capacity of seeds, **Manasa *et al.*, (2020)** and **Elwaziri *et al.*, (2023)** studied sweet potatoes to enhance productivity and tuber quality. The observed effects of potassium humate and whey protein on tiger nut milk composition align with previous research on organic fertilizers and plant growth promoters. Potassium humate improves soil structure and nutrient uptake, indirectly influencing milk composition, while whey protein directly enhances plant metabolism and nutrient assimilation, leading to changes in milk composition.

Conclusion

Overall, the results of the paper indicated that the utilization of tiger nut in conjunction with soil enhancers and the application of whey protein through foliar spraying resulted in the promotion of plant growth and the enhancement of chemical constituents in tiger nut plants. These findings highlight the importance of agricultural techniques in influencing the cultivation of tiger nut crops, the milk quality it produces, and the potential for its transformation into various dairy products, such as tiger nut rayeb.

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