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EFFECT OF VINASSE WASTE AS POTASSIUM ORGANIC SOURCE ON GROWTH AND YIELD OF MAIZE

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ABSTRACT

Sandy soils face significant challenges due to their low moisture retention and nutrient content. This study aimed to improve soil fertility, nutrient uptake, and maize yield (variety: Pioneer P4444) by applying six mixtures of Dry Vinasse Waste (DVW) as organic fertilizer and different NPK fertilizer rates, alongside a control, with three replicates. Maize was grown in pots for one season, and soil properties, plant parameters, and productivity were evaluated. Results indicated that soil salinity was increased across all treatments, while pH decreased with Vinasse application. Organic matter content improved in all Vinasse treatments, except when a full NP dose was combined with mineral and organic K sources. Soil K content significantly increased with Vinasse application, while N and P concentrations showed inconsistent trends. Plant N content was highest with a full NP dose and K from both mineral and organic sources, comparable to full mineral NPK treatment. However, plant P and K content responses were inconsistent. Ca and Mg levels were highest under a recommended NP dose combined with K fully from organic or mixed sources. Seed yield and chlorophyll content increased significantly in all treatments compared to the control. The greatest plant height and elongation rate were observed with a recommended NP dose

and full K from mineral or mixed sources. These findings highlight the potential of Vinasse, in combination with optimized NP rates, to enhance soil fertility and maize production in sandy soils.

Keywords: Dry Vinasse Waste, potassium fertilization, Maize.

INTRODUCTION

Maize (*Zea mays* L.) is a vital cereal crop globally, serving as a staple food, animal feed, and industrial raw material due to its high yield and adaptability (**Kaushal *et al.,* 2023**). It provides food and oil for humans and fodder for animals (**Afzal *et al.,* 2009; Song *et al.,* 2010; Bukhsh *et al.,* 2011; Asif *et al.,* 2020**). In Egypt, maize is one of the most important cereal crops, ranking third after rice and wheat. However, due to the depletion of natural resources, rapid population growth, and climate change, there is a growing gap between maize production and demand, posing a challenge to food security and agricultural sustainability (**Seada *et al.,* 2016**).

Finding out an alternative way to obtain potassium from organic wastes is crucial due to the limited resources and high cost of mineral fertilizers. Organic waste like Vinasse is a promising alternative. Potassium fertilizer is of great importance to plants where it protects plants against water stress and enhances grain quality. It is considered the dominant cation in plants. It was found that potassium deficiency leads to the accumulation of dissolved nitrogen compounds, while the nitrogen content of plants decreases. It was also found that lack of potassium leads to a slow photosynthesis and increased respiration. Potassium also has a substantial effect in regulating the metabolism of carbon in plants and plays an important role in the transport of sugars and proteins in plants, and thus it affects the storage of carbohydrates in the storage organs **(Shah *et al*, 2024)**.

Vinasse is a byproduct of the ethanol manufacturing process **(Carrilho *et al.,* 2024)**. The chemical composition of Vinasse depends on the raw materials used for ethanol production **(Espana *et al.,* 2011)**.

Vinasse can be added to crops through fertigation using drip irrigation systems **(Hoarau *et al.*, 2018)**. Vinasse is a viable alternative to inorganic fertilizers due to its richness in potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), in addition to phosphorous (P), nitrogen (N), and organic matter **(Madejon *et al.*, 2001)**. Therefore, Vinasse can partially replace potassium and sulfur fertilizers besides N fertilization **(Luz, 2005; Osman, 2010; Silva *et al.*, 2015)**. The addition of Vinasse increased the organic matter and nitrogen content in the soil **(Moran-Salazar *et al.*, 2016)**.

The applied Vinasse at the proper time enhanced the absorbed and reserved nutrients, increased organic matter in soil, enhanced biochemical properties, improved physicochemical characteristics and soil quality, increased phenolic chemicals, acids, and insoluble fractions, and improved crop productivity **(Gómez and Rodriguez, 2000; Arafat and Yassen, 2002; Armengol *et al.*, 2003; Parnaudeau *et al.*, 2008; Vadivel *et al.*, 2014)**. Potassium is involved in a multitude of internal processes **(Pettigrew, 2008; Bukhsh *et al.*, 2012)**. Potassium influences multiple systems within the plant to improve tolerance to stresses, both abiotic and biotic **(Wang *et al.*, 2013)**. Maize consumed 38% of K (5.2 kg K/ha/day) during peak flowering period **(White, 2000; Rehman *et al.*, 2008)**. **Hussain *et al.* (2007)** indicated that the high doses of both potassium and phosphorus fertilizers significantly increase the weight per ear, grains per ear and the 1000-grain weight. The sole effect of potassium found non-significant for grain yield but in interaction with phosphorus levels and maize varieties, potassium produced a better yield. **Bender *et al.* (2013)** showed that the pattern of K uptake was a sigmoidal curve with the majority of uptake happening before anthesis and the highest accumulation rate for K in maize is around 2.4 kg K_2O/day/acre. Most of the K buildup was before blooming stage **(Pettigrew, 2008; Ciampitti *et al.*, 2013; Bell *et al.*, 2021)**. The applied rates of Vinasse for soil fertilization regulated based on potassium content **(CETESB, 2015)**.

To enhance physicochemical and biological properties of light-textured soils should be applied mixture of organic and mineral fertilizers therefore improving soil quality and fertility as well as increasing crop yield and its quality because of higher nutrients uptake and build up in the yield. Vinasse has great attention due to its contribution in improving physicochemical properties of soil **(Aquino *et al.*, 2015)**. It was noticed that the residue increased potassium content and it varied with the soil types due to the applied of Vinasse **(Elgharbawy, 2021)**.

Maximizing fertilizers efficiency and soil health programs should be more attention to address the challenges of fertilizers and food shortages. The manufacturing of fertilizers by recycling wastes with the least environmental impacts is necessity urgent **(Silva *et al.*, 2017)**. Mineral fertilizers are a major challenge because of its high cost and are one of the polluted sources in the agricultural environment. Organic fertilizers and recycling organic wastes are used to avoid these problems. Low cost and friendly organic wastes such as Vinasse and molasses can used as a source of organic fertilizers. Applied the optimum mixture of chemical fertilizer and organic fertilizer, or biofertilizers might be a one of the promising methods of nutrient management. The aim of this study was to test and evaluate the contribution of Vinasse as an organic fertilizer to supply plant with K and improve soil properties for reducing chemical fertilizers demand, partially.

MATERIALS AND METHODS

This experiment conducted to quantify the response of maize (variety: pioneer P4444) (*Zea mays* L.) to the application of K supplied from organic waste (Vinasse)) as a source of K and mineral fertilizers (NPK) to evaluate the contribution of organic waste (Vinasse) for improving maize growth, seed production and reducing applied mineral fertilizers.

Experimental site

A pot experiment was conducted at Al-Kifah village, Badr city, El Beheira governorate, Egypt (30° 38′ 44″ N, 30° 31′ 32″ E).

Soil analyses

Soil physical analysis

Soil samples were collected from the experimental site at 0–30 cm depth to determine the main physical and chemical characteristics of the soil. The soil physical parameters such as particle size distribution determined by hydrometer method as described by **(Gee and Bauder, 1986)** then soil texture class defined as described by **FAO (1970)**. Soil bulk density determined in undisturbed soil samples using the core method **(Black and Hartge, 1986)**. Saturated hydraulic conductivity measured in the laboratory according to **Klute and Dirksen (1986)** and soil moisture content on volume basis at suctions of 33 and 1500 kPa determined by using pressure plate apparatus. The main physical parameters of the soil samples are presented in **Table (1)**.

Table (1): Main physical properties of soil samples

Texture class	Particle size (%)			Available water* (mm)	Ks ($m\ s^{-1}$)	Bulk density ($Mg\ m^{-3}$)
	Clay	Silt	Sand			
Sandy Loam	10	30	60	33.15	5.17×10^{-6}	1.55

* Calculated as average moisture contents at −10 and −33 kPa minus moisture contents at −15000 kPa, saturated hydraulic conductivity (Ks)

Soil chemical analysis

Chemical properties of soil samples such as pH, electrical conductivity (EC), soluble cations and anions content (in soil water extract 1:1), were measured according to **Jackson (1958)**. Available K extracted by 1N of ammonium acetate solution measured by flame photometer **(Jackson, 1958)**. Available P extracted with 0.5N of $NaHCO_3$ solution and measured by Spectrophotometer **(Olsen and Sommers, 1982)**. Available N in the soil samples was determined using

Kjeldahl method according to **Peach and Tracey (1956)**. Soil organic matter (OM) determined by modified Walkley-Black method as described by **Nelson and Sommers (1983)**. Main chemical characteristics of the soil samples were presented in **Table (2)**.

Table (2): Main chemical properties of soil samples

pH (1:2.5)	EC (dS m^{-1})	Available N (ppm)	Available P (ppm)	Available K (ppm)	OM (%)		
8.3	0.4	120	14	105	0.30		
Soluble cations (meq/l)				Soluble anions (meq/l)			
Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}
1.68	0.51	1.02	0.87	0	1.34	1.41	1.26

Fertilizer sources and application rates

According to the recommendations of the Egyptian Ministry of Agriculture **(MALR, 2007)**, the need for Maize (pioneer P4444) during its life period is 120 units of nitrogen, 30 units of phosphorus and 25 units of potassium. As for sources of mineral fertilizers, some well-known fertilizers in Egypt, such as urea (46% nitrogen), were used as a source of mineral nitrogen. MAP fertilizer (61% P_2O_5) as a source of mineral phosphorus, and potassium sulfate fertilizer (50% K_2O) as a source of mineral potassium. Dried Vinasse waste (DVW) - that is a by-product from fermentation and distillation of molasses liquid from sugar and yeast industry – was used, as a source of K fertilization, where it was taken from the factory of Angel Yeast Co., Ltd., China located at Beni Sweif Governorate, Egypt which contains (0.7% nitrogen, 0.46% phosphorus, and 12% potassium). From these mineral fertilizers and organic waste, the quantities required for each of the seven fertilizer treatments were calculated and then added during the season. The addition was applied through fertigation.

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Fertilizer treatments

The experiment included seven treatments: (T1) control, (T2) recommended mineral NPK, (T3) recommended NP with K from Vinasse, (T4) recommended NP with K from mineral K and Vinasse equally, (T5) half NP with full K from Vinasse, (T6) half NP with K from mineral K and Vinasse equally, and (T7) full K from Vinasse only.

Preparation and the experimental design

A composite soil samples were collected from the surface layer (0–30 cm depth), air-dried, and sieved through a 2-mm sieve. Twenty-one cylindrical pots with a diameter of 28 cm and height of 25 cm were thoroughly washed and cleaned. The bottoms of those pots are punched to make holes to drain out excess water. To avoid the heating effect, the pots were buried in the soil surface, while the soil surface inside the pots was almost like the soil surface of the open field. Suitable 21 holes made in the soil with the same dimensions of the pots. The pots were buried inside holes in a Randomized Complete Block Design (RCBD) with three replicates. Each pot was filled with 25 kg of prepared soil and labeled with the corresponding treatment.

Sowing and watering of the experiment

The sowing date was on 8 August 2022 then irrigated without any fertilizer additions, to ensure the best seed growth. The irrigation is done every 3 days at the rate of adding 100 cm^3 water per pot. After the first 15 days, the fertilization started the different fertilizer treatments with the water of irrigation in five doses between every 15 days.

Data collection

The soil chemical properties such pH, EC, OM, Available NPK, and soluble cations and anions were measured after maize harvest as the same methods mentioned above **(Sun *et al.*, 2022)**. The plant height

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after 45 and 75 days of planting and elongation rate also were determined as an average of four measurements after 15, 30, 45 and 60 days according to **Equation 1**. Chlorophyll content index was measured by (SPAD-502, Minolta, Japan). Also, both fresh and dry weight (at 110°C) of 100 kernels were determined beside moisture content was calculated as a percentage of seeds fresh weight. After the final harvest stage, leaves samples were taken to analysis of the NPK content: the N content determined by wet digestion according to the Ginsberg method and Kjeldahl distillation, phosphorus was determined calorimetrically by molybdenum blue method and K was determined by using a flame photometer **(Peterburgskii, 1986)**.

$$ER = \frac{\frac{H_{15}}{15} + \frac{H_{30} - H_{15}}{15} + \frac{H_{45} - H_{30}}{15} + \frac{H_{60} - H_{45}}{15}}{4}$$

Where ER is elongation rate in mm/day; H_{15}, H_{30}, H_{45} and H_{60}, is plant height in mm after 15, 30, 45 and 60 days, respectively.

Statistical analysis

To test for statistical differences, an analysis of variance (ANOVA) was conducted using General Linear Models (PROC GLM), followed by Fisher's protected least significant difference (LSD) test for mean comparisons using the Statistical Analysis System software ver. 13.1 **(SAS, 2013)**. A significance level of 5% (α = 0.05) was selected to minimize the risk of a Type II error during the analysis of growth parameters.

RESULTS AND DISCUSSION

Soil pH, Total Dissolved Solids (TDS), Organic Matter (OM), and chlorophyll content:

The results illustrated in Figure 1 (A) reveal a significant increase in total dissolved salts (TDS) across all treatments compared to the control, likely due to the accumulation of dissolved salts in the soil solution. This aligns with the findings of **Seddik *et al.* (2016)** and

Bueno *et al.* (2009), who attributed TDS increases to elevated sodium concentrations. The highest TDS values were recorded in T6 (137.36 ppm) and T7 (135.38 ppm), significantly surpassing T3, T4, and T5, possibly due to higher organic matter content enhancing nutrient retention. Regarding soil reaction Figure 1 (B), pH levels ranged from 7.64 (T7) to 8.37 (T2), with T1 and T2 exhibiting the highest values (~8.3), while T3, T4, T5, and T7 showed a notable decline, likely due to Vinasse application. The large standard deviation in T1 was attributed to a single high-pH replicate (8.9).

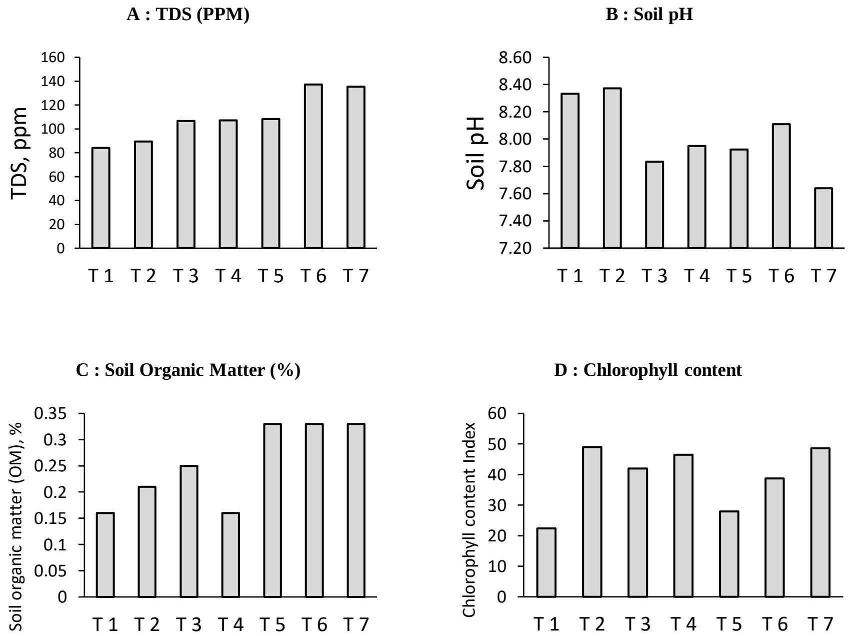

Figure (1): Mean values of A: soil pH, B: total dissolved solids (TDS), C: organic matter (OM), and D: chlorophyll content of maize after treatments with T1: control, T2: NPK, T3: NP with K from Vinasse, T4: NP with K from mineral K and Vinasse equally, T5: half NP with full K from Vinasse, T6: half NP with K from mineral K and Vinasse equally, and T7: full K from Vinasse only.

These findings align with **Osman *et al.* (2016)**, who observed a pH reduction with increased Vinasse and K-mineral fertilizers, explained by **El-Leboudi *et al.* (1988)** as a result of organic acid and hydrogen ion production. As for soil organic matter Figure 1 (C), T5, T6, and T7 exhibited the highest levels (0.33%), significantly surpassing other treatments, while T3 (0.25%) differed notably from T2 (0.21%). T1 and T4 recorded the lowest values (0.16%). The results suggest that a full NP dose combined with mineral and organic K sources may reduce OM content, whereas Vinasse application effectively enhances it, consistent with **Yassen *et al.* (2002)**, **Osman *et al.* (2016)**, and **Seddik *et al.* (2016)**.

Lastly, chlorophyll content index Figure 1 (D) was highest in T2 (48.97), T7 (48.58), and T4 (46.43), with no significant differences among them, while T1 recorded the lowest value (22.33). Treatments without a full NP dose generally had lower chlorophyll levels, except for T7. These results align with **Fridgen and Varco (2004)**, who highlighted nitrogen's role in chlorophyll synthesis, whereas potassium's effect was inconsistent. **Zhao *et al.* (2001)** further explained that early-stage potassium deficiency severely limits photosynthesis and chlorophyll production in plants.

Soil available (N – P – K – Ca)

The results in Figure 2 (A) illustrate that T2 exhibited the highest soil available N content (45.2 ppm), followed by T5 (35.6 ppm) and T7 (31.1 ppm), whereas the control (T1) recorded the lowest value (12 ppm). Treatments T3, T4, and T6 showed relatively similar N levels (28.1–28.6 ppm). The significant increase in soil N content with vinasse application is consistent with **Osman *et al.* (2016)**, **Seddik *et al.* (2016)**, and **Yassen *et al.* (2002)**, who reported that vinasse enhances soil N availability. The lower N content in T1, which received no additional nitrogen, may be attributed to the lack of external inputs and potential losses due to plant uptake and leaching. Meanwhile, T2, receiving full NPK mineral fertilization, exhibited the highest available N content, likely due to the immediate availability of mineral nitrogen. The gradual decline in N across other treatments aligns with the slow-release nature of vinasse-derived nitrogen, as previously described by **Osman *et al.* (2016)** and supported by **Delin and Engstrom (2010)**.

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Regarding phosphorus Figure 2 (B), T6 and T7 recorded the highest available P levels (1.29 ppm), likely due to the organic matter in vinasse improving P solubility. Treatments T3 and T4 showed slightly lower but comparable values, while T2 and T5 had moderate levels. T1, which received no P fertilizer, recorded the lowest P availability. Interestingly, despite previous findings by **Yassen *et al.* (2002)**, **Osman *et al.* (2016)**, and **Seddik *et al.* (2016)** suggesting that mineral P fertilizers increase soil P levels, the results here indicate that factors such as P fixation, plant uptake, and organic matter interactions may influence P availability. As shown in Figure 2 (C), all vinasse-treated soils had significantly higher K levels, in line with findings from **Yassen *et al.* (2002)**, **Bueno *et al.* (2009)**, **Osman *et al.* (2016)**, and **Seddik *et al.* (2016)**.

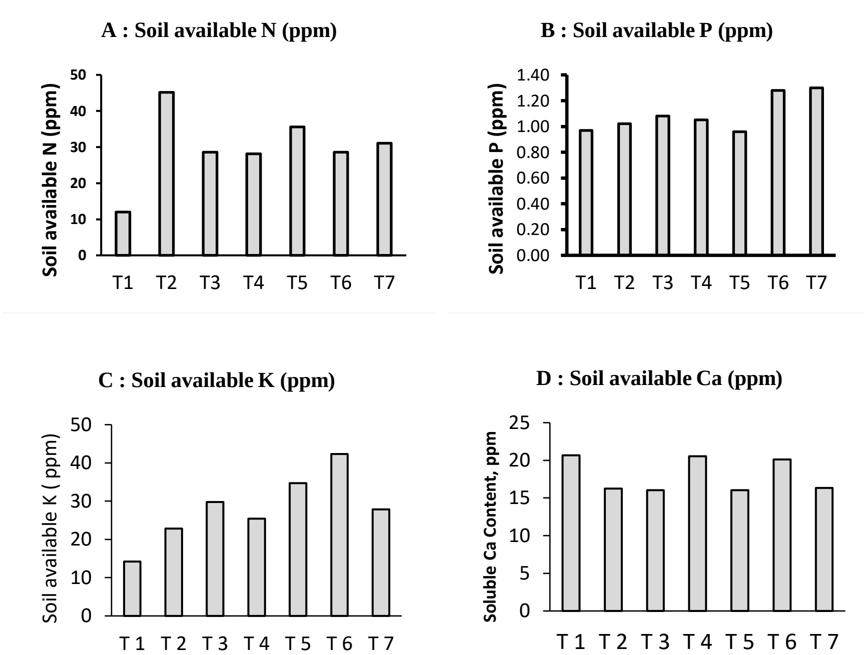

Figure (2): Mean values of A: soil available N, B: soil available P, C: soil available K, and D: soil available Ca after the application of T1: control, T2: NPK, T3: NP with K from Vinasse, T4: NP with K from mineral K and Vinasse equally, T5: half NP with full K from Vinasse, T6: half NP with K from mineral K and Vinasse equally, and T7: full K from Vinasse only.

The highest K content was observed in T6 (42.34 ppm), followed by T5 (34.74 ppm), though the latter, expected to provide a full K dose via half NP and vinasse K, recorded slightly lower K content, possibly due to differences in K availability from mineral sources. Lastly, Figure 2 (D) shows that T1, T4, and T6 exhibited slightly increased soluble Ca content compared to other treatments, with T4 at an intermediate level. However, no significant differences were observed among the other treatments, which aligns with **Pinto *et al.* (2022)**, who reported that vinasse application in soybean, maize, and pasture did not significantly alter soil Ca levels.

Soil (Mg – Na – Cl) content

The results in **Figure 3 (A)** show that T5 and T7 in recorded the highest soil soluble Mg content (14.42 and 14.56 ppm, respectively). Except for T6, all treatments showed a significant increase compared to T2, while T1, despite not receiving any mineral fertilizers, achieved a relatively high Mg level (12.28 ppm), making it second only to T5 and T7. The observed increase in Mg content, except for T6 and T1, aligns with the findings of **Pinto *et al.* (2022)** and **Tejada *et al.* (2009)**, which indicate that vinasse application enhances soil Mg levels. However, the unexpected increase in T1 remains unclear, possibly due to maize's ability to extract Ca at four times the rate of Mg (**Caires and Da Fonseca, 2000**) or the antagonistic effect of K on Ca and Mg uptake (**Yang *et al.* (2024)**).

The variation among treatments suggests that multiple factors may be influencing Mg dynamics, but further investigation is needed. Regarding Na+, **Figure 3 (B)** reveals that T7 exhibited the highest significant increase, while no significant differences were detected among the other treatments except for T1 and T3, which showed intermediate levels. Although **Tejada *et al.* (2009)** reported that vinasse application generally raises soil Na content, only T7 displayed a notable increase. This could be linked to the plant's increased K uptake in T7, which likely reduced Na absorption, as reflected in the decreased soil K content in the same treatment. The elevated Na content in T1 may be due to pre-existing high Na levels in the soil, as indicated by the high standard deviation, where one replicate showed 20.98 ppm while the other two recorded around 10.40 ppm. Notably, excessive Na levels can inhibit K activity in the soil solution, thereby reducing K availability (**Wang *et al.* (2013)**). As depicted in **Figure 3 (C)**, T1 recorded the highest soil soluble Cl- content (56.38 ppm), followed by T3 (49.42 ppm), while T2 and T4 showed no significant differences. The lowest Cl- levels were found in T6, followed by T5 and T7. This variation in soil Cl- content may be linked to K dynamics, as increased K levels influence Cl- and Na uptake through voltage-gated K+ transporters at the plasma membrane. Sufficient K plays a crucial role in osmotic regulation, solute accumulation, and maintaining plant cell turgor under osmotic stress (**Wang *et al.* 2013**).

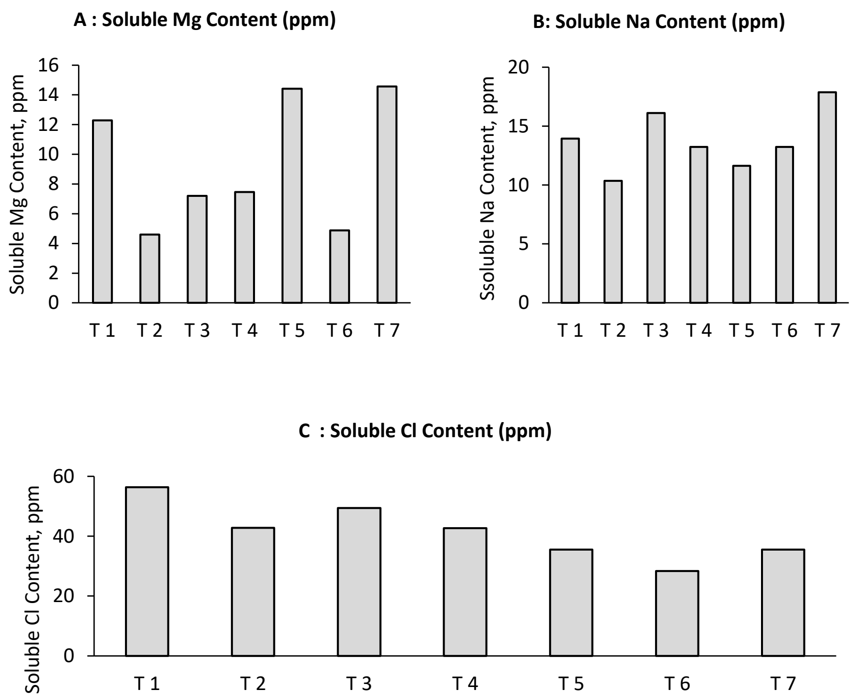

Figure (3): A: Mg, B: Na, and C: Cl contents of soil planted with maize after treatments with T1: control, T2: NPK, T3: NP with K from Vinasse, T4: NP with K from mineral K and Vinasse equally, T5: half NP with full K from Vinasse, T6: half NP with K from mineral K and Vinasse equally, and T7: full K from Vinasse only.

Soluble sulfur (SO_4^{2-}) and bicarbonate (HCO_3^-)

As shown in **Figure 4**, treatments T1, T4, and T6 recorded the highest levels of soluble sulfate (SO_4^{2-}) in soil (~48 ppm), with no significant differences among them, while the lowest SO_4^{2-} content was observed in T2, T3, T5, and T7 (~38 ppm). Sulfate availability in soil is primarily influenced by sulfur fertilization, organic matter decomposition, and microbial activity, which explains the variations among treatments (**Havlin *et al.* (2014)**). Regarding bicarbonate (HCO_3^-) levels, T7 exhibited the highest concentration (183.15 ppm), significantly differing from all other treatments, followed by T5, T2, and T4, whereas T1, T3, and T6 recorded the lowest HCO_3^- content (~134 ppm), showing no significant differences among them. Bicarbonate accumulation is typically linked to alkaline soil conditions, irrigation water quality, and carbonate mineral dissolution, which can impact nutrient availability, particularly phosphorus solubility (**Marschner, 2012**). The observed variations indicate that different fertilization regimes and soil amendments influence sulfur and bicarbonate dynamics, highlighting the importance of balanced nutrient management to maintain optimal soil chemistry and enhance plant growth.

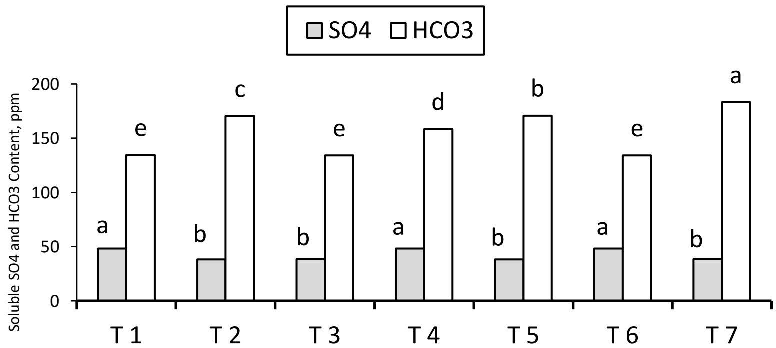

Figure (4): Effect of different treatments (T1: control, T2: NPK, T3: NP with K from Vinasse, T4: NP with K from mineral K and Vinasse equally, :T5: half NP with full

K from Vinasse, T6: half NP with K from mineral K and Vinasse equally, and T7: full K from Vinasse only on soluble sulfate and bicarbonate contents in planting soil.

Effect of applied mineral fertilizers and Vinasse on maize nutrient content, growth, and yield

N, P and K content in maize plant

As shown in **Figure 5**, treatments T2 and T4 (about 3.8 % N content) demonstrated a higher significant plant N content than all other treatments (with notation b). It is presumed for both T3 and T4 to achieve a higher plant N content due to the application of full mineral NP dose but only T4 exhibited this increase may be the application of K from two sources, one of them in a mineral form contributed in this increase which concords with the results of **Seddik *et al.* (2016)** who explained that the decrease in plant N, P and K total content in the case of applying Vinasse without mineral source of K may be due to the fact that the increase of Na content in Vinasse than K which gives an antagonistic relationship between Na and K where higher soil absorption could have reduced plant K absorption which also aligns with **Mansoori *et al.* (2014)**.

According to the findings of **Arafat and Yassen (2002)**, Vinasse has led to an increase in the level of N, P and K, but this does not mean that the increase is steady with increasing rates and this, with the discussion beforehand, could explain the inconsistent responses in the finding of the current study. In the case of K, T5 showed the highest response (0.79%) followed by T6 (0.73%) while T1 exhibited the lowest level of K, T2 and T7 demonstrated the same response. The increase in T5 and T6 could be related to the application of Vinasse, however the inconsistent response could also be related to the antagonistic relationship between Na content in Vinasse and K or because of the synergetic influence of N and K on plant growth where in the case of insufficient optimum growth rates of one of them, the utilization of other would be impaired where higher K supply enhances translocation of nitrogenous compounds from roots and straw toward the grains **(Hébert *et al.*, 2001)**.

Plant uptake of N by roots could also be affected by K and vice versa where there is evidence that nitrate nutrition helps in cations uptake including K **(Kirkby, 1968; Mengel *et al.*, 1976; Ouyang *et al.*, 1998; Szczerba *et al.*, 2008)**. Concerning plant content of P, the highest significant one was achieved by T6 (0.92%) followed by T1, T2 and T3 which exhibited an intermediate level between T6 and T4 where the latter with T5 and T7 exhibited the lowest levels of P content.

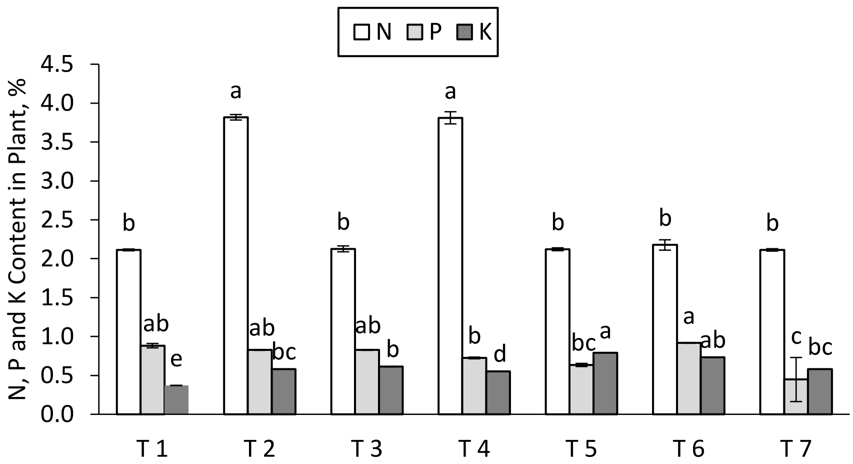

Figure (5): Effect of different treatments (T1: control, T2: NPK, T3: NP with K from Vinasse, T4: NP with K from mineral K and Vinasse equally, :T5: half NP with full K from Vinasse, T6: half NP with K from mineral K and Vinasse equally, and T7: full K from Vinasse only) on N, P, and K content in maize plant for maize.

Despite T6 received half dose of NP from mineral fertilizers and a full dose of K from mineral source and Vinasse, it achieved the highest level of plant P content. It is supposed that the application of Vinasse raises the plant P which aligns with the findings of **Arafat and Yassen (2002)**. However the other treatments like T5 and T7 demonstrated a lower level, this could be explained because T7 did not received any dose from mineral source of P and for T5 its K source was only organic which may has a relationship with P utilization, despite T1 was not treated it showed the second highest level, its ought to be that T2, T3 and T4 to have a higher level of plant P content due to receiving a recommended dose of mineral P but the explanation of irregular response is still inconclusive. It is known that the effect of the so-called "luxury consumption" of K on both N and P could lead to depression in yield if accompanying N and P are not sufficient **(Bajwa and Rehman, 1996; Tisdale *et al.*, 1990)**. It is also known that luxury consumption of K can be reduced by splitting K application at no more than half the N rates on soils kept low in available K **(Burton and Jackson, 1962)**.

Ca and Mg content in maize plant

As depicted in **Figure 6**, T1 (0.64%) showed the highest Ca content in plant while there were variations in the values of other treatments but there was no significant difference between them, it is noticeable from error bars that T1 was of the highest standard deviation where there were three replicates the lowest one was of 0.090% while the others was of 0.910 and 0.920%.

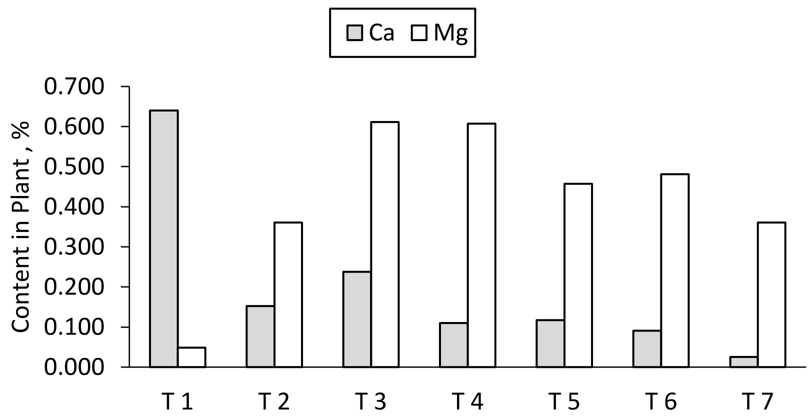

Figure (6): Effect of different treatments (T1: control, T2: NPK, T3: NP with K from Vinasse, T4: NP with K from mineral K and Vinasse equally, :T5: half NP with full K from Vinasse, T6: half NP with K from mineral K and Vinasse equally, and T7: full K from Vinasse only) on Ca and Mg content in maize plant for maize.

The results suggest that all treatments which included K application exhibited a lower level in Ca content, this may be explained according to **Yang *et al.* (2024)** where that increase could be related to the effect of K on Ca and Mg uptake where K has a fairly consistent effect on lowering tissue concentration of Ca and Mg. Also for Mg content in plant, it is presumed that the ability of maize to extract Ca is four times more than Mg **(Caires and Da Fonseca, 2000)**, however T3 and T4 demonstrated the highest response of Mg content in maize plant (0.61%) followed by T6 (0.48%) and T5 (0.46%) while the lowest was T1 (0.05%). At the end, the explanation for such results is still inconclusive.

Plant height and elongation rate

As shown in **Figure 7**, plant height and elongation rate varied significantly among treatments, with T4 achieving the highest plant height (268.67 cm) and elongation rate (35.8 mm/day), followed by T6 (234.67 cm, 31.3 mm/day) and T1 (195 cm, 26 mm/day). The superior performance of T4 can be attributed to the balanced supply of both mineral and organic potassium (**K**), which plays a crucial role in osmotic regulation, enzyme activation, and photosynthesis efficiency, all of which enhance cell expansion and shoot elongation (**Marschner, 2012**). Potassium also improves water uptake and turgor pressure, sustaining growth even under varying soil conditions (**Pettigrew, 2008**). The moderate growth in T2, T3, and T5, which received either mineral or organic **K** alone, suggests that a combined application provides superior results, as seen in previous studies where integrating organic and inorganic **K** sources enhanced nutrient-use efficiency and plant productivity (**Zahoor *et al.* (2017); da Silva *et al.* (2020**).

The lower performance in T1 (control) indicates that the absence of additional K fertilization limited the plant's ability to sustain high elongation rates despite potential residual K in the soil. These findings align with research showing that potassium application significantly improves plant architecture, biomass accumulation, and elongation rates (**Pettigrew, 2008; Sofyan *et al.* (2019)**). Therefore, incorporating both mineral and organic fertilizers as **K** sources is essential for optimal plant growth, as organic amendments provide a slow-release nutrient supply, complementing the immediate availability from mineral fertilizers, ensuring sustained growth throughout the crop cycle.

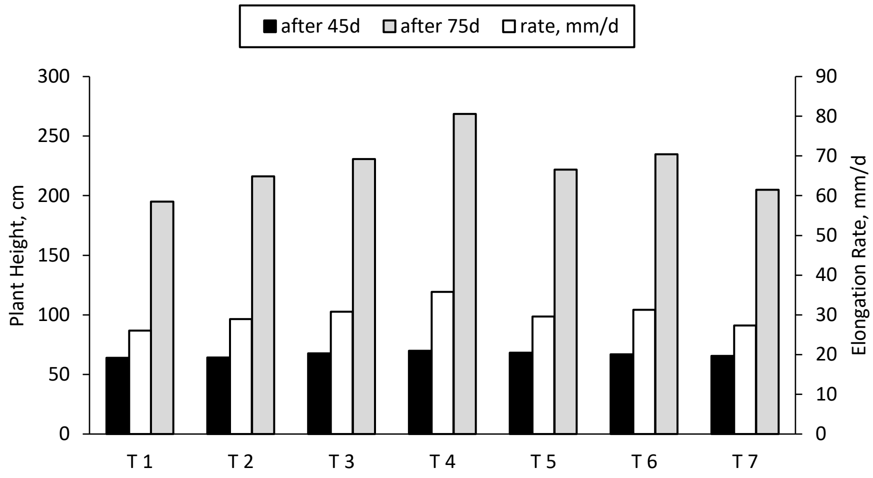

Figure (7): Effect of different treatments (T1: control, T2: NPK, T3: NP with K from Vinasse, T4: NP with K from mineral K and Vinasse equally, :T5: half NP with full K from Vinasse, T6: half NP with K from mineral K and Vinasse equally, and T7: full K from Vinasse only) on plant height after 45 and 75 days of planting and elongation rate for maize.

Seed yield

As depicted in **Figure 8**, the highest seed yield was achieved by T2 (9.84 ardab/feddan), followed by T3, T6 and T4 (9.38, 9.2 and 9.08 ardab/feddan, respectively) while the lowest level was of T1 (7.18 ardab/feddan). The results suggest that there is a need for a full NP mineral dose. Also, in the case of half dose of mineral NP at least, there is a need for a full dose of K from both mineral and organic source to achieve a high seed yield. According to the findings of **Osman *et al.* (2016)**, there was an increase in the availability of N, P and K by applying K-mineral fertilizer with diluted Vinasse compared to Vinasse only and the same trends was exhibited for the yield also.

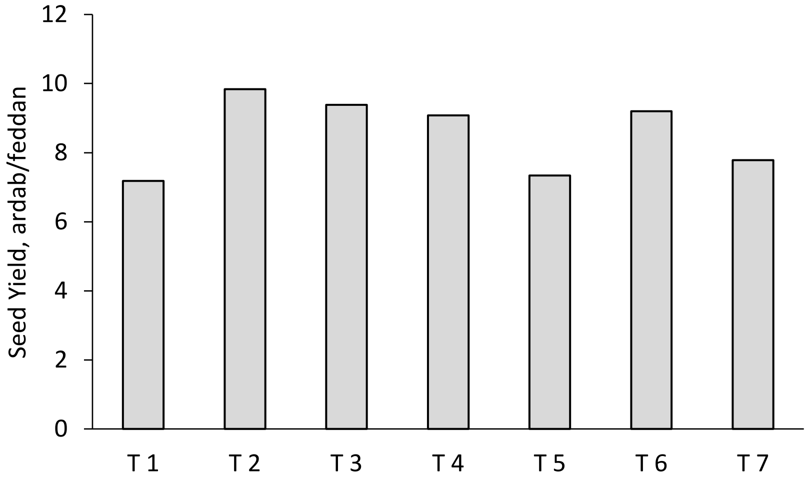

Figure (8): Effect of different treatments (T1: control, T2: NPK, T3: NP with K from Vinasse, T4: NP with K from mineral K and Vinasse equally, :T5: half NP with full K from Vinasse, T6: half NP with K from mineral K and Vinasse equally, and T7: full K from Vinasse only) on seed yield for maize.

Fresh and dry weight of 100 kernels

As depicted in **Figure 9**, T7 demonstrated the highest fresh weight (F.W.) of 100 kernels (22.95 g) followed by T3, T1 and T7 ((21.87, 21.47 and 21.18 g, respectively) while the lowest one was of T6. Concerning the dry weight (D.W.) of 100 kernels, T1 and T2 achieved the same level, and it was the highest (19.51 g) followed by T2 (18.18 g) while the lowest was of T6 (15.21 g). Also, the highest moisture content was of T5 (10.43% F.W.) while the lowest was of T7 (8.21% F.W.). It is presumed that the application of Vinasse contributes in the increase of the weight of 100 kernels of wheat compared with control treatment (T1) as reported by **Yassen *et al.* (2002)** but the data exhibited inconsistency to such conclusion, however what reported by **Mahmoud *et al.* (2019)** may explain these variations where the application of Vinasse only compared to mineral fertilizers contributed significantly in the decrease of fresh and dry yield of both spinach and barely plants in the first and second cut while application of Vinasse with fertilizers caused a significant increase in fresh and dry weight.

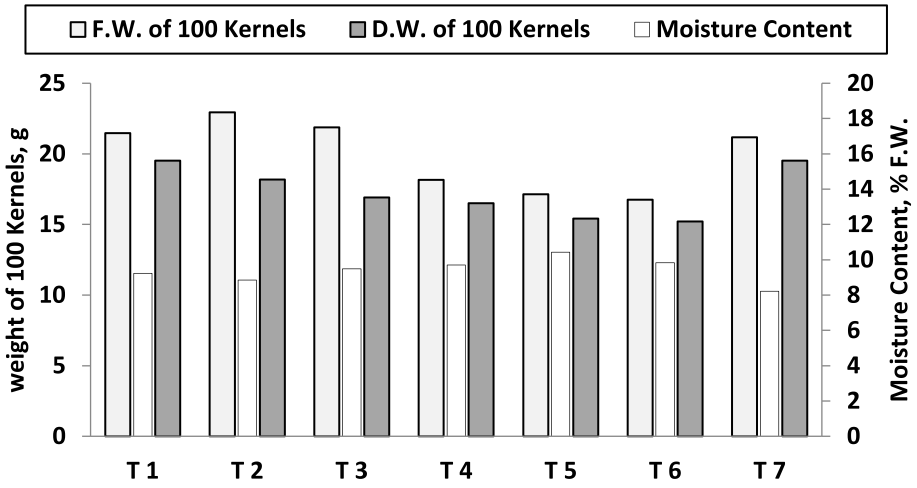

Figure (9): Effect of different treatments (T1: control, T2: NPK, T3: NP with K from Vinasse, T4: NP with K from mineral K and Vinasse equally, :T5: half NP with full K from Vinasse, T6: half NP with K from mineral K and Vinasse equally, and T7: full K from Vinasse only) on fresh and dry weight of 100 kernels and seed moisture content for maize.

CONCLUSION

The application of appropriate organic wastes as fertilizers, combined with lower doses of mineral fertilizers, is essential to minimize the environmental impact of excessive mineral fertilizer use while reducing costs and improving yield quality. The findings of this study revealed an increase in soil organic matter and **K** levels, though soil **N** and **P** contents, along with other soil nutrients, exhibited inconsistent responses. Notably, the highest plant height and elongation rate were achieved with a recommended **NP** dose and a full **K** dose derived from both mineral and organic sources, which also resulted in the highest **N** content in plants, showing no significant difference from the full mineral **NPK** treatment. However, **P** and **K** content in plants displayed an inconsistent response. The highest levels of **Ca** and **Mg** in plant tissues were recorded in treatments receiving the recommended

NP dose and a full **K** dose, either entirely from organic sources or from a combination of mineral and organic sources. Additionally, all treatments significantly increased seed yield and chlorophyll content index compared to the control. Further research is needed to explore the promising effects of integrating **Vinasse** with specific **NPK** dosages to enhance maize production in sandy soils, as well as to assess its long-term impact across different growing seasons.

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الملخص العربي

تأثير مخلفات الفيناس كمصدر عضوي للبوتاسيوم على نمو وإنتاجية الذرة

أ.د/ السيد عبد الرؤوف ، أ.د/ عماد فاروق ابو كيله ، أ/ محمد علي ، و د/ هبه سالم

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تواجه التربة الرملية تحديات كبيرة بسبب قدرتها المحدودة على الاحتفاظ بالرطوبة ونقص محتواها من العناصر الغذائية. استهدفت هذه الدراسة تحسين خصوبة التربة وزيادة امتصاص العناصر الغذائية ورفع إنتاجية محصول الذرة صنف (Pioneer P4444) باستخدام ستة خلطات من مخلفات الفيناس الجافة (Vinasse) كسماد عضوي إلى جانب معدلات مختلفة من سماد NPK، جنبًا إلى جنب مع معاملة كنترول وثلاث مكررات لكل معاملة. تمت زراعة الذرة في أصص خلال موسم واحد، وتم تقييم خصائص التربة والمعايير النباتية والإنتاجية. أظهرت النتائج ارتفاع ملوحة التربة في جميع المعاملات، بينما انخفض الأس الهيدروجيني (pH) عند إضافة الفيناس. كما تحسن محتوى المادة العضوية في جميع معاملات الفيناس، باستثناء المعاملة التي تضمنت جرعة كاملة من النيتروجين والفوسفور مع مصادر معدنية وعضوية للبوتاسيوم. ولوحظت زيادة كبيرة في محتوى التربة من البوتاسيوم، في حين أظهرت تركيزات النيتروجين والفوسفور اتجاهات متباينة. أما بالنسبة للنبات، فكان أعلى محتوى نيتروجين في المعاملة التي تضمنت جرعة كاملة من NP مع K المستمد من مصادر معدنية وعضوية، وكانت هذه الاستجابة مكافئة لمعاملة التسميد المعدني الكامل بـ NPK، بينما لم تتبع استجابات الفوسفور والبوتاسيوم نمطًا واضحًا. كما سجل أعلى تركيز للكالسيوم والمغنيسيوم عند تطبيق الجرعة الموصى بها من NP مع الـــ K من مصادر عضوية أو مختلطة. وعلى مستوى الإنتاجية، ارتفع إنتاج البذور ومحتوى الكلوروفيل بشكل ملحوظ في جميع المعاملات مقارنةً بالكنترول. بلغ أعلى معدل نمو واستطالة للنباتات عند استخدام الجرعة الموصى بها من NP مع الـــ K من كل من المصادر المعدنية أو المختلطة. تؤكد هذه النتائج أن استخدام الـــ Vinasse، عند دمجه مع معدلات محسّنة من النيتروجين والفوسفور يمكن أن يكون نهجًا فعالًا لتحسين خصوبة التربة الرملية وزيادة إنتاجية الذرة.

الكلمات الدالة : مخلف الفيناس المجفف، التسميد البوتاسى، الذرة.