ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

ISSN (print):2218-0230, **ISSN (online):** 2412-3986, **DOI: http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

Integrated interaction between Nano, conventional potassium fertilizer and Zeolite on kinetic K-release from calcareous soil

Sarkawt Taha Ahmed[1], Haifa Sadik Yaseen Akrawi[1]
[1] Department of soil & water, College Agriculture Engineering science, University of Salahaddin, Erbil, Kurdistan region, Iraq.

ABSTRACT:

Calcareous soil suffers from deficiency in available of potassium due to its high contain of $CaCO_3$. So, it is important to increase the availability of potassium. Potassium release rate constant is an important indicator for the ability of soil to supply potassium. A field experiments in sulaimani governorate was conducted to evaluate the effect of soil amendment with natural zeolite at rate of (0 and 2 t ha^{-1}), three levels of Nano potassium fertilizer (0, 5 and 10 kg ha^{-1}), three levels of conventional fertilizer K_2SO_4 (0, 100 and 200 kg ha^{-1} K_2O) and their interactions on kinetic of potassium release within 55 days. Results revealed that there was significant effect of application Zeolite on cumulative K-release that increased by 13.27 % relative to the control treatment. the application Nano, conventional K fertilizer and their interaction with zeolite at level of 5 kg ha^{-1} Nano, 200 kg ha^{-1} K_2O and 10 kg ha^{-1} Nano + 100 kg ha^{-1} K_2O amendment with 2 t ha^{-1} zeolites increased the cumulative K-release from 33.55 to 35.35 and 42.45 mg kg^{-1} respectively as a compared with control (24.00 mg kg^{-1}). Kinetic data were best described by parabolic diffusion, power function and Elovich models. The cumulative K-release rate constants for parabolic models indicated that all types of fertilizers applied to soil gave high and significant increase in rate of K release compared to the control treatment.

KEY WORDS: Nano K fertilizer, kinetic models, K-release, Calcareous soil, Zeolite.
DOI: http://dx.doi.org/10.21271/ZJPAS.35.1.6
ZJPAS (2023) , 35(1);56-67 .

1.INTRODUCTION :

Potassium has been forgotten in fertilizer recommendation for long time in Iraq due to widespread belief that Iraqi soils are in general well supplied with native K. The results of recent laboratory investigations and field experiments have shown this assumption is not always correct (Al-Zubaidi, 2003); (Akrawi, 2010). The rate of potassium release is low and does not meet the need of many crops especially with intensive cultivation and with crops of higher need of potassium.

In addition, organic and inorganic soil amendments can influence the potassium dynamics in many aspects such as, distribution, release and fixation in the soil (Najafi-Ghiri, 2014); (Akrawi, 2018). Potassium release is an important process for K supplying ability of the soil in long-term cropping systems and many substances can enhance the soil to encourage the release of K such as the Zeolite.

Zeolite are crystalline aluminosilicate minerals that not only consider as environmental friendly that improve soil physical and chemical properties but also enhance nutrient uptake and fertilizer use efficiency (Nakhli et al., 2017). The high of cation exchange capacity CEC, water holding capacity in the free channels, and adsorption capacity are the three main properties of zeolite (Mumpton, 1999), natural zeolite has higher affinity for NH_4^+ and K^+ relative to Na^+, or Ca^{2+} and Mg^{2+} because of the dimension of interior channels (0.40 – 0.72 mm diameter) and the negative charge location and density in the structure (Ming and Boettinger, 2001).

In various soil types' especially calcareous soils, the application of zeolite resulted in a remarkable increase of the concentration of soluble and exchangeable K (Najafi-Ghiri, 2014). Recently Haniati et al.,(2019) observed that increase 11% and 22% in potassium availability with increasing zeolite rates zero t ha^{-1} to 2 and 5 t

---

* **Corresponding Author:**
Sarkawt Taha Ahmed
E-mail: sarkawt.Ahmed@student.su.edu.krd
Article History:
Received: 03/07/2022
Accepted: 06/09/2022
Published: 20/02 /2023

ha^{-1} respectively. Also Thabit (2021) tested the effect of zeolite application to distribution and releases rate of potassium, results showed that zeolite application increased the soluble, exchangeable, and cumulative K^+ release.

Kinetics of chemical reaction in soil is very essential, various kinetic equation has been used to estimate the rates of soil chemical process (Sparks, 2003). A series of laboratory and field experiments were carried out to investigate the kinetics of K^+ release in Iraqi soils reported by Al-Obaidi and Al-Zubaidi (2000); Mam Rasul (2008); Akrawi (2010) found that the parabolic diffusion models considered as the best mathematical equation to describe the kinetic of K^+ release from different Iraqi soils.

Al-Obaidi and Al-Zubaidi (2000) showed that the K^+ release proceeds two stages, the first one involved a rapid release of exchangeable K^+, while the second one involved the release of K^+ with very slow-release rate. According to the classification proposed by Goulding and Loveland (1986), the capacity of K^+ release was classified as low and high, while the rate of K^+ release from mica was classified as very low, the very low rate of K^+ release may explain the response of most Iraqi soils to K-fertilizer in spite of high content of K^+. Akrawi (2010) recorded that the parabolic diffusion equation was the best equation to describe the reaction rate of cumulative K^+ release from sixteen soils sample in Kurdistan region, since it has the highest value of determination coefficient $R^2 = 0.98$ and lowest value of standard error of estimation SE = 0.02.

The slope and intersection parameters for each equations represent the interpretation and release of potassium from soils.

The objectives of this study were (i) To Investigate the effect of Zeolite on K^+ release from soil fertilized by different type and levels of potassium. (ii) To find the best kinetic models that describes K^+ release from studied soils.

2. Material and Methods:

2.1 Land preparation:

The experiments were conducted at Kanypanka Agricultural Research, Sulaimani governotare from Iraqi Kurdistan region with GPS reading latitude $35^o\ 22^-\ 25.2''$ N longitude $45^o\ 43^-\ 25''$ E at 544 m above the mean sea level. The surface soil sample (0-0.3m) was air dried and ground to pass through a 2 mm sieve for the laboratory analysis. The analysis of some chemical and physical properties of the soil and Zeolite were shown in (Table 1). Pipette method used to determine particle size distribution, soil and zeolite pH and EC were measured in 1:2 suspension by using pH meter HANA model (HI 83141) and EC meter model (HI 2314) respectively (Rowell, 1996). Organic matter (OM) was determined using Walkley and Black method as mentioned by (Motsara and Roy, 2008). Total calcium carbonate was determined by titration method. Cation exchange capacity (CEC) for soil and Zeolite was determined by saturating the sample with 1 *M* NaOAc at pH 8.2 and washed with ethanol (exchangeable Na was replaced with 1 *M* NH_4OAc) then Na concentration was analyzed by flame photometer (Motsara and Roy, 2008).

2.2 Zeolite:

The zeolite used in the present experiment was the natural Iranian zeolite which consist about 80% of (clinoptilolite) and the remainder 20% (bantonite)(Rezaei and Naeini, 2009). Some chemical analysis pH, EC and CEC are shown in (Table 1).

2.3 Type of K fertilizer

Two type of potassium fertilizer used in the present experiment:

- Nano chelated potassium 27% K
- Conventional potassium fertilizer K_2SO_4 content 50 % K_2O

Evaluation the effect of (2 levels of zeolite,3 levels Nano potassium fertilizer and 3 levels of K_2O by using chemical fertilizer (K_2SO_4) and their interaction on potassium release in calcareous soil.

2.4 Experimental design:

The field experiment was laid out in a factorial design based on randomized complete block design (RCBD) with three replications. The net plot area of experiment was 4 m^2 (2*2) which involved 4 rows. Distance between the blocks and between the plots was 2 and 1 m respectively. Sweet-corn (Hybrid F1 Roi Soleil) seed were planted in the plots in 3 rows at 75 cm distance between the rows and 20 cm distance between the plant to plant in rows and specialized one row for Ca-resin 20 cm distance between the Ca-resin.

2.5 Factors and treatments:

The factorial experiment included three factors: -

- First factor includes three levels of Nano potassium fertilizer in the form of Nano chelated potassium content 27% K (0, 5, 10 kg ha^{-1} Nano fertilizer) symbolized as (N_0, N_1, N_2) respectively.
- Second factor include three levels of Potassium sulphate K_2SO_4 content (50% K_2O) conventional fertilizer (0,100, 200 kg ha^{-1} K_2O) symbolized as (K_0, K_1, K_2) respectively
- Third factor two levels of zeolite (0 and 2 t ha^{-1} zeolite) symbolized as Z_0, Z_1 respectively.

Zeolite and fertilizers with different rate added to the soil at the same date of seed sowing.

Treatments	Level of zeolite t ha^{-1} with Nano and/or conventional K fertilizer and their interaction kg ha^{-1}
$Z_0N_0K_0$	zero zeolite + zero Nano fertilizer + zero c conventional fertilizer (Control)
$Z_0N_0K_1$	zero zeolite +zero Nano fertilizer + 100 kg $ha^{-1}K_2O$ (conventional fertilizer)
Z_0N_0K2	zero zeolite +zero Nano fertilizer +200 kg $ha^{-1}K_2O$ (conventional fertilizer)
$Z_0N_1K_0$	zero zeolite+5 kg ha^{-1} Nano fertilizer + zero chemical fertilizer
Z0N1K_1	zero zeolite, + 5kg ha^{-1} Nano fertilizer, +100 kg $ha^{-1}K_2O$ (conventional fertilizer)
$Z_0N_1K_2$	zero zeolite+ 5 kg ha^{-1} Nano fertilizer, +200 kg $ha^{-1}K_2O$ (conventional fertilizer)
$Z_0N_2K_0$	zero zeolite+10kg ha^{-1} Nano fertilizer, zero K_2O (conventional fertilizer
$Z_0N_2K_1$	zero zeolite, + 10kg ha^{-1} Nano fertilizer + 100 k $ha^{-1}K_2O$ (conventional fertilizer)
$Z_0N_2K_2$	zero zeolite +10kg ha^{-1} Nano fertilizer +200kg.$ha^{-1}K_2O$ (conventional fertilizer)
$Z_1N_0K_0$	2ton ha^{-1} zeolite + zero Nano fertilizer + zero conventional fertilizer
$Z_1N_0K_1$	2ton ha^{-1} zeolite +zero Nano fertilizer +100 kg $ha^{-1}K_2O$ (conventional fertilizer)
$Z_1N_0K_2$	2ton ha^{-1} zeolite + zero Nano fertilizer+ 200 kg $ha^{-1}K_2O$ (conventional fertilizer)
$Z_1N_1K_0$	2ton ha^{-1} zeolite +5kg.ha^{-1} Nano fertilizer + zero conventional fertilizer
$Z_1N_1K_1$	2ton ha^{-1} zeolite + 5kg ha^{-1} Nano fertilizer +100 k. $ha^{-1}K_2O$ (conventional fertilizer)
$Z_1N_1K_2$	2ton ha^{-1} zeolite + 5kg ha^{-1} Nano fertilizer + 200 kg $ha^{-1}K_2O$ (conventional fertilizer)
$Z_1N_2K_0$	2ton ha^{-1} zeolite +10kg ha^{-1} Nano fertilizer + zero conventional fertilizer
$Z_1N_2K_1$	2ton ha^{-1} zeolite + 10kg ha^{-1} Nano fertilizer+100 kg $ha^{-1}K_2O$ (conventional fertilizer)
$Z_1N_2K_2$	2ton ha^{-1} zeolite +10kg ha^{-1} Nano fertilizer + 200 kg $ha^{-1}K_2O$ (conventional fertilizer)

2.6 Ca saturated Resin preparation:

Purolite MB400 resin (mix bed) was Ca-saturated with 1 M $CaCl_2$ and let to stand for 24 hours for equilibrium, to remove any native exchangeable K. Then the Ca saturated resin used in the K release reaction (Havlin et al., 1985).

2.7 Resin experiment:

Purolite MB400 resin was used in the study of potassium release in surface soil. Ten g of Ca- saturated resin were packed into 150µm opening polyester bag, and tied with braided polyester thread to form tight sphere with a diameter of 2.5 cm and a surface area of 19.64 cm^2 (Sherif and Hedia, 2001). Six Resin bags were placed in the soil at the depth 0.15 m later were collected gradually in each plot in the field within 55 days at interval (10, 17, 24,31,44,55 days). After each interval resin was leached with 50 ml of 1M HCl to release the exchangeable K by resin, and the extract was analyzed for K concentration directly by using flame photo meter. For total accumulative quantity recovered from the resin is referred to as the resin adsorption quantity (RAQ).

2.8 Kinetics of K Release from Ca-Resin:

The following kinetic models were used to describe cumulative K^+ release from Ca-Resin with time (Sparks, 1999):

Zero order model $(K_0 – K_t) = a – k_0t$ ……………1

First order model $\ln (K_0 – Kt) = a – k_1t$ …………..2

Parabolic diffusion model $K_t = a + k_p t^{1/2}$ ………………….3

Power function model $\text{Ln } K_t = \ln a + b \ln t$……………...4

Elovich model $K_t = a + (1/\beta) \ln t$ ……………….5

Where *K_0 – is the maximum released K (mg kg^{-1}); K_t – is the cumulative released K (mg kg^{-1}) at time days and a – intercept; vital term of these equations is the rate constant k_0, k_1, k_p, b and 1/β index of K^+ release rates.

The rate constants were calculated from the slope of the linear regression equation which was fitted Least square regression analysis was used to determine which mathematical model best described K release from soils. The least square regression of measured vs. predicted values yielded the coefficients of determination (R^2). Standard errors of the estimate were calculated by

$$SE = [\sum(Kt-Kt^*)^2/n-2]^{0.5}$$

where Kt and Kt^* represent the measured and predicted released potassium, respectively, and n is the number of data points assessed.

2.9 Statistical analysis:

SPSS 26 program used for analyzing data. The differences between treatment means were compared by least significant difference (LSD) test.

3 Results

3.1 Cumulative K release

The data in Figure (1 a and b) illustrated that, the cumulative potassium release from Ca-resin-extracted in all treatments amended with Zeolite levels increased when compared with unamended. Zeolite substantially increased cumulative released-K by 4.12 units which equivalent to 13.27% from (31.033 mg kg^{-1}) in without zeolite treatment to (35.152 mg kg^{-1}) in with zeolite treatment.

The addition of Nano potassium fertilizer had a significant impact on cumulative K- release comparing with control treatment (Table 2). The highest increase in cumulative K-release 30.15 $mgkg^{-1}$ was recorded in 5 kg ha^{-1} Nano K fertilizer treatment, while the lowest value 24.00 mg kg^{-1} was recorded in control treatment. Moreover, the increased cumulative K release from Ca-resin induced by Nano K-fertilizer was greater at second level (5 kg ha^{-1} Nano K fertilizer) than third level (10 kg ha^{-1} Nano K fertilizer) treatment (Table 2). Regarding amending soil with Nano K fertilizer + Zeolite increased the cumulative K release significantly from 24 mg kg^{-1} in control treatment to 33.55 mg kg^{-1} in 2 t ha^{-1} Zeolite + 5 kg ha^{-1} Nano K fertilizer treatment. It means caused 13.85% increase comparing with the without zeolite amendment (Table 2).

The presented data in (Table 3) showed that, cumulative K^+ release increased with increasing the levels of conventional potassium fertilizers when compared with the control treatment. The highest increase K^+ release 33.35 mg kg^{-1} was recorded at the third level of conventional K fertilizer (200 kg ha^{-1} K_2O) while the lowest value was recorded from control treatment. There's no significance difference between the application of 100 and 200 kg ha^{-1} K_2O on cumulative K^+ release. Similar increase was also recorded when amending soil with conventional K fertilizer + Zeolite increased the cumulative K^+ release significantly from 24 mg kg^{-1} in control treatment to 35.35 mg kg^{-1} in 2 t ha^{-1} Zeolite + 200 kg ha^{-1} K_2O treatment which was increased by 47.29% relative to the control (Table 3).

Amending soil with interaction Nano, conventional K fertilizer without Zeolite increased the cumulative K release significantly from 24.00 mg kg^{-1} in control treatment to 36.65 mg kg^{-1} in 0 t Zeolite + 10 kg ha^{-1} Nano K fertilizer + 100 kg ha^{-1} K_2O in combination treatment (Table 4). The amount of cumulative K^+ release significantly increases with increased level of interaction Nano, conventional K fertilizer with zeolite amendment. The higher increase 42.45, 42.05 mg kg^{-1} cumulative K release throws the interaction was recorded in 2 t ha^{-1} Zeolite + 1o kg ha^{-1} Nano K fertilizer + 100 kg ha^{-1} K_2O **(**Z_1N_2K1) and 2 t Zeolite + 10 kg ha^{-1} Nano K fertilizer + 200 kg ha^{-1} K_2O $Z_1N_2K_2$ treatment respectively, while the lowest value 24 mg kg^{-1} was recorded in untreated control treatment.

3.2 Cumulative Potassium release curve

Potassium release curve for all interaction treatments of the study soil during 55 days shown in Figure (2 a and b). Plots of cumulative K^+ release consist two parts in all treatments, the cumulative K^+ release curve showed an initial rapid release followed by slow release of K^+ from study soils.

3.3 kinetic models describe potassium release:

Various mathematical kinetic models were used to describe the rate of cumulative K-release in Ca-Resin from soil treated with Nano, conventional potassium fertilizer and their interaction with and without Zeolite amendment. And mainly the best fitted models have been selected in accordance to highest value of coefficient of determination (R^2) and the lowest value of standard error of estimate (SE) (Sparks, 2003). Table (5) shows that all models describe successfully the reaction rate of cumulative K-release in the studied soils. The mean values of (R^2) were 0.94, 0.82, 0.98, 0.96, and 0.98 for Zero order, First order, Parabolic diffusion, Power function, and Elovich equation respectively. According to these data, Parabolic diffusion, Elovich, and power function are suitable equations to describe rate of cumulative K^+ release for this study. In this investigation the parabolic equation was preferred that has R^2 (98) SE (1.868) because this equation depends on Fack's law and which K-releases from higher to lower concentration region and also constant parameter can be used to evaluated the K availability according to Kinetic approach (Goulding and Loveland, 1986) movement of molecules from higher concentration to lower concentration region.

The parabolic diffusion model was used for describe cumulative K release from the studied soils illustrated in Figure (3). Two parameter slope and intercept for linear parabolic diffusion equation represent diffusion rate constant and initial potassium concentration (a). The data in Table (6) indicated that, the K-release rate constant in all treatment amended with 2ton ha^{-1} zeolite increased when compared with unamended soil except in $Z_1N_2K_0$ decrease to (4.3406) mg kg^{-1} as compared with $Z_0N_2K_0$ increase to (4.547) mg kg^{-1}. In comparison to the control the value of constant ''k_p'' increased from 3.957 to 6.014 (mg $kg^{-1})^{1/2}$ in the 2 t ha^{-1} Zeolite treatment, which was increased by 52% relative to the control. With application Nano K fertilizer only, highest value 5.456 (mg $kg^{-1})^{1/2}$ of K-release rate constant was recorded in 5 kg ha^{-1} Nano K fertilizer, and lowest value 3.957 (mg $kg^{-1})^{1/2}$ was recorded in control treatment. However combined Nano K fertilizer + 2 t ha^{-1} Zeolite led to increase K-release rate constant from 3.957 to 6.211 (mg kg^{-1}) in control and 5 kg Nano K fertilizer + 2 t ha^{-1} Zeolite ($Z_1N_2K_0$) treatment. Also, application of K-conventional fertilizer only led to increased K-release rate constant from 3.957 to 6.044 (mg $kg^{-1})^{1/2}$ in control and 100 kg ha^{-1} K_2O treatment respectively (Table 6). However, the K-release rate constant values increase from 3.957 (mg $kg^{-1})^{1/2}$ in control to 7.470 (mg $kg^{-1})^{1/2}$ in 10 kg ha^{-1} Nano + 100 kg ha^{-1} K_2O with application of interaction Nano + conventional K fertilizer without Zeolite amendment (Table 6). While the lower value was recorded in control treatment and the highest value 8.941(mg $kg^{-1})^{1/2}$ was recorded in 2 t ha^{-1} Zeolite+ 10 kg ha^{-1}Nano K^+ 100 kg ha^{-1} K_2O.

4 Discussion

4.1 Cumulative Potassium release

The data in Figure (1) show that, the cumulative potassium release was higher in treatments amendment with Zeolite, comparing with control (without zeolite). This may be due to the zeolite minerals have high specific surface area and high cation exchange capacity CEC (131 $Cmol_c$ kg^{-1}) and its high affinity for K^+ (Table 1). This may relate to the characteristics of Zeolite to be a carrier of K^+ and a medium for exchangeable that will improve accumulative K release in soils. A similar conclusion of observation was recorded by (Haniati et al., 2019) observed that the amendment soil with 2 t ha^{-1} increase 11% in potassium availability relative to control treatment. Thabit (2021) observed that the cumulative K release significantly increased from 252 mg kg^{-1} in control to 308.90, 387.30 mg kg^{-1} in soil treated with 1 and 2% (wt/wt) zeolite respectively.

In comparison to the control treatment the value of cumulative K-release increased significantly with application of Nano potassium fertilizer (Table 2). This may be due to high surface area of Nano K fertilizer causes by small dimensions of Nano-fertilizer particles ranges (1 to 100 nm), led to increase sorption capacity, other benefits of Nano fertilizer which controlled release kinetics to target sites; this proves them as a smart delivery system (Raliya et al., 2017). These results might be happened due to the fact that Nano-fertilizer can be adsorbed on clay colloid, and then slowly released into the soil solution which prevents the loss of nutrient. Similar result was observed by Jyothi and Hebsur (2017), who revealed that Nano-fertilizer use in soil improved obtainable P and K under Nano-fertilizer treatment compared with the control treatment. Qureshi et al. (2018) they show Nano fertilizer control the release of nutrients in soil.

The application of (Nano-K fertilizer + Zeolite) increased the cumulative K release significantly (Table 2). This may be due to two reasons first high charge surface of zeolite and smaller size of Nano fertilizer while be encourage K release (Lin and Xing, 2008). Zhou and Huang (2007) mention that ion exchangeability of the zeolites with selected nutrient cations, enhance the slow, steady and increase of potassium release from Nano-Zeolite fertilizer. Khan et al. (2021) also reported that the nutrient release increased with amendment soil with Nano-Zeolite compost fertilizer.

In comparison to the control the cumulative K-release increased with increasing level of conventional K fertilizer (Table 3), this may be due to application of potassium fertilizer would lead to increased potassium content in soil and would increase cumulative K release. The results agree with Tian et al. (2017) observed that increase level of K_2SO_4 fertilizer from 0 to 1.37 g plant led to increase K release from 76.00 to 116.82 (mg kg^{-1}) respectively. Increase the cumulative K release significantly when amending soil with (conventional K fertilizer + Zeolite) (Table 3). This may be due to the high surface area and high CEC of Zeolite, it had prominent role in increasing the fertilizer use efficiency. Ahmed et al. (2010) recorded that the addition zeolite significantly affected on potassium fertilizer use efficiency (KUE).

Amending soil with interaction treatment Nano, conventional K fertilizer without Zeolite increased the cumulative K release significantly (Table 4). The amount of cumulative K release significantly increases with increased level of interaction treatment Nano, conventional K fertilizer with zeolite amendment. This may be due to interaction terms between the main properties of zeolite, Nano and conventional K-fertilizer that enhance even more the K release.

4.2 Cumulative Potassium release curve

The potassium release during 55 days are shown in Figure (1 a & b) can be divided in to two stages rapid and slow cumulative K-release. That's mean there are more than one mechanism controlled the release of K^+ from the treated soils. This could be due to the first curvilinear part indicated to rapid K^+ release from the planer and edge sites, while the second linear part represented the K^+ release from internal site (Al-Obaidi and Al-Zubaidi 2000). Relatively higher surface coverage of soil with K and the easy replacement of the adsorbed K^+ may be attributed to a higher initial potassium release from the soil. The gradual reduction in K release rate with time may be a result of decreased surface charge and subsequent decrease in the interaction between the adsorbed K^+ as release reaction progressed. This finding agrees with the results of Al-Zubaidi (2003); Mam Rasul, (2008); Akrawi (2010) They reported two parts of K^+ release in Iraqi soils.

4.3 Potassium release by kinetic models.

According to result (Table 5) and fack's law Parabolic diffusion that has R^2 (98) and SE (1.868) was the best model to describe cumulative K release rate constant from all treatments and their interaction applied with and without Zeolite amendment. This result consistent with Thabit (2021) which reported that the Elovich, power function and parabolic diffusions as the best descriptive models for K release soil- amended with zeolite.

The slop of the best model parabolic diffusion is shown in (Table 6), used to estimate the relative K release rate. The value of confection of K^+ rate increase with increasing level of potassium fertilizer and Zeolite amendment which increase availability of K^+ in soil and Zeolite according to its high CEC. The value of slops can be used as an index for the K release rate. The K-release rate values are known to correlate well with K in plant tissue or with K content in crop released from the non-exchangeable K^+ phase (Mengel and Uhlenbecker, 1993). When plant uptake dose not positive correlate with the K release rate value, this may represent the soils inability to meet the K^+ demand of the crop. On the other hand, a high positively correlation can be an indication of adequate K^+ release from the non-exchangeable K^+ to meet the crop K^+ needs.

5 Conclusion:

The purpose of adding environmentally amendments such as Zeolite to calcareous soils is due to the effect of this amendment on chemical and physical properties of soils, which leads to an increase in potassium release and thus an increase in its availability for plants.

The resalts confirmed that the addition of zeolite increase potassium release significantly in all binary and triple interaction between Nano and conventional fertilizers according to parabolic diffusion equation which considered as one of the best modules to describe potassium kinetics in studied soils.

Table 1: Main physical and chemical properties of the experimental soil and zeolite.

Sample	Sand mg kg^{-1}	Silt mg kg^{-1}	Clay mg kg^{-1}	Soil texture	pH	EC dsm^{-1}	Soluble k mmol/l	O.M gkg^{-1}	$CaCO_3$ gkg^{-1}	CEC $cmol_c\ kg^{-1}$
Study soils	88.3	502.8	408.9	Silty clay	7.8	0.3	0.130	19.3	185	51
Zeolite	-	-	-	-	7.93	0.4	-	-	-	131

Table (2): Effect of Nano K fertilizer with and without Zeolite amendment on cumulative K release using Ca-Resin from study soils.

Level of Nano- K fertilizer kg ha^{-1}	K release mg Kg^{-1} by using Ca-Resin		
	Without Zeolite (Z_0)	With Zeolite (Z_1)	Mean N*
N_0	24	30.5	27.25
N_5	30.15	33.55	31.85
N_{10}	26.4	27.67	27.035
Mean Z*	26.85	30.573	

LSD at 5% = 1.350, 1.654 and 1.779 for zeolite, Nano K fertilizer and interaction between zeolite and Nano K fertilizer respectively.

Table (3): Effect of conventional potassium fertilizer with and without Zeolite amendment on cumulative K release using Ca-Resin from study soils

Level of conventional- K fertilizer kg ha^{-1}	K release $mgKg^{-1}$ by using Ca-Resin		
	Without Zeolite (Z_0)	With Zeolite (Z_1)	Mean
K_0	24	30.5	27.25
K_1	32.25	34.15	33.2
K_2	33.35	35.35	34.35
Mean	29.867	33.333	

LSD at 5% = 1.349, 1.652 and 1.779 for zeolite, conventional K-fertilizer and interaction between zeolite and conventional K-fertilizer respectively.

Table (4): Effect of interaction Nano, conventional potassium fertilizer with and without Zeolite amendment on cumulative K release using Ca-Resin from study soils.

Treatment / type of Potassium fertilizer Kg ha^{-1}		K release mg Kg^{-1} by using Ca-Resin		
Nano- K fertilizer	Conventional K fertilizer	Without Zeolite (Z_0)	With Zeolite (Z_1)	Mean
N_0	K_0	24	30.5	27.25
	K_1	32.25	34.15	33.2
	K_2	33.35	35.35	34.35
N_1	K_0	30.15	33.55	31.85
	K_1	31.3	34.7	33
	K_2	34.1	35.45	34.775
N_2	K_0	26.4	27.67	27.035
	K_1	36.65	42.45	39.55
	K_2	31.1	42.05	36.575
Mean		31.033	35.152	

LSD at 5% = 1.655 for interaction between zeolite and conventional K-fertilizer and Nano fertilizer.

Table 5: Mean value of coefficient of determination (R^2) and standard error of estimate (SE) of various kinetic models for cumulative K-release by used Ca-Resin in study soils.

	Zero order	First order	Parabolic diffusion	Power function	Elovich
SE	2.818	0.285	1.868	0.201	1.77
R^2	0.94	0.82	0.98	0.96	0.98

Table (6) Liner equation of Parabolic diffusion models describe rate constant of K release from Nano, conventional K fertilizer and their interaction with and without zeolite amendment.

Treatment		Parabolic diffusion $K_t = a + k_p t^{1/2}$					
type of Potassium fertilizer Kg ha^{-1}							
Nano- K fertilizer	conventional K fertilizer	With Zeolite (Z_1) 2 t ha^{-1}			Without Zeolite (Z_0)		
		Linear equation	R^2	Slope	Linear equation	R^2	Slope
N0 (control)	K_0 (control)	y= 6.014 x- 13.320	0.98	6.014	y= 3.957 x- 5.359	0.99	3.957

N_1		y= 6.211 x -11.146	0.98	6.211	y= 5.4563 x- 9.378	0.98	5.456
N_2		y= 4.3406x – 3.4778	0.97	4.3406	y= 4.5474 x-6.735	0.99	4.547
N_0	K_1	y= 6.785 x - 14.779	0.98	6.785	y= 6.044 x-11.785	0.99	6.044
	K_2	y= 7.106x - 16.847	0.99	7.106	y= 5.9938 x - 10.019	0.99	5.994
N_1	K_1	y= 6.574x - 14.715	0.99	6.574	y= 5.8676 x-11.558	0.98	5.868
	K_2	y= 7.368x -18.444	0.99	7.368	y= 6.5613 x- 13.385	0.99	6.561
N_2	K_1	y= 8.941 x -22.027	0.99	8.941	y= 7.4702 x- 17.078	0.98	7.470
	K_2	y= 7.425 x- 11.133	0.97	7.425	y= 5.6595 x- 8.863	0.94	5.660

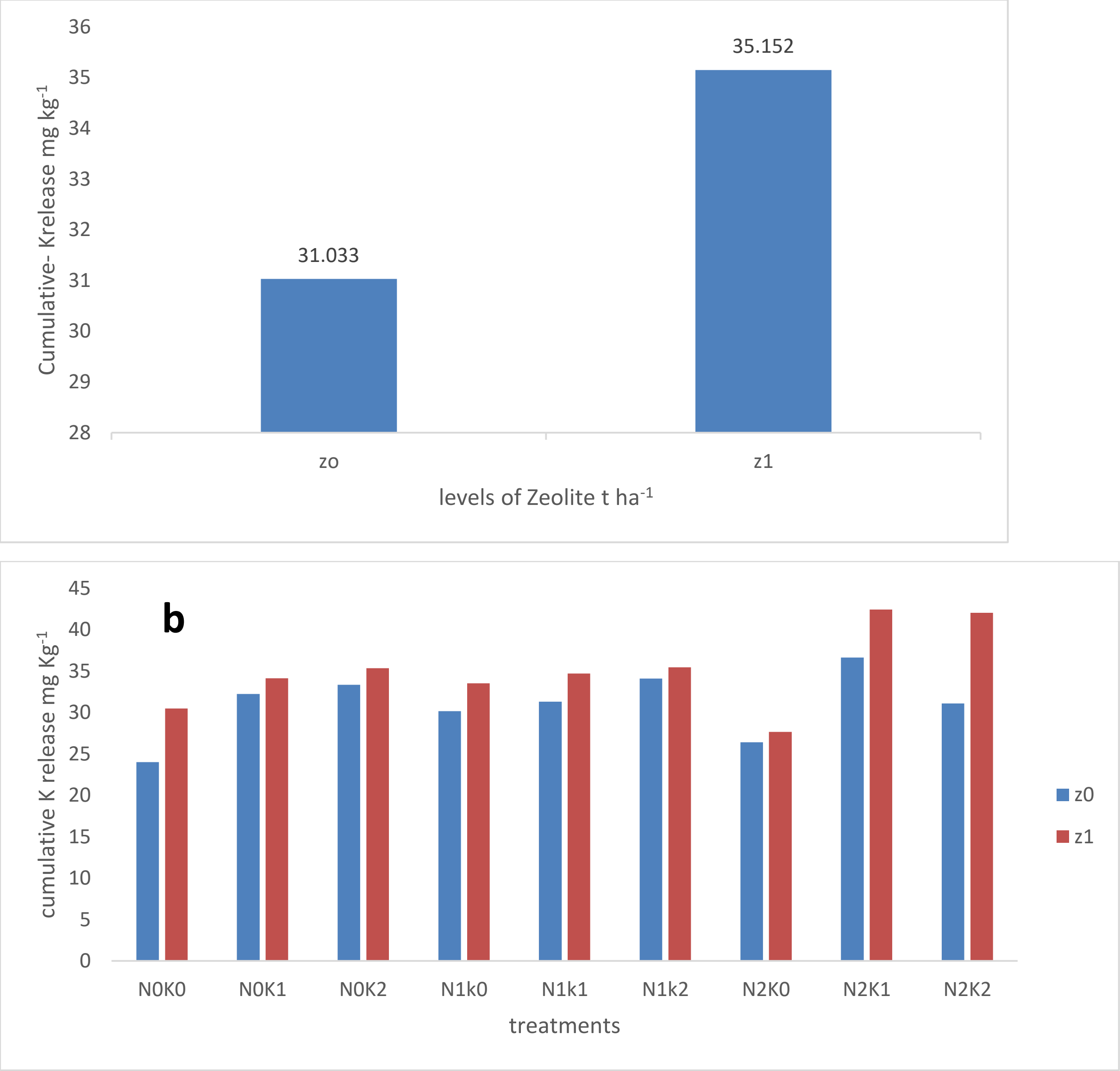


Figure (1): Effect of Zeolite amendment (a) mean (b) all treatment on Cumulative K release in studied soil

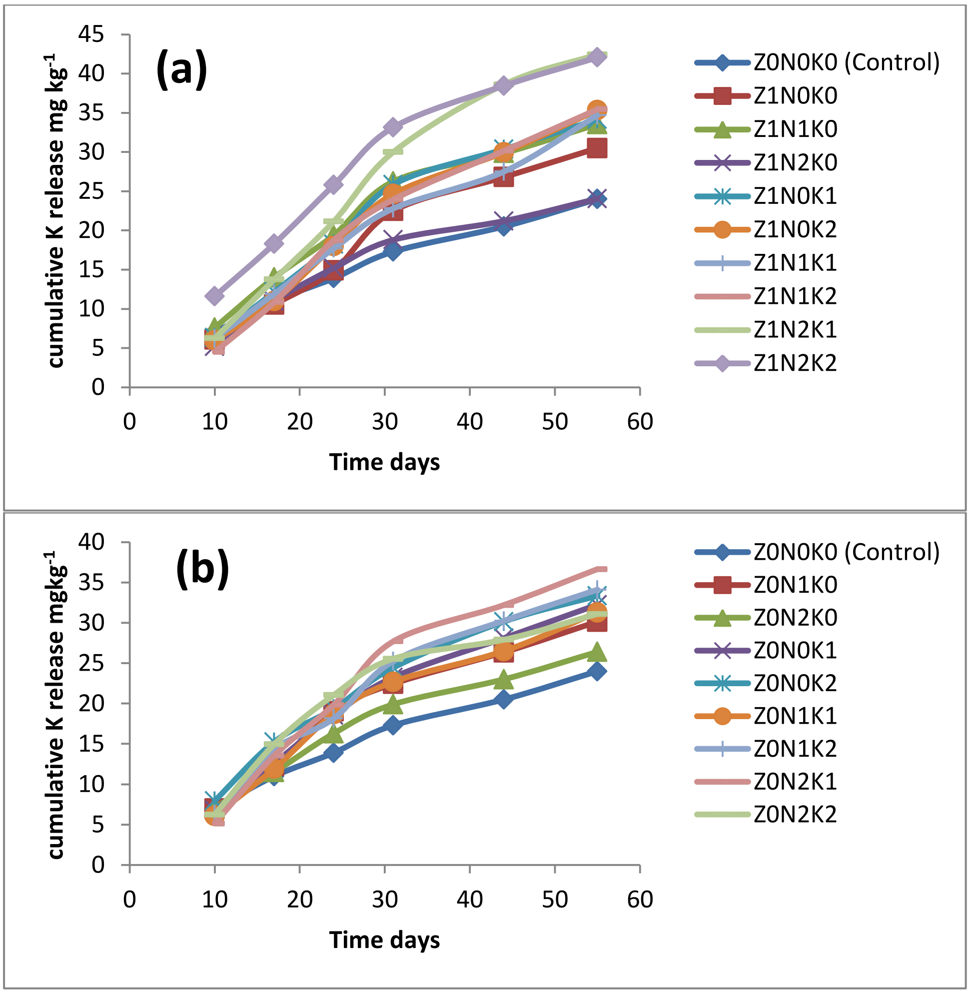
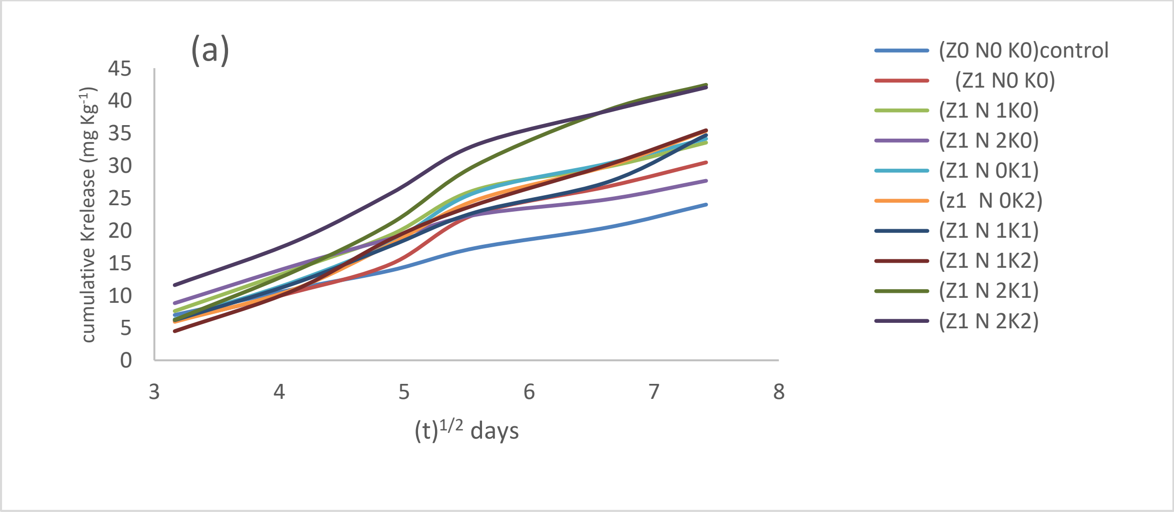


Figure (2): Effect of Nano and conventional K fertilizer and their interactions (a) with Zeolite (b) without Zeolite on cumulative K- release curve.



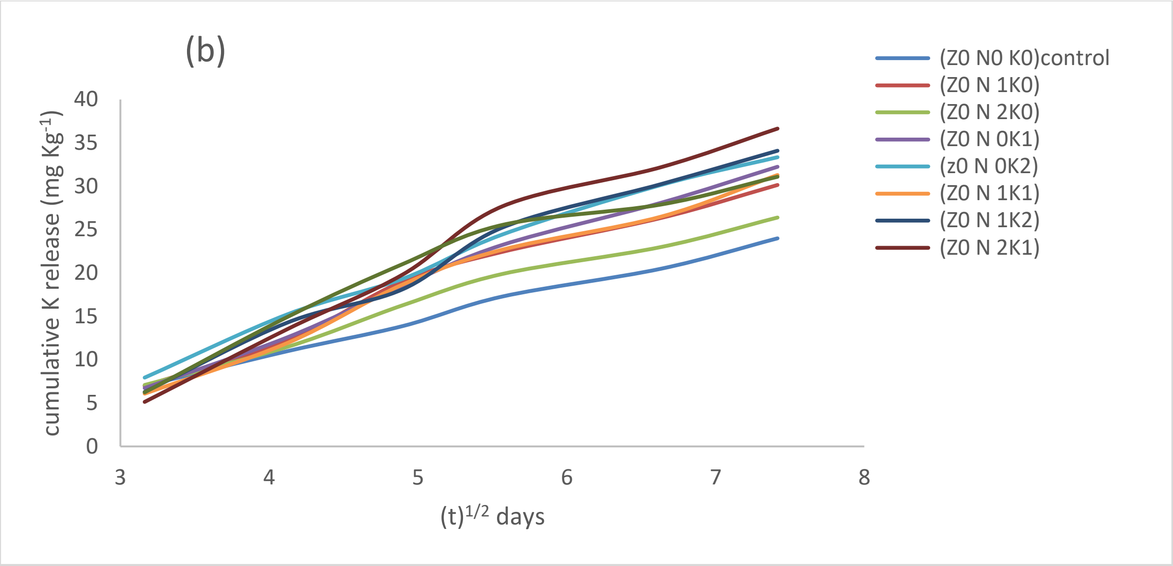


Figure (3) Kinetics of cumulative K release from studied soil (a) with Zeolite (b) without Zeolite as described by parabolic diffusion equation.

References:

AHMED, O., SUMALATHA, G. & MUHAMAD, A. N. 2010. Use of zeolite in maize (*Zea mays*) cultivation on nitrogen, potassium and phosphorus uptake and use efficiency. *International Journal of the Physical Sciences,* 5**,** 2393-2401.

AKRAWI H. S.Y., 2010. Effect of clay minerals on K–Thermodynamic and kinetics properties of some soil orders at Kurdistan region - Iraq (Ph.D.Thesis). College of Agriculture, Salahaddin University, Iraq.

AKRAWI, H. 2018. Effect of organic and inorganic fertilizer on availability of potassium in soil and yield of chickpea (*Cicer arietinum L.*). *Iraqi Journal of Agricultural Sciences,* 49.

AL-OBAIDI, M. A., AND A. AL-ZUBAIDI 2000. Kinetic of potassium release in some Iraqi soils. *Mesoptamia J. of Agric., 32, 33-40.*

AL-ZUBAIDI, A. 2003. The status of potassium in Iraq soil: potassium and water management in west Asia and North Africa. *The National Center for Agricultural research and technology transfer, Amman, Jordan***,** 129-142.

GOULDING, K. & LOVELAND, P. 1986. The classification and mapping of potassium reserves in soils of England and Wales. *Journal of Soil Science,* 37**,** 555-565.

HANIATI, I., MINARDI, S., NASTITI, A., HARIENI, S., SYAMSIYAH, J. & HARTATI, S. The utilizing of zeolite and manures for increasing potassium availability, uptake, and yield on soybean in Alfisols. IOP Conference Series: Materials Science and Engineering, 2019. IOP Publishing, 012012.

HAVLIN, J., WESTFALL, D. & OLSEN, S. 1985. Mathematical models for potassium release kinetics in calcareous soils. *Soil Science Society of America Journal,* 49**,** 371-376.

JYOTHI, T. & HEBSUR, N. 2017. Effect of Nanofertilizers on growth and yield of selected cereals-A review. *Agricultural reviews,* 38.

KHAN, M., ISLAM, M., NAHAR, N., AL-MAMUN, M., KHAN, M. & MATIN, M. 2021. Synthesis and characterization of Nanozeolite based composite fertilizer for sustainable release and use efficiency of nutrients. *Heliyon,* 7**,** e06091.

LIN, D. & XING, B. 2008. Root uptake and phytotoxicity of ZnO Nanoparticles. *Environmental science & technology,* 42**,** 5580-5585.

Mam Rasul G.A, 2008. PHYSICO-CHEMICAL BEHAVIOR OF POTASSIUM IN PREDOMINANT SOIL ORDERS OF SULAIMANI GOVERNORATE- Iraq (Ph.D.Thesis). College of Agriculture, University of Sulaimani, Iraq

MENGEL, K. & UHLENBECKER, K. 1993. Determination of available interlayer potassium and its uptake by ryegrass. *Soil Science Society of America Journal,* 57**,** 761-766.

MING, D. W. & BOETTINGER, J. L. 2001. Zeolites in soil environments. *Reviews in mineralogy and geochemistry,* 45**,** 323-345.

MOTSARA, M. & ROY, R. 2008. Guide to laboratory establishment for plant nutrient analysis (19): Food and Agriculture Organization of the United Nations Rome. *FAO Viale delle Terme di Caracalla,* 153.

MUMPTON, F. A. 1999. La roca magica: Uses of natural zeolites in agriculture and industry. *Proceedings of the National Academy of Sciences,* 96**,** 3463-3470.

NAJAFI-GHIRI, M. 2014. Effects of zeolite and vermicompost applications on potassium release from calcareous soils. *Soil and Water Research,* 9**,** 31-37.

NAKHLI, S. A. A., DELKASH, M., BAKHSHAYESH, B. E. & KAZEMIAN, H. 2017. Application of zeolites for sustainable agriculture: a review on water and nutrient retention. *Water, Air, & Soil Pollution,* 228**,** 1-34.

QURESHI, A., SINGH, D. & DWIVEDI, S. 2018. Nano-fertilizers: a novel way for enhancing nutrient use efficiency and crop productivity. *Int. J. Curr. Microbiol. App. Sci,* 7**,** 3325-3335.

Rowell, D. L., 1996. Soil science. Methods and application. Univ. of Reading. UK.

RALIYA, R., SAHARAN, V., DIMKPA, C. & BISWAS, P. 2017. Nanofertilizer for precision and sustainable agriculture: current state and future perspectives. *Journal of agricultural and food chemistry,* 66**,** 6487-6503.

REZAEI, M. & NAEINI, S. M. 2009. Kinetics of potassium desorption from the loess soil, soil mixed with zeolite and the clinoptilolite zeolite as influenced by calcium and ammonium. *Journal of Applied Sciences,* 9**,** 3335-3342.

SHERIF, F. & HEDIA, R. 2001. Evaluation of resin capsules for monitoring availability and movement of nutrients in Egyptian soils. *Alexandria Journal of Agricultural Research,* 46**,** 119-128.

Sparks, D.L. 1999. Kinetics and mechanisms of chemical reactions at the soil mineral/water interface, in Soil Physical Chemistry. CRC Press, Boca Raton, Florida, USA, p. 135-191.

SPARKS, D. L. 2003. Environmental soil chemistry: An overview. *Environmental soil chemistry,* 2**,** 1-42.

THABIT, F. N. 2021. Kinetics of potassium release from soil amended with clinoptilolite zeolite and maize stalks biochar. *International Journal of Agricultural and Applied Sciences,* 1**,** 50-56.

TIAN, X.-F., LI, C.-L., ZHANG, M., LU, Y.-Y., GUO, Y.-L. & LIU, L.-F. 2017. Effects of controlled-release potassium fertilizer on available potassium, photosynthetic performance, and yield of cotton. *Journal of Plant Nutrition and Soil Science,* 180**,** 505-515.

ZHOU, J. & HUANG, P. 2007. Kinetics of potassium release from illite as influenced by different phosphates. *Geoderma,* 138**,** 221-228.