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Peanut (*Arachis hypogaea l.*) Yield response and natural radionuclides uptake at different combinations of Mineral and organic fertilizers in a new reclaimed Sandy soil in Egypt

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THE USE of chemical (synthetic) fertilizers can increase soil production, but they also seriously jeopardize food safety, ecosystem components, and long-term soil fertility. Sustainable farming methods can maintain soil fertility and productivity while slowing the depletion of natural resources. During mineral weathering, organic fertilizer derived from natural sources (food waste, livestock manure, agricultural biomass, etc.) promotes the release of nutrients into the soil and serves as a source of microbial culture. The application of chemical (synthetic) fertilizers can boost soil productivity; however, it often compromises long-term soil fertility, food safety, and environmental sustainability. In newly reclaimed sandy soils, such as those in Egypt, integrating mineral and organic fertilizers offers a promising approach to address these challenges. Organic fertilizers from natural sources, such as food waste, livestock manure, and agricultural biomass, not only support microbial activity and nutrient cycling but also improve soil physical properties. This study evaluates the yield response of peanut (Arachis hypogaea L.) and the uptake of natural radionuclides under various combinations of mineral and organic fertilizers, emphasizing their role in enhancing soil structure and ensuring food safety. Four combinations of nitrogen mineral and organic fertilizers at rates of (100% MN+0% ON), (75% MN+25% ON), (50% MN+50% ON), (25% MN+75% ON), (0% MN+100% ON) were applied, in a new reclaimed sandy soil in Egypt. The evaluation parameters of yield were water application efficiency (%), nitrogen uptake, (gN m^{-2}), seeds yield (kg ha^{-1}) water productivity (kg m^{-3}) and protein and oil content (%). The results indicated that the best farming practices was (50% MNF+50% ONF) in term of seeds yield, nitrogen uptake, water productivity and both protein and oil content. The result also revealed that the transfer of the ^{226}Ra, ^{232}Th were not occurred where for and ^{40}K the transfer factor was higher than 1. These results emphasize the promoting of organic fertilizer in reducing the added mineral fertilizers and achieve food safety.

Keywords: Sustainable agriculture practices, Organic fertilizer, Peanut, Natural radioactivity.

1. Introduction

Due to water scarcity and little precipitation in the Arab Republic of Egypt, crop water productivity is crucial (Abdelraouf and Ragab, 2018). Lack of water is one of the main challenges to food production in desert areas. Therefore, in order to rationalize and minimize the consumption of irrigation water (IW), it is imperative to design innovative irrigation systems that efficiently preserve water (El-Metwally et al., 2015; Abdelraouf et al., 2015; Abdelraouf and Hamza, 2024). Producing more food with less water is Egypt's agricultural dilemma. This can be accomplished in part by increasing crop yields per unit of water used. Water productivity, or agricultural production per unit of water, must be increased to fulfill the increasing demand for food caused by population expansion (Abdelraouf, 2019; Bakry et al., 2012; Eid and Negm, 2019; Abdelraouf et al., 2021). Egypt is facing a severe water shortage, and competition for these scarce resources is intensifying. New irrigation techniques are required to increase the yield and quality of farmed crops

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(Marwa et al., 2017; Abdelraouf et al., 2020; Dewedar et al., 2023). In the Arab Republic of Egypt, which has relatively low average rainfall (Eid et al., 2023; Abdelraouf et al., 2019; Hozayn et al., 2013; El Habbasha et al., 2015), where rainfall ranges from 0 mm in desert regions to 200 mm in northern coastal areas, with an average of 12 mm per year. Additionally, there is only 1.8 billion m^3 of precipitation per year (Abdel-Shafy et al., 2010). In semi-arid regions such as Egypt, it is crucial to promote the use of water-saving technologies like micro-irrigation and related techniques so that some of the irrigation water (IW) that is conserved can be used to develop other areas (Abdou et al., 2024; Abdelraouf et al., 2024; Abdelaal, et al., 2025).

While there are numerous approaches to enhance agricultural water productivity in arid regions like Egypt, adding more organic matter-particularly to sandy soils—is the most crucial and long-term solution. Numerous past and present studies have noted that adding more organic matter to sandy soil, in any form, can improve the soil's capacity to hold irrigation water put to it (Abdelraouf, et al., 2020; Abdelraouf, et al., 2012; El-Tohory et al., 2016). The use of organic fertilizers to supplement mineral fertilization has expanded as a result of the local and worldwide trend toward less reliance on mineral fertilizers alone for crop fertilization (Alhashimi et al., 2023; El Habbasha et al., 2015; Saad, et al.,2025; El-Sayed et al., 2023).

Peanut (*Arachis hypogaea* L.) is a significant oil and food crop, grown mainly for the production of oil (seed oil 43–55%) and protein (seed protein 25–28%) (Hosseinzadeh et al., 2009). The crop is cultivated primarily for human consumption and has several uses either as whole seeds or as a processed product for use in peanut butter, oil, and other products. The cultivation of peanut globally covers a total area of 24.07 million ha (Noorhosseini and Damalas, 2018). They supply food for direct human sustenance as well as a variety of other food products. For farmers in dry and semi-arid areas, peanuts are a legume cash crop. According to Abou Kheira (2009), peanut seeds have significant levels of edible oil (43–55%), protein (25-28%), and minerals (2.5%). Additionally, nuts are a wonderful source of oil that has more unsaturated fatty acids than saturated fatty acids. (Fagbemigun and Oguntola, 2019; Sabate, 2003).

All parts of the Peanut plant can be utilized for both human and livestock consumptions. Peanut butter, oil, and other items are made from processed seeds. The vegetative part (steam, leaves) is a rich protein hay for ruminant livestock. The pods and shells can be ground to form as high fibre roughage in livestock feed and is employed in the production of fertilizer and particle board. Both animal feed and soil fertilizer are made from the leftover cake from oil processing. Peanut shells are used to make cellulose, mucilage (glue), plastic, wallboard, abrasives, and fuel. Through the nodules on their roots, peanut plants fix biological nitrogen into the soil, making them a great cover crop for degraded soils. (Woodroof, 1983). The Peanut cultivated area in Egypt is estimated to be 64000 hectares which produces approximately 205000 ton with an average yield of 3.2 ton/ha according to World Agricultural Production (WAP) Circular (Abd El-Monem and Khaled, 2023).

The peanut crop may grow well on light soil and improves the qualities of recently reclaimed sandy soils, which sometimes have limitations like poor physical qualities and nutrient deficiencies. Although numerous studies have been conducted on groundnut response to mineral and organic fertilizer, however few researches were carried out on the transfer of natural radioactivity from new reclaimed soil to peanut seeds (Ali et al., 2016).

Fertilization is required to supply the macro- and micronutrients required for plants to attain high productivity in the recently recovered land (Hegedűs et al., 2017; (Ramadan, et al., 2020). Although mineral fertilizers are beneficial for agriculture, their use also causes soil contamination by various pollutants, such as radionuclides (Boukhenfouf and Boucenna, 2012; Hegedűs et al., 2017), which may be the source of radioactivity in soil that is not naturally occurring. According to Chauhan and Kumar (2015), peanuts grown on fertilized agricultural areas have the ability to absorb radionuclides through their root systems, and these radionuclides can enter the bodies of humans and animals through the food chain and build up, resulting in internal exposure.

Assessing radionuclide emissions into the environment is crucial for maintaining public health (Azeez et al., 2019). The ratio of activity concentrations of specific radionuclides in plant and soil samples is known as the soil-to-plant transfer factor (TF), and it is one of the crucial elements for radiological evaluation (Asaduzzaman et al., 2014). The plant species, soil type, radionuclide availability, and climate conditions are only a few of the variables that can affect the TF value (Greger, 2004; Huy et al., 2012).

Therefore, there is an urgent need to quantify the transfer of some natural radionuclides such as ^{226}Ra, ^{232}Th, and ^{40}K from soil and added fertilizers to different consumed parts of peanut crop. Moreover, to investigate the impact of supplementary organic fertilizer on reducing the applied mineral fertilizer taking on consideration the peanut productivity.

The present work aimed at investigating the impact of applying different combination between mineral and organic fertilizers on the transfer of natural radionuclides from soil to peanut crop cultivated in new reclaimed area and also its effect on crop productivity.

2. Materials and methods

Experimental site: At the National Research Center's (NRC) research farm in Nubaryia Region, Al Buhayrah

Governorate, Egypt, two field experiments were conducted. during two successive summer seasons 2021 and 2022 cultivated with peanut (Arachis hypogaea L, cv. Giza 6). The experimental farm is located at a latitude of 30^o 30' 1.4" N, longitude of 30^o 19' 10.9" E, and 21 m a.m.s.l (above mean sea level). The climate of the experimental region is arid, with hot, dry summers and chilly winters. The local weather station at El-Nubaryia Farm provided the maximum and minimum temperature, relative humidity, and wind speed data as shown in Figure (1). In the first and second seasons, peanut seeds were seeded on May 12 and May 15, respectively. Using Arabic gum (40%) as an adhesive, the seeds were inoculated with the particular strain of Rhizobium japonicum prior to being sowed in hills at a rate of 100 kg seed ha^{-1}, spaced 10 cm apart.

Rhizobium in the root nodules helps groundnuts fix nitrogen from the atmosphere. This aids in meeting some of its nitrogen needs. However, the development of root nodules takes roughly 25–30 days. The best time to harvest is when 75% of pods exhibit darkening on the inner side of the hull, the majority of pods have a veined surface, and the seed coats are colored. In the first and second seasons, the peanuts were manually picked on September 15 and September 19, respectively.

The soil's and irrigation water's physical and chemical characteristics: According to mechanical examinations, the experimental site's soil was categorized as sandy with 85.4% coarse and fine sand, 8.6% silt, and 5.7% clay. An irrigation channel that ran through the experimental area provided the irrigation water.

The electrical conductivity (EC) of the irrigation water was 0.45 dS m^{-1}, and its pH was 7.41. At the start of the field trial, the primary physical and chemical characteristics of irrigation water and organic fertilizer were assessed both in situ and in the lab (Table 2).

Fertilizers practices: The recommended dose of phosphorus in the form of calcium superphosphate (15.5 % P_2O_5), is 75 kg P_2O_5 ha^{-1} about 480 kg ha^{-1} was added during the seed bed preparation and the recommended dose of potassium in the form of potassium sulphate 48.52 % K_2O was applied at the rate of 125 kg ha^{-1} and take two equal dosages before to the first and third irrigations.

At a level of 72 kg N ha^{-1}, the recommended dosage of nitrogen fertilizer was applied in various combinations of organic fertilizer (compost) and mineral fertilizer (ammonium nitrate, 33.5%). The mineral nitrogen fertilizer was applied in three equal doses starting from sowing date, 15 days after sowing and 30 days after sowing, while the nitrogen organic fertilizer in the form of compost was added 20 days to the soil before planting. According to analyses of compost content, it contained 0.92 % of nitrogen, this means the total amount of compost that satisfy 100% organic nitrogen was calculated by dividing the 72 kg N ha^{-1} by the percentage of N in compost fertilizer which leads to 7.83 t ha^{-1}. Assuming that roughly half of the applied compost will be examined in the following year, the total amount of compost applied, at 100%, is 15.65 t ha^{-1}. Table (3) displays the rate of each integrated nitrogen fertilization for all treatments based on the previously provided data.

Experimental design: The experimental work was established using a random block design with three replicates. Each replicate consisted of five treatments represent the Integrated Nitrogen Fertilizer (INF1, INF2, INF3, INF4, INF5) ratios between mineral and organic fertilizers: [(INF1:100%MN+0%ON), INF2:75%MN+25%ON), (INF3:50%MN+50%ON), (INF4:25%MN+75%ON), (INF5:0%MN+100%ON)] where, MN stands for Mineral nitrogen fertilizer and ON for Organic nitrogen fertilizer as shown in Figure (2).

Filtration unit, control pressure head, and pumping system: A 45 m^3.h^{-1} centrifugal pump, a screen filter, a backflow prevention device, a pressure regulator, pressure gauges, control valves, and a flow meter made up the irrigation system. The water was transported from the source to the primary control sites in the field via the main line, a 110 mm Ø polyvinyl chloride (PVC) pipe. PVC pipes with a 75 mm Ø were used as sub-main lines that were connected to the main line. The sub-main line was connected to manifold lines, 63 mm polyethylene (PE) pipes, control valves, and discharge gauges. The emitters were constructed in 50-meter-long, 16-mm lateral PE tubes. The emitters were spaced 30 cm apart and had a 4 l h^{-1} discharge at 1.0 bar operating pressure.

Requirements for irrigation: Peanuts' irrigation water needs under a drip irrigation system were computed (5280 and 52٦0 m^3 ha^{-1} for ٢٠٢١ and ٢٠٢٢ seasons, respectively) according to the following equations 1.

$IRg = [(ET_o \times Kc \times Kr) / I_E] - R + LR$ ……. (1)

Where: IRg: Gross irrigation needs per day, measured in millimeters; Kc: Peanut crop factor (FAO-56), Kr: Reduction factor, and ETO: Reference evapotranspiration, mm/day; IE stands for irrigation efficiency, percentage; R for rainfall, millimeters; and LR for the amount of water needed to leach salts, millimeters.

Soil and plant Samples preparation: Soil and plant samples were collected at the end of each growing season. The soil samples were collected from all plots at a depth of 30 cm then each sample was dried at 105 ˚C for 24 hr and then it was ground and sieved to ≤ 2 mm. Similarly, full plant samples included the above ground biomass and the underground roots and pods were collected. Each plant part was separated into three portions, first portion includes the biomass of leaves, stems and roots, second portion includes shells and the third portion includes seeds of Peanut. Before being ground and sieved to < 2 mm, each part was freshly weighed and dried in an oven set to 105 ˚C for 48 to 72 hours.

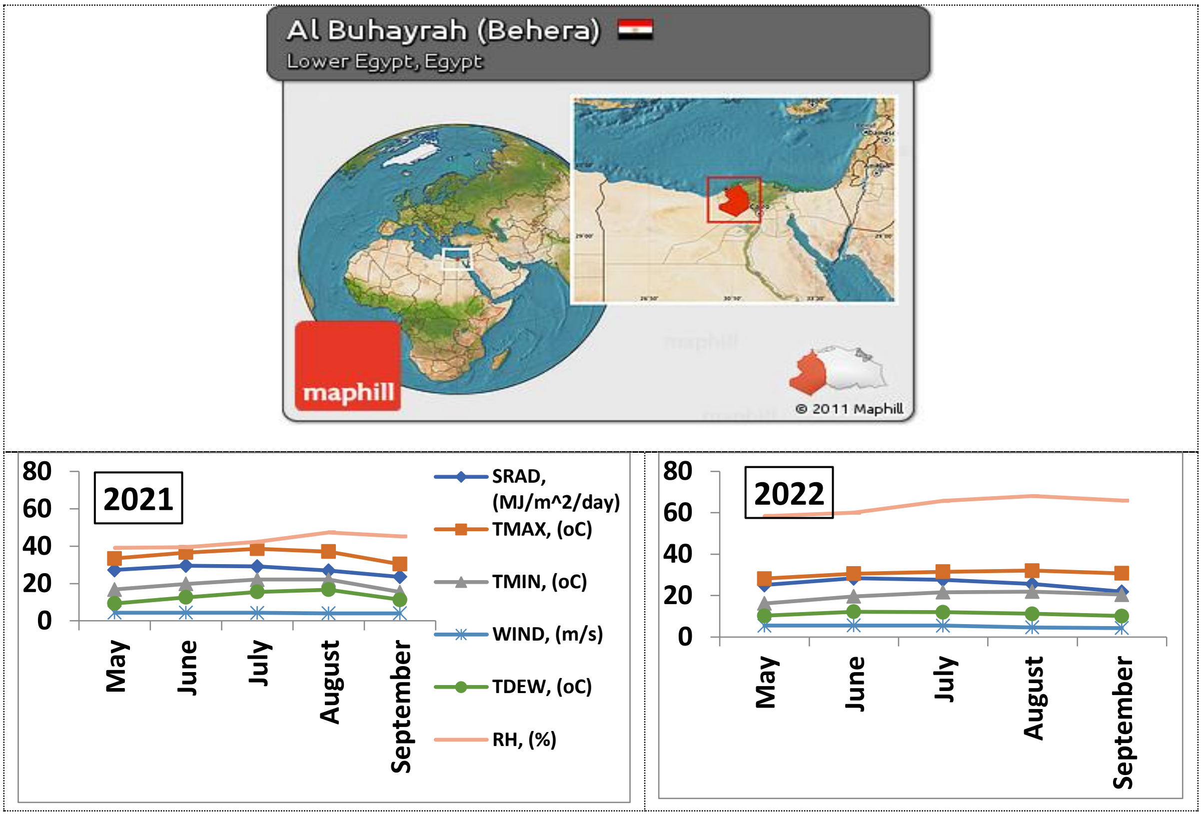


Fig. 1. Field experiment site and climatic data in Nubaria area, Egypt.

Table 1. The soil's physical and chemical characteristics in the test region.

Physical properties			
Soil layer depth (cm)	0–15	15-30	30-45
Texture	Sandy	Sandy	Sandy
Coarse sand (%)	47.54	54.75	38.74
Fine sand (%)	49.72	41.63	57.43
Silt+ clay (%)	2.74	3.62	3.83
Bulk density (t m^{-3})	1.66	1.68	1.68
Chemical properties			
$EC_{1:5}$ (dS m^{-1})	0.47	0.56	1.24
pH (1:2.5)	8.54	8.75	9.35
Total $CaCO_3$ (%)	7.34	2.45	4.71

EC: Electrical Conductivity

Table 2. Chemical examination of irrigation water and organic fertilizer.

Item		**Compost, 2021**	**Compost, 2022**	**Irrigation water**
pH		5.87	6.02	7.41
EC*, (ds/m)		0.73	0.74	0.45
Anions (meq./L)	HCO_3^-&CO_3^{2-}	1.25	1.31	0.03
	Cl^-	3.53	3.51	2.75
	SO_4^{2-}	2.96	2.91	1.36
Cation (meq./L)	Ca++	2.04	1.97	1.06
	K+	2.32	2.16	0.24
	Mg+	1.01	1.12	0.41
	Na+	2.37	2.48	2.43
Organic Matter (%)		97.4	97.6	-
Moisture Content (%)		19.0	20.0	-
Nitrogen (%)		0.92	0.94	< 0.02
Phosphorus (%)		0.83	0.81	-
Potassium (%)		0.89	0.92	0.24

*EC: Electrical Conductivity

Table 3. Distribution treatments of the experimental design.

Treatments	Total MN, kg $_{\text{ammonium nitrate (33.5\%)}}$ kg ha^{-1}	ON, ton ha^{-1}, 2021	ON, ton ha^{-1}, 2022
INF1:100%MN+0%ON	215	0	0
INF2:75%MN+25%ON	161.25	3.91	3.83
INF3:50%MN+°0%ON	107.5	7.83	7.66
INF4:25%MN+75%ON	53.75	11.74	11.49
INF5:0%MN+100%ON	0	15.65	15.32

INF: Integrated N-Fertilizer Ratio is the ratio between MN: Mineral Nitrogen and ON: Organic Nitrogen; The 100% of MN equals to 72 kg N ha^{-1} in the form of ammonium nitrate (33.5% N) = 215 kg ha^{-1} where, the 100% of ONF equals to 15.65 ton ha^{-1} for season 2021 and 100% ONF =15.32 ton. ha^{-1} for season 2022. The natural radioactivity specific concentration of soil with no fertilizer and added organic and mineral fertilizers were measured individually to quantify the concentration of natural radionuclides found in each source.

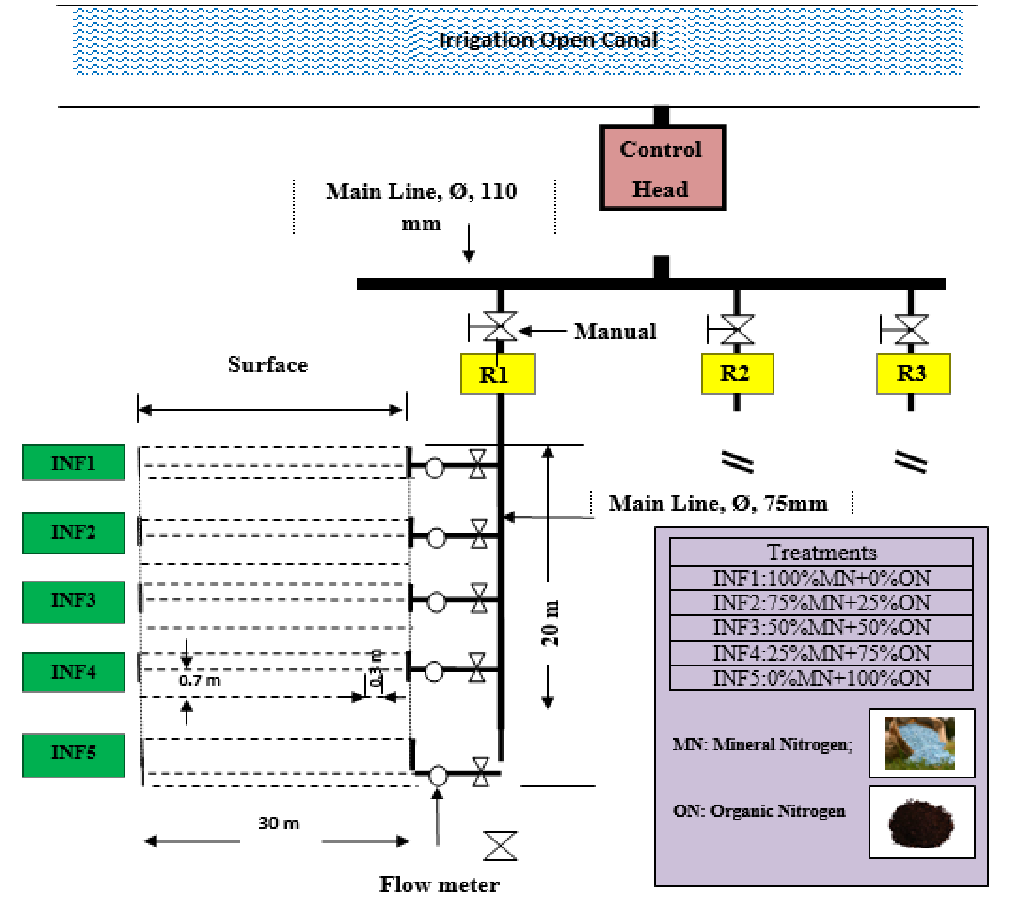


Fig. 2. Layout of experimental design.

Finally, all samples were packaged into 0.5 l cylindrical beakers appropriate for gamma analysis and left for four weeks before being measured to attain radioactive secular equilibrium between radioactive materials and daughter nuclei (IAEA, 2014; Kassab et al., 2022; Abdelaal et al., 2022; Hegazi et al., 2023).

Radioactivity measurements: Using a broad energy High Purity Germanium (HPGe) detector, gamma detector (BE3830 model) with cryostat CP5-PLUSE-SL, and iPA-Sl preamplifier, the activity concentrations of 226 Ra, 232 Th, and 40 K in the different samples were determined. The HPGe is characterized by a relative efficiency of 30%, insulated with lead to reduce background, with FWHMs of 450 eV at 5.9 keV, 750 eV at 122 keV, and 1900 eV at 1332.5 keV. Genie 2000 software ran the detector, while LABSOCS software, which was based on the Monte Carlo model, was used for mathematical calibration (Kassab et al., 2022). Energy and efficiency were both used to calibrate the system. A range of radioactive standards with known energies, such as ^{137}Cs (661.67 KeV) and ^{60}Co (1332 and 1172 KeV), were purchased in order to calibrate the energy. Instead of using the conventional source, Canberra's Geometry composer was used to calibrate the efficiency (Canberra, 2013). For analytical quality control, IAEA reference materials No. IAEA-RGTh-1 were utilized.

At the 95% level of confidence, the measurement uncertainty ranged from 5% to 10%, with the counting time set at 172800 seconds. Canberra's Genie2000 PC application has been used to assess each sample's spectrum in order to estimate its natural radioactivity.

From the photopeaks of ^{214}Pb (295.22, 351.93 KeV) and ^{214}Bi (609.31, 1120.29, 1764.49 KeV), the radioactive concentration of ^{226}Ra was determined. The ^{228}Ac (911.2, 968.97 KeV), ^{212}Pb (238.63 KeV), and ^{208}Ti (583.19, 2614 KeV) photopeak's were used to resolve the ^{232}Th concentration, whilst the 1460.8 keV photopeak was used to resolve the 40K.

Water stress inside root zone peanut: Field capacity and wilting point were included as evaluation factors for the water stress "WS" exposure range of tree roots, according Abdelraouf et al. (2020). The soil moisture in the effective roots zone was measured before watering. Soil depths at the mid-growth stage were measured. The soil's moisture content was measured using a profile probe device.

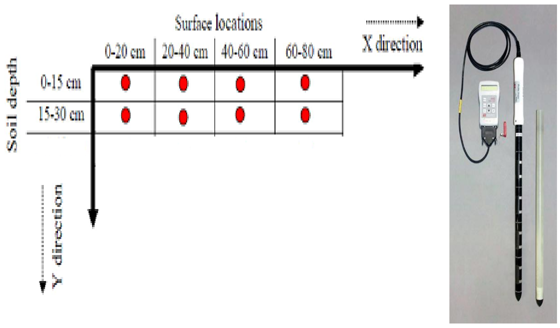
Water application efficiency: The actual storage of water in the root zone relative to the water applied to the field is known as application efficiency of irrigation water (AEIW). Equation 2 was utilized to determine AEIW:

$$AE_{IW} = Ds/ Da \text{ ………………………… } (2)$$

Where AEIW is the irrigation water application efficiency, expressed as a percentage, Da is the applied water depth (mm), and Ds is the root zone water storage depth, expressed in mm using equation 3.

$$Ds = (\theta_1 - \theta_2) * d * \rho \text{ …………… } (3)$$

Where ρ is the relative bulk density of soil (dimensionless), d is the depth of the soil layer (mm), θ_1 is the average soil moisture content in the root zone after irrigation (g/g), and θ_2 is the average soil moisture content in the root zone before irrigation (g/g) at peak water requirements. as depicted in Figure (3).



Soil moisture content locations prior to and following irrigation   Profile probe

Fig. 3. locations of the profile probe's soil moisture content both before and after irrigation.

Water productivity of peanut: WP peanut was computed using equation (7) in accordance with James (1988) as follows:

$$\text{WP peanut} = \frac{\text{Ey}}{\text{Ir}} \text{………..}(7)$$

Where Ey is the economical yield (kg ha^{-1}), Ir is the applied amount of irrigation water (m^3 water ha^{-1} season^{-1}), and WP peanut is the water productivity of peanuts (kg $_{peanut}$ m^{-3} $_{water}$).

Oil content and oil yield: According to the procedure outlined by the A.O.A.C. (1990), the percentage of oil in the seed was ascertained, and the protein content of the seed was computed by multiplying the total nitrogen concentration by 6.25.

Soil-to- peanut seeds transfer factor (TF): The potential of plants to absorb naturally occurring radionuclides from the soil is frequently assessed using the soil-to-seeds transfer factor. The following formula was used to determine the TF (IAEA, 2010.:

$$TF = A_{p,i} / A_{s,i}$$

Where A_p, i represents the radioactive activity concentration in peanut seeds (Bq kg^{-1}) for dry mass, for example, i is the radionuclide index in a sample, and i is the activity concentration of radionuclides in soil (Bq kg^{-1}) for dry mass (Alomari et al., 2020; Thien et al., 2020).

Statistical analysis: In order to compare the means of various treatments using the Tukey test, all of the data collected from the two study seasons were statistically evaluated using the analysis of variance method (ANOVA) utilizing Origin software (OriginPro 8) at significant differences of (L.S.D. at 5% level).

3. Results and discussion

Water stress inside root zone peanut

The soil moisture content of the root zone was highly significantly affected by integrated nitrogen fertilization (organic and mineral) as shown in Figure (4). The higher the percentage of organic matter in the fertilization, the higher the percentage of moisture content, whether before or after irrigation. The reason for this is that the more organic matter in the root zone, the greater the soil's ability to retain water for the longest possible period, which means increasing the soil's ability to retain irrigation water. This means that the more organic matter, the lower the water stress, which results in healthy growth of the planted plants and increased rates of absorption of water and fertilizer nutrients from the soil. The previous results obtained were consistent with both Mansour et al., (2023); Marwa et al., (2017); Okasha et al., (2016); Ramadan, (2016); Sabra, et al., (2023) and Sahar, et al., (2021)

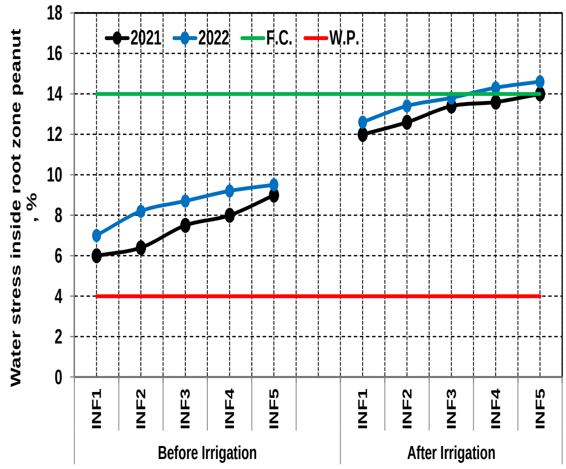


Fig. 4. Water stress inside root zone response to different combination between mineral and organic fertilizers in 2021 and 2022 growing season.

(F.C.: Field Capacity; W.P.: Welting Point; INF: Integrated N-Fertilizer Ratio is the ratio between Mineral Nitrogen and Organic Nitrogen)

Water application efficiency

The results indicated that water application efficiency gradually increased proportionally as ONF precent increased. As the organic matter increased in the soil as a result of adding organic fertilizer and the measured moisture content before and after irrigation showed closed value which reflects the ability of the cultivated soil to sustain moisture content. The statistical analysis (ANOVA), show significant difference between the population means of water application efficiency (%) at a level of 0.05 for the following combination between mineral and organic fertilizers (INF3, INF1); (INF4, INF1); (INF5, INF1); (INF5, INF2); (INF5, INF3) where no significant difference was found between means for the rest of combinations. The water application efficiency (%) in the second growing season 2022 showed higher values in comparison with those obtained in 2021, these finding reflects the stability of soil structure and the effect or residual organic fertilizer from the previous growing season. Figure (5) illustrate the increment of water application efficiency (%) as the percentage of organic fertilizer increased. The obtained results agree with Ali et al. (2018) and Abou Hussien, et al. (2020).

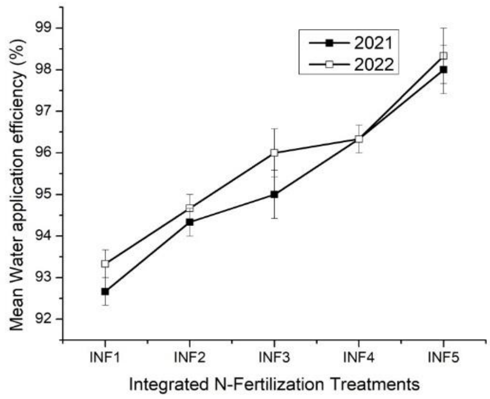


Fig. 5. Mean water application efficiency response to different combination between mineral and organic fertilizers in 2021 and 2022 growing season.

(INF: Integrated N-Fertilizer Ratio is the ratio between MN: Mineral Nitrogen and ON: Organic Nitrogen)

Yield and Water productivity of peanut

The results indicated that the maximum obtained seeds yield and water productivity in both 2021 and 2022 growing seasons were at INF3 which reflect the optimum combination between mineral and organic fertilizers. This could be mainly due to the ability of Peanut crop to absorb the mineral fertilizer in the presence of organic matter which maintain the mineral fertilizer in the root zone from one hand and enhancing the physical properties of the sandy soil. The statistical analysis (ANOVA), show significant difference between the population means of both seeds yield and water productivity at a level of 0.05 for the all combination between mineral and organic fertilizers for all combination except for population means between INF3 and INF2. All observations emphasize the beneficial effect of combining mineral and organic fertilizers, however the lowest seeds yield and water productivity were obtained where 100% organic fertilizer was applied. Similarly, the obtained results in the second growing season 2022 showed higher values in comparison with those obtained in 2021 which in mainly due to the stability of soil fertility due to the decomposition of organic fertilizer from the previous season as mentioned in Figure (6).

Oil content and oil yield

Similarly, the maximum obtained results for protein and oil content were achieved at INF3 for both 2021 and 2022 growing season. The lowest values were obtained at INF5. The statistical analysis (ANOVA), show significant difference between the population means of protein content in 2021 at a level of 0.05 for the following combination between mineral and organic fertilizers for all combination (INF4, INF2); (INF4, INF3); (INF5, INF1); (INF5, INF2); (INF5, INF3) and there was no significant difference for population means for the rest of combinations. In 2022, The statistical analysis (ANOVA), show significant difference between the population means of protein content for all combination except for (INF2, INF1); (INF3, INF1); (INF3, INF2). Generally, the obtained value of protein content was higher for 2022 growing season than for 2021 except for INF5 it was almost equal. Figure (7) shows the mean protein content at different combinations of mineral and organic fertilizers.

The oil content of peanut seeds showed a maximum value at the INF3 and lowest value at INF5 for both seasons 2021 and 2022. The statistical analysis (ANOVA), show significant difference between the population means of oil content in the growing season 2021 for the following combination (INF2, INF1); (INF4, INF2); (INF4, INF3); (INF5, INF2); (INF5, INF3); meanwhile all combinations were significantly different in season 2022 except (INF4, INF1).

Generally, the obtained value of oil content was higher for 2022 growing season than for 2021 except for INF5 it was lower in 2022 than in 2021. Figure (5b) shows the mean oil content at different combinations of mineral and organic fertilizers.

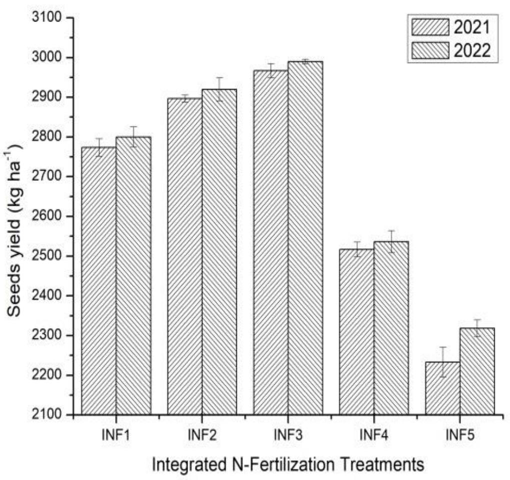
Soil-to- peanut seeds transfer factor (TF)

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in unfertilized soil, compost, and mineral fertilizers are summarized in Table (4). The measured activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in soil and peanut seeds were compiled in Table 5.

Table (7) displays the computed values of TF for natural radionuclides from soil to peanut seeds at the conclusion of the season, the calculated value of the TF for ^{226}Ra are 0.14 and 0.18 for INF3 and INF5 respectively. The value of TF for ^{232}Th are 0.16, 0.15, 0.37 and 0.11 at the combinations INF1, INF2, INF4 and INF5 where in INF3 there is no transfer from soil to peanut seeds. and for ^{40}K the transfer factor was obtained in all combination between mineral and organic fertilizer as shown in Table 7.

From the above-mentioned results, we can conclude that there is no transfer of ^{226}Ra, ^{232}Th from soil to peanut seeds and the values of transfer factor for ^{40}K are slightly higher than reported value in UNSCEAR (1993) which is 1, Potassium ^{40}K had the most astounding TF in these investigations; this is because the new reclaimed area are poor soil in terms of fertility and there is a crucial need to add potassium as it is a key factor for plant fertilization.

A



B

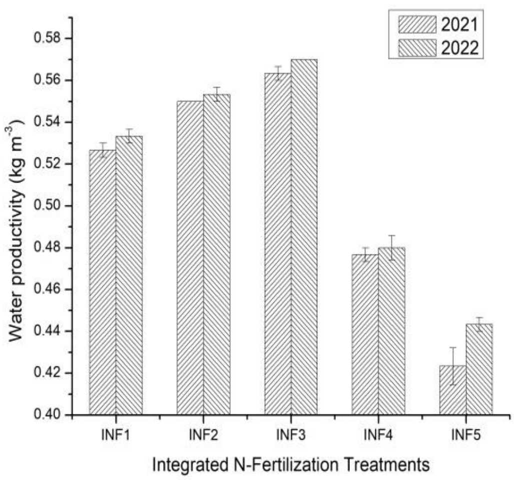
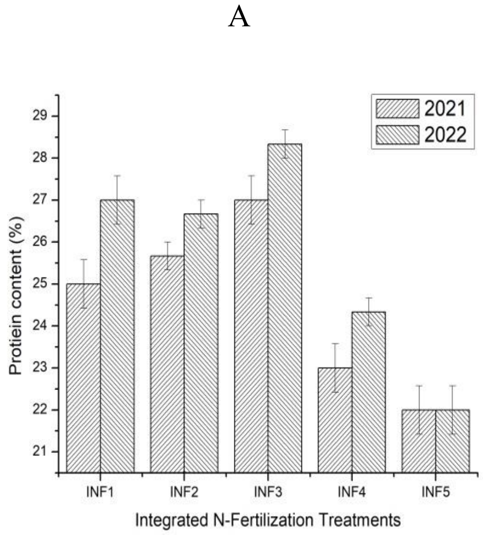


Fig. 6. A) Mean seeds yield and B) water productivity response to different combination between mineral and organic fertilizers in 2021 and 2022 growing season. (F.C.: Field Capacity; W.P.: Welting Point; INF: Integrated N-Fertilizer Ratio is the ratio between Mineral Nitrogen and Organic Nitrogen).



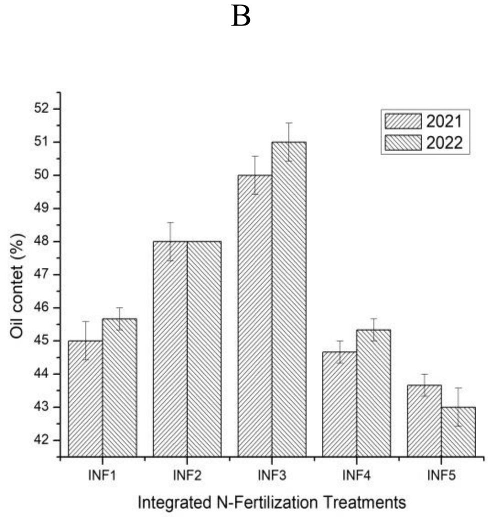


Fig. 7. A) Mean protein content and B) oil content response to different combination between mineral and organic fertilizers in 2021 and 2022 growing season.
(F.C.: Field Capacity; W.P.: Welting Point; INF: Integrated N-Fertilizer Ratio is the ratio between Mineral Nitrogen and Organic Nitrogen).

Table 4. The activity concentrations of natural radionuclides (Bq kg^{-1}) in soil with no fertilizer and used fertilizers (mineral and organic).

Items	**Activity concentration (Bq kg^{-1})**		
	^{226}Ra	**^{232}Th**	**^{40}K**
Soil with no fertilizer	<MDA	12.378 ± 0.4	198.7 ± 4.3
Compost	<MDA	3.620.23	55.2±2.4
Calcium super phosphate	1.3±0.6	19 ± 2	182 ± 29
Ammonium nitrate	<MDA	6.9 ± 0.6	151.6± 23
Potassium sulphate	1.8±0.7	<MDA	9656 ± 424

*MDA is the minimal detectable activity.

Table 5. The activity concentrations of natural radionuclides (Bq kg^{-1}) in soil at different combination of mineral and organic fertilizers.

Items	Activity concentration (Bq kg^{-1})		
	^{226}Ra	^{232}Th	^{40}K
INF1	9.6 ± 0.1	9.3± 0.6	170 ± 14
INF2	9.31± 0.3	9.46± 0.3	169± 7.1
INF3	9.62± 0.3	9.03± 0.3	164.18± 7.2
INF4	9.57± 0.4	9.68± 0.4	165.35± 5.8
INF5	9.87± 0.3	9.5± 0.4	168.4± 7.6

*MDA is the minimal detectable activity; INF: Integrated N-Fertilizer Ratio is the ratio between MN: Mineral Nitrogen and ON: Organic Nitrogen

Table 6. The activity concentrations of natural radionuclides (Bq kg^{-1}) in Peanut seeds at different combination of mineral and organic fertilizers.

Items	**Activity concentration (Bq kg^{-1})**		
	^{226}Ra	**^{232}Th**	**^{40}K**
INF1	<MDA	<MDA	190±11.4
INF2	<MDA	<MDA	203.6±10.1
INF3	<MDA	<MDA	198±11.9
INF4	<MDA	<MDA	199.5±12
INF5	<MDA	<MDA	190.5±9.5

*MDA is the minimal detectable activity; INF: Integrated N-Fertilizer Ratio is the ratio between MN: Mineral Nitrogen and ON: Organic Nitrogen

Table 7. Transfer factor of natural radioactivity from soil to peanut seeds at different combination of mineral and organic fertilizers.

Items	Transfer Factor (TF)		
	^{226}Ra	^{232}Th	^{40}K
INF1	ND	ND	1.12
INF2	ND	ND	1.20
INF3	ND	ND	1.21
INF4	ND	ND	1.21
INF5	ND	ND	1.13

INF: Integrated N-Fertilizer Ratio is the ratio between MN: Mineral Nitrogen and ON: Organic Nitrogen.

4. Conclusion

In this research, we investigated the effect of integrated nitrogen fertilizer through combination between mineral and organic fertilizer on the water application efficiency, yield and water productivity of peanut, protein and oil content, and transfer factor of natural radionuclides from soil to peanut seeds. The main finding is that INF3 which contains 50% of mineral and 50% of organic fertilizer was the best integrated nitrogen fertilizers which leads to high seed yield of peanut and high-water productivity in addition to the enhance protein and oil content. The equal combination between organic and mineral fertilizer enhanced the transfer of potassium from soil to peanut seeds and therefore the amount of added potassium can be reduced in order to fit with the standard of UNSCEAR (1993).

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