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Effected Irradiated Sewage Sludge and Compost on Jatropha Yield Production and Using ^{15}Nitrogen

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Authors' contributions

This work was carried out in collaboration between both authors. Author AAM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MMI managed the analyses of the study. Also managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Studies on irradiation of sewage sludge indicated its feasibility both economical and hygienically but work in this point is limited. Also the effect of non-irradiated and irradiated sewage sludge as a source of N on yield production and improvements fertility of sandy soil. In this research using the organic manure, the effects were increased soil fertility and crop yield. Aseeds yield production by *Jatropha curcas* L., these treatments can be arranged in the following descending order: T5> T6> T7> T4> T2> T3> T1. The best value of Ndff% recorded with rate 50% gamma irradiated sewage sludge + 50% ammonium sulphate fertilizer. Values of Ndfo % for 75.2%, 74.8% and 73.3% for (50% non-irradiated sewage sludge + 50% ammonium sulphate), (50% compost + 50% ammonium sulphate) and irradiated sewage sludge + 50% ammonium sulphate respectively. In general, the FUE% with 100% ammonium sulphate was ammonium sulphate alone lower than those recorded with ammonium sulphate plus none or irradiated sewage sludge and compost when T5, T7, T6 and T1 treatments were considered.

Keywords: Irradiation; sewage sludge; compost; ^{15}nitrogen; Jatropha plant.

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1. INTRODUCTION

Jatropha curcas the new cultivated and promising crop is convenient to adapt in Egypt for increasing the local planted production [1]. I guess the seeds are used to grow the Jatropha crop, which is further converted to biofuel. In 2004–05, the area planted with J. curcas was about 238 feddan, increased seven times to about 1666 feddan in 2007. The rate of increase is 175%, which is really very high [1].

Jatropha curcas seeds are rich in various micro-elements, i.e. manganese, iron, and zinc which recorded 28.37, 0.38 and 47.13 mg/kg, respectively as well as macro- elements, i.e., potassium, calcium, sodium, magnesium and phosphorous, which recorded 103.13, 34.21, 8.44, 109.89 and 185.17 mg/kg, respectively [2].

The first pilot scale sewage sludge gamma irradiation (using ^{60}Co as a source) plant was established in Geiselbullach (near Munich) in Germany in 1973. This plant had the capacity to irradiate 150 m^3 of sewage sludge per day and the irradiated sewage sludge was used primarily for agricultural research.

With increase in human population and rapid urbanization along with industrialization there is a progressive increase in disposal problem of sewage sludge.

Sewage sludge can be considered both as a fertilizer and environmental pollutant. It improves fertility status and acts as a soil conditioner. But it also contains potentially toxic heavy metals which may affect the plant vis-a-vis human and animal through food-chain [3].

Land application of municipal sewage sludge is being practiced throughout the world at different levels and their beneficial effects include increases in crop yields, soil organic matter, cation exchange capacity, water-holding capacity and soil fertility in general. High levels of nitrogen, phosphorus and micronutrients found in sewage sludge make it an excellent fertilizer. In addition, the high organic matter levels present can improve soil structure, particularly that of sandy soils in arid and semi-arid areas [4]. The main objective of this work was to investigate the effect irradiated- non sewage sludge and compost with application ^{15}N technique on nutrient uptake state of (N, P and K) and production of *Jatropha curcas* L under sandy soil condition.

2. MATERIALS AND METHODS

A field experiment was carried out at the Soils & Water Research Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt, on *Jatropha curcasL*. as an indicator plant using the materials described below. Plants *Jatropha curcasL*, supplied by theAgriculture Research Centre (ARC), Giza, Egypt were used. *Jatropha* plants were spaced at 300 cm apart. Chemical and physical analyses of experimental soil samples were determined according to [5]. Thephysical and chemical properties of used sandy soil were 88.5% sand, Silt 2.7%, and 8.8% clay, pH (1:2.5) 7.97, EC(dS m^{-1}) 0.27, O. C 0.017%, O.M 0.03%, T.N 0.007%, C/N Ratio 2.43, Ca CO_3 1.0%. Sewage sludge collected from El-Gabal El-Asfar farm and treated by Gamma cell at dose 10 KGy (Nuclear Research Center), radiation technology is recommended for sewage sludge disinfection, a dose of 10 KGy is for sewage sludge [6].

2.1 Sewage Sludge

The chemical properties of applied sewage sludge were pH (1:5) 6.80, EC 4.11 dS m^{-1}, C/N ratio 8.50, O.M 45.92%, N 3.2%, P 1.25%, K 0.23%, Fe 14650 mg kg^{-1}, Cu 593 mg kg^{-1}, Mn 413.42 mg kg^{-1}, Zn 1459 µg kg^{-1}. The compost was collected from soils and Water Research Department, Nuclear Research Center were made by [7]. The chemical properties of compost the used investigated were pH (1:5) 6.60, EC 8.50 dS m^{-1}, C/N ratio12.63, O.M 68.92%, N 1.25%, P 0.85%, K 0.658%.$Fe_2o_3$2897.5µg kg^{-1}, Cu 215.58µg kg^{-1}, Mn 203.42µg kg^{-1}, Zn 163.92µg kg^{-1}. Experimental design was complete randomized block with three replicates.The experiment included seven treatments, T1 treatment (100% mineral fertilizer), T2 rate 100 % gamma irradiated sewage sludge T3 rate 100% non-irradiated sewage sludge, T4 rate 100 % compost, T5 rate 50% gamma irradiated sewage sludge + 50% ammonium sulphate fertilizer, T6 rate 50% non-irradiated sewage sludge + 50% ammonium sulphate fertilizer, T7 rate 50% compost + 50% ammonium sulphate fertilizer. Dose of organic manure was applied to each tree spaces (3 x 3 m^2) at the rate of 24 m^3/ ha as organic material. Nitrogen-fertilizer was applied in the form of ^{15}N-labeled ammonium sulphate with 2% ^{15}N atom excess at rate of 120 kg N ha^{-1} to treatment of mineral fertilizer alone and half quantity with sewage sludge and compost as one full single dose after three weeks. No other fertilizer was used during plant growth. After 180 days, plants were harvested, the dry weights of whole plants and plant parts, total nitrogen, Nitrogen derived from fertilizer (%Ndff), Nitrogen derived from soil (Ndfs%), Nitrogen derived from organic compost or sewage sludge (%Ndfo) and Fertilizer use efficiency (FUE%) were calculated. shoot, roots andseeds then dried at 70ºC, weighed and digested. The total nutrition transport from soil (mg kg^{-1}) was calculated by subtracting the amount of nutrients concentration in soil after planting from the amount of nutrients concentration in soil before planting.

2.2 Translocation Ratio (TR) and Transfer Factor (TF)

This parameter is necessary for environmental transfer models which are useful in prediction of the nutrients concentrations in agricultural crops for estimating dose intake by man [8]. TR is calculated by the relation: the ratio of concentration of nutrients in the shoot to the concentration of nutrients in the roots [9]. TR = (Concentration of nutrients) shoot/(Concentration of nutrients) root (1).

TF is given by the relation: the ratio of the concentration of nutrients in the shoots to the concentration of nutrients in the soil [10]. The transfer factor (TF) is a value used in evaluation studies on the impact of routine or accidental releases of nutrients into the environment. TF = (Concentration of nutrients) $_{shoot}$/ (Concentration of nutrients) $_{soil}$ (2).

These factors were used to evaluate the macro-elements (N, P, K) uptake by J. curcas plant. Total nitrogen of the sample was determined by Kjeldahl method [11]. For determination of P and K contents of leaf, plant samples were air-dried and were then ground. P was measured spectrophotometric ally by reaction with ascorbic acid. Potassium was determined by flame photometry. The $^{15}N/^{14}N$ ratio was determined by emission spectrometry ^{15}N-analyzer (Model NOI-6PC) following the description of [12]. % Ndff, % Ndfs, % Ndfo and %FUE were calculated according to [13]. Statistical analysis, data were statistically analyzed to test the ANOVA As (two way and three way) and least significant different LSD using MSTAT software according to the standard statistical methods [14].

3. RESULTS AND DISCUSSION

Data presented in Fig. 1 show the effect of Irradiated and non-irradiated sewage sludge and compost alone or plus ammonium sulphate added to the sandy soil on seeds *Jatropha curcas L*. Both the compost and irradiated and non-irradiated sewage sludge application has led to increase in seeds yield *Jatropha curcas L* when compared to the 100% mineral fertilizer (controls) in Fig. 1. Results indicated that irradiated sewage sludge enhanced seeds yield of jatropha by 11.0% on an average over non-irradiated sludge treatments. Highest seeds yield was produced by the application of gamma irradiated sewage sludge + 50% ammonium sulphate fertilizer from non-irradiated sludge+ 50% ammonium sulphate fertilizer followed by fertilization equivalent of 50% compost + 50% ammonium sulphate fertilizer. According to the effect of the used treatments on the yield of *Jatropha curcas L*, these treatments can be arranged in the following descending order: T5> T6> T7> T4> T2> T3> T1. Sewage sludge is generated from wastewater treatment plant. Sewage sludge is typically organic in nature. Sludge is also a rich sourceof many macro (N, P, and K) and micronutrients essential for soil. Assewage sludge still contains microbes, viruses and worm eggs, whichunder certain circumstances can be dangerous for human beings andanimals, it must be disinfected before it is deposited on to agriculturalareas [6]. The effects of irradiation of sludge in terms of crop yield in relation to N status of sludge-amended field soils is seldom reported. As stated above, increases in crop yields and N uptake are thought to be due to inactivation of pathogenic microorganisms and growth inhibitors due to the irradiation of sludge [4].

Utilization of enriched hygienized sewage sludge and water were effectively applied for growing grapes in Gujarat where most of the land has very low fertility. The hygienized sludge is an ideal medium for nitrogen fixing bacteria like Rhizobium to grow and hence can be converted easily into a bio-fertilizer. Many crops have been tested in actual fields with excellent results. Soil condition improves considerably after application of hygienized sludge [6]. [15] who demonstrated that the effects of the application of sewage sludge as a N source on ratoom cane yield and on some technological characteristics were similar to the effects of the application of N via a mineral source.

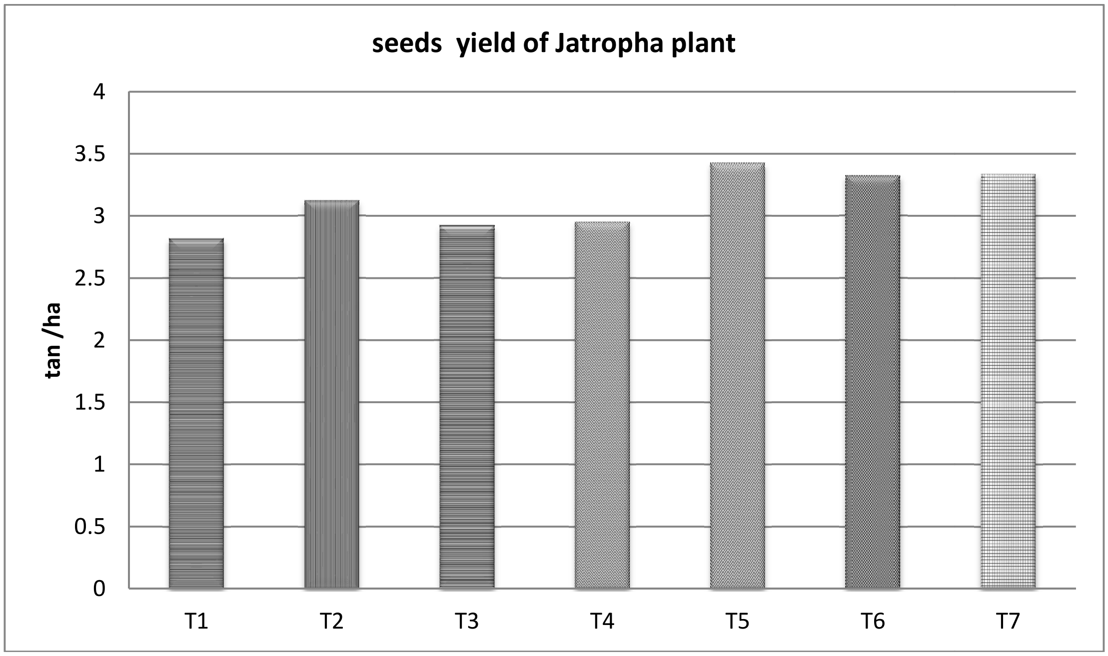

Fig. 1. Effect none irradiated and irradiated sewage sludge and compost on seeds yield production

The content of macro-elements in Jatropha (seeds, shoot and roots) were also determined Table 1. Data indicated thatseeds contained N, P and K, at levels higher than those detected in shoots and roots .Results indicated that irradiated sewage sludge alone or companion with mineral fertilizer enhanced nitrogen concentration of jatropha seeds by 8.57% on an average over non-irradiated sewage sludge and compost treatments. Highest concentration nitrogen of Jatrophashoot yield and roots was produced by the application of 50% irradiated sewage sludge plus 50% mineral fertilizer from %100 mineral fertilizer alone or 100% non-irradiated sewage sludge followed by fertilization with%100 compost. This holds true with all treatment. Data showed that increased N concentration values byJatropha seedsyield, shoot and roots where recorded, T5, T7, T2 andT6 accumulated 380, 360, 360 and 360 mg N kg^{-1}, respectively against 350, 330,320 and 300 mg N kg^{-1} for T6, T1, T4 and T3. Among the organic treatments, T5 seemed to be the best ones. The lowest value of N concentration by seeds yield was recorded with rate 100% non-irradiated sewage sludge treatment followed by rate 100% compost. However values of the N concentration achieved under the Jatropha seeds yield seemed to be higher than the corresponding ones achieved compared than the N concentration to shoots and roots. Application of %50 irradiated sewage sludge plus% 50 mineral fertilizer as effect source of the organic material in seeds yield, shoot and roots. Data reveal that according to the mean values these organic material sources shoot and root followed the descending order: shoot T5>T7> T6>T2>T1>T4>T3. Roots: T5 > T6> T7 ≥ T2> T4≥ T3≥ T1. In contrast, K and P were detected in seeds at levels higher than those recorded in shoots and roots. Phosphorus was the highest mean values of macro-elements detected in the seeds, shoots and roots analyzed samples with T5 compared all treatment while T1 lower than all treatment, however, these values are comparatively lower than the content (830 mg/kg) [16]. On the other hand in our results, K followed the content of N in Jatropha. The content of K in Jatropha is lower than the content of N. K concentration in part of Jatropha plant as affected by addition irradiated sewage sludge alone or companion with mineral fertilizer and compost plus ammonium sulphate this true with treatment T5. [17] found that *Jatropha curcas* seeds are considered good or moderate source of micro (Mn, Fe and Zn) and macro-elements (K, Ca, Na, Mg and P) elements Although, the content of macro-elements in some

Table 1. Effect none irradiated and irradiated sewage sludge and compost on nutrient uptake (N.P.K) by Jatropha plant

Treatment	Concentration of N (mg/kg)			Concentration of P (mg/kg)			Concentration of K (mg/kg)		
	Root	Shoot	Seeds	Root	Shoot	Seeds	Root	Shoot	Seeds
T_1	50	170	330	31	41	140	38	79	130
T_2	60	180	360	37	67	146	40	89	161
T_3	50	150	300	39	49	149	39	83	160
T_4	50	160	320	46	66	148	43	87	161
T_5	80	200	380	44	74	154	47	105	177
T_6	70	190	350	43	53	151	46	98	169
T_7	60	200	360	46	66	153	44	100	171
L.S.D.0.05	2.993	3.036	5.508	2.439	2.405	3.426	2.231	2.304	3.020

cases is lower in Jatropha, these elements are very important. Phosphorus is an essential component of nucleic acid and nucleoproteins, which are responsible for cell division reproduction and heredity. Potassium is an essential nutrient and has important role in the synthesis of amino acids and proteins [18]. From these results, Jatropha seeds consider good or moderate source of benefit macro-elements N, P, and K [19].

[20] reported that nitrogen from urea produced higher plant yield than N from sewage sludge when both were applied at an equal rate. Moreover, our results showed that significant difference in yield production and total N uptake with respect to the N application timing (splitting the N- ammonium sulphat application, single sewage sludge application). It appears that the crop's ability to meet the yield level depends on the level of N available to the crop throughout the growing season prior to the timing and mineral form of fertilizer application and requires the synchronization of fertilizer-N availability and crop-N.

3.1 Translocation Ratio (TR) and Translocation Factor (TF) of Nitrogen Element in *Jatropha curcas* as Influenced by Different Treatments

Data in (Figs. 2 and 3) show the translocation ratio of nitrogen under investigation ranged between 1 to 3.4. The lowest translocation ratio was observed in the T_4 (1.0, 2.3 and 2.0 for Roots, shoot and seeds tonitrogen element, respectively), which may imply the restriction in soil to root and root to shoot and shoot to seeds transfer at higher nitrogen concentrations in the soil. Highest translocation ratio of nitrogen element of Jatropha root and root to shoot and shoot to seeds was produced by the application of T1data recoded 2.0, 3.4, 3.4 respectively. Alsodata demonstrated low TF at nitrogen concentrations on cultivation of jatropha in sewage sludge contaminated soil with T1. In average, the transfer factor of nitrogen element under different treatments equal 0.5 to 1.0 with roots, 0.29 to 0.40 with shoot, 0.50 to 0.56 with seeds respectively.

Elements are translocate from roots to shoots via a number of physiological processes, including metal unloading into root xylem cells, long-distance carrying from the xylem to the shoots and metal reabsorption, by leaf mesophyll cells, from the xylem stream. Similar results were found by [21]. [22] also reported low TR at higher nitrogen concentrations on cultivation of *Justicia gendarussa* in textile sludge contaminated soil. In average, the transfer factor of Cu under different treatments equal 0.06.

3.2 Nitrogen Derived from Fertilizer (Ndff%)

Data presented in generally showed that the larger portion of nitrogen utilized by jatropha plants that was derived from irradiated sewage sludge and compost (%Ndfo) and derived from soil (Ndfs%).

The highest percentages of Ndff in total biomass of jatrophaplants were recorded when the application of organic material as compared to mineral fertilizer. The nitrogen fertilizer was add at the rate 50% gamma irradiated sewage sludge + 50% ammonium sulphate fertilizer and 50% compost + 50% ammonium sulphate fertilizer from 50% non-irradiated sludge+ 50% ammonium sulphate fertilizer and 100% ammonium sulphate fertilizer showed an increase of (Ndff%) comprising to 26% and 24.5% atrate 50% gamma irradiated sewage sludge + 50% ammonium sulphate fertilizer and 50% compost + 50% ammonium sulphate fertilizer, comprising to 24% and 20% with application ofnon-irradiated sewage sludge + 50% ammonium sulphate fertilizer and 100% ammonium sulphate respectively.

The best value of Ndff% recorded with rate 50% gamma irradiated sewage sludge + 50% ammonium sulphate fertilizer .This holds true with total biomass . But the portion derived to T5 increased than that derived to T1. Application of non-irradiated and irradiated sewage sludge and compost treatments was enhanced in nitrogen derived from fertilizer by Jatropha plant as compared to 100% ammonium sulphate.

These findings are consistent with the results of other studies conducted on Sudan grass that demonstrated that a decrease in N derived from soil did not affect the total N uptake by the plant because it was compensated for by an increase in N fertilizer uptake [23]. These levels of sewage sludge N recovered by Sudan grass were similar to those reported by [24] for Fescue grass in soils amended with municipal sludge, who found that the total recovery of applied N in the harvested grass was 24% of the municipal-sludge N for the first five harvests.

The recovery of ^{15}N-urea decreased significantly from32 to 25% as the nitrogen level increased from 150 to 350kg N/ha. Similar results were reported by [25] who found that the ^{15}N recovery from mineral nitrogen dropped as the fertilizer application rate increased. It is likely that a significant amount of the applied N moved below the root zone when there was a high application rate, and that this resulted in much of the N not being available to crops. These findings indicate that the application rate needs to be matched to the needs of the crops to minimize the risk of pollution.

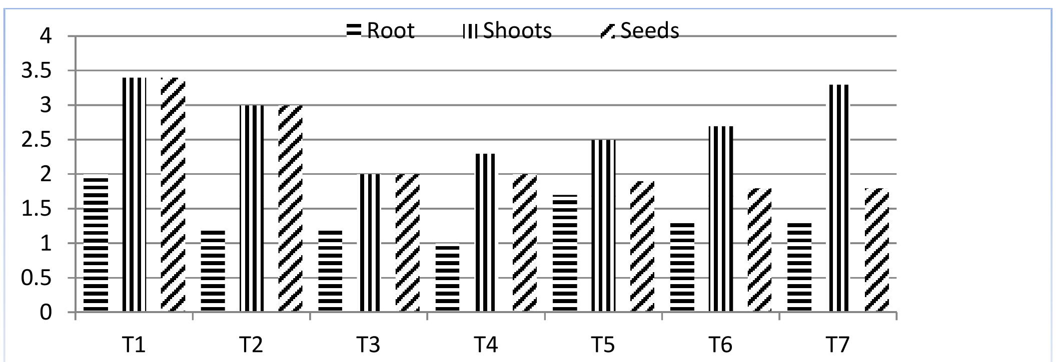

Fig. 2. Translocation ratio (TR) of nitrogen element in *Jatropha curcas* as influenced by different treatments

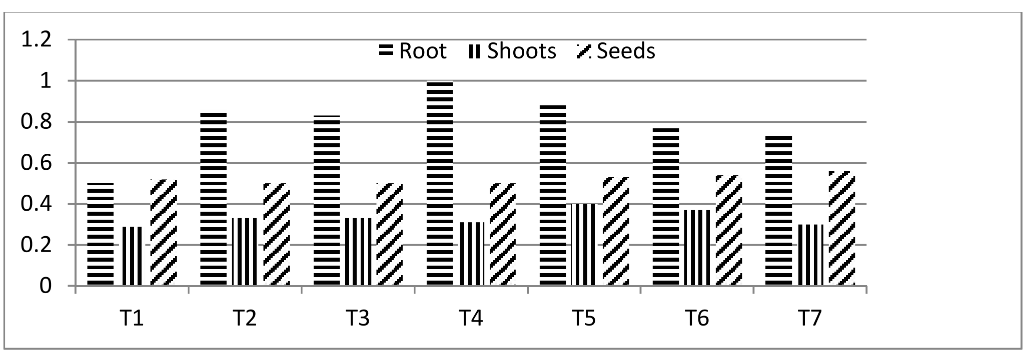

Fig. 3. Translocation factor (TF) of nitrogen element in *Jatropha curcas* as influenced by different treatments

3.3 Nitrogen Derived from Organic (Ndforganic %)

Values of nitrogen derived from organic materials is present in in (Fig. 4). Data showed that the highest value of nitrogen derived from non irradiated sewage sludge and compost was recorded as compared to irradiated sewage sludge + 50% ammonium sulphate in total biomass of jatropha plants. Application of rate (50% non-irradiated sewage sludge + 50% ammonium sulphate) and 50% compost + 50% ammonium sulphate was the highest value of Ndfo % as compared to rate (irradiated sewage sludge + 50 % ammonium sulphate) respectively. Values of Ndfo % for 75.2%, 74.8% and 73.3% for (50% non-irradiated sewage sludge + 50% ammonium), (50% compost + 50% ammonium sulphate) and irradiated sewage sludge + 50% ammonium sulphate respectively.

3.4 Nitrogen Derived from Soil (% Ndfs)

Values of nitrogen derived from soil is present illustrated graphically in (Fig. 4) Ndfs was enhanced by increasing N fertilizer rate indicated the priming effect of fertilizer on soil nitrogen pool. there was no significant difference between treatments .Nitrogen derived from soil induced increase with 50% non irradiated sewage sludge + 50 % ammonium were 0.8% compared other treatment when N fertilizer was applied as 100% ammonium sulphate . The corresponding values in the total biomass of jatropha plants were 0.8%, 0.7%, 0.7% and 0.6% respectively. For 50% none irradiated sewage sludge + 50% ammonium sulphate, 50% compost + 50% ammonium, 50% irradiated sewage sludge + 50% ammonium sulphate, 100% ammonium sulphate.

3.5 Fertilizer Use Efficiency (Fue%)

The percentages of efficient use of either chemical fertilizer or organic manure up taken by total biomass of jatropha plants are listed in graphically illustrated by Fig. 4. Generally, the mineral fertilizer either applied solely was not efficiently but in combination with irradiated sewage sludge and compost was efficiently used by jatropha plants. In case of rate 100% ammonium sulphate alone, the percent of fertilizer use efficiency not exceeds 33.3% when chemical fertilizer was totally applied. The application of organic compost treatments showed low efficiency especially under T6 (50% non irradiated sewage sludge + 50% ammonium sulphate) treatments. High % FUE was only recorded with T5 (50% irradiated sewage sludge + 50% ammonium sulphate) treatment. In general, the %FUE with 100% ammonium sulphate was ammonium sulphate alone lower than those recorded with ammonium sulphate plusnone or irradiated sewage sludge and compost when T5, T7, T6 and T1 treatments were considered.

Regardless the organic material and ammonium sulphate fertilizer type, our data about %FUE are in accordance either for biomass with those obtained by [26] who found that the fertilizer N recovery in plant biomass tuber and foliage ranged from 35.9% to 68.5% at growth stage. Also, they added that placement of fertilizer N in the ridge had a positive effect on N recovery, when the total N amount was applied at planting. In broadcast application, fertilizer N recovery was higher when the fertilizer doses were split, as compared with a single broadcast application at planting. When fertilizer N was applied in split doses, the effect of N placement became negligibly small. Fertilizer N recovery in soil ranged from 33.3% to 43.3%. Rainfall between planting and plant emergence, and conditions restricting plant development in early developmental stages were related with unaccounted fertilizer N losses. Therefore, the positive effects of split N applications or fertilizer placement are most likely to occur under unfavorable growing conditions. In agreement with the results of a study conducted by [27] our results of the paper suggest that application of nitrogen as ammonium sulphat at a rate of 120 kg Nha^{-1} or as sewage sludge at a rate of $24m^3ha^{-1}$appears to be sufficient for covering jatropha N needs, leading to maximum yields. Furthermore, sludge-N leads to similar crop yield and nitrogen uptake than N-ammonium sulphat (Fig. 4 and Table 1) suggesting a higher efficiency of sewage sludge as N fertilizer.

Similar results were reported by [28], who concluded that applying nitrogen as a surface band or injecting it into the soil enhanced nitrogen-use efficiency and increased yields. Moreover, according to [29] the selection of optimum fertilization (rate, type, nitrogen application timing, specific soil placement of N fertilizer) as a function of the crop needs, soil characteristics and climate, along with effective management practices, should attempt to draw up on all the possible options of increasing N-use efficiency, which untimely can lead to more profitable crop production and a safer environment.

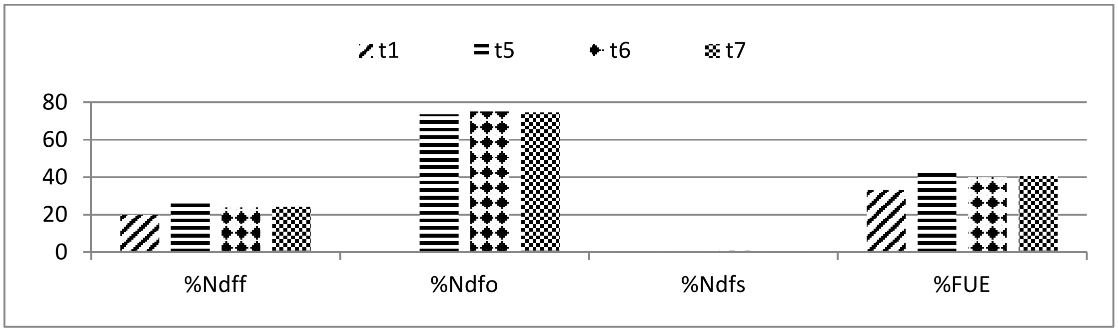

Fig. 4. Effect none irradiated and irradiated sewage sludge and compost on %Ndff, %Ndfo, %Ndfs and %FUE by Jatropha plant

4. CONCLUSION

The data obtained in the present study support the following conclusions: Nitrogen [15] isotope aided studies indicated that fertilizer nitrogen accumulation yield, Nitrogen% derived from fertilizer and N% recovery by jatropha were reasonably high under treatments with gamma ray irradiated sewage sludge. Results of this study indicate that the behavior of sewage sludge and compost is similar to that of ammonium sulphate fertilizer as regards N supply to Jatropha plant. Thus, sewage sludge could be used as an alternative to this mineral fertilizer. Also results indicate that greater carere garding fertilization and nutrition, such as careful evaluation of the application of method, is necessary to optimize the effects of sewage sludge and compost application on sandy soil fertility and Jatropha yield production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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